

**POPULATION AND RESOURCE UTILISATION BY REPTILES IN UPPER
NILGIRIS, NILGIRI BIOSPHERE RESERVE, WESTERN GHATS, INDIA**

Thesis Submitted to the

BHARATHIAR UNIVERSITY, COIMBATORE

for the

DEGREE OF DOCTOR OF PHILOSOPHY

in Zoology

by

A. MATHEWS NIXON ARMSTRONG, M.Sc.



Division of Environmental Impact Assessment

Sálim Ali Centre for Ornithology and Natural History

Coimbatore 641 108

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SUMMARY

Herpetofauna (reptiles and amphibians) are important components of both terrestrial and wetland ecosystems as they play a major role in energy flow and nutrient cycling. Both of them are also excellent indicators of environmental degradation. Being poikilotherms, reptiles tend to partition time and space more often than homeotherms as their physiology and behaviour are closely linked to environmental conditions. However, quantitative data on the population and resource use by reptiles are scanty in India.

Resource use can be studied with respect to the three most often recognized niche axes: spatial (habitat use), temporal (activity period) and trophic (food). Herpetofauna of India, one of the most diverse taxa, is poorly known regarding their ecology and population characteristics. Major objectives of this study was to (1) assess the population status of reptiles and factors determining their distribution in various habitats of Upper Nilgiri plateau (2) determine the habitat use and food habits of reptiles, and (3) to understand the resource use at spatio-temporal and trophic levels by reptiles in Upper Nilgiris.

The study area, the Mukuruthi National Park is a part of the Western Ghats Biogeographic zone, which is one of the 25 globally recognized biodiversity hot spots. This Park forms an important part of the Nilgiri Biosphere Reserve. Field study was conducted in and around the National Park (MNP: 11° 10' to 11° 22' N and 76° 26' to 76° 38' E) during October 2000 to October 2002. Total area of the Park is 78.46 km², and the major vegetation type is Southern Montane Wet Temperate Forest, herein considered as Shola and Grassland. Plantations such as Wattle, Pine, Eucalyptus and Tea also occupy a major portion of the Upper Nilgiris.

Area (Quadrat) and Time (Visual Encounter Survey) constrained sampling techniques were used for data collection. Sampling was restricted to day hours between 0800 and 1500 hrs due to activity of the species in the cold climatic conditions prevailing in the area and limited logistic support. On locating a reptile species, morphometric measurements and sex of each individual were noted. The forest type was considered as habitat and location of an individual as microhabitat. Location of an individual when first sighted from the ground was considered as its vertical position. Habitat variables such as number of trees, fallen logs, boulders and leaf litter cover in each quadrat were noted. Atmospheric temperature was recorded using a digital thermometer. Gut contents of reptiles were analyzed depending on the availability of specimens opportunistically from road kills, killed by plantation workers and cattle grazier in close vicinity to the study area.

Population parameters such as species richness, diversity, sex ratio, relative abundance and biomass were calculated using standard methods. The data was statistically analyzed using Analysis of Variance (ANOVA), Correlations and Regressions. With respect to food, percentage frequency of prey, prey volume and Importance index (I_x) of the food item were calculated. Relationship between the snout-vent length and prey length has been worked out. Mann Whitney-U test was performed to know the difference in the prey use among species. Aspects such as habitat, microhabitat and vertical position of the reptiles, food and emergence of hatchlings were considered for analyzing resource use pattern. Further, morphometric data, especially the head length and width and jaw length were used to supplement the results obtained with respect to spatial use pattern. Canonical Discriminant Analysis (CDA), niche breadth (β) and overlap (Φ) were used to understand the reptile community. Cluster analysis was done to find out the reptile species assemblages in Upper Nilgiris.

Eleven species of reptiles were observed in Upper Nilgiris during this study. However, only eight were observed in close vicinity to the Mukuruthi National Park. Species accumulation pattern using estimators such as the First order Chao; second order Jackknife, Coleman rarefaction and Bootstrap showed that number of species in the area is eight to 10. Lower number of reptile species in Upper Nilgiris could be due to factors such as colder climatic conditions, poor availability of microhabitats, effect of altitude on species and geometric constraints.

Grasslands had the highest ($H' = 1.24$) and Pine plantation the lowest ($H' = 0.21$) species diversity. Reptile density was higher in Grasslands and Shola compared to plantations. The number of species and the density of snakes were found to be higher in Grasslands. In general, the average density of lizards was high (2.9 /ha) compared to snakes (1 /ha). Relative abundance of *Cnemaspis indica* was the highest (43.2 %) followed by *Salea horsfieldii* (36.46%) and *Xylophis perroteti* (0.34 %) was the lowest. Populations of snakes were low compared to lizards, and relative abundance of *Ahaetulla perroteti* and *Plectrurus perroteti* was high among snakes.

In all, lizards contributed nearly 80% of the total reptile biomass of the Upper Nilgiris. At species level, the endemic agamid lizard, *Salea horsfieldii* contributed the maximum biomass (about 68%). Overall, the biomass contributed by each lizard species was higher than that of snake species. At habitat level, the highest reptile biomass was observed in Shola (108 g/ ha) followed by Grasslands (64.8 g/ ha) and lowest in Pine (32.1 g/ha). The size class distribution of both lizard and snake species showed a unimodal right skewed pattern, which indicates a healthy population with higher number of adults that has potential to breed. All species, but *Scincella bilineatum* and *Xylophis perroteti* had negative impact when habitats were modified/ altered.

Higher proportion of *Cnemaspis indica* (82%) and *Scincella bilineatum* (57.1 %) were found in Grasslands. A considerable proportion of *Salea horsfieldii* was found in all habitats, which indicates its versatile nature in habitat use compared to other lizard species. Among snakes, *Plectrurus perroteti*, *Ahaetulla perroteti* and *Trimeresurus strigatus* largely used Grasslands. Similar to *Salea horsfieldii* in lizards, *Ahaetulla perroteti* was generalist in habitat use among snakes. Chi-square (χ^2) analysis showed significant differences in habitat use among reptile species found in Upper Nilgiris. Higher proportion (>50%) of the reptiles of Upper Nilgiris used boulders as their microhabitats. About 87.5% of *Cnemaspis indica* was found under boulders. *Salea horsfieldii*, *Ahaetulla perroteti*, *Cnemaspis indica* and *Trimeresurus strigatus* used above ground layers and the mean vertical position was 79.02, 7.4, 7.4 and 27.1 cm respectively. Due to the prevailing cold conditions in the region, microhabitat utilisation by most of the species was at ground level.

Tree density was the highest in Wattle (117.5 / 100 m²) followed by Shola (20.5 trees/100m²). The highest density of boulders was found in Grasslands (6.22/100m²) and the lowest in Pine plantations. Mean temperature recorded at 1200 hrs showed that Tea plantations and Grasslands were warmer than other habitats. Reptile density had significant correlation with only two variables, namely atmospheric temperature and tree density. Boulder density and its relation with reptiles showed both positive and negative influence on reptile species: lower boulder density had positive effects while the higher density showed negative impacts. Snakes in general, with the exception of *Plectrurus perroteti*, showed negative correlation with boulders. All species of reptiles, barring *Salea horsfieldii* showed negative relation with tree density.

Altogether, eighteen food taxa were identified for three species of lizards, but it was only five items for snakes. At broader level, nine taxa of insects and one plant remains were identified from the gut contents of lizards. Coleopterans, Hymenopterans and Lepidopterans contributed the highest

food volume in *Cnemaspis indica*, *Salea horsfieldii* and *Scincella bilineatum* respectively. Importance index (I_x) of food also showed a similar result. *Plectrurus perroteti* fed exclusively on earthworms and other (3) snake species largely fed on vertebrates. Dietary variability among three species of lizards was statistically significant. A significant correlation was found between the Snout-Vent Length of *Cnemaspis indica* and prey length ($r = 0.544$, $P = 0.01$, $N = 24$). In the case of *Salea horsfieldii* and *Scincella bilineatum* no such significant relation was found.

Three-dimensional plots of head length and width, and jaw length showed that various (syntopic) species of reptiles occupied different position in the multidimensional space. Canonical analysis also confirmed the above findings (lizards: $K = 0.902$; snakes: $K = 0.976$). The present study showed that the hatchling of lizards and snakes emerged for an extended duration, especially during dry season (non-monsoon months).

Mean niche breadth (β) of reptile species varied from 1.22 to 4.38, showing that the reptiles of Upper Nilgiris have low to moderate survival capabilities with respect to the resources under consideration in the present study. *Salea horsfieldii* was a generalist compared to other species as indicated by the highest mean niche breadth ($\beta = 4.38$), whereas *Plectrurus perroteti* was a specialist ($\beta = 1.22$). High overlap was found at habitat level, which was reduced considerably at microhabitat level. Species such as *Salea horsfieldii* differed from others in the use of various vertical layers. At trophic and temporal levels, many species showed relatively low overlap in resource use.

Species grouping was observed at spatial, temporal and trophic levels. With respect to overall assemblages, species packing was somewhat sparse without definite groupings. Of all species studied, *Cnemaspis indica* and *Scincella bilineatum* were the nearest neighbors. *Salea horsfieldii* was distinct in resource utilisation from other species inhabiting the Upper Nilgiris.

The present study shows that the distribution of reptiles in Upper Nilgiris is largely determined by temperature, microhabitat availability and various geophysical constraints. Habitat alterations in Upper Nilgiris impacted almost all endemic reptile species of the area. Regarding their food habits, lizards were more opportunistic feeders than snakes. Niche analysis showed that the reptiles of this region have low to moderate survival capabilities with respect to utilisation of various spatio-temporal and trophic resources. As all species of reptiles found in the Upper Nilgiris are largely endemic to Western Ghats and restricted to the higher altitude areas, their survival depends on the conservation of their endemic habitat, the Southern Montane Wet Temperate Forest, locally known as Shola and Grasslands.

CHAPTER - I INTRODUCTION

Spatial and temporal patterns of animals play an important role in structuring ecological communities, especially reptiles (Harvey *et al.* 1998). Numerous factors influence the landscape and resources use of the animals. Microclimate, food, shelter and predators vary spatially and provide opportunities for partitioning spatial resources, and hence there are niche differentiations among potentially competing species (Melville and Swain, 1997). Resource use can be studied with respect to the three most often recognized niche axes, namely spatial, temporal and trophic (Pianka, 1986). Community complexity has made comparisons of all species coexisting in a given place difficult (Ricklefs, 1979; Diller and Wallace, 1996). Being poikilotherms, reptiles tend to partition time and space more often than homeotherms as their physiology and behaviour are closely linked to environmental conditions (Schoener, 1977). Globally, quantitative data on the resource use by reptiles are scanty (Harvey *et al.* 1998).

Studies on the abundance and population of herpetofauna (reptiles and amphibians) are also scanty. Very little attention is so far given to study various attributes of populations such as density, distribution, natality, mortality and age structure (Odum, 1971; Yablokov, 1986; Begon *et al.* 1996 a, b) with emphasis on these groups of animals. Recent data indicate that herpetofauna are critical components of both terrestrial and wetland ecosystems (Werner and McCune, 1979; Gibbons, 1988) as they play a major role in energy flow and nutrient cycling (Burton and Likens, 1975; Pough, 1980; Bury, 1988). Additionally, these taxa are excellent indicators of environmental degradation – amphibians due to their aquatic/terrestrial life cycle and permeable skin – and reptiles due to their high positioning in trophic level. Reptiles are less mobile compared to most birds and mammals; therefore, their population cannot be readily supplemented from surrounding areas by dispersal or local migration (Caughley and Gall, 1983; Nally and Brown, 2001). As activities of the

amphibians and reptiles are highly driven by local meteorological factors such as precipitation and temperature, assessing their populations is rather difficult (Gibbons and Semlitsch, 1981; Vogt and Hine, 1982).

Reptiles are one of the first vertebrate taxa that had adapted for terrestrial mode of life. Consequently, they were equipped with dry and scaly skin for protecting their body from desiccation. Pough *et al.* (1998) states that six thousand species of reptiles occur in the world, which include four taxa: turtles, crocodiles, squamates (snakes and lizards) and tuatara. Recent years have seen more species getting added to the faunal list. Varied activity patterns (e.g. uni or bimodal pattern), social (solitary and gregarious) behaviour and temporal movement pattern have made them focal in ethological studies in recent years. Herpetofauna play an important role in the food chain, and they make up a large proportion of vertebrates in certain ecosystems (Bury and Raphael, 1983). Reptiles and amphibians are prey for several vertebrate predators (Pough *et al.* 1987), and thus, are important components supporting the biological diversity of vertebrates.

Herpetofauna of India is one of the most diverse and poorly known taxa in terms of their ecology (Inger *et al.* 1987). Daniels (1994), notes that studies on the population and ecology of reptiles are scanty in India. According to Das (2003), 506 species of reptiles are known to occur within the political boundary of India that includes about 38% of endemic species. The Western Ghats is one of the 25 globally recognised biodiversity hot spots (Myers *et al.* 2000). Human induced changes in landscapes or habitats continuing unabated have major realized and predicted impacts on ecological and evolutionary processes in biodiversity (Saunders *et al.* 1991).

The Nilgiri Hills of the Western Ghats show several ecologically unique characteristics. Since the occupation of the area by plainsmen and the British during the past century, it has undergone considerable changes.

The fast pace of changes was ushered by development of a large number of plantations such as tea, coffee and wattle. Over 80% of the Southern Montane Wet Temperate Forests (locally known as Shola and Grasslands) of Upper Nilgiris have been lost since 1850 (Saravanakumar *et al.* 1993). Climate of the area is near temperate and reptiles found in the area are largely endemic to this forest type. Till today, no intensive study on the ecology of reptiles has been undertaken in Upper Nilgiris. Hence, the present study was initiated. Field data collection was done from October 2000 to October 2002 in and around Mukuruthi National Park, Nilgiri Biosphere Reserve, Western Ghats, Tamil Nadu, and India.

1.1. OBJECTIVES

Major objectives of the present study were to,

- (1) Assess the population status of reptiles and the factors determining their distribution in various habitats of Upper Nilgiri plateau,
- (2) Determine the habitat use and food habits of the reptiles, and
- (3) To understand the resource use at spatio-temporal and trophic levels by reptiles in Upper Nilgiris.

1.2. LITERATURE REVIEW

Population of several species that inhabit an area or habitat form a community. This concept embodies interaction of species, which results in spatial and temporal patterns of abundance and distribution among organisms (Begon *et al.* 1996a, b). Animal communities are reportedly structured by the processes of niche segregation primarily through spatial or temporal regimes (MacArthur, 1972; Cody, 1974; Pianka, 1975; Diamond, 1978; Vitt, 1995). Aspects of resource include macro and microhabitats, daily and seasonal activities and food (Pianka, 1973; Thorpe and Crawford, 1979). In this review, major studies available on the aspects of population of reptiles and their resource utilisation patterns, especially at spatial (habitat, microhabitat), temporal (breeding seasonality) and trophic (food) levels were examined. Even though, the temporal use pattern includes aspects such as activity pattern (feeding

rhythm and breeding- egg laying and emergence of hatchling), only that on breeding is included in this compilation. While compiling literature, emphasis was given to the studies involving multiple species rather than single species. Although older studies were examined, recent studies (after 1985) were given emphasis for the review. Prominent studies on the population and resource use pattern concerning reptiles from other countries are described first followed by studies in India.

1.2.1. Studies from Abroad

Important aspects or characters of population are number (abundance and density), age structure, sex ratio, size class and natality and mortality (Chapman and Reiss, 2000). Spatial patterns of animals often reflect the availability and distribution of resources relative to the physiological requirements of an organism (Whiting *et al.* 1997). Major factors that influence the populations of reptiles are temperature and microhabitat availability. Vitt *et al.* (1998a) noted that almost all aspects of the biology of lizards depend on temperature. Most of the reptiles require warmer temperature for incubation and successful development of embryos (Greenberg, 2001).

A review on the species richness pattern in relation to altitude is presented by Rahbek (1995). Studies revealed a monotonic decrease in species richness with increasing elevation (MacArthur, 1972; Stevens, 1992; Grytnes and Vetaas, 2002). It is found that about 50% of the studies detected a mid altitude peak. A recently recognized factor that contributes to a humped relationship between species richness and altitude is the geometric constraint on species range (Colwell and Lee, 2000). The range of a species along an altitudinal gradient is geometrically constrained as the bottom of a valley as a lower boundary and the top of a mountain or ecophysiological constraints as an upper boundary (Grytnes and Vetaas, 2002). It is reported that tropical rain forests also act as barriers constraining species dispersal at least in the case of lizards (Gainsbury and Colli, 2003).

Studying large-scale biodiversity patterns that link species richness to variation in species traits within and across the ecological community are important for conservation (Etienne and Olf, 2004). This includes information on species area curve, distribution, relative abundance and diversity. It is also reported that the species body size patterns reflect the species trophic status (Etienne and Olf, 2004). Thompson *et al.* (2003) used species richness accumulation curve for predicting species richness, and determined the trapping effort required to catch a nominated percentage of the predicted number of species in an area. Relationship in species accumulation curve with diversity and rarity of small reptiles using pitfalls (Thompson *et al.* 2003) and day survey data (Andreone *et al.* 2003) have been worked out. The asymptotic nature of the curve indicates the detection of all species present in the area (Persons and Nowak, 2004).

Some notable studies on the population of reptiles are that in Iberian Peninsula (Schall and Pianka, 1977), Argentina (Fitzgerald *et al.* 1999), New Zealand (Greenberg, 2001), and in North Carolina (Willson and Dorcas, 2004). Density of reptiles may be very high eg. Skink, *Leiopisma zelandica* 2224/ ha (Barwick, 1959), Crayfish snake and Swamp snake, *Regina alleni* and *Seminatrix pygaea* 1200/ ha (Godley, 1980), Ring necked snake, *Diadophis puntatus* 1000/ ha (Fitch, 1975) and Green snake, *Opheodrys acstivus* 800/ ha (Plummer, 1997).

In nature, theoretically, sex ratio of an animal population may be one (Ehrlich, 1986). Balanced sex ratio has been reported for various species of reptiles: *Uta stansburiana* (Pianka, 1975), *Opheodrys aestivus* (Plummer, 1997) and *Anolis carolinensis* (Ruby, 1984; Jenssen, 1995). However, this ratio may deviate due to various factors such as incubation temperature (Lovich, 1996). Variations in sex ratio may have important consequences in population regulation.

Reptiles and amphibians are relatively uncommon subject of study compared to birds and mammals (Vitt, 1987). This is mainly due to their

cryptic nature, occurrence in low densities and seasonal activity (Diller and Wallace, 1996). Heyer *et al.* (1994), provided various procedures for sampling herpetofauna, but these methods have largely been used in temperate conditions (in Western countries), and their applicability or limitations in the tropical ecosystems are unknown. Prominent sampling methods include Transect, Quadrat, Pitfall, Funnel Trap, Road Cruising and Visual Encounter Survey. Various researchers used Quadrat (Thorpe and Crawford, 1979; Jaeger and Inger, 1994; Martin-Vallejo *et al.* 1995; Hadden and Westbrooke, 1996; West and Skelly, 1997; Schlaepfer and Gavin, 2001), Visual Encounter Surveys (Campbell and Christman, 1982; Lips, 1999; Toral *et al.* 2002; Persons and Nowak, 2004), Pitfall Traps and Mark Recapture methods (Welsh and Lind, 1989; Hadden and Westbrooke, 1996; Plummer, 1997; Willson and Dorcas, 2004).

Resource may be defined as environmental components and factors that are directly used by an organism and may potentially influence individual fitness. Quantitative data on habitat use by sensitive species are needed to formulate conservation and management plans (Bright and Morris, 1990; Buhlmann, 1995; Beauchamp *et al.* 1998). However, data on the spatio-temporal distribution or resource use by reptiles are scarce (Harvey *et al.* 1998). Relative role of species interactions, temporal and spatial variations in resource availability and phylogeny appear to be complexly intertwined in determining diets of sympatric species (Vitt and Zani, 1998a). The spatial distribution of resources will influence the likelihood that a community will be structured by biotic interactions (Creusere and Whitford, 1982).

Canopy removal results in warmer and drier microclimate, and reduced leaf litter could cause certain species to desiccate (Petranka *et al.* 1993; deMaynadier and Hunter, 1995). Heinen (1992) found higher abundance and biomass (of reptiles) in more disturbed sites, but species diversity was greater in less recently disturbed areas in Costa Rica. Inger (1980) found greater species richness in logged forests and plantations than in

rainforests and suggested that this may be due to environmental factors such as temperature. Greenberg (2001) reported increase in the reptile abundance, richness, and diversity in open areas compared to closed canopy area.

Study of the habitat utilisation gives an idea how organisms use the area, their preference, role of the habitat in species survival and their interrelations. Important studies on the habitat use of reptiles include, that on Caribbean anolis lizards (Losos, 1990; Losos *et al.* 1998; Vanhooydonck and Damme, 1999; Irschick *et al.* 2000) and Broad-headed skink, *Eumeces laticeps* (Cooper, 1993). Partridge (1978) defined habitat selection by animals as active choice of an area from a range of alternatives. Knowing the characteristics of a species and how individuals move within and among habitats, can lead to a greater understanding of the ecology in a patchy environment (Mills *et al.* 1995). It is reported that variations in body size influence interspecific habitat use among reptiles (Vitt *et al.* 1981; Reaney and Whiting, 2003). Habitat partitioning may influence the structure of lizard assemblage in different forest types (Conroy, 1999). Forest edges provided best opportunities for thermoregulation to reptiles as reported in Black rat snake, *Elaphe obsoleta obsoleta* (Demers and Weatherhead, 2001).

Differential habitat use among males, females and juveniles in Anolis lizards have been reported (Irschick *et al.* (2000). Lillywhite and Hunderson (1993) studied the habitat use by vipers and reported that juveniles were arboreal but abandon arboreality when they mature. However, no such changes were observed in *Trimeresurus stejnegeri stejnegeri* (Tu *et al.* 2000). In a habitat, a portion may be utilised by a species or a group of species. It has been reported that many species of lizards and frogs in tropical forests used edges (Schleapferq and Gavin, 2001; Toral *et al.* 2002). Lizards such as the Tree agama (*Acanthocercus atricollis atricollis*) and Broad headed skink (*Eumeces laticeps*) are reportedly selective even in usage of certain trees (Cooper, 1993; Reaney and Whiting, 2003;).

Microhabitat is defined as the animal's immediate physical environment. Microhabitat components of reptiles are diverse because their body temperature is derived from the surrounding environment (poikilotherms) and not by metabolic process. Terrestrial amphibians and reptiles are excellent indicators of relative abundance and rarity of microhabitats in the ecosystems (Jones, 1986). Microhabitats provide environmental conditions necessary for a wide variety of ecological functions such as reproduction, foraging, predator avoidance or escape, thermoregulation and resting. Wikramanayake and Dryden (1993) studied thermal ecology of two monitor lizards based on microhabitat use and reported that *Varanus bengalensis* used warm open microhabitats compared to high preference to aquatic habitats by *Varanus salvator*.

Ecomorphological studies are important in understanding the relationship between species morphology and ecology (Arnold, 1983). Herrel *et al.* (2002) used morphology to explain the microhabitat use of Phrynosomatid lizards. Microhabitat use of two sympatric lizards, namely *Anolis scriptus* and *Leiocephalus psammotromus* has been studied, and a high degree of overlap between them was observed (Smith, 1995). Herpetofaunal community and the microhabitat availability were assessed to manage the remnant Buloke woodlands (Hadden and Westbrooke, 1996).

Low energy requirement and prolonged inactive period of reptiles due to aestivation and hibernation during unsuitable climatic conditions make the food habit studies difficult. The energy requirements and food consumption rates of reptiles are much lower than those of similar sized birds and mammals (Pough, 1980; Nagy, 1983). Most of the lizards are fairly opportunistic and consume whatever prey items they encounter, within a broad range of type and size (Pianka, 1969). It is reported that prey size may be an important factor in food selection by certain reptiles (Diaz, 1995).

A number of studies are available on the food habits of reptiles in western countries and Australia. Among them, the pioneering and seminal works are that of Pianka (1975, 1976, 1977, and 1986). Pianka has studied lizard community for over 20 years in Australia, Africa and America. Other recent works are that of Vitt *et al.* (1998 a, b, 2000, 2001, and 2002) undertaken in South American tropics. These studies reported wide varieties of food in the lizards (ants, beetles, grasshoppers and crickets, non-ant hymenopterans, insect larvae, pupae, eggs, spiders and termites). Other notable works on the food habits of reptiles are on South African scincid *Mabuya striata wahlbergii* (Heideman and Bates, 1999); Lacertid lizards, *Psammodromus algirus*, *Podarcis bocagei*, *Lacerta schreiberi* and *L. monticola* (Diaz, 1995), Pygopodids, (Legless lizards; Patchell and Shine, 1986), and *Crotalus viridis* and *Pituophis melanoleucus* (Diller and Wallace, 1996). Thus, reptiles are highly variable in their food consumption from specialist (single item feeder) to generalist (consuming varied food items).

Various animals use time effectively for activities such as feeding and breeding, which may effectively avoid competition. Several studies are available on the temporal use patterns of reptiles in the western countries and Australia. Activity pattern and thermal preference of Great Basin snake community was studied for several years by Brown and Parker (1977) and Brown (1982). Temporal use of aquatic snakes significantly varied during drought compared to normal years (Seigel *et al.* 1995). Diller and Wallace (1996) studied the activity of snakes based on capture frequency during various hours or time. Habitat selection, body temperature and activity cycles in sympatric populations of the lacertid lizards *Podarcis muralis* and *P. hispanica* in Central Spain have been studied by Martin-Vallejo *et al.* (1995). Creusere and Whitford (1982) have reported seasonal variations in the activity of lizards inhabiting Chihuahuan Desert.

Reptiles are prolific breeders and are both seasonal and non-seasonal in their breeding habits. This seasonality may affect their life history and demography (Lemos-Espinal *et al.* 2003). Lizards show seasonality in reproduction in tropics, which may be during either dry season or wet season (Vitt and Goldberg, 1983; Clerke and Alford, 1993) or it is continuous (Vitt, 1982, 1991). Inadequate understanding of incubation regimes and their effects on reptilian physiology and reproduction may hamper conservation and management of some species (Hare *et al.* 2002). It is reported that many tropical lizards have extended breeding period (Lichtenbelt and Albers, 1993). Pianka (1970) worked on the *Cnemidophorus tigris* in different parts of its geographic range in Western United States and Northern Mexico, and found significant variations in the breeding of this species including egg-laying frequency. Significant correlation between mean number of eggs per clutch and precipitation was also reported.

Pianka has been involved in studying comparative ecology of desert lizards. These field investigations provided pertinent information on population, reproduction, thermal relations, diet, habitat and microhabitat associations and niche segregation in lizards (Pianka, 1973, 1978, 1986). MacArthur (1970) studied the species packing and competitive equilibrium for many species, and MacArthur and Wilson (1967) have provided descriptions on island biogeography. A theoretical model of size distributions among species has been worked out by Hutchinson and MacArthur (1959). A large number of studies on the lizard assemblages in various habitats of tropical South America are available (See Diaz, 1995; Vitt, 1995; Vitt and Carvalho, 1995; Vitt and Zani, 1996).

Various diversity indices (Shannon and Weiner, 1949; Simpson 1949) and models have been formulated to describe the structure of the community in terms of its diversity (MacArthur, 1957). During 60's MacArthur and Wilson (1967) have emphasized the importance of size of the area and invasion rate in maintaining the diversity of a community (Patrick, 1967).

The rate of embryonic development in reptiles is temperature dependent; warmer temperature in general results in faster development and thus shorter incubation periods. Rapid embryonic development as a potential adaptation to cold climate in *Sceloporus* lizards has been studied by Andrews *et al.* (1999).

1.2.2. Studies in Indian Subcontinent

General information on the taxonomy and distribution of the reptiles of Indian region (India, Pakistan, Bangladesh, Sri Lanka and parts of Southeast Asia) are available (Boulenger, 1890; Smith, 1931-1943). Ghalib *et al.* (1976) prepared an inventory of the reptiles of Pakistan, which was later revised by Khan (1994). Auffenberg and Khan (1991) studied the reptiles of Pakistan, especially freshwater turtles. Herpetology of Nepal, particularly natural history, distribution and zoogeography has been documented (Swan and Leviton, 1962). A review on the distribution of land tortoises of Nepal (Frazier, 1992a), and ecogeography of reptiles are provided by Shrestha (1981). Shrestha (2001) documented the biogeography of herpetofauna in the Himalayan region including Nepal based on the work by the author and his students for more than three decades. A compilation of the distributional records of the testudines of the Indian and Burmese sub-region is also available (Frazier and Das, 1994). Khan (1982) and Khan and Whitaker (1982) studied the chelonians and monitor lizards of Bangladesh and reported about their conservation and sexing problems. Deraniyagala (1953, 1955) provided descriptions of the taxonomy, systematics and classification of the reptiles of Ceylon (Sri Lanka). Wikramanayake and Green (1989) studied the habitat use, thermoregulation and activity pattern of *Varanus bengalensis* and *Varanus salvator* in detail and other works on monitor lizards include Wikramanayake (1995) and Rathnayake *et al.* (2003). De Silva (1999) studied habitat preference and status of the amphibians and reptiles in Horton Plains of Sri Lanka. Descriptions on the natural history of the marsh dwelling herpetofauna of Sri Lanka have also been reported (Porej, 2001).

Knowledge on the herpetofauna of India is largely from the survey and collections over last 130 years. Currently, most of these materials are largely found at the National Museum (ZSI), Kolkatta and Museum of the Bombay Natural History Society, Mumbai in India and in British Museum of Natural History, United Kingdom. The information generated from these surveys is largely pertaining to taxonomy and distribution and are mostly scattered in the *Journal of the Bombay Natural History Society* (JBNHS), *Hamadryad* and in the *Records of the Zoological Survey of India* (RZSI; e.g. Murthy, 1985, 1990). It may be noted that ecological research on the Indian reptile fauna is still in infant stage. Recent advances in taxonomy, systematics and classification on the Indian reptiles are reviewed by Das (2003). Over 30 new species of reptiles have been described within two decades or so (Inger *et al.* 1984; Das, 1991; Captain and Patel, 1997; Das and Bauer, 2000; Das and Sengupta, 2000; David *et al.* 2001; Bauer, 2002). Studies on Indian reptiles are largely limited to individual taxon or species, namely Crocodiles (Andrews and Whitaker, 1994; Vijayakumar *et al.* 1995; Whitaker and Andrews, 2003), Sea turtles (Dash and Kar, 1990; Pandav, 2001, Shanker *et al.* 2003), and *Scincella himalayanum* (Duda and Kaul, 1977). In the past couple of decades, emphases were given for resurvey to ascertain the status of certain endangered species, (e.g. Freshwater turtles and tortoises: Moll, 1986; Moll and Vijaya, 1986; Rao and Singh, 1987; Rao, 1990; Bhupathy and Choudhury, 1995; Choudhury *et al.* 2000). Distributional pattern of reptiles at macro level (Himalayas at altitudinal gradients) has been analysed by Waltner (1991).

Studies on the population and ecology of reptiles in India are largely undertaken on single species, *Varanus bengalensis* (Auffenberg, 1986), *Calotes versicolor* (Sunderesan and Daniels, 1994), *Lepidochelys olivacea* (Dash and Kar, 1987; Kar, 1992; Pandav, 2001), *Python molurus* (Bhupathy and Vijayan, 1989), *Lissemys punctata* (Bhupathy and Vijayan, 1993), *Barkudia insularis* (Rao and Rao, 1997). Baring a few extensive surveys such as in Ponmudi Hills, (Inger *et al.* 1983), Srivilliputhur forest

(Malhothra and Davis, 1991), Mundanthurai Kalakkad (Ishwar *et al.* 2001) and Nilgiri Biosphere Reserve (Daniels, 1993), exhaustive ecological studies on the reptiles of Western Ghats are scarce. A consolidated checklist of the reptiles of Tamil Nadu is available (Bhupathy, 2004).

Studies on the community ecology of the herpetofauna of India are rare. Inger *et al.* (1987) studied the herpetofaunal community in the Ponmudi Hills, Kerala. Brown (1992a) attempted to study the reptile community organisation in Chalakkudy Forests, Kerala. Brown (1992b) also made a brief attempt to study the reptile community in the scrublands near Madras. Distribution and aspects of population ecology of Travancore Tortoise along the Western Ghats range have been studied by Bhupathy and Choudhury (1995). Bhupathy and Kannan (1997b) studied the distribution, habitat and microhabitat utilisation by agamid lizards in the Western Ghats. A more recent study on the impact of rain forest fragmentation on small mammals and herpetofauna provided some information on the response of reptiles to such changes (Ishwar *et al.* 2001 and 2003).

The above review shows that India is far behind in ecological research on reptiles compared to the diversity it harbours. It may be noted that many species may get extinct before they are discovered or rediscovered as habitat destructions and alterations of natural forests are rampant. Species conservation plans without the understanding of their ecology will be futile (Frazier, 1992b). Hence, the present study was initiated in the high altitude Southern Montane Wet Temperate Forest (Shola) and Grassland ecosystem of the Western Ghats.

CHAPTER- II

STUDY AREA

2.1. WESTERN GHATS

The Western Ghats is one of the 25-biodiversity hotspots of the world (Myers *et al.* 2000). Geographic position, varied topography, climate and forest types make this hill range rich in biodiversity. It is a chain of mountains that extends from the Tapti (Tapi) River (21°N) in Gujarat to Kanyakumari (Cape Comorin; 8°N), Tamil Nadu, the southern most tip of Indian Peninsula (Plate.2.1). Geologically these Ghats fall into two sectors; (1) The Ghats north of Krishna basin formed of fragile Basalt rocks of the Deccan Trap (Vajravelu and Vivekananthan, 1996) and (2) South of Krishna basin formed of pre-Cambrian archean, crystalline hard rocks such as granites, schist, gneiss and quartzites. The highest peak of this hill range is Anaimudi (2695m) followed by Doddabetta (2637m), which are found, in the later sector. Descriptions on the soil types of Western Ghats are available in Seth and Yadav (1959). Various forest types and a large number of Protected Areas are found along the Western Ghats ranges (Puri *et al.* 1989; Rodgers and Panwar, 1988).

2.2. NILGIRI BIOSPHERE RESERVE

The Nilgiri Biosphere Reserve (NBR; $10^{\circ} 45'-12^{\circ} 5' \text{N}$ and $76^{\circ} 10'-77^{\circ} 10' \text{E}$; Plate 2.2) was formed under the aegis of Man and Biosphere (MAB) Programme of the Ministry of Environment and Forests (MoEF), Government of India. This reserve is a part of the Western Ghats Biogeographic Zone (Rodgers and Panwar, 1988), and encompasses about 5520 km^2 covering three states; Karnataka, Kerala and Tamil Nadu. Forest types of this Biosphere Reserve vary from Tropical Thorn Forests (scrub land) in low altitudes to Wet Temperate Forest (Montane Shola) Grasslands in the high altitudes. Apart from several reserve forests, important Sanctuaries and National Parks, namely Silent Valley and Mukuruthi National Parks and Wayanad, Mudumalai, Bandipur and Nagarhole Wildlife Sanctuaries are found in NBR.

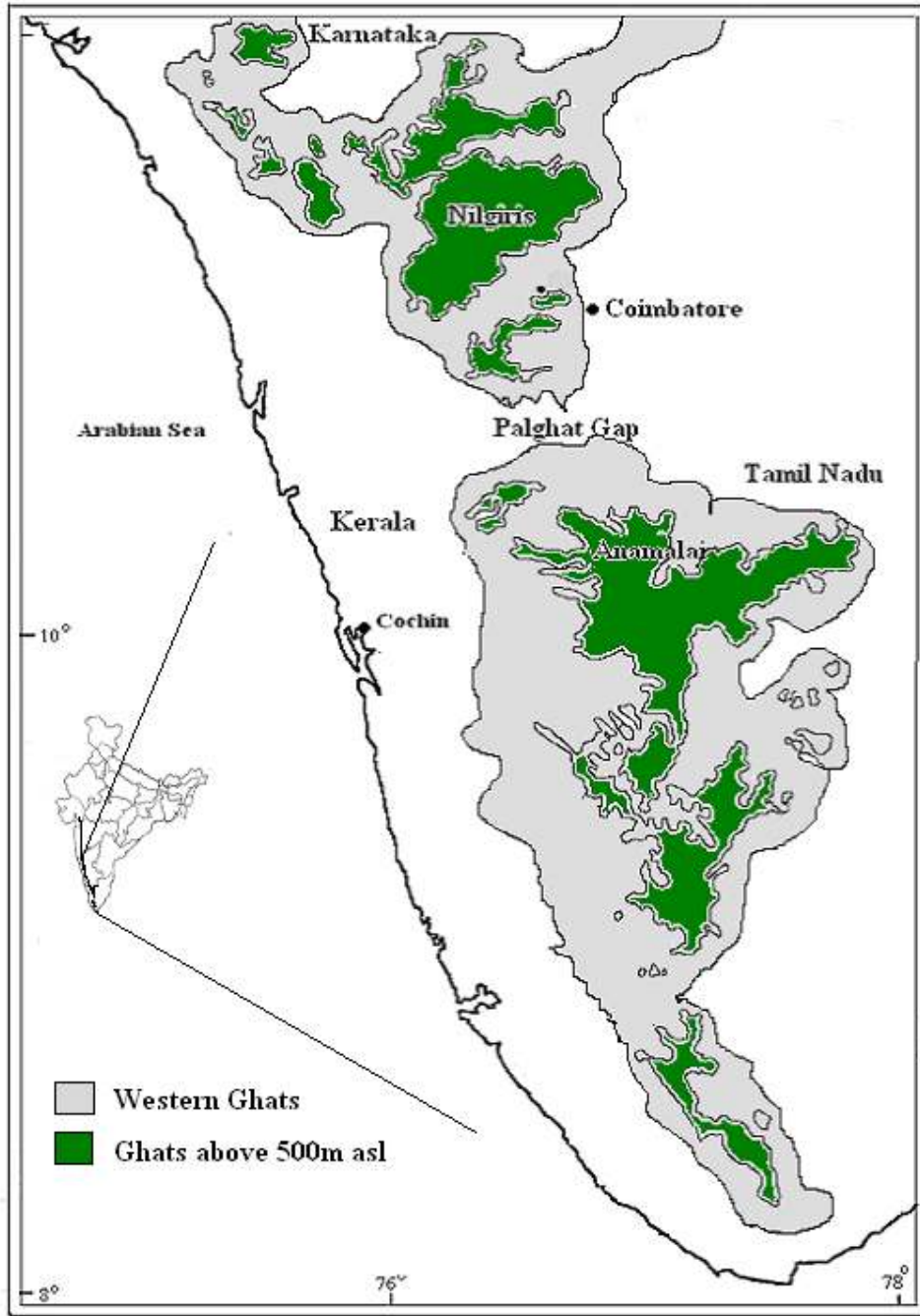


Plate 2.1. Map of southwestern India showing the Western Ghats and Nilgiris.

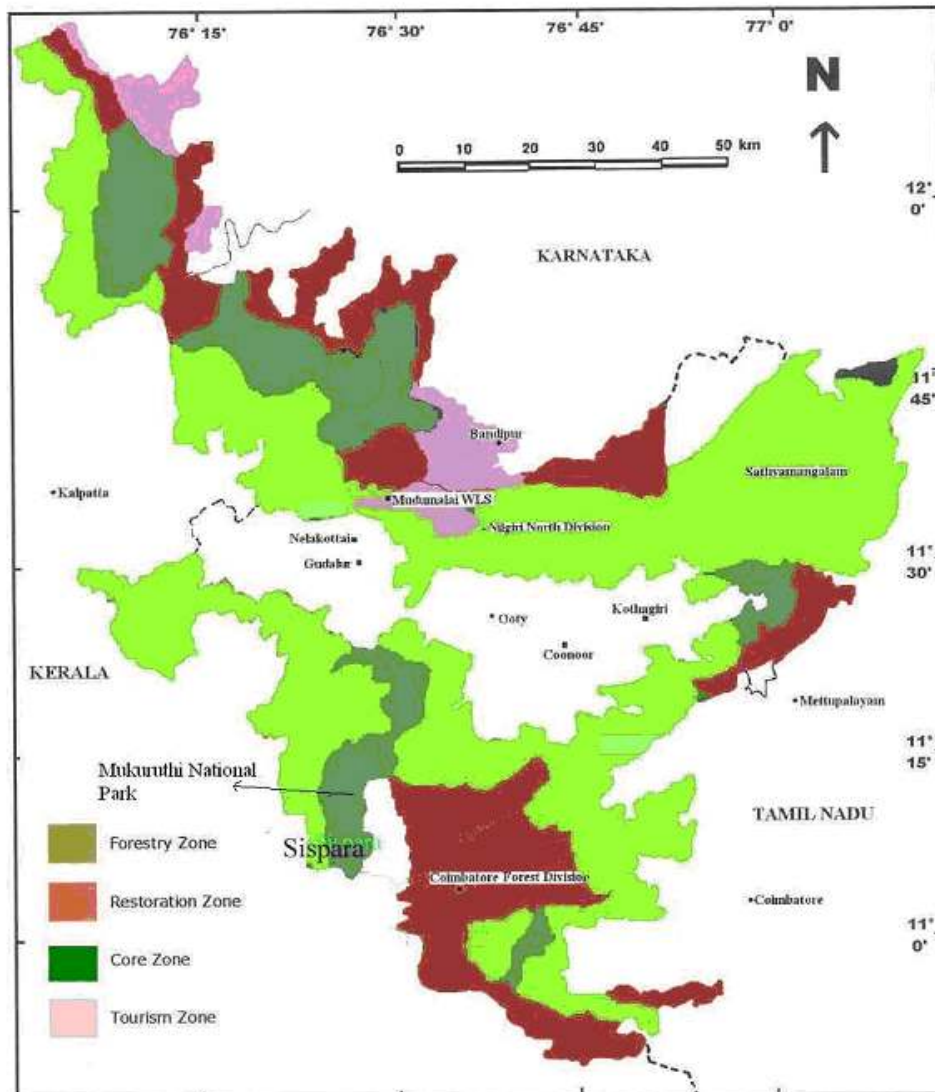


Plate 2.2. Nilgiri Biosphere Reserve, Western Ghats. Source: Bhupathy and Nixon (2004).

It is reported that in the past, majority of the high altitude (2000 - 2500 m) areas of NBR was covered with Grasslands interspersed with Southern Montane Wet Temperate Forests (Champion and Seth, 1968) herein considered as Montane Shola. However, an estimated 80% of Shola forests and Grasslands have been lost largely due to the conversion of these habitats into monoculture plantations (Sarvanakumar *et al.* 1993; Table 2.1). Hydroelectric dams had also submerged a considerable portion of this unique ecosystem.

2. 3. UPPER NILGIRIS AND MUKURUTHI NATIONAL PARK

2.3.1 Location and Topography

Geologically the Nilgiri district can be divided into four distinct regions: (1) Upper Nilgiri plateau, (2) the Nilgiri Wayanad, (3) the Sigur plateau and (4) the outer slopes (The Nilgiri Gazetteer, 1995). The present study was conducted in Upper Nilgiri plateau (above 2000 m msl), especially in and around the Mukuruthi National Park (MNP; 11° 10' to 11° 22' N and 76° 26' to 76° 38' E), including the adjacent Nilgiri South Forest Division and tea estates (Plate 2.3). The MNP is located on the western fringe of the Upper Nilgiri plateau. The area of MNP is 78.46 km² and is largely made up of Metatropic Archean (Precambrian) rocks such as gneiss, charnokites and schist (The Nilgiri Gazetteer, 1995). The highest peak in the study area is Kolaribetta (2630 m); other peaks include Mukuruthi (2556 m) and Nilgiri (2477 m). Most of the parts of Nilgiri hills are made up of charnockite rocks of Nilgiris gneiss varying from acid to ultra basic ones. The western edge with the granite cliffs drops from 2400 m to plains. The study area is criss-crossed by numerous streams and most of them drain into the river Bhavani, a tributary of river Cauvery.

2.3.2. History

This area was first declared as Sanctuary in 1980 and upgraded into National Park in 1990. It is a part of the Nilgiri Biosphere Reserve. Tribal of the area are Thothavas and Thodas, and no settlements are found within the National Park. In 1866, Britishers introduced Trout (*Salmo iridius*)

in the Nilgiri district. A Trout hatchery had been set up at Avalanche during 1909, for rearing and the hatchlings were introduced in to the Mukuruthi Lake for game hunting.

2.3.3. Climate

Descriptions on the weather and climate of the Nilgiris are available in Legris and Blasco (1969). Humidity of the area is as high as 80-90% during the southwest monsoon (June–September). The mean temperature of the coldest month is 15°C. Night frost may occur from the third week of October to second week of April. On the whole, the Upper Nilgiri plateau has a mild day temperature (Fig.2.1). Mean maximum temperature (26°C) was recorded during December. Mean minimum temperature (3°C) was recorded during January. The area receives rain from both southwest and northeast monsoons. Average annual rainfall of the area during 1998 - 2001 was 2778 mm. The rainfall ranged between 2160 and 3132 mm. The heaviest rainfall was recorded during July (Fig. 2.2). Winter and early summer (November-April) were comparatively dry with out notable rainfall.

2.3.4. Vegetation

Wide range of climate and peculiar topographic features of the Nilgiri Biosphere Reserve provide opportunity for a diversity of its vegetation communities. Vegetation of the Nilgiri plateau is one of the interesting subjects with respect to Phyto-geography. Natural vegetation of the plateau consists of vast stretches of Grasslands interspread with numerous isolated, compact, sharply defined and usually small woodlands, which are known as Shola forest that fall under a category of tropical rain forest occurring under extreme and limiting conditions of the montane locations (Plate 2. 4). Floristic of Shola includes tropical as well as temperate elements. The Shola forest occupies the depressions and valleys and is classified as Southern Montane Wet Temperate Forest (Subgroup II A/ I; A/ I; type II A/C I; Champian, 1936; Champian and Seth, 1968).

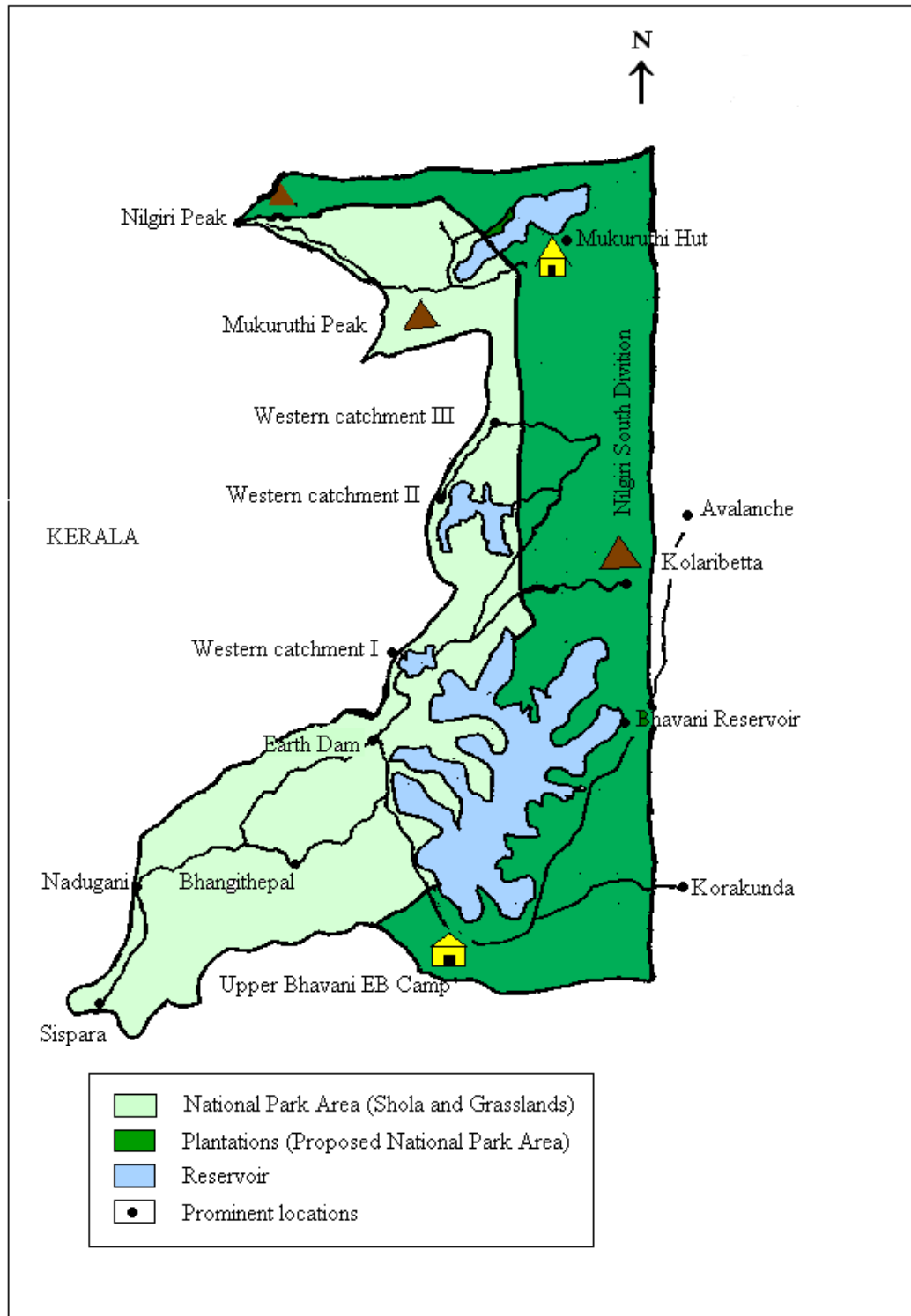


Plate 2.3. Mukuruthi National Park, Nilgiri Biosphere Reserve, Western Ghats.

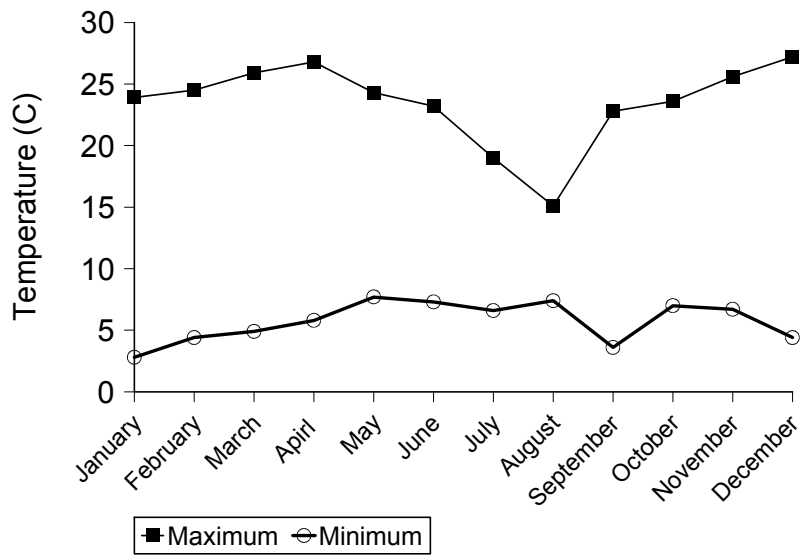


Fig.2.1. Temperature (max-mini) recorded in the Upper Nilgiris, Western Ghats.

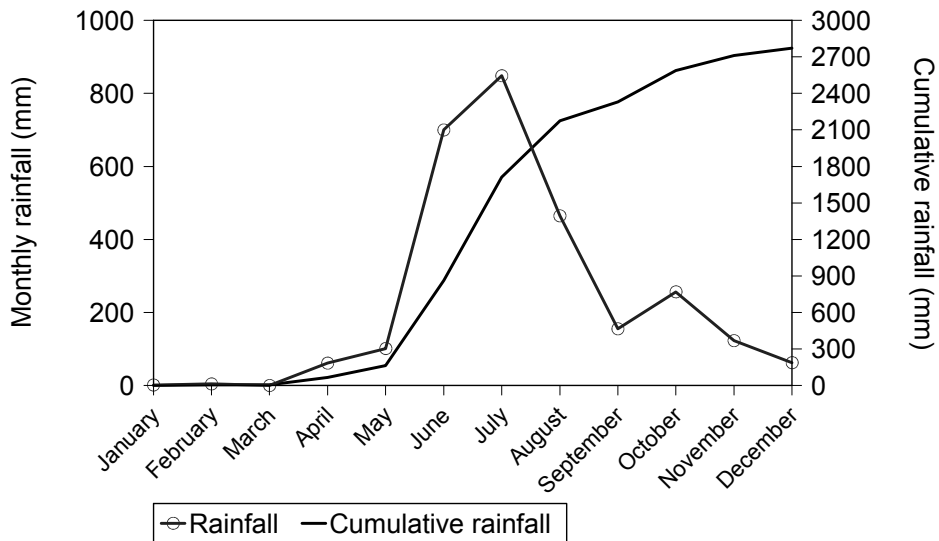


Fig. 2.2. Rainfall pattern of the Upper Nilgiris, Western Ghats.

Various researchers have documented the flora of Nilgiris. Sharma *et al.* (1983) reviewed the flora of this region and reported 2760 species of vascular plants including 2611 angiosperms belonging to 942 genera and 163 families. Remaining species belong to gymnosperms and ferns or fern allies. Blasco (1970) observed 82 species endemic to the higher altitudes of the Nilgiris. The Sispara slope leading to the Silent Valley National Park was considered as an area of high biological diversity (Sharma, 1977). Sukumar *et al.* (1993, 1995) studied the climate change and its impact on tropical montane ecosystems in south India. Late quaternary vegetational and climate changes in the tropical peats of south India have also been reported (Rajagopalan *et al.* 1997).

2.3.5. Shola Forest and Grasslands

The Southern Montane Wet Temperate Forest is herein considered as Shola forest. This forest is different from that of other forest types of the Western Ghats, and is characterized by high humidity because of low evaporation rate. The moisture content of the soil is also high. Soil and air temperature inside the Shola is more equable than that of outside. Plant species distribution in Shola is regular and dense in the edges than the interior portion (Murugan, 1996). Several reservoirs commissioned during mid 1950s in the Upper Nilgiris mainly for generating electricity inundated several hundred hectares of Shola and Grasslands (The Nilgiri Gazetteer, 1995). Based on records, it is estimated that nearly 80% of the Shola and Grasslands have been lost since 1850 (Table 2.1; Saravanakumar *et al.* 1993). According to Vijayan *et al.* (2000), the western portion of Upper Nilgiris, especially the Mukuruthi National Park and its environs have about 64% of Grasslands, 13% Shola and 19% of Wattle plantation. A list of common tree, shrub and grass species of this area is given in Appendix 1.

Table 2.1. Comparative account of habitat loss (Area in Km²) of Upper Nilgiris, Western Ghats; Source: website.www.nilgiribioshpere.reserve.com

Habitat	Year	
	1849	1992
Shola	86.0	42.25
Grassland	298.75	47.00
Cultivation	108.75	124.00
Tea	0	114.75
Wattle	0	97.75
Eucalyptus	0	51.50

2.3.6. Plantations

The Upper Nilgiri plateau had been the scene of numerous experiments to naturalize exotic species. Australian species such as the Wattle, Eucalyptus and Pine were introduced during early 1840s. The attempt to introduce species of the temperate regions of India and Europe has generally not been successful in this region. The climate of the Nilgiri plateau appears to be unsuitable for the growth of conifers. *Calitris rhomboidea* of Australia is the only conifer that established in the area to some extent. *Acacia decurrens* (green wattle) and *Acacia mollissima* or *mearnsii* (black wattle) have also survived well (Plate 2.5). Black wattle is most favored by the tanning industries and hence, the cultivation of wattle is now confined mainly to this particular species. The Black wattle had been planted for the reason of high yield of the most desired tanning extract. This species regenerates naturally from seeds in cleared plantation areas, and it is observed that a light fire running over the harvested areas results in their high regeneration.

Unfortunately, till recently, the Grasslands in India have not been viewed as a habitat. With the impetus given by the National Forest Policy (1952), an attempt was made to convert over 90% of the Grasslands of the Nilgiri plateau into plantations dominated by the above exotic species (The Nilgiri Gazetteer, 1995). This has destroyed large tracts of natural Grasslands. The extent of commercial forestry (eucalyptus, wattle and pines) should be reviewed so that the area of such plantations can be phased out to the

unavoidable minimum over a period. Agriculture was practically absent in the high ranges till the cash crop plantation practice was brought in by the European planters during late 18th century. Tea estates are largely located on the fringes of this Park, and Kora Kundha Tea estate has been monitored during the present study (Plate 2.6). The Wattle plantations in the area are partly disturbed due to logging operation, and the Tea plantations are prone to regular human disturbance because of routine maintenance activities.

2.3.7. Fauna

The Nilgiri tahr, *Hemitragus hylocrius* endemic to the Western Ghats in Southwestern India, is one of the rare mountain ungulates inhabiting the Shola and Grasslands of Mukuruthi National Park. Some aspects of its ecology have been studied by Sumithran (1997) and Murugan (1997). Also, small mammal community has been studied in Shola and plantations (Shanker, 2001; Shanker and Sukumar, 1999). Nilgiri Wildlife and Environment Association and Forest Department have studied some aspects of the ecology of small carnivores in recent years (Haridoss, 2001). Seventy-four species of birds mostly of hill dwellers have been reported from Upper Nilgiris. Ecology and behaviour of Black and orange flycatcher (*Muscicapa nigrorufa*) has been studied in the area (Khan, 1977). Birds such as the Nilgiri laughing thrush and Nilgiri pipit are endemic to the high altitude. Data on the population and habitat use by Nilgiri laughing thrush (*Garrulax cachinnans*) is available (Vijayan *et al.* 2000).

Wall (1922) provided some information on the herpetofauna of Nilgiri hills. The Nilgiri Gazetteer reports 86 reptiles and 30 species of amphibians from these hills. Daniels (1993) has highlighted the Importance of Nilgiri Biosphere Reserve and its role in conserving Indian Biodiversity. All these reports are general and not particular to any specific locality. No exhaustive ecological study on the reptiles of Upper Nilgiris has been undertaken.

CHAPTER- III

POPULATION

3.1. INTRODUCTION

Population is defined as a group of organisms of the same species, which live together in one geographical area at the same time (Odum, 1971; Begon *et al.* 1996a, b; Chapman and Reiss, 2000). Population of individual species is a product of organic evolution that, in a multitude of different assemblages, makes up the communities of living organisms. Some important aspects or characters of population are number (abundance and density), sex ratio, size class distribution, and natality and mortality. Herpetofauna have ecological and physiological characteristics that make them particularly sensitive to large and small-scale environmental changes (Herbeck and Semlitsch, 2000). The amphibians and reptiles are perhaps best indicators of the availability of microhabitats in the ecosystem (Jones, 1986).

Population changes may reflect the availability and distribution of resources relative to the physiological requirements of an organism (Whiting *et al.* 1997). Data obtained from the reptile population studies may be useful to prepare conservation and management plan for an area as these species are highly parochial and utilise local resources. Several researchers (MacArthur, 1972; Stevens, 1992; Navarov, 1992; Vazquez and Girmish, 1998; Sanders, 2002) have reported monotonic decrease in species richness with increasing altitude. Pianka (1986) has reported increase of species richness towards lower latitude. Ehrlich (1986) reported that theoretically sex ratio of an animal population is one, and has been recorded so in various species of reptiles; *Uta stansburiana* (Pianka, 1975), *Opheodrys aestivus* (Plummer, 1997), *Agama agama africana* (Enge *ET al.* 2004) and *Lygosoma laterale* (Brooks, 1967). However, this ratio may deviate as well; in Fijian crested iguana, *Brachylophus vitiensis* the ratio was male biased (1: 0.2; Cogger and Sadlier, 1986) and in species such as *Kachuga tecta* and *K. smithii* (in Jammu and Kashmir,

India), it is female biased (1: 2.03; Duda *et al.* 1993). Variations in sex ratio may have important consequences in the regulation of population. Biased sex ratios could be due to factors such as the incubation temperature (Lovich, 1996).

The body size of an organism is its most obvious characteristic, and has enormous life-history implications (Shine *et al.* 1998). Comparative analysis have revealed a strong association between body size and life-history traits, such as age at maturity, reproductive output, and the direction and degree of sexual size dimorphism (Calder, 1984; Harvey and Pagel, 1991; Shine, 1994).

Species inventories for a particular habitat or landscapes are required for conservation and management (Southwood and Henderson, 1999). Complete inventory of a species is rarely feasible, and hence, estimating total number of species and their relative abundance of an area using a reliable statistical method is important. Poor sampling may result in misleading patterns in community structure as reported by Brown and Parker (1976). Rarefaction curve has been used to determine sampling intensity to achieve an accurate estimate of number of cave inhabiting species (Schneider and Culver, 2004). Species accumulation analysis has been utilised to estimate the herpetofauna of Nosy Be, Northwest Madagascar (Andreone *et al.* 2003). Various estimators are available to predict the number of species distributed in a given locality. They include rarefactions, jackknives and bootstrap estimators. Species accumulation curves can indicate the expected number of species from a collection of random samples and represent what is statistically expected from the area (Gotelli and Colwell, 2001). Hellmann and Fowler (1999) provide descriptions on the bias, precision and accuracy with respect to species richness measures.

As noted earlier, studies on the population ecology of reptiles in India are scanty (Daniels, 1994), barring species such as the Olive ridley sea turtles,

Lepidochelys olivacea in Orissa coast (Kar and Dash, 1984; Shanker *et al.* 2003) and Pythons, *Python molurus molurus* in Keoladeo National Park, Rajasthan (Bhupathy and Vijayan, 1989; Bhupathy, 1990). Distribution of forest floor reptiles in the rain forest of Kalakad-Mudanthurai Tiger Reserve, Western Ghats, has been studied by Ishwar *et al.* (2001). Bhupathy and Kannan (1997a) and Ishwar *et al.* (2003) provided information on aspects of the population of agamid lizards in the Western Ghats. However, all the above-mentioned studies deal only with one or two aspects of the population of a taxon. Nixon and Bhupathy (2004) attempted to quantify the impact of plantations on the reptiles of Upper Nilgiris. This Chapter describes certain aspects of population of reptiles inhabiting the Upper Nilgiris, Western Ghats. Parameters covered include species richness, density, morphometry and distribution.

3.2. METHODOLOGY

Reptiles are cryptic and occur in low densities, their activities are seasonal and hence difficult to study. Techniques used for studying terrestrial amphibians and reptiles are considerably similar. Heyer *et al.* (1994) suggested various procedures for sampling herpetofauna, but these methods have largely been used in temperate conditions (in the Western countries), and their applicability or limitations in tropical ecosystems are largely unknown. Prominent reptile sampling methods include Transect, Quadrat, Pitfall, Funnel Trap, Road Cruising and Visual Encounter Survey. However, lack of standardised sampling methodology with respect to herpetofauna has been a major concern (Pearman *et al.* 1995), and it is particularly true for tropical Asia. Due to various behaviour, macro and microhabitat selection and seasonality in their activity, no single method is sufficient for successful sampling of reptiles. In the present study, Area (Quadrat) and Time (Visual Encounter Survey) constrained sampling techniques were used for quantitative data collection.

3.2.1. Quadrat Sampling

Quadrat sampling includes searching for reptiles in an area, and is also known as area constrained sampling. The quadrat size and number may vary depending upon target (study) animals. Several researchers used quadrats with various dimensions, which ranged from 30X30m (Thorpe and Crawford, 1979) to 3X6 m (West and Skelly, 1997). Bhupathy and Kannan (1997a), used 25X25 m quadrats for studying agamid lizards in the Western Ghats, and Schlaepfer and Gavin (2001) used 10X10m quadrats for surveying lizards and frogs in tropical forest fragments of Fila Cruces, Costa Rica. Many researchers used smaller quadrats as well for sampling herpetofauna (i.e. 8X8m; Lloyd *et al.* 1968; Das and de Silva, 1998; Jaeger and Inger, 1994; Martin-Vallejo *et al.* 1995). Much smaller quadrats (3X6m) have also been used to survey woodland salamanders and fossorial snakes such as Eastern worm and ring-necked snakes (West and Skelly, 1997). Quadrat method may be difficult to use effectively in habitats with dense ground cover, on irregular or steep terrain. This sampling may not be effective when the study animals are fast moving, as they would leave the quadrat before the observers detect them. One of the important preconditions of this sampling is that quadrats must be placed randomly.

3.2.2. Visual Encounter Survey

Visual Encounter Surveys (VES) involve searching an area or habitat (Campbell and Christman, 1982), recording all animals encountered. To avoid complications of factors such as visibility, fixed time may be used to survey in all habitats to be compared. As in the quadrat method, all microhabitats were searched. Species richness and their relative abundance may be calculated from this data. Number of animals located is expressed in terms of effort (e.g. encounter/ effort).

The VES is also known as time constrained surveys, if fixed duration is used for sampling. This method may yield only semi quantitative data, and the data may not be useful for determining density, as the area sampled is

unknown. All individuals actually present in an area are unlikely to be visible during the survey. However, using visual encounter surveys in conjunction with mark-recapture method, density can be estimated reasonably. Major limitations with visual encounter surveys are unequal success in sampling various microhabitats and habitat types. These limitations may be avoided by strictly giving equal search effort in each habitat types. Lips (1999) and Toral *et al.* (2002) used visual encounter survey to study the populations of anurans in Western Panama and Ecuador. This method has been used most extensively for rapid evaluation of large forest areas, especially in uniform habitats, where visibility is good. Visual encounter survey is better suited, especially to study reptiles dwelling forest under story and litter.

Generally, such surveys are better suited for inventorying certain target species, because not all species in an assemblage can be observed equally (Crump and Scott, 1994). A visual encounter survey is often the best way to survey species that are rare or unlikely to be caught with traps (Crump and Scott, 1994). In this method, searching is not depending on the activity of the animals but intensity of the effort. Visual encounter surveys have been used to study the reptiles of the Western Ghats (Bhupathy and Kannan, 1997a; Giri and Chaturvedi, 2001; Bhupathy and Nixon, 2004).

In the present study, 10X10 m quadrats were used to quantify reptile populations. Random quadrats were laid in various habitats (Grasslands, Shola, and Wattle and Tea plantations), and searched for reptiles (Campbell and Christman, 1982). 10X10 m quadrat was laid using a nylon rope tying the corners with wooden pegs. The interior portion of the quadrat was not disturbed to avoid flushing of the reptiles. Two or three field personnel searched the quadrat area systematically checking for all microhabitats including boulders, grass clumps, fallen logs and tree trunks. Approximate time taken for a thorough searching of a quadrat took about 30-50 minutes. After a reconnaissance survey for over six months, regular

monthly field samplings were conducted from October 2000 to October 2002. Sampling was restricted to day hours between 0800 and 1500 hrs due to cold climatic conditions prevailing in the area, activity of the species and logistic support in the field. Sampling effort in different habitats was largely based on the extent of the same.

On locating a reptile species, atmospheric temperature was taken using a digital thermometer at each observation site. Morphometry (snout-vent length, tail length and weight), sex and breeding status of the reptiles were assessed based on the presence of developing eggs in female and breeding colour in males. Species identification was done following Smith (1935, 1943). Identity of the species was confirmed by comparing specimens deposited in the Museum of the Bombay Natural History Society (BNHS), Mumbai.

3.2.3. Data Analysis

Data analyses include aspects such as species richness, diversity, biomass, density and abundance.

1. Species richness: Number of species observed.
2. Non-parametric estimators (Chao, Bootstrap, and Jackknife) were used to estimate number of species (EstimateS, Version 7; Colwell and Coddington, 1994; Colwell, 2004).
3. Species diversity (H') = $-\sum p_i \cdot \ln p_i$ (Shannon and Wiener, 1949).
Where, p_i = Proportion of total sample belonging to i^{th} species,
 \ln = Natural logarithm.
4. Hill's diversity (N_1) = $e^{H'}$
Where, H' = Species diversity.
5. Encounter rate = No. of individuals sighted/total hours surveyed.
6. Relative abundance of a species (%) = (Number of observation of a species/ total observation of all species) X100.
7. Density = No. of individuals sighted/ area sampled.
8. Biomass of a species was calculated as follows.

Biomass= mean body weight of the species X density of the species.

9. Impact of plantation on the reptiles (I) = $(d_1-d_0)*100/d_0$, where d_0 = Species density in shola and Grasslands (natural habitat), d_1 = Species density in a particular plantation; + Positive impact, - Negative impact.

3.3. RESULTS

3.3.1. Reptile Sampling Techniques

Pooled data at species level from various habitats using quadrat and visual encounter methods showed largely a similar trend in species detection (Fig. 3.1). Data collected using both these methods were used for determining species diversity, richness and abundance of reptiles.

During the study a total of 27.06 ha were sampled in various habitats and only on an average of 5 % of the quadrats had reptiles (Table 3.1). In Grasslands the highest of 6.2 % of quadrats had reptiles and the lowest (3.2 %) in the Shola. In all, reptiles were searched for 680 hours following VES. The encounter of reptiles was highest in Grasslands (1.8 reptiles/hr) and the lowest in Tea (0.38 reptiles /hr, Table 3.2). The data generated from quadrat method was more quantitative compared to visual encounter survey. However, both VES and quadrat method gave the same trend in the results (Fig. 3.1). This could be due to the large sampling effort. VES is an ideal technique for inventory studies.

Table 3.1. Number of reptiles detected during quadrat (10X10) sampling in Upper Nilgiris, Western Ghats.

Habitat	No. of quadrats	No. of quadrat with reptiles	No. of individuals	No. of species	No. of reptiles/ ha
Grassland	840	52 (6.2%)	125	7	14.9
Shola	345	11 (3.2%)	51	2	14.6
Wattle	840	42 (5%)	69	5	8.2
Pine	201	4 (4%)	10	2	6.9
Tea	480	27 (5.6%)	27	3	5.6
Total	2706	136 (5.03%)	282	7	10.42

3.3.2. Reptile Fauna

A total of 875 reptiles belonging to eight species were recorded using both Quadrat and Visual Encounter Surveys (VES). This includes one species each of lizards belonging to Geckkonidae (geckoes), Agamidae (Garden lizard) and Scincidae (skink) and five species of snakes (Plate 3.1 & 3.2).

Table 3.2. Number of reptiles detected during visual encounter surveys in Upper Nilgiris, Western Ghats.

Habitat	No. of Hours searched	No. of species observed	Individuals recorded	Reptiles/h
Grassland	156	6	292	1.87
Shola	230	5	115	0.50
Wattle	144	7	121	0.84
Pine	30	2	19	0.63
Tea	120	4	46	0.38
Total	680	8	593	0.87

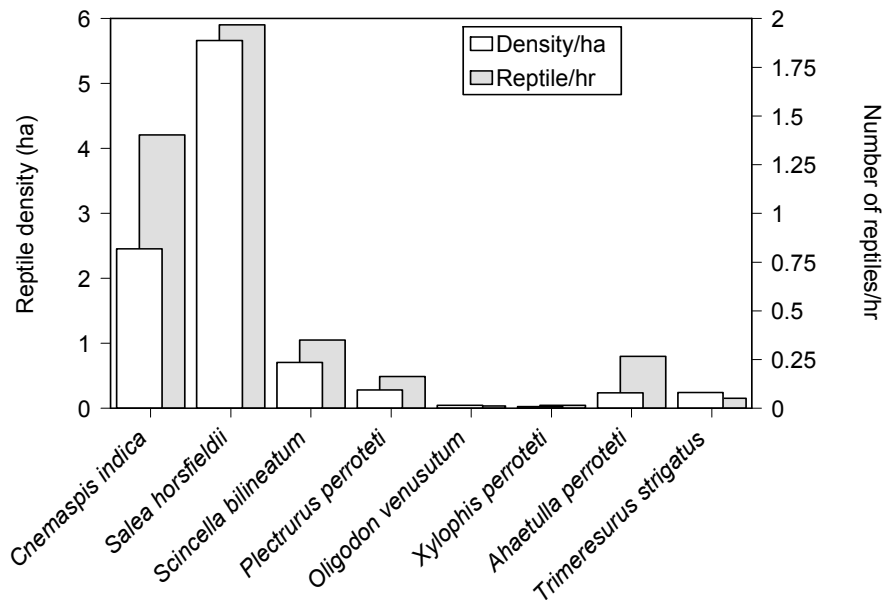


Fig.3.1. Comparison of Quadrat and Visual Encounter Survey techniques with respect to detection of reptiles in Upper Nilgiris, Western Ghats.

Apart from these, additional three species were observed opportunistically within 10 km of this Park. They were *Psammophilus blanfordanus* (Rock agama), *Ptyas mucosus* (Rat snake) and *Xenochrophis piscator* (Checkered keelback water snake). Including all, one species each of

gecko, skink and two species of agamid lizards and seven species of snakes were observed in the Upper Nilgiris. Further analysis was restricted to eight species found in close vicinity to the Mukuruthi National Park and the description is restricted only to these species in the following sections. Distributional status of reptiles observed in the Upper Nilgiris is given in Appendix 2.

Cnemaspis indica

Round pupil differentiates *Cnemaspis* from all other geckoes of the Western Ghats. Lateral sides of the body (flanks) without spine-like projections, dorsal side with similar keeled scales, which are smaller than the ventrals, and males with 4 - 5 femoral pores are important identification features of this species. It is endemic to the Western Ghats, and has been recorded from Nilgiri, Coorg and Malabar Hills (Smith, 1935). A total of 202 geckoes were considered for morphometry analysis. Mean Snout-Vent Length (SVL), tail Length (tL) and weight (wt) of them were 3 ± 0.6 cm, 2.9 ± 1.1 cm and 1.6 ± 0.65 g respectively (Table 3.3). This species grows up to 4 cm in SVL. Number of males was marginally higher than females (male: female=1.1:1). It has extended breeding season from October to April, and lays eggs communally under stones or in crevices (Bhupathy and Nixon, 2002).

Salea horsfieldii

Among the agamids of Western Ghats, *Salea* lizards have unequal dorsal scales. Two species have been reported from this hill range (Smith, 1935). Gap between the nuchal and dorsal crests and absence of shoulder fold separate *Salea horsfieldii* from its congener, *Salea anamallayana*. Male lizards have prominent nuchal and dorsal crests, but dorsal crest is not prominent in females. *Salea horsfieldii* is endemic to the Western Ghats and is reported from 1800-2500 m msl of the Nilgiri and Palni Hills (Smith, 1935). The reported occurrence of *Salea horsfieldii* in Palni Hills (Smith, 1935) requires confirmation. In all, 310 lizards were measured during this study and the mean SVL, tL and wt are given in Table 3.3.



Indian day gecko
Cnemaspis indica



Nilgiri or Horsfield's salea
Salea horsfieldii



Two-lined ground skink
Scincella bilineatum



Perrotet's shieldtail snake
Plectrurus perroteti

Plate 3.1. Reptiles of Upper Nilgiris



Narrow-headed snake
Xylophis perroteti



Black spotted kukri snake
Oligodon venusutum



Bronze-headed vine snake
Ahaetulla perroteti



Horse-shoe pit viper
Trimeresurus strigatus

Plate 3.2. Reptiles of Upper Nilgiris

Males were comparatively larger (SVL- 10 cm) than females (SVL- 7.5cm). Number of males in the population was marginally higher than females (sex ratio 1.1:1, male: female). Barring monsoon (June-July and September) females had developing eggs throughout the year. The smallest female with eggs measured was 4.5 cm in SVL indicating the size at maturity of this species.

Scincella bilineatum

Scincella bilineatum may be identified based on the presence of transparent disc on the lower eye-lid, 22-26 scales round the mid body, 16-20 lamellae under the fourth toe and four pre-anal scales. The pre-anals are pointed posteriorly in males. *Scincella bilineatum* is closely related to *S. laterimaculatum*, which will have only one pair of pre-anals, and is endemic to the Western Ghats (Smith, 1935). Recently, all species of *Scincella* distributed in the Western Ghats have been assigned to a new genus *Kaestlea*, and *Scincella bilineatum* as *Kaestlea bilineata* (Eremchenko and Das, 2004). During this study 77 skinks were measured. Mean SVL, tL and wt of them were 4.4 ± 1.1 cm, 5.5 ± 2.1 cm and 3.3 ± 1 g respectively (Table 3.3). Sex ratio of *S. bilineatum* is close to one (male: female; 1.2: 1, n = 77).

Table 3.3. Morphometry of reptiles observed in Upper Nilgiris, Western Ghats; \pm is Standard Deviation; all linear measurements in *cm* and weight in *gram*.

Species	Snout-vent length	Tail length	Weight	Sex ratio
<i>Cnemaspis indica</i> (202)	3 ± 0.6	2.9 ± 1.1	1.6 ± 0.65	1.1:1
<i>Salea horsfieldii</i> (310)	5.49 ± 1.5	12.04 ± 4.3	6.5 ± 3.8	1.1:1
<i>Scincella bilineatum</i> (77)	4.4 ± 1.1	5.5 ± 2.1	3.3 ± 1.0	1.2:1
<i>Plectrurus perroteti</i> (34)	16.7 ± 5.3	1 ± 0.4	6.4 ± 3.2	-
<i>Oligodon venusutum</i> (3)	27.2	3.4	13.5	-
<i>Xylophis perroteti</i> (6)	28.8 ± 13.9	3.7 ± 3.4	19.4 ± 18.8	-
<i>Ahaetulla perroteti</i> (44)	31.02 ± 6.6	10.9 ± 2.6	18.07 ± 8.04	1.1:1
<i>Trimeresurus strigatus</i> (12)	24.4 ± 7.04	3.5 ± 0.8	17.2 ± 10.5	1:1.4

Number in parentheses indicates sample size.

Plectrurus perroteti

Shieldtail snakes are largely endemic to the Western Ghats (Smith, 1943; Rajendran, 1985). *Plectrurus perroteti* may be identified from other shield tails based on the laterally compressed tail with two simple spines on the terminal scute, 15 rows of scales round the mid body, 152-180 ventral and 6-12 caudal scales. The distribution of *P. perroteti* is restricted to Nilgiri and Anamalai Hills. Mean morphometry of 34 snakes measured 16.7 ± 5.3 cm (SVL), 1 ± 0.4 cm (tL) and 6.4 ± 3.2 g (wt). This is an ovoviviparous species, giving birth to 3-6 young ones during July- August (Smith, 1943; Rajendran, 1985).

Oligodon venusutum

Oligodon venusutum may be identified based on the presence of 17 rows of scales round the mid body, single anterior temporal scale, elongated post nasal and absence of loreal scale. It is endemic to the Western Ghats and, it is reported to occur in Wayanad, Nilgiri, Palni, Cochin and Travancore Hills (Smith, 1943). Only a few individuals of this species were observed during three years of this study, which indicates its rarity.

Xylophis perroteti

Two species of narrow headed snakes (Genus: *Xylophis*) are known from the Western Ghats. *Xylophis perroteti* is differentiated from the other species (*Xylophis stenorhynchus*) by the combination of following features; (i) head narrow and not distinct from the neck (ii) 13 rows of scales around the mid body and (iii) presence of small internasal, and larger supraocular compared to post ocular. Anterior genials are large and are in contact with the ventral scales. The upper parts of the snake is brown and the under side is yellow with black spots. It is an endemic species reported only from Nilgiri and Palni Hills of the Western Ghats. Mean morphometry of six snakes is given in Table 3.3.

Ahaetulla perroteti

Ahaetulla perroteti may be identified from its congeners by the

combination of following characters; 13-15 rows of scales round the mid body, one pre and post ocular, absence of loreal scale and dermal projection on the snout. *Ahaetulla perroteti* is endemic to the Western Ghats, and is distributed in Nilgiri, Anamalai and Agasthiyamalai Hills (Smith, 1943). Mean SVL, tL and wt of 44 snakes measured 31.02 ± 6.6 cm, 10.9 ± 2.6 cm and 18.07 ± 8.04 g respectively (Table 3.3). Sex ratio of this species was close to one (male: female, 1.1:1, n = 44).

Trimeresurus strigatus

Trimeresurus strigatus may be distinguished from other pit vipers of the peninsular India based on the presence of small internasal, 21 rows of keeled scales round the mid body and single row of scales between labials and sub-oculars. Common name of the species is based on the presence of a pale buff horse- shoe mark on the nape. *Trimeresurus strigatus* is distributed in Nilgiri, Anamalai, Palni and Tirunelveli Hills of the Western and Shevroy Hills in the Eastern Ghats (Smith, 1943). Mean SVL, tL and wt of 12 snakes measured 24.4 ± 7.04 cm, 3.5 ± 0.8 cm and 17.2 ± 10.5 g respectively.

3.3.3. Population Attributes

Species Richness

Data from both VES and Quadrat sampling were used to find out the species accumulation patterns in various habitats. Due to small sample size and area, data from Pine plantations were excluded from this analysis. Including opportunistic observations, data from Quadrat and VES were used to find out the simple richness S_{sim} (Hellmann and Flower, 1999), which is only eight species. Estimators such as Chao, Jackknife, Bootstrap and Cole rarefaction were used to estimate the number of species in each habitat. These estimators were also used to plot the species richness accumulation pattern.

Estimated number of species present based on Quadrat sampling in each habitat of Upper Nilgiris varied from 1 to 7 (Table 3.4). The graphical

representations of these estimators for various habitats using VES and Quadrat data are given in Appendix 3 and 4. None of the estimated number of species was very different from the observed number. For instance, the observed number of species in Grasslands was seven. The highest estimated number of species was 7.25. Only four species were observed using Quadrat sampling in Wattle but the highest estimated number of species was 7.8. The variation in estimated number of species could be due to difference in the analytical characters of each estimator. Further sampling may be required in Wattle to reach the actual number of species distributed in this habitat.

Rarefaction curves generated from the data of Grasslands reached an asymptote, and the curve was parallel to the X-axis (Fig. 3.2) because species accumulated more quickly in Grasslands. When no new taxa were added, an asymptote should, in principle, be reached. Using Chao's estimator, total species richness was seven, whereas it was 7.25 using the Bootstrap estimate (Table 3.4). Results of the following estimators, First order Chao, Second order Jackknife, Coleman rarefaction and Bootstrap of Grasslands showed that the species accumulated more quickly and the Coleman rarefaction curve was closer to the observed species richness curve. Second order Jackknife curve rose steeply, crossing other curves because of lower species richness value (Fig. 3.2) of the reptile community of the Upper Nilgiris.

By all methods including opportunistic observations, only eight species (S_{mim}) were observed in all habitats of Upper Nilgiris. Based on various estimators, it may be reasonably proposed that the number of species observed in the present study may be considered as actual number of species occurring in the respective habitats (Appendix 3, 4). The present study shows that in all, reptile species richness is low in Upper Nilgiris, which is about 8 -10 species only.

Species Diversity

Statistics of reptile community of the Upper Nilgiris, including the species diversity is given in Table 3.5. Grasslands had the highest diversity ($H' = 1.24$) compared to other habitats and Pine had lowest ($H' = 0.21$). Other densely vegetated habitats such as Shola and Tea also had low reptile diversity. The Hill's diversity ($e^{H'}$) provides an index of number of contributing species to the diversity or the common species. The highest of 3.5 contributing species was found in Grasslands and lowest 1.2 in Pine. The Wattle plantation also had high diversity (Table 3.5). The pattern of species diversity (Shannon–Weiner Index) and Hill's diversity showed a similar trend in the study area.

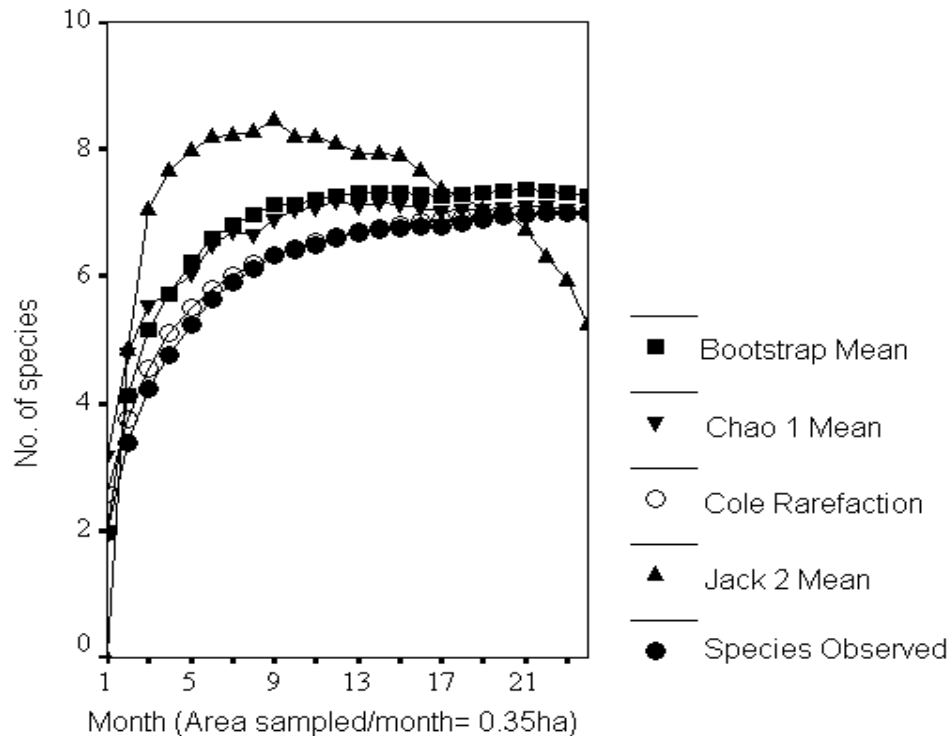


Fig 3.2. Reptile species richness accumulation curve generated using various estimators for Grasslands based on quadrat data (Colwell, 2000).

Table 3.4. Summary of the estimated number of species obtained for various habitats of Upper Nilgiris, Western Ghats; data based on quadrat sampling.

Estimates	Grassland	Shola	Wattle	Tea
Observed species	7	2	5	3
Chao –First order	7	1	6	2
Cole rarefaction	7	1	4	2
Bootstrap estimator	7.25	1	4.72	2.11

Table 3.5. Reptile species diversity of the Upper Nilgiris, Western Ghats; Number in parentheses indicates area (in ha) sampled.

Statistics	Grassland (8.4)	Shola (3.45)	Wattle (8.4)	Pine (2.01)	Tea (4.8)
Density (/ha)	14.8	14.6	8.2	6.96	5.6
Species richness (N)	6	2	5	2	3
Species diversity (H')	1.24	0.34	1.23	0.21	0.66
Hill's Diversity	3.5	1.4	3.4	1.2	1.9

Density of Reptiles

Reptile density was high in Grasslands and Shola compared to plantations (Wattle, Pine and Tea). An estimated 15 reptiles/ ha in Grasslands and 14.6 reptiles/ ha in Shola was observed. Density of *Cnemaspis indica* was high (9.4/ha) in Grasslands. However, highest density of *Salea* was observed in Shola (14/ha). In plantations density of none of the reptile species was high. In general, the density of snakes was low in all habitats. Grasslands had the highest density of *Plectrurus perroteti* (Table 3.6).

Higher density of *Cnemaspis indica* was recorded in Grasslands compared to Shola, Pine and Tea. Among plantations this species was recorded only in Wattle. Highest percentage, two out of three species of lizards used Grasslands. *Salea horsfieldii* used all habitats; Grassland, Shola, Wattle, Pine and Tea in equal proportion. In Wattle, Pine and Tea the density was low compared to Shola but higher than the density in Grasslands (Table 3.6). Overall density of *Scincella bilineatum* was low in all habitats compared to other lizards. Grasslands and Wattle had

considerable density of this species. Higher number of species and density of snakes was found in Grasslands. All species, barring *Xylophis perroteti* were found in Grasslands. *Plectrurus perroteti* and *Ahaetulla perroteti* was higher than that of other snakes in Grasslands. In Tea plantations *Plectrurus perroteti* was recorded in low density. No snakes were observed in Pine plantations during this study. Highest density of *Trimeresurus strigatus* was recorded in Shola. *Xylophis perroteti* was found only in plantations that too in low density (Table 3.6). In general, the average density of lizards was high (2.9 lizards/ha) compared to snakes (1 snake/ha).

Relative Abundance

Information on the relative abundance of a species would provide an idea on the common and rare species distributed in a given locality. Data from both VES and Quadrat samplings together were used in this analysis. Relative abundance of *Cnemaspis indica* was the highest (43.2 %) followed by *Salea horsfieldii* (36.45%) and which was lowest in *Xylophis perroteti* (0.34 %). Relative abundance of snakes was low compared to lizards (Fig. 3.3). Among snakes, *Ahaetulla perroteti* (5.03%) and *Plectrurus perroteti* (4%) were relatively high compared to other species.

Table 3.6. Density of reptiles in different habitats of Upper Nilgiris, Western Ghats.

Species	Grassland	Shola	Wattle	Pine	Tea
<i>Cnemaspis indica</i>	9.4	0	2.86	0	0
<i>Salea horsfieldii</i>	1.19	13.7	3.9	4.5	5
<i>Scincella bilineatum</i>	1.4	0	1.19	0.5	0.42
<i>Plectrurus perroteti</i>	1.19	0	0	0	0.21
<i>Ahaetulla perroteti</i>	1.07	0	0.12	0	0
<i>Oligodon venusutum</i>	0.24	0	0	0	0
<i>Xylophis perroteti</i>	0	0	0.12	0	0
<i>Trimeresurus strigatus</i>	0.36	0.86	0	0	0
Overall density (ha)	15	14.6	8.2	4.98	5.6

Biomass of Reptiles

In all, lizards contributed nearly 80% of the total reptile biomass and the rest by snakes. At species level, the endemic agamid lizard, *Salea horsfieldii* contributed about 68% of the biomass (Fig. 3.4). Overall, the biomass contributed by each lizard species was higher than that of each species of snakes. At habitat level, the highest reptile biomass was observed in Shola (108 g/ ha) followed by Grasslands (64.8 g/ ha). Lowest reptile biomass was observed in Pine (32.1 g/ha). In general, reptile biomass was low in plantations compared to natural habitats such as Shola and Grasslands. The biomass distribution of each species was different among all the habitats. It was dominated by *Ahaetulla perroteti* followed by *Cnemaspis indica* in Grasslands. The contribution of *Salea horsfieldii* was high in all other habitats at various proportions (Table 3.7).

Size Structure

Size structure of various species of reptiles was derived based on SVL. *Cnemaspis indica* was the smallest of all reptiles found in the area, and variation in its size was not much (1.5- 4 cm). Two distinct groups in size structure were observed; the first group consisted of lizards and the other by snakes. SVL of none of the lizards reached beyond 10 cm. On the other hand, smallest SVL of snakes started only from 10 cm barring *Plectrurus perroteti*. Among snakes, *Plectrurus perroteti* was the smallest and its size class marginally overlapped with that of lizards (Fig. 3.5 a,b).

Table 3.7. Biomass (gm/ ha) of reptile species in various habitats of Upper Nilgiris, Western Ghats; Number in parentheses is %.

Species	Mean wt.	Grassland	Shola	Wattle	Pine	Tea
<i>Cnemaspis indica</i>	1.56	14.7 (23)	0	4.5 (11)	0	0
<i>Salea horsfieldii</i>	6.8	8.1 (13)	93.2 (86)	26.7(67)	30.5(95)	34(93)
<i>Scincella bilineatum</i>	3.3	4.7 (7)	0	3.9 (10)	1.7 (5)	1.4(3)
<i>Plectrurus perroteti</i>	6.3	7.5 (12)	0	0	0	1.3(4)
<i>Ahaetulla perroteti</i>	19.8	21.2 (33)	0	2.4 (6)	0	0
<i>Oligodon venusutum</i>	10.13	2.4 (4)	0	0	0	0

<i>Xylophis perroteti</i>	18.3	0	0	2.2 (6)	0	0
<i>Trimeresurus strigatus</i>	17.2	6.2 (10)	14.8 (14)	0	0	0
Total biomass		64.8	108.0	39.7	32.1	36.7

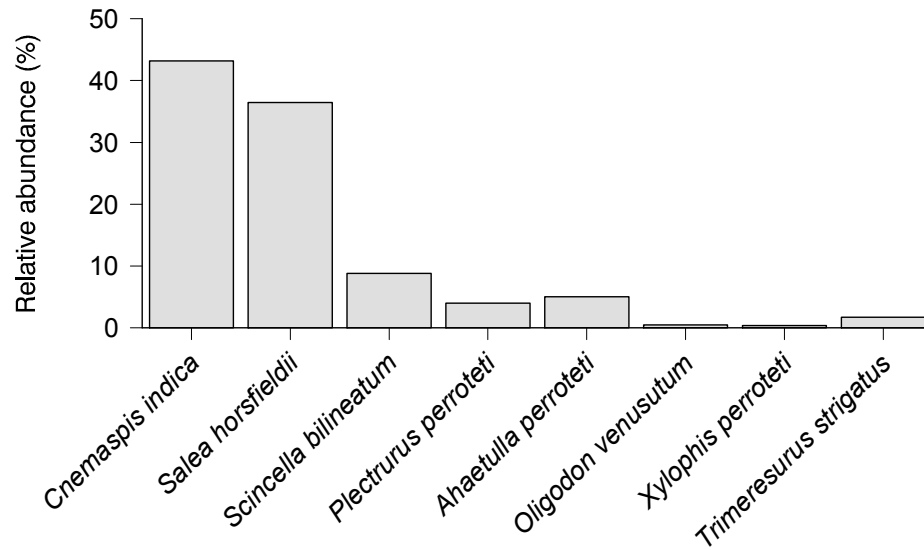


Fig. 3.3. Relative abundance of reptiles observed in Upper Nilgiris.

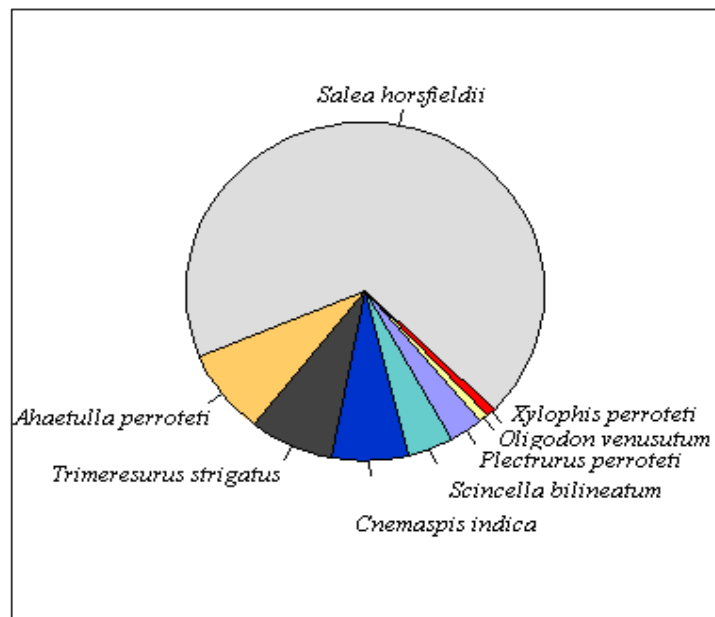


Fig. 3.4. Relative biomass (/ha) of reptiles studied in Upper Nilgiris, Western Ghats.

Both lizards and snake species size class showed a unimodal right skewed distribution. Mean size of each reptile species observed was different (Fig. 3.6). *Cnemaspis indica* had the lowest mean body size, whereas *Ahaetulla perroteti* had highest. The mean body size of all species found in Upper Nilgiris did not overlap much. However, there could be overlap in body size among young ones of these species. Among lizards, adults of *Cnemaspis indica* and young ones of *Salea horsfieldii* were overlapping and *Scincella bilineatum* overlapped with other lizard species. Similarly notable overlap among smaller snakes (*Plectrurus perroteti*) and juveniles of other species were also found (Fig. 3.6).

3.3.4. Impact of Habitat Alterations

Both Shola and Grasslands formed a single system and are ecologically inseparable. Hence, a comparison was done with Shola and Grasslands (natural habitat) with plantations (modified/ altered habitats). The analysis showed that all, but two species (*Scincella bilineatum*, *Xylophis perroteti*) had negative impact when habitats were altered (Table 3.8). The above two species have marginally benefited by the alteration of habitat. *Xylophis perroteti* was not found in Natural habitats (in Shola and Grasslands). When there is fire in Grasslands, Shola forest may offer shelter to species inhabiting adjoining areas. This is supported by the occurrence of higher number of reptiles near Shola edges with healed wounds caused by fire. During summer, species such as *Trimeresurus strigatus*, *Plectrurus perroteti* and *Ahaetulla perroteti* might move towards the edges of Shola to escape from fire in Grasslands. The results suggest that the endemic species largely depend on natural habitats (Shola and Grasslands) and these species may get severely affected compared to generalists.

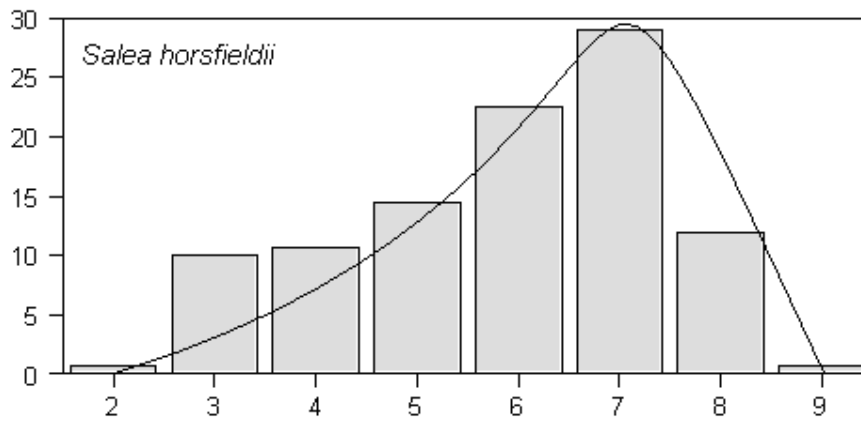
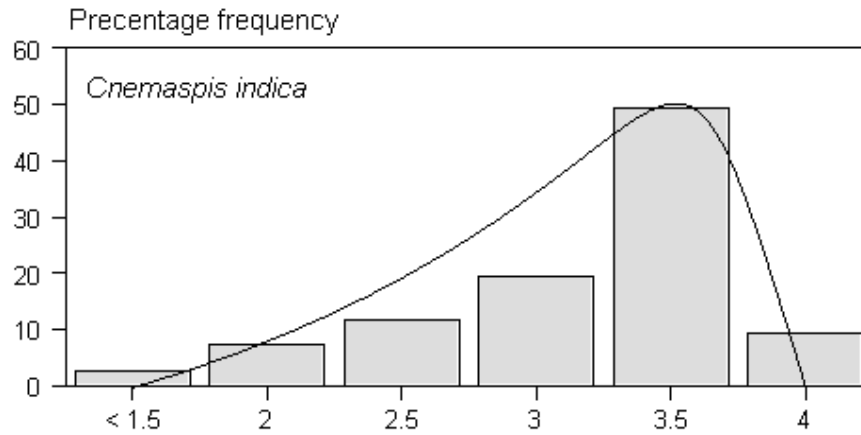
3.4. DISCUSSION

The pattern of reptile species detected using VES and Quadrat was similar. This may be due to the larger sampling effort. However, data from these methods are not comparable as they differ in quality (number of reptiles/ hour and number of reptiles/ ha). Similar trend of results in both methods indicates that when sample size is higher, one of the methods may be suitable for community study. Heyer *et al.* (1994) suggested various herpetofaunal sampling techniques, but they are largely untested in tropical conditions (Pearman *et al.* 1995). This study provides some information on this line.

In most of the recent population studies, capture and recapture of reptiles in conjunction with pitfall traps or other methods were followed (Colli *et al.* 1998; Conroy, 1999; Schlaepfer and Gavin, 2001; Nally and Brown, 2001; Greenberg, 2001; Gainsbury and Colli, 2003; Willson and Dorcas, 2004). However, given the local conditions and rigid administrative regulations in the Indian Protected Areas such as National Parks, methods such as pit fall and marking techniques could not be used. It is suggested that visual encounter surveys may be useful for inventory and quadrat sampling for scientific studies requiring comparison and monitoring (Bhupathy and Nixon, 2004). It is reported that visual encounter survey is the best way to sample rare or trap-shy species (Crump and Scott, 1994).

Despite intense samplings over two and half years, only eight species were observed in and around Mukuruthi National Park and 11 species (in all) in the vicinity. Species richness accumulation curves indicate the expected number of species from a collection of random samples and represent what is statistically expected from the area (Gotelli and Colwell, 2001). Slight variations in the estimated number of species could be due to varied behaviour and functions of these estimators. For instance, Hellmann and Fowler (1999) reported the suitability of second order Jackknife analysis for data with small sample size. Also, it is reported that the selection of the estimator (Chao, Jackknife or Bootstrap) may depend

upon the community composition, especially number of species. The observed and estimated number of species of reptiles in the present study area was not different, and this indicates the completeness of the sampling.



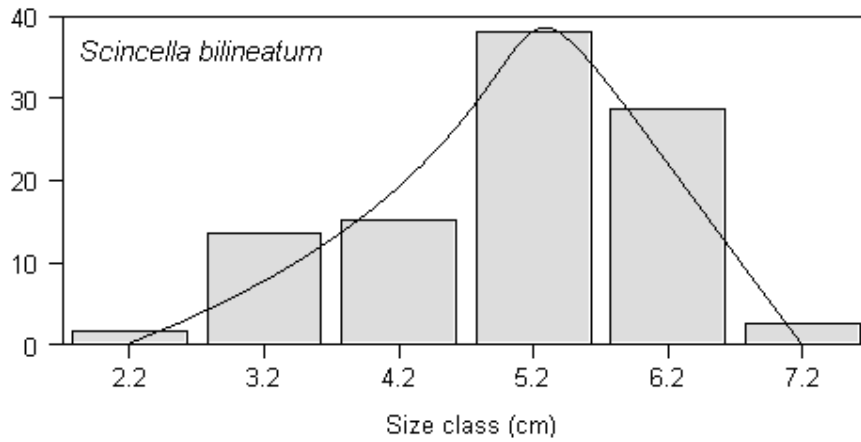
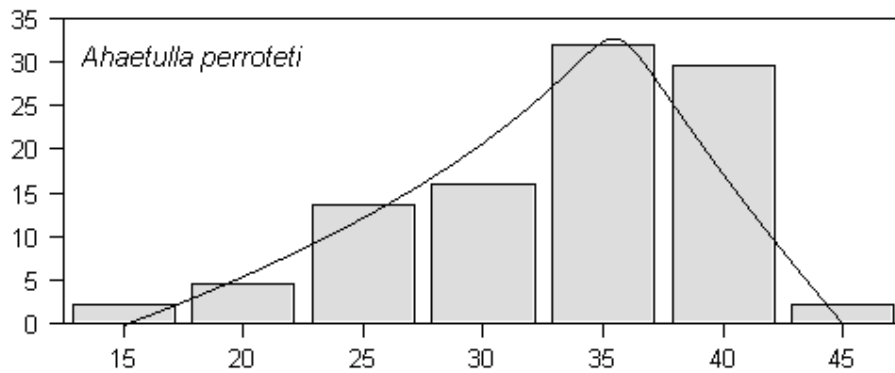
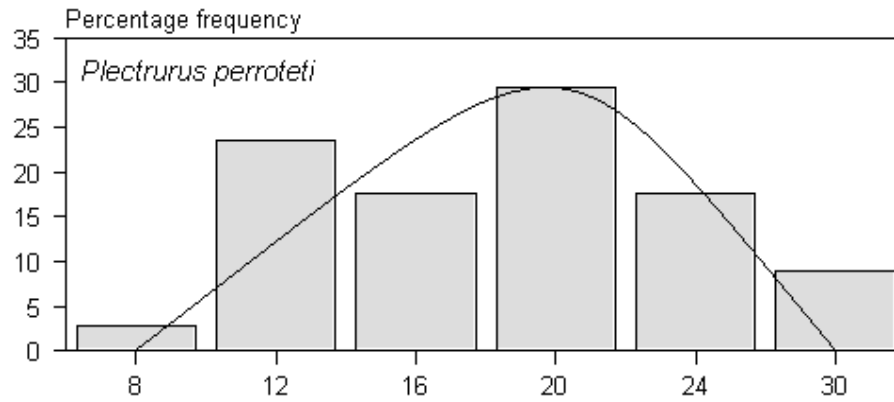


Fig. 3. 5a. Size structure of lizards observed in Upper Nilgiris, Western Ghats.



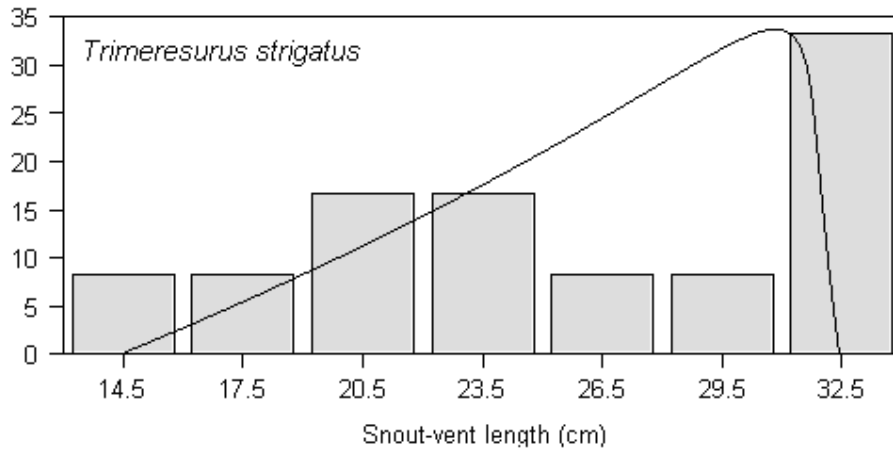


Fig. 3. 5b. Size structure of snakes observed in Upper Nilgiris, Western Ghats.

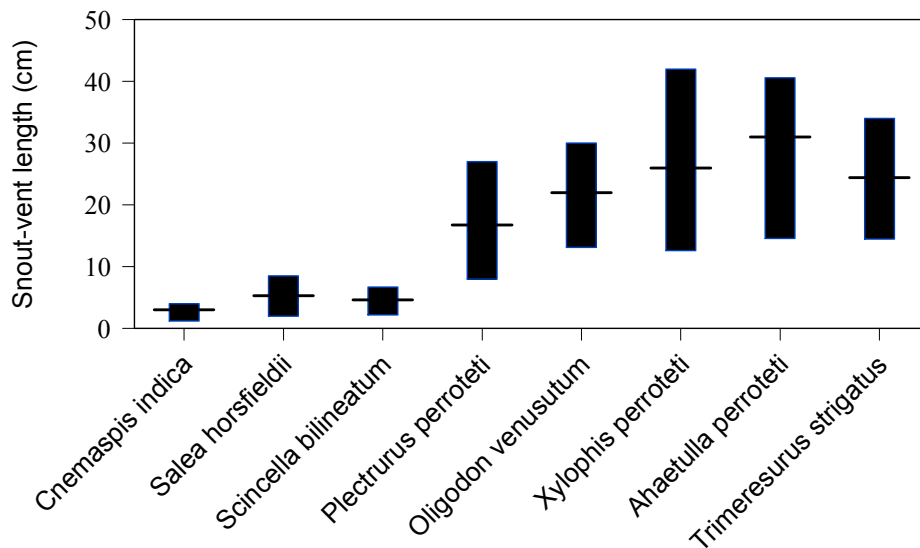


Fig.3.6. Mean Snout-Vent Length of reptiles observed in Upper Nilgiris, Western Ghats.

Table 3.8. Comparison of density of reptile species in Shola-Grasslands and plantations; Impact of plantation on the reptiles $(I) = (d_1 - d_0) * 100 / d_0$, where d_0 = Species density in natural habitat, d_1 = Species density in plantations + Positive impact, - Negative impact.

Scientific name	Natural habitats	Plantations	Impact (%)
-----------------	------------------	-------------	------------

	(d ₀)	(d ₁)	(l)
<i>Cnemaspis indica</i>	4.70	1.43	-69.6
<i>Salea horsfieldii</i>	7.45	4.46	-40.1
<i>Scincella bilineatum</i>	0.71	0.80	+12.7
<i>Plectrurus perroteti</i>	0.6	0.10	-83.3
<i>Xylophis perroteti</i>	0	0.06	+
<i>Oligodon venusutum</i>	0.12	0	-100
<i>Ahaetulla perroteti</i>	0.54	0.06	-88.9
<i>Trimeresurus strigatus</i>	0.61	0	-100
Overall density	14.7	6.92	-52.9

It is surprising to find two non-endemic species, the Checkered Keelback water snake (*Xenochrophis piscator*) and Rat snake or Dhaman (*Ptyas mucosus*) in such a specialised bio-climatic zone (i.e. near temperate zone). These two species are distributed all over India, especially common in plains. *Ptyas mucosus* would have found its way to the higher altitudes through plantation activities. The plantations might have provided ideal habitats for invading rodents (Shanker and Sukumar, 1999) that in turn would have formed prey base for this species. *Xenochrophis piscator* might have reached the higher altitudes through channels made for diverting water by the Tamil Nadu Electricity Board (TNEB), and would have continued to thrive in permanent water bodies such as dams and reservoirs. Both these species were common in certain localities supporting the above views. For instance, at Hindustan Photo Films Limited water storage area (Udaghamandalam, 2400 m) *Ptyas mucosus* was common, and *Xenochrophis piscator* around Avalanche and Emerald reservoirs. The former locality is found near plantations and human settlements, whereas the later localities are connected with water diverting systems such as flumes constructed by the TNEB. Invasion of *Ptyas mucosus* to the higher altitudes have been reported in Sri Lanka (De Silva, 1999).

Study on how these species establish and survive in colder climatic

conditions is needed and this would throw further light on the species adaptability. This type of study would also give pertinent information on the impact of global warming (change in temperature) and movement of species to higher altitude or vice-versa.

Similar to the present observations, lower number of reptile species have been reported from colder and high altitude regions (Navarro, 1992; Raxworthy *et al.* 1997; Valquez and Givnish, 1998). Species found in Upper Nilgiris could acclimate to colder temperatures and remained active on sunny winter days without hibernation, as reported for Green Anoles, *Anolis carolinensis* (Bishop and Echternacht, 2003). Fewer species could be mainly due to factors such as colder climatic conditions, poor availability of microhabitats, effect of altitudes on species and geometric constraints. The low species richness in Mukuruthi National Park supports the view of McCoy (1990) that the “ends are bad” hypothesis, as distribution of species are limited by climatic severity in the hard boundaries of the highest mountain tops and reduced availability of resources. According to Sanders (2002), climatic severity in the hard boundaries of the highest mountaintops geography and area available limit species richness.

Even though the present study was restricted to the altitudinal range between 2000 and 2500 m, available information on the lower altitude are indicative of high species richness in the lower altitudes of the same general range of hills. Voris (1977) reported that in Sumatran rain forests the species richness was intermediate compared to Thailand (low) and Ecuador (high) with respect to buttress communities of rain forest. For instance, over 50 species have been recorded in Mudumalai Wildlife Sanctuary (800-1000m; Bhupathy and Nixon, under preparation), a part of the Nilgiri Biosphere Reserve. Mukherjee and Bhupathy (2004) reported fifty-five species of reptiles from Anaikatti Hills, whereas only eight species have been observed from Upper Nilgiris during this study. Studies on various taxa also demonstrated that there are fewer species at higher

altitudes compared to lower altitudes, or that there are no species above a certain altitudes (Weber, 1943; Brown, 1973; Janzen, 1973). It was reported that species richness of leaf litter ants in a Malaysian rainforest decreased exponentially with increasing altitude (Bruhl *et al.* 1999). As in the present study, decreasing trend in species richness with altitude has been reported for birds (Navarro, 1992), mammals, reptiles, insects, and amphibians (Stevens, 1992) and plants (Vazquez and Girnish, 1998). In general, two patterns of species distribution were reported (1) a monotonic decrease in species richness with increasing altitude (MacArthur, 1972; Stevens, 1992) and (2) a hump at the middle altitude; species richness increases from the lower elevation and it attains peak in the middle and the richness decreases in higher (Waltner, 1978; Inger *et al.* 1983; Bhupathy and Kannan, 1997a; Ishwar *et al.* 2001; Gytne and Vetaas, 2002), where number of species is high in middle altitudes. Janzen (1973) hypothesised that “middle is good” because the productivity is highest at this segment.

A recently recognized factor that may contribute to a humped relationship between species richness and altitude is the geometric constraints on species range (Colwell and Lee, 2000). Range of the species along an altitudinal gradient is geometrically constrained as levels or the bottom of a valley as a lower boundary and the top of a mountain or an ecophysiological constraint as an upper boundary (Grytnes and Vetaas, 2002). The present study area faces both geometrical and ecophysiological constraints together as this is a hill top plateau and constrained by severe cold conditions. Geometrically, the present study area is constrained by bottom of a valley on the western side (Silent Valley NP) with steep gradient gorge. Apart from steep gorges and elevation, the forest type in the next lower layer or altitude is tropical evergreen with more stable climatic regime. It is reported that evergreen forest acts as barrier in constraining species dispersal (Gainsbury and Colli, 2003).

Size structure (SVL class) reflects important parameters such as

reproduction rate, mortality rate and the rate of generation replacement (Yablokov, 1986). Size structure is expressed as a ratio of several absolute age classes, a ratio of different generations, progenies and different age class, ratios of pre-reproductive, reproductive and post reproductive periods and patterns of individual growth. The findings of this study showed that the size structure of many species were right skewed and indicated the presence of higher number of adults with healthy breeding population. Similar to the present observations, most of the reptile studies reported a unimodal with right skewed curve with respect to size structure (Brown, 1995; Dixon *et al.* 1995; Bakker and Kelt, 2000; Etienne and Olff, 2004).

Globally studies on the biomass of reptiles per unit area are scarce. Herpetofauna could also be very abundant and comprise significant components of vertebrate biomass in certain terrestrial and freshwater ecosystems (Hairston, 1987; Heyer *et al.* 1994). It is stated that in some area, the biomass of reptiles is much higher than any vertebrate taxa (Seburn and Seburn, 2000). The biomass of the consumer taxa may be directly related to primary production. The biomass of reptiles was much higher in Shola habitat compared to others such as Grasslands and plantations. Further studies are required to understand the relationship between primary production and biomass of various taxa. A comparative study on the biomass by various vertebrate taxa at local and regional level is essential.

Heinen (1992) found higher abundance and biomass (species richness) of reptiles in more disturbed sites, but species diversity was greater in less recently disturbed locations in Costa Rica. Inger (1980) found greater species richness in logged forests and in plantation than in rainforests and suggested that this may be due to environmental factors. In the present study, species diversity was high in Grasslands followed by Wattle. The Wattle plantations found in the study area are comparatively older stands (>50 years). The canopy cover of this plantation is low/ open compared to

Pine, and or even Shola. Hence, Wattle plantations had higher number of species. Most studies of herpetofaunal response to timber harvesting conducted in the southern Appalachians focus on a small part of the picture by addressing salamander response alone, whereas the response of reptiles has received virtually no attention.

The Snout-Vent Length in *Cnemaspis indica*, *Salea horsfieldii* and *Scincella bilineatum* distribution showed unimodal right skewed. *Plectrurus perroteti* and *Trimeresurus strigatus* showed bimodal distribution. Similarly in North Carolina snake species such as *Carphophis amoenus* exhibited a bimodal size frequency distribution. Most of the studies report a unimodal, right skewed for the species body size distribution in reptile communities (Brown, 1995; Dixon *et al.* 1995; Bakker and Kelt, 2000; Etienne and Olf, 2004). Several authors suggested that size difference explain spatial niche partitioning. Warren and Lawton (1987) and Dixon *et al.* (1995) have reported that the species body size pattern reflect the species trophic levels as well. In the present study, average size of each species has differed, and it perhaps indicates the level of morphologically mediated niche segregation among the species.

Variation in the density of species could be mainly due to changes in factors such as temperature and microhabitats. Significant microhabitat and temperature difference was observed in natural habitats and plantations (see Chapter -Habitat Use). Vitt *et al.* (1998b) reported that almost all aspects of the biology of lizards depend on temperature and the overall data in the present study show significant reduction in the density of lizard species in plantations compared to natural habitats, which augments the above report. Availability of larger stones or boulders is important for reptiles as they give shelter during colder nights. However, this microhabitat is almost reduced by plantation activities (See Chapter Habitat use). Mean boulder density of Shola forest, Grasslands, Wattle and Tea Plantations were 5.3/100 m², 2.8/100 m², 0.6/ m² and 0.3/ m² respectively. The mean density of trees also varied much among the

natural habitats and plantations (Shola 7/ha, Grasslands 0.5 /ha, Wattle 11.2 /ha, Tea 1.2 /ha). Higher tree density was reflected in the reduction of temperature. It was observed that lower the temperature, number of reptile species got reduced. This shows that to conserve reptile community in the colder Upper Nilgiris, maintaining the Grasslands, which offer suitable temperature required for their daily activity.

The analysis indicates that barring *Scincella bilineatum* and *Xylophis perroteti*, other species would locally disappear in long run, if the plantation activity were continued. Habitat alterations may have both positive and negative impacts (Vitt *et al.* 1998b; Dickerson, 2001). The present study clearly shows the negative impact of the plantations on reptiles in terms of species richness, diversity and density. Reduction in the aspects of reptile populations is largely influenced by changes in various abiotic (temperature, availability of microhabitat parameters) and biotic (tree density) factors (Martin, 2001). It is revealed that the plantations do not provide enough surface litter and other microhabitat for upland herpetofauna (Dickerson, 2001). As reported by Vitt *et al.* (1998b) changes in habitat structure (e.g. tree density) appear to influence species diversity, density and composition of reptiles in the present case as well. Pawar (1999) mentioned that the plantations (matured) provide marginal habitat for a larger herpetofaunal community. This study also brings out the need for protecting natural habitats (Shola forests and Grasslands), and habitat restoration in the Upper Nilgiris.

3.5 SUMMARY

- Area (Quadrat) and Time (Visual Encounter Survey) constrained sampling techniques were used for data quantification. On locating a reptile species, morphometric parameters and sex of each individual were recorded. Pooled data at species level from various habitats using both methods showed largely a similar trend in species detection.

- Eleven species of reptiles were observed in Upper Nilgiris during this study. However, only eight species were recorded in close vicinity of Mukuruthi National Park. Species accumulation pattern using estimators such as First order Chao; second order Jackknife, Coleman rarefaction and Bootstrap showed that number of species in the area is 8 to 10. Lower number of reptile species in Upper Nilgiris could be due to factors such as colder climatic conditions, poor availability of microhabitats, effect of altitudes on species and geometric constraints.
- Grasslands had the highest diversity ($H' = 1.24$) compared to other habitats and Pine had the lowest ($H' = 0.21$). Reptile density was higher in Grasslands and Shola compared to plantations. Higher number of species and density of snakes was found in Grasslands. In general, the average density of lizards was high (2.9 lizards/ha) compared to snakes (1 snake/ha).
- Relative abundance of *Cnemaspis indica* was highest (43.2 %) followed by *Salea horsfieldii* (36.46%) and it was lowest in *Xylophis perroteti* (0.34 %). Among snakes, relative abundance of *Ahaetulla perroteti* (5.03%) and *Plectrurus perroteti* (4%) were high compared to other species.
- In all, lizards contributed nearly 80% of the total reptile biomass of the Upper Nilgiris. At species level, the endemic *Salea horsfieldii* contributed the maximum biomass (about 68%). At habitat level, the highest reptile biomass was observed in Shola (108 g/ ha) followed by Grasslands (64.8 g/ ha) and lowest in Pine plantations (32.1 g/ha).
- The size class distribution of both lizards and snake species showed a unimodal right skewed pattern, which indicate a healthy population with higher number of adults.

- The analysis showed that barring *Scincella bilineatum* and *Xylophis perroteti*, other species had negative impact while habitats were altered. These species may locally disappear in long run, if the plantation activity is continued.

CHAPTER- IV

HABITAT USE

4.1. INTRODUCTION

The term habitat is used in a variety of ways such as area of a particular relief, vegetation and soil-structure. It is thought that the structure of an animal community is determined by the habitat structure of an area (Shenbrot and Krasnov, 1997). Another concept considers habitat as related to a particular species or group of species. In this concept, habitat is a patch with a set of environmental conditions and resources promoting the occupancy, survival and reproduction by the species (Morrison *et al.* 1992). Study on the habitat utilisation gives an idea how organisms use the area, its preference, and the role of the habitat in their survival and interrelations with the biotic and abiotic environs. Quantitative data on the habitat use by a species or group of species are required to formulate conservation and management plans (Bright and Morris, 1990; Buhlmann, 1995; Beauchamp *et al.* 1998). A species may use a particular habitat for food, shelter and to avoid competition. Partridge (1978) defined that habitat use or selection by animals as an active choice of an area from a range of alternatives. Knowing the habitat characteristics of a species and how individuals move within and among them can lead to a greater understanding of its ecology (Mills *et al.* 1995). Irschick *et al.* (2000) reported differential habitat use between juveniles and adults. Also, Shine (1991) reported that in most of the snake species there are divergent habitat selections between gravid female and other members of the population. However, no such differential habitat selection was recorded in *Trimeresurus stejnegeri stejnegeri* (Tu *et al.* 2000).

Studies on the population ecology of Central American Anole have contributed considerable insights into the biology of lizards (Losos, 1990;

Vitt and Zani, 1996; Losos *et al.* 1998; Irschick *et al.* 2000; Vitt *et al.* 2001). Cooper and Vitt (1992) have studied the substrate selection by North American *Eumeces* skinks in Kiawah Island and reported that these lizards are found frequently on trees than on the ground. Habitat selection by *Lacerta lepida* has been studied in Mediterranean oak forest using sighting frequency in different habitats in relation to their availability (Castilla and Bauwens, 1992). Conroy (1999) reported that the habitat partitioning influences the structure of lizard assemblage in different forest types. Demers and Weatherhead (2001) studied the Black rat snake, *Elaphe obsoleta obsoleta* and reported that the forest edges provide best opportunities for thermoregulation and feeding.

Microhabitat is defined as the animal's immediate physical environment. As reptiles do not derive body temperature from metabolic processes but from the surroundings, microhabitats may play an important role in the survival of a species. Changes in microhabitats of an ecosystem influence variations in the distribution, abundance and diversity of reptiles (Jones, 1986). Microhabitat components are habitat specific and provide environmental conditions necessary for a wide variety of ecological functions such as reproduction, foraging, predator avoidance or escape, thermoregulation, and resting. Morphometry in relation to microhabitat use on Phrynosomatid lizards was studied by Herrel *et al.* (2002). Substrate characteristics such as rock, litter, bare ground or sand, tree and wall were considered as microhabitat (Smith, 1995). This Chapter deals with the habitat use of reptiles found in Upper Nilgiris and parameters, such as habitat, microhabitat use and vertical distribution are described. Factors that determine the habitat use such as tree density, microhabitat and temperature were analyzed and correlation attempted.

4.2. METHODOLOGY

Area (Quadrat) and Time (Visual Encounter Survey) constrained sampling techniques were used for data collection. Details of the sampling protocol are given in Chapter III- Population. In each quadrat sampled,

microhabitats including boulders, fallen logs and standing trees were quantified. On locating a reptile species, microhabitats and vertical position of the species and atmospheric temperature were recorded. Forest/habitat type (e.g. Grasslands or plantations) was considered as macrohabitat. Information on the observation site of the reptile was noted descriptively and later segregated as different microhabitat categories (Brown, 1992b). Data on sex and morphometry of reptiles were recorded in most cases while handling them.

Atmospheric temperature was recorded using a digital thermometer at each Quadrat and observation site of a species. Location of an individual of a species when first sighted from the ground was considered as vertical position. Habitat variables assessed in each Quadrat include number of trees, fallen logs, boulder and litter cover.

4.2.1. Data Analysis

The following analyses were done.

1. Chi-square test was performed to describe the homogeneity in sighting frequency of species in different habitats (Chadha, 1992).
2. The Analysis of variance (ANOVA) was used to compare density variation within species with habitat characteristics.
3. Correlation coefficient was estimated to determine the relationship between reptile density and various continuous independent variables such as number of boulders and trees.
4. Variables providing the greatest relationships were determined by scatter plots and the critical points of significance of the correlation coefficients were used for subsequent analyses.
5. Regression analysis was employed to develop a model of the relationship between species richness and the microhabitat

categories. This procedure would select the variable or variables that contribute the most to predicting the reptile species richness.

4.3. RESULTS

4.3.1. Habitat Use

Habitat use of a species was determined in terms of its relative usage of the habitats. Habitat (forest type) use by reptiles found in Upper Nilgiris is given in Figure 4.1 & 4.2a, b. Higher proportions of *Cnemaspis indica* (82%) and *Scincella bilineatum* (57.1 %) were found in Grasslands. A considerable proportion of *Salea horsfieldii* was found in all habitats, which indicates its versatile nature in habitat use compared to other two lizard species. *Cnemaspis indica* was found only in Grasslands and Wattle, but larger proportion (82%) of them was found in Grasslands (Fig. 4.1). Among snakes, three namely *Plectrurus perroteti*, *Ahaetulla perroteti* and *Trimeresurus strigatus* largely used Grasslands. *Trimeresurus strigatus* used only Shola and Grasslands (Fig. 4.2b). *Ahaetulla perroteti* was versatile among snakes in using various habitats compared to other snakes. This species was found in all habitats barring Tea plantations. *Oligodon venusutum* and *Xylophis perroteti* were found only in plantations. Barring *Oligodon venusutum* and *Xylophis perroteti*, the Chi-square value of sighting frequency distribution of reptile species was significantly different in various habitats (Table 4.1).

Table 4.1. Chi-square analysis showing significant difference in habitat use by the reptiles of Upper Nilgiris, Western Ghats; Degree of freedom (df) = 4.

Species	χ^2 value	Significance level
<i>Cnemaspis indica</i>	137.1	0.0001
<i>Salea horsfieldii</i>	801.5	0.0001
<i>Scincella bilineatum</i>	87.4	0.0001
<i>Plectrurus perroteti</i>	67.4	0.0001
<i>Oligodon venusutum</i>	3.5	0.30
<i>Xylophis perroteti</i>	5.3	0.30
<i>Ahaetulla perroteti</i>	78.7	0.001
<i>Trimeresurus strigatus</i>	24	0.001

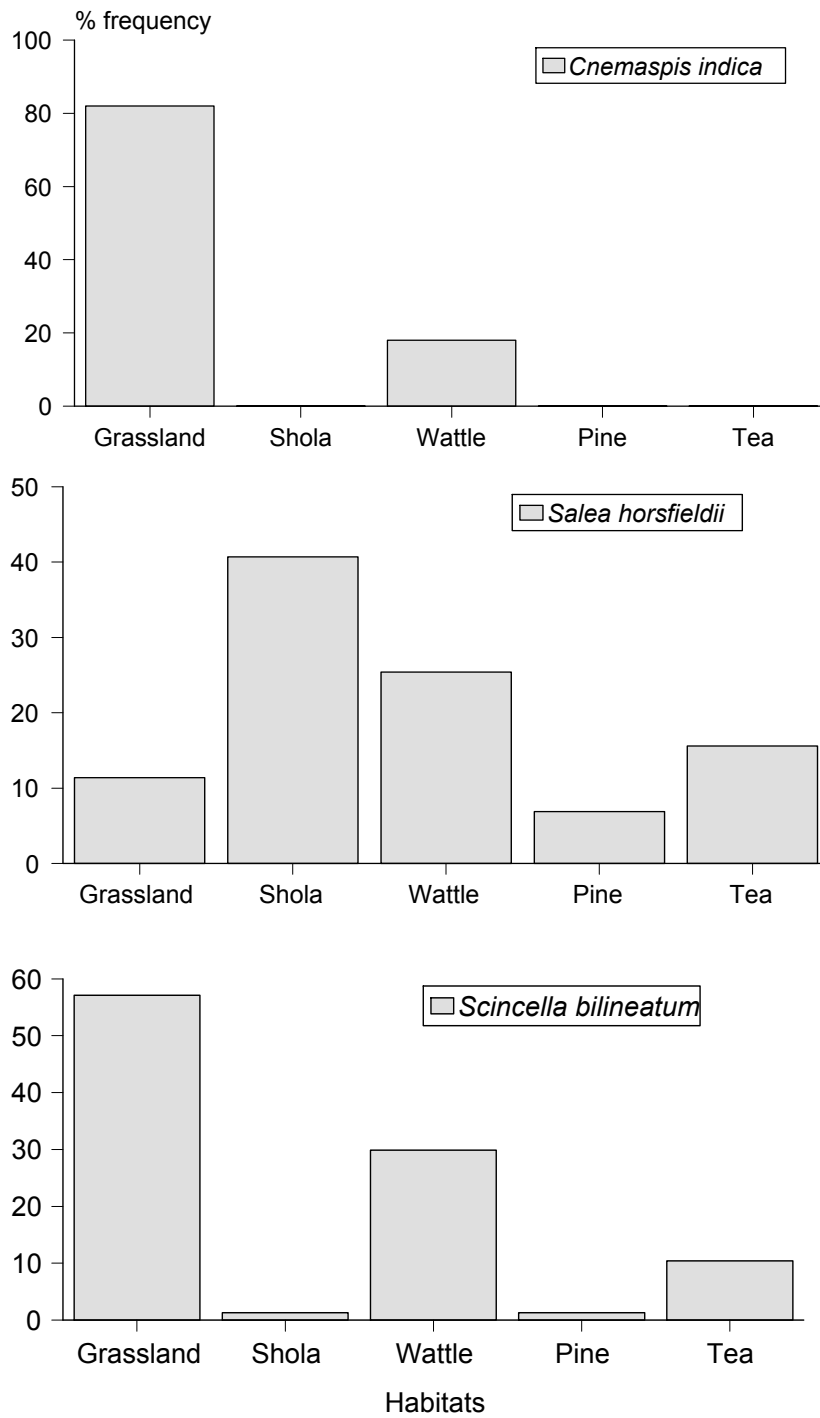


Fig.4.1. Percentage frequency of lizards observed in various habitats of Upper Nilgiris, Western Ghats.

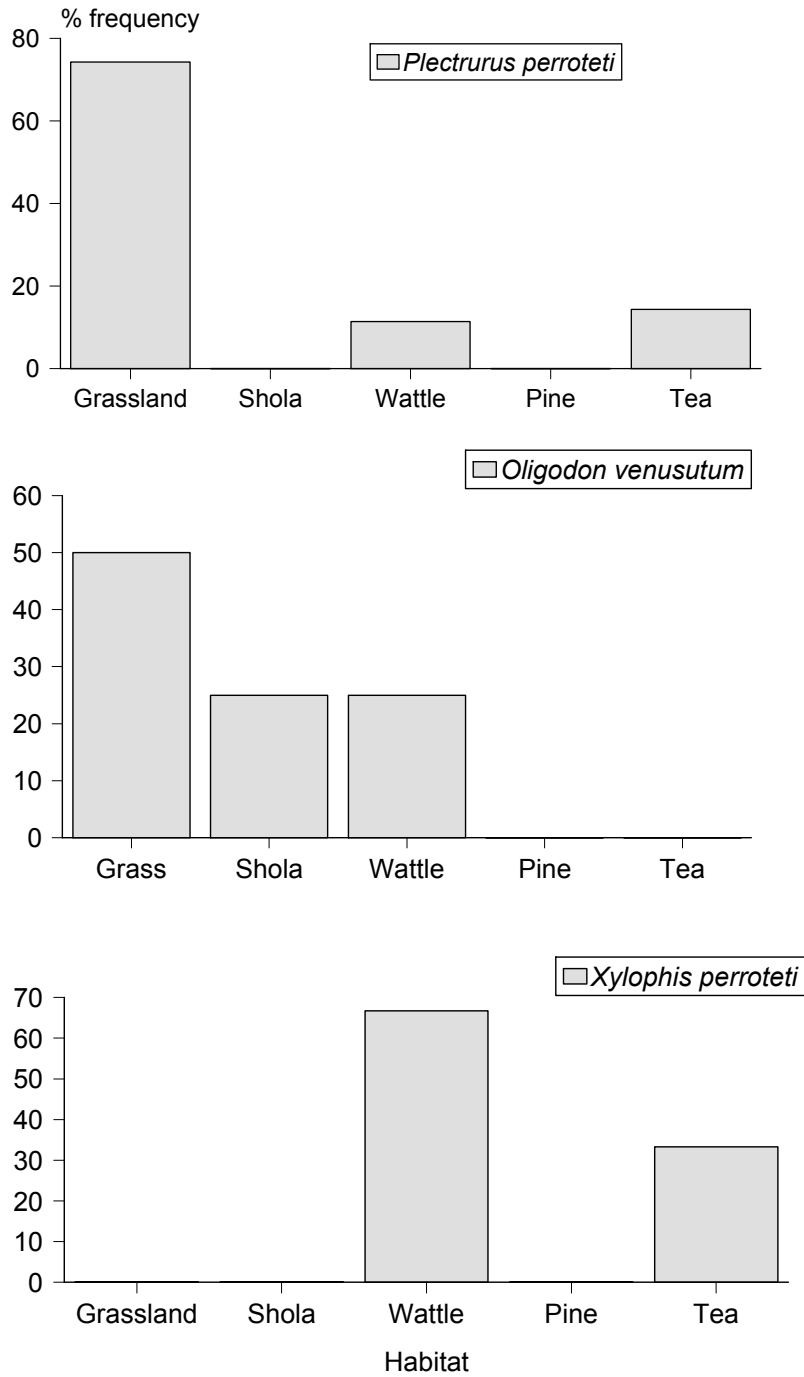


Fig.4.2a. Percentage frequency of snakes observed in various habitats of Upper Nilgiris, Western Ghats.

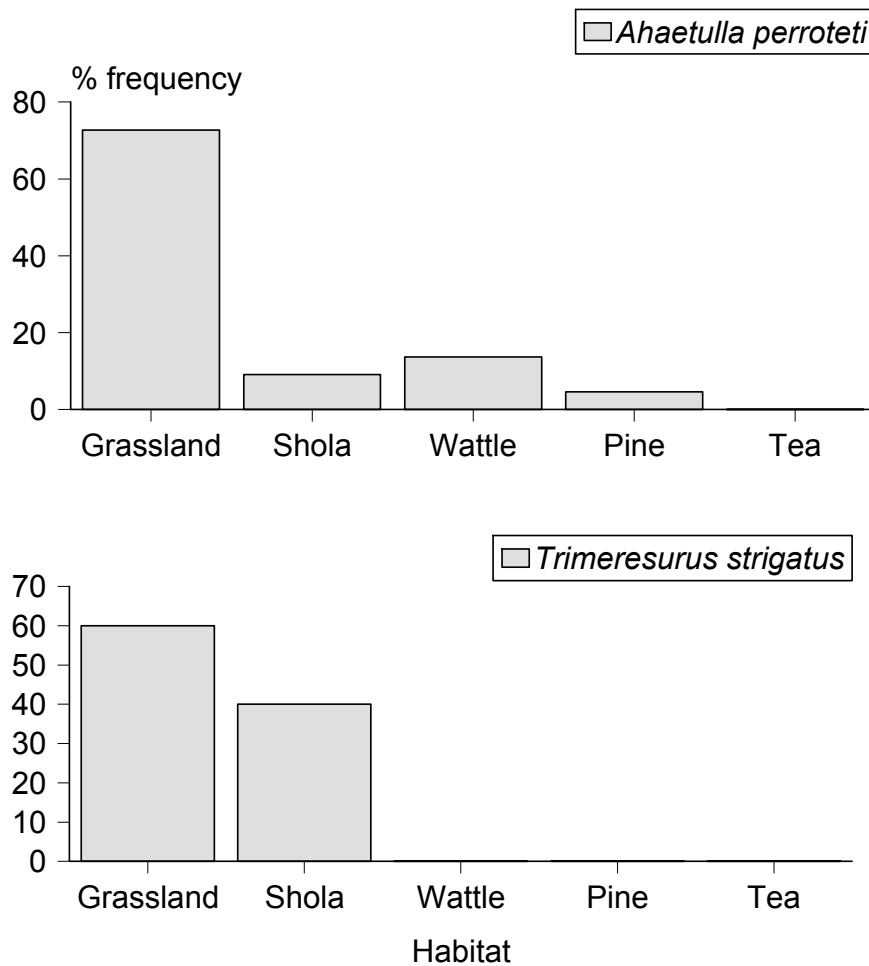


Fig.4.2b. Percentage frequency of snakes observed in various habitats of Upper Nilgiris, Western Ghats.

4.3.2. Microhabitat Use

Descriptive data on the microhabitats were clumped into ten categories. Higher proportion (>50%) of reptiles used boulders. In all, only a few reptiles were observed under grass and soil. About 87.5% of *Cnemaspis indica* was found under boulders and fewer individuals on bare ground (1.3%). However, *Cnemaspis indica* was also recorded on tree trunk and under bark in Wattle plantations (Fig. 4.3). Among lizards, *Salea horsfieldii* used a variety of microhabitats, especially the above ground ones. *Salea horsfieldii* was predominantly found on bushes and on trees (Fig. 4.3). *Scincella bilineatum* used boulders as their retreat and some times were found on bare ground (Fig. 4.3). However, other two species, *Cnemaspis*

indica and *Scincella bilineatum* used boulders as their microhabitat/shelter. All *Plectrurus perroteti* (100%) used ground microhabitats such as boulders (Fig. 4.4a). *Oligodon venusutum* used these microhabitats, but was frequently found on ground (50%; Fig. 4.4a). *Ahaetulla perroteti* used five microhabitat categories, but was frequently found on above ground microhabitats (Fig. 4.4a) and occasionally under grass clumps and under boulder (2.27%). *Xylophis perroteti* was frequently found under boulder (Fig. 4.4b). In the present study, only one species of pit viper (*Trimeresurus strigatus*) was recorded, which showed some arboreality in microhabitat use (Fig. 4.4b) while most of the sightings were on the ground.

4.3.3. Vertical Distribution

Position of reptile species with respect to ground level is shown in Fig. 4.5. Among (8) species of reptiles observed in Upper Nilgiris, four of them have been using above ground layers. They were, *Salea horsfieldii*, *Ahaetulla perroteti*, *Cnemaspis indica* and *Trimeresurus strigatus* and their mean (and standard deviation) height from the ground were 79.02 (\pm 51.6), 7.4 (\pm 21.4), 7.4 (\pm 22.4), 27.1 (\pm 42.5) cm respectively. Remaining four species were found on or under ground. *Salea horsfieldii* is versatile with respect to the utilisation of various tree or shrub layers. *Cnemaspis indica* was predominantly found on ground layer and under boulders. In plantations, this gecko may be seen above ground (70 cm) as well. Due to the prevailing colder conditions, most of the species found in this region largely inhabited underground (subterranean) microhabitats such as under boulders.

It is reported that the arboreal snakes may have longer tail. Hence, the Snout Vent Length and tail Length ratio would be low for species using above ground microhabitats. The results showed that this ratio was high with respect to *Plectrurus perroteti*, *Xylophis perroteti* and *Oligodon venusutum* compared to *Ahaetulla perroteti* and *Trimeresurus strigatus*. The former species utilised ground microhabitats, whereas the latter ones

were predominantly found on or above ground microhabitats. In snakes, lower SVL and tL ratio showed higher arboreality as it has been observed in *Ahaetulla perroteti* in the present case (Table 4.2). It may be noted that longer tail facilitates free movement of snakes in bushes and canopy.

Table 4.2. Snout-Vent Length and tail Length ratio of snakes observed in Upper Nilgiris, Western Ghats; number in parentheses indicate sample size.

Species	Snout-vent length (SVL)	Tail length (tL)	SVL: tL
<i>Plectrurus perroteti</i> (34)	16.7	1	16.7
<i>Ahaetulla perroteti</i> (44)	31.02	10.9	2.8
<i>Oligodon venusutum</i> (3)	27.2	3.4	8
<i>Xylophis perroteti</i> (6)	28.8	3.7	7.8
<i>Trimeresurus strigatus</i> (12)	24.4	3.5	6.9

4.3.4. Habitat Characteristics

Data on density of trees, boulders and litter cover of various habitats were quantified. Density of trees was highest in Wattle 117.5 / 100 m² followed by Shola 20.5 trees/100m². As expected, the lowest tree density was observed in Grasslands (0.22 tree/100 m²). Even though Tea plantations were well vegetated, trees were used as shade for the crops and hence, they were planted at regular interval. This resulted in lower density of trees in Tea plantations. Highest density of boulders was found in Grasslands (6.22/100m²) and the lowest in Pine (Table 4.3). In Pine plantations stones or boulders were covered by thick layer of litter and hence, neither visible nor available for reptiles to use. The Tea plantations also had lower number of boulders as it was managed on regular basis. Availability of rock crevices followed the same trend as in boulders (Table 4.3). High percentage of fallen leaf litter was found in Pine plantations followed by Shola. The lowest litter cover was observed in Grasslands.

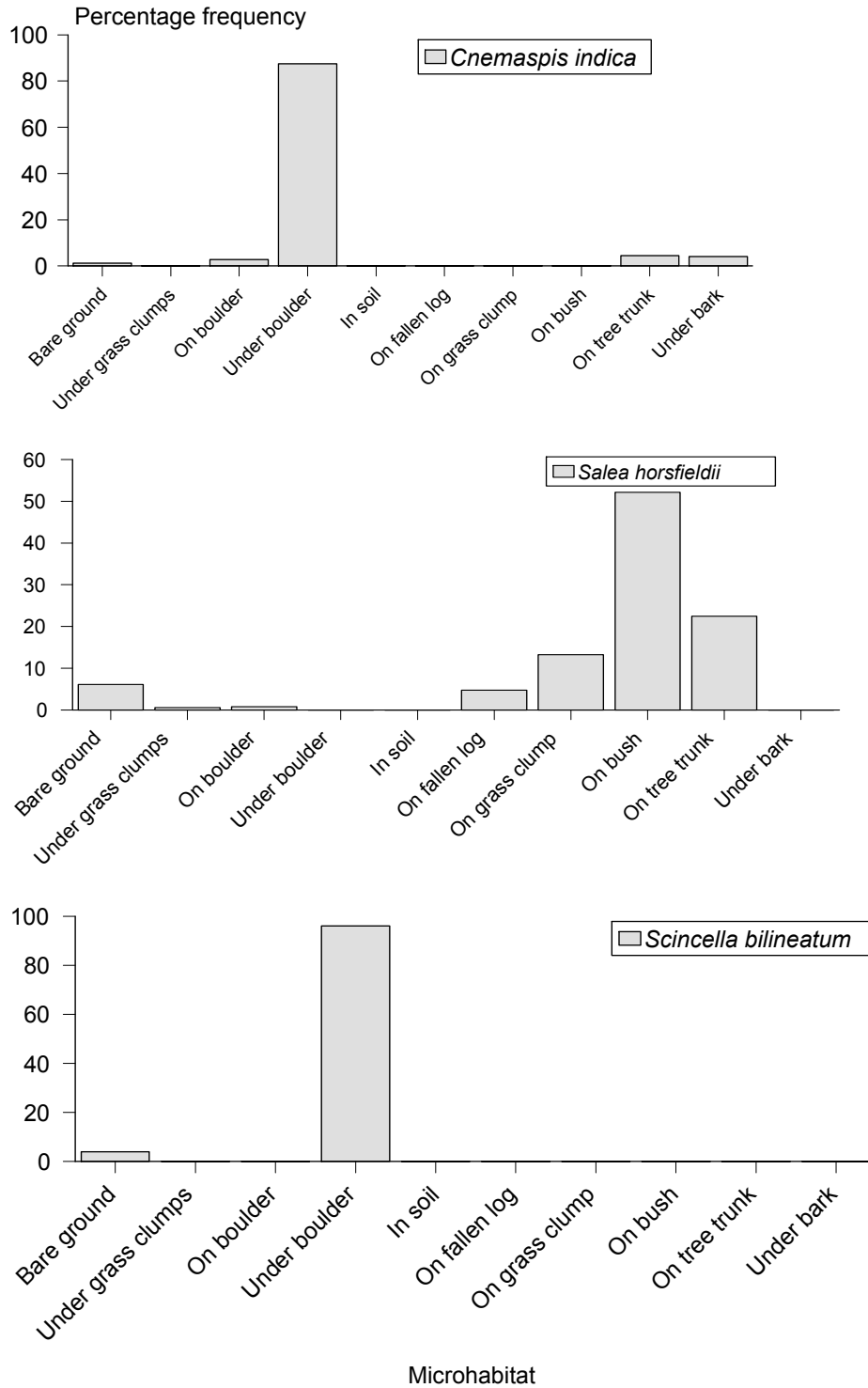


Fig.4.3. Microhabitat use by lizards in Upper Nilgiris, Western Ghats.

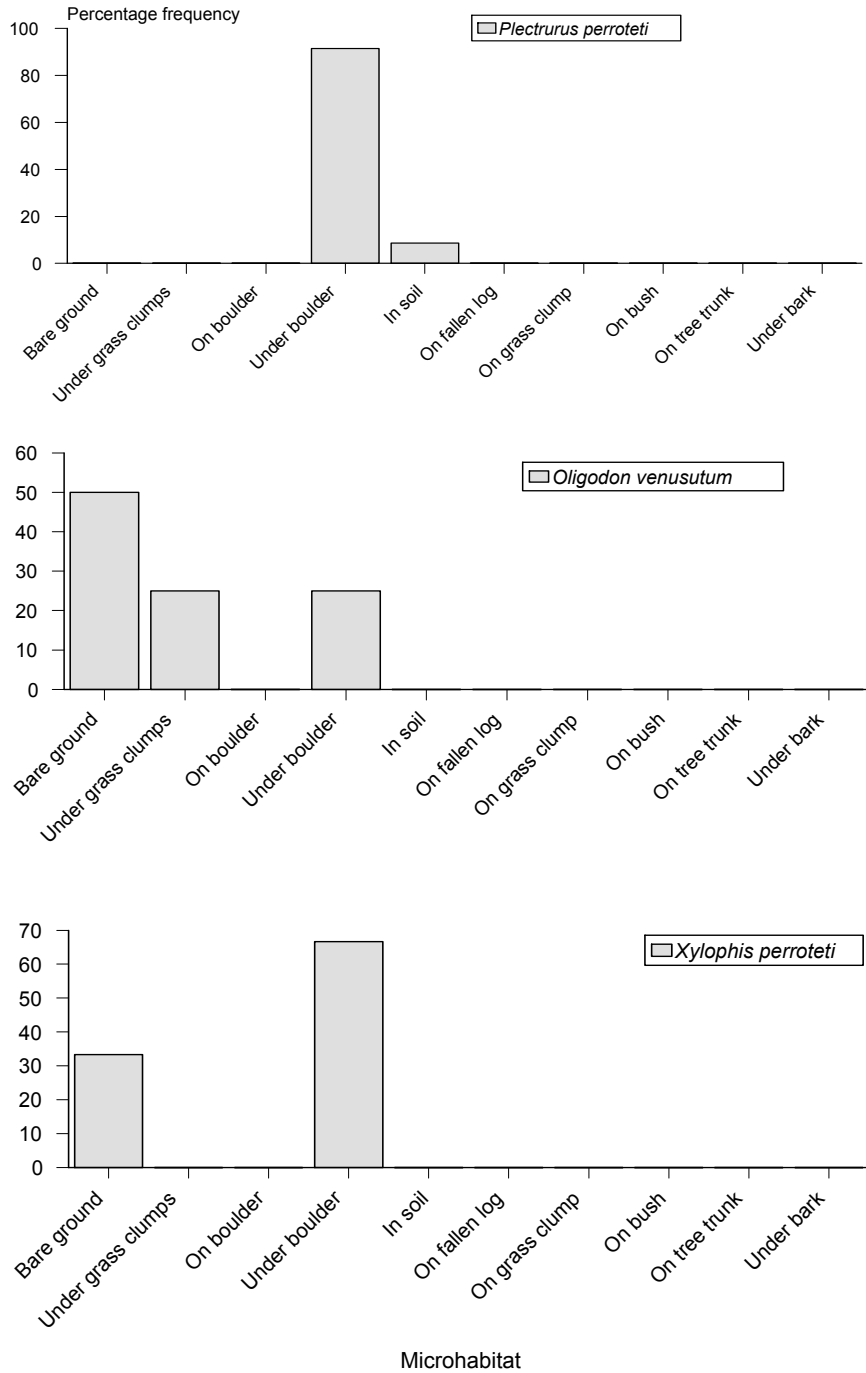


Fig. 4.4a. Microhabitat use by snakes in Upper Nilgiris, Western Ghats.

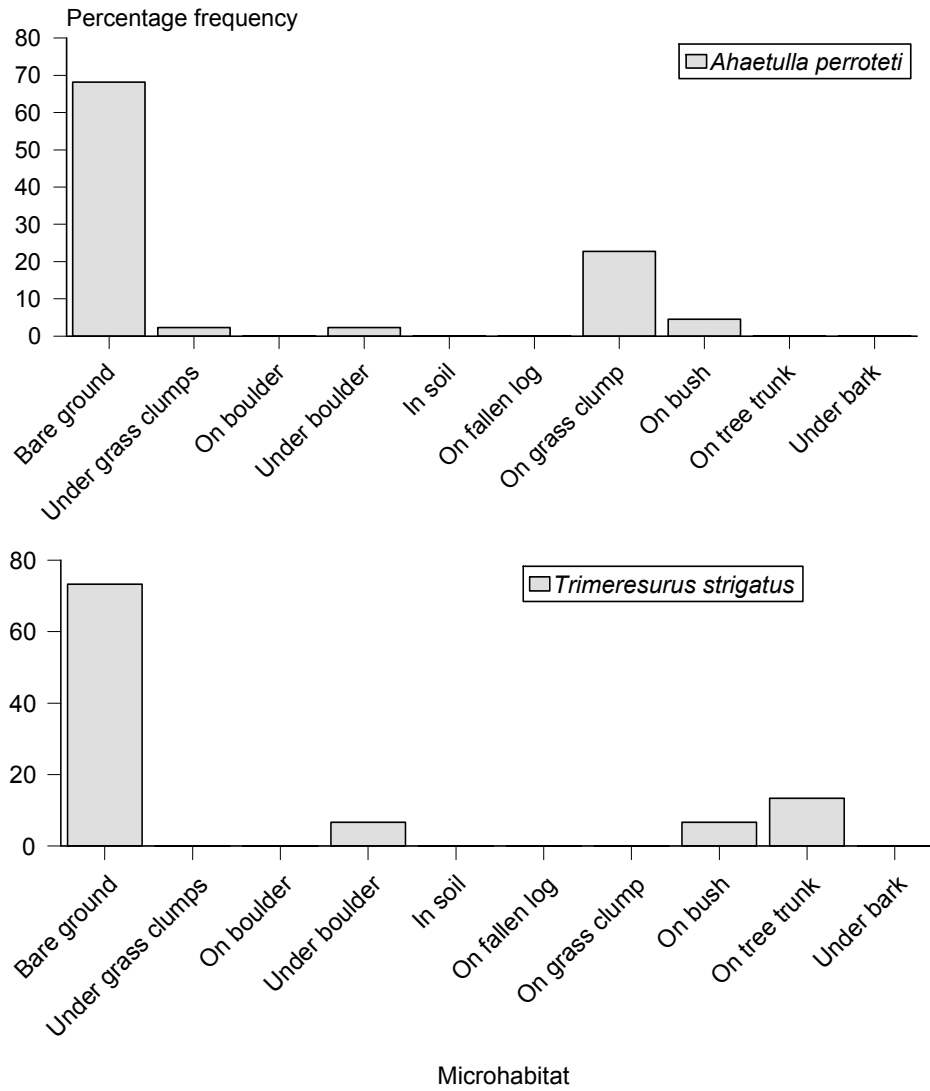


Fig. 4.4b. Microhabitat use by snakes in Upper Nilgiris, Western Ghats.

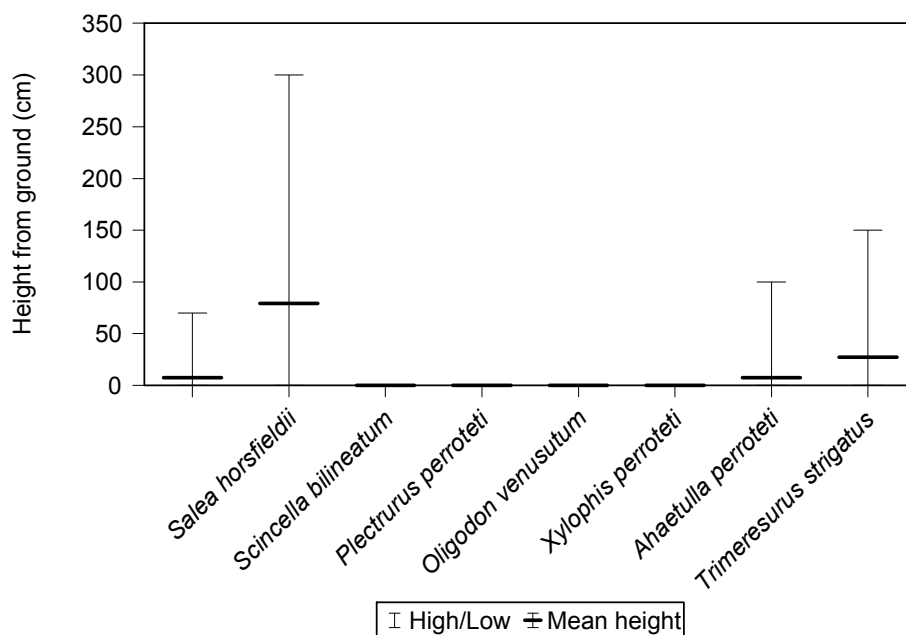


Fig.4.5. Vertical distribution of reptiles in Upper Nilgiris, Western Ghats.

Mean temperature recorded at 1200 hrs in various habitats showed that Tea plantations and Grasslands were warmer than other habitats. Pine and Shola were colder compared to other habitats.

Table 4.3. Habitat variables recorded in Upper Nilgiris, Western Ghats; numbers in parentheses indicate area (in ha) sampled.

Habitat variables	Grassland (8.4)	Shola (3.5)	Wattle (8.4)	Pine (2.01)	Tea (4.8)
No of trees/100 m ²	0.22	20.5	117.5	6.7	2.9
No. of fallen logs/100 m ²	0.15	6.5	20.8	1.4	0.7
No. of boulders/100 m ²	6.22	6.1	2.5	0.24	0.6
No. of rock crevices/100m ²	1.18	0.49	0.23	0	0
Percentage leaf litter	0.06	57.35	25.7	81.5	47.9
Mean Temperature ° C (at 1200 h)	19	15	18	13	19

In all, the number of reptiles observed (all species together) did not correlate significantly with many of the habitat variables. Only two variables had significant relation with reptile density; atmospheric temperature ($r = 0.047$, $P < 0.05$) and tree density ($r = -0.061$, $P < 0.01$). With temperature the relation was positive, whereas it was negative with

respect to tree density. Insignificance of other habitat variables could be due to the artifact of clumping data. Paired *t* – test with select variables between habitat pairs showed some significant differences, in tree density and temperature among habitat pairs (Table 4.4). However, boulder density varied only marginally, and the differences were significant for habitat pairs Grasslands-Tea and Grasslands-Wattle (Table 4.4). Habitat variables such as boulder and tree density were correlated with individual species. Various species behaved differently with respect to these parameters (Table 4.5).

Boulder

Boulder density had both positive and negative influence on species. To explain the relationship between the boulder and species, cubic relation was found fitting. Increase in species density was found to be non-linear with boulder number or density. The density of *Cnemaspis indica* increased with increase in boulder density ($R^2= 0.707$, Fig 4.6a). The overall density differed significantly among the boulder classes (ANOVA, $F = 4.823$, $df = 5$, $P = 0.05$). *Salea horsfieldii* had negative relation with boulders and maximum frequency in the quadrats with fewer boulders (Fig 4.6a). The skink, *Scincella bilineatum* had unimodal distribution pattern; density of this species increased up to certain boulder density (Fig. 4.6a). This shows that lower as well as higher density of boulders would affect the density of this lizard species and hence, the abundance of this species is predicted by the availability of boulders ($R^2= 0.725$).

Table 4.4. Comparison of select habitat variables in various habitat pairs in Upper Nilgiris, Western Ghats; Significant difference at *** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$.

Tree density

Habitat	Grassland	Shola	Wattle	Pine	Tea
Grassland	-	-2.007*	-4.852 ***	-2.719 **	0.869
Shola		-	-3.959 ***	-0.917	-1.776
Wattle			-	3.505 ***	-4.778 ***

Pine				-	-2.524 *
Tea					-
Boulder density					
Habitat	Grassland	Shola	Wattle	Pine	Tea
Grassland	-	-1.992	-2.216 *	-1.941	-2.161 *
Shola		-	-1.347	-1.830	-0.500
Wattle			-	-1.542	-1.847
Pine				-	-1.215
Tea					-
Temperature (°C)					
Habitat	Grassland	Shola	Wattle	Pine	Tea
Grassland	-	4.899 ***	3.719 **	-5.451 ***	3.780 **
Shola		-	-9.552 ***	-1.170	-3.336 **
Wattle			-	-5.735 ***	-1.770
Pine				-	2.758 **
Tea					-

In general, snakes excluding *Plectrurus perroteti* showed negative relation with respect to boulders (Fig. 4.6b). *Oligodon venusutum* and *Xylophis perroteti* were omitted from this analysis due to paucity of data. Density of each snake species in Upper Nilgiris did not vary with boulder density (Table 4.5).

Tree

As in boulder category, snakes such as *Oligodon venusutum* and *Xylophis perroteti* were omitted from the analysis due to small sample size. All species of reptiles except *Salea horsfieldii* showed negative trend with respect to tree density (Fig 4.7a and 4.7b). Barring *Salea horsfieldii*, variation in the density was significant with the increase in tree density or number (Table 4.5).

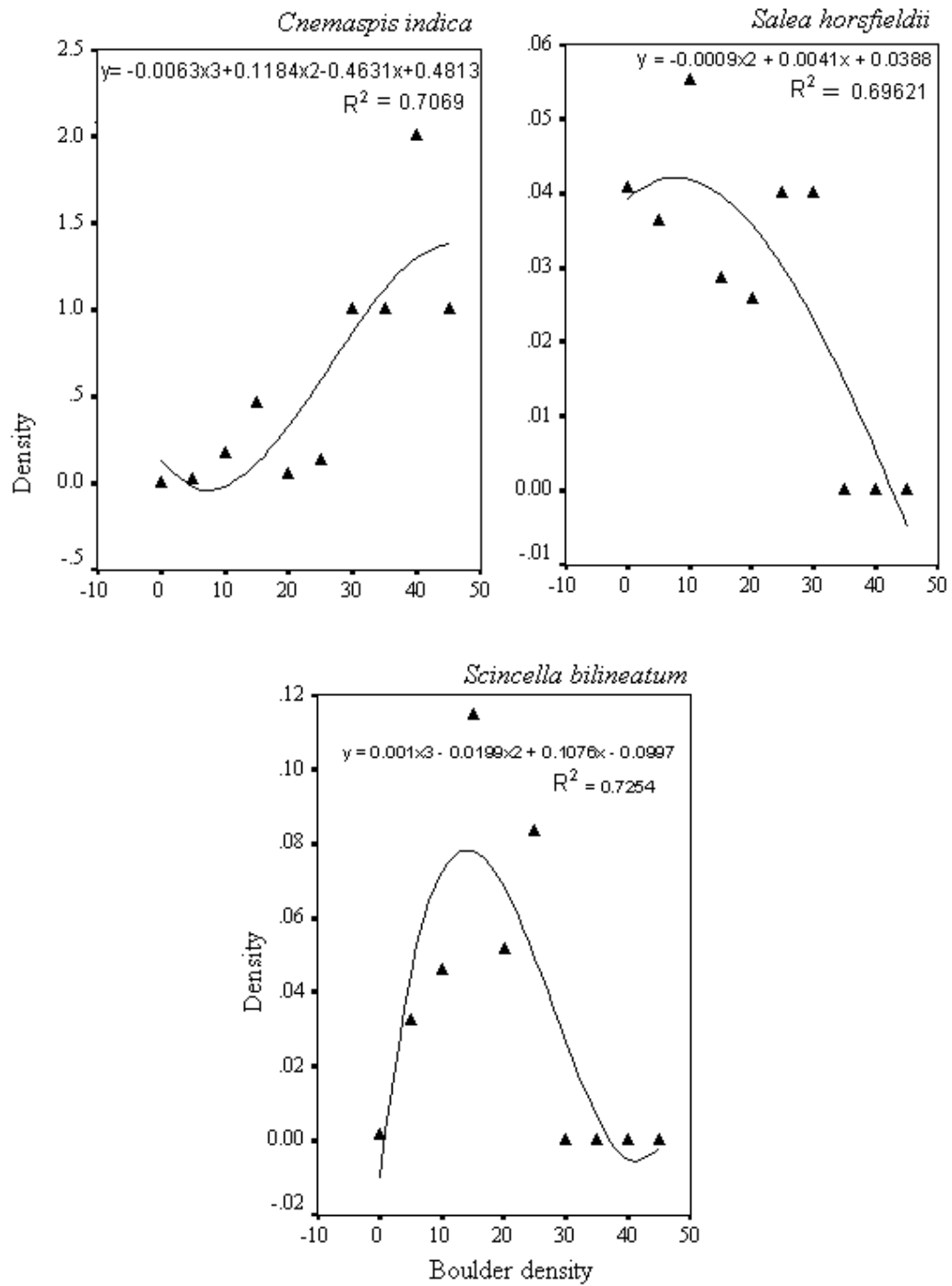


Fig. 4.6a. Relationship between the density of boulders and lizards in Upper Nilgiris, Western Ghats.

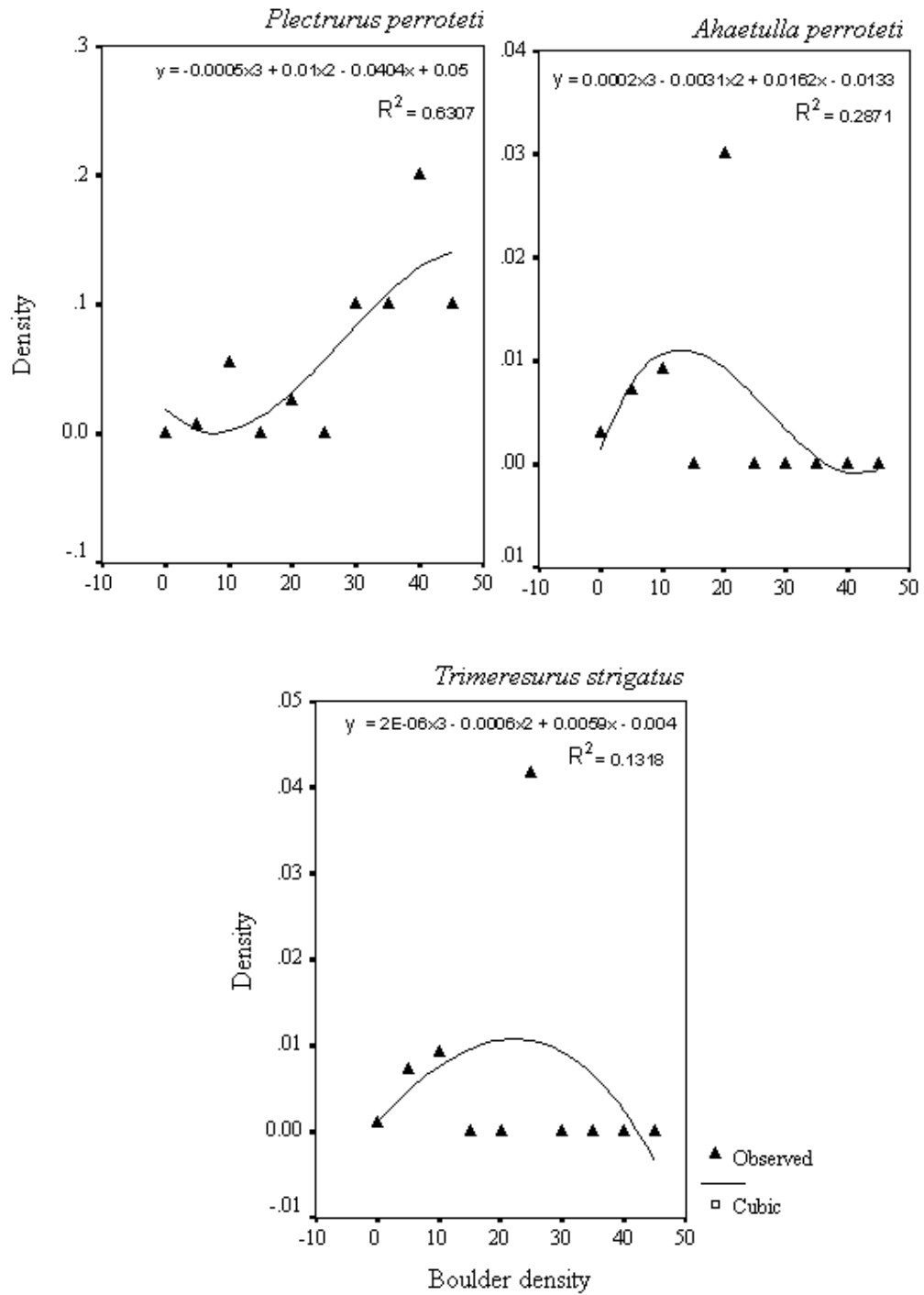


Figure 4.6b. Relationship between the density of boulders and snakes in Upper Nilgiris, Western Ghats.

Table 4.5. Relationship (cubic relation) between the density of species and boulder and tree in Upper Nilgiris, Western Ghats. Significance at $P=0.01^*$, $P= 0.05^{**}$, $P= 0.005^{***}$, $P= 0.0001\#$,

Species	Boulder density		Tree density	
	R ²	F	R ²	F
<i>Cnemaspis indica</i>	0.7069	4.824**	0.7247	10.28***
<i>Salea horsfieldii</i>	0.6962	4.583**	0.0175	0.063
<i>Scincella bilineatum</i>	0.7254	4.622**	0.7054	20.72#
<i>Plectrurus perroteti</i>	0.6307	3.699	0.6001	3.98**
<i>Ahaetulla perroteti</i>	0.2871	0.632	0.7143	6.715*
<i>Trimeresurus strigatus</i>	0.1318	0.296	0.2066	33.242#

4.4. DISCUSSION

Reptile community of the Upper Nilgiris, Western Ghats largely used Grasslands (Fig. 4.1 and 4.2). All species but *Xylophis perroteti* were found in Grasslands. In the present study, lower altitude species such as *Ptyas mucosus*, *Xenochrophis piscator* and *Xylophis perroteti* were recorded in the adjacent area of the Mukuruthi National Park. All these species are common in lower altitudes, which are probably invading in to higher altitudes, and *Xylophis perroteti* appears to be establishing in the vicinity of the Mukuruthi National Park (Bhupathy and Nixon, 2004). As the climatic condition is rigorous, the invasion rate appears to be low. Smith (1943) reported that *Oligodon venusutum* was not uncommon below 2000m in Nilgiris, Palni hills and Wayanad, and this species is rare in almost all areas of the present study (> 2000m). Patrick (1967) found that the size of area, number of species in the pool which are capable of invading, and the rate of invasion greatly influence the number of species and the diversity of community. The distribution of a few species in Upper Nilgiris could also be due to various geophysical constraints (See Chapter-III Population). Invasion of species could be due to change in temperature regime due to global warming at larger scale (Martin, 2001) or to clearing Shola forests at local level. This condition provides opportunity for temperature driven taxa such as reptiles for invasion.

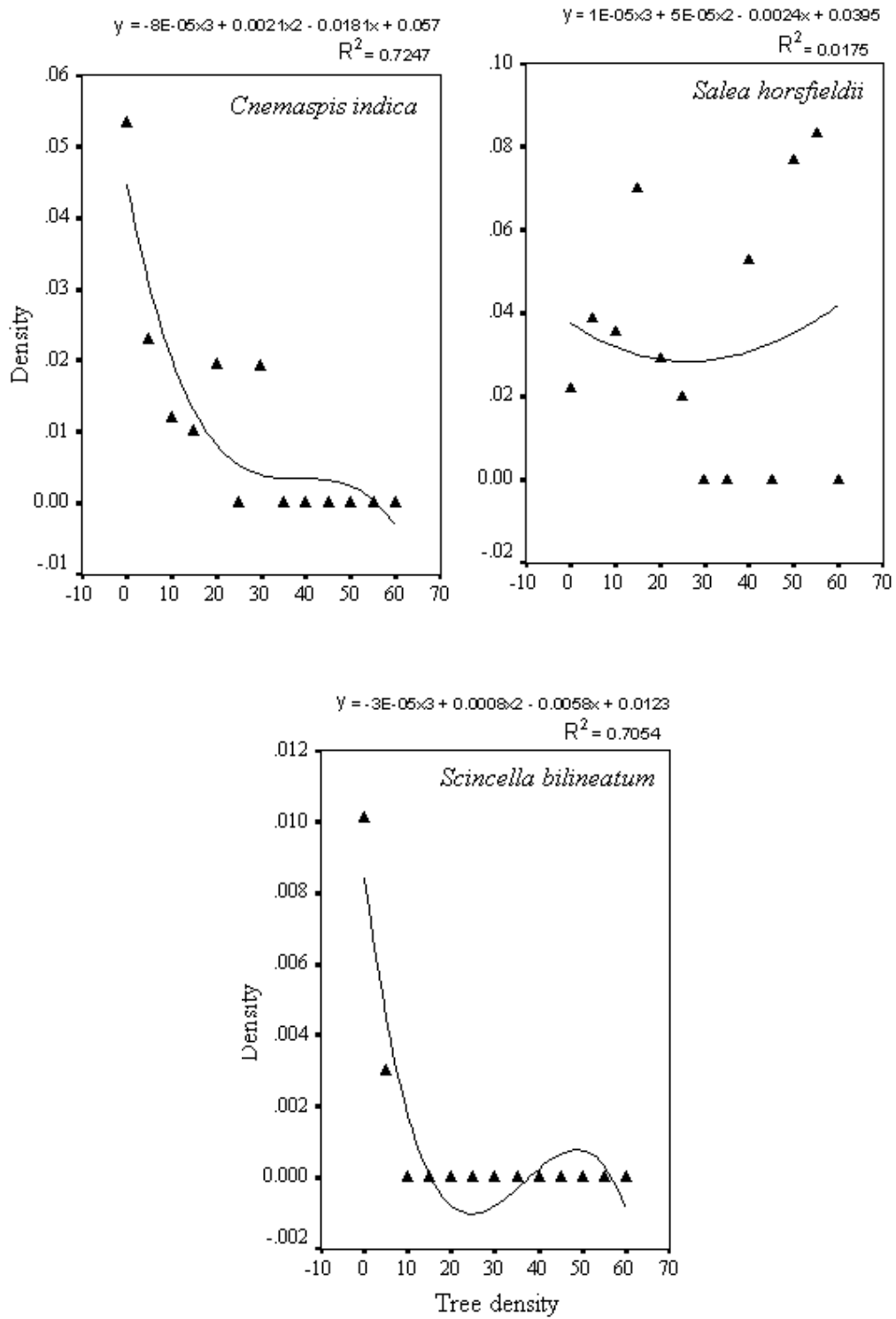


Fig. 4.7a. Relationship between the density of trees and lizards in Upper Nilgiris, Western Ghats.

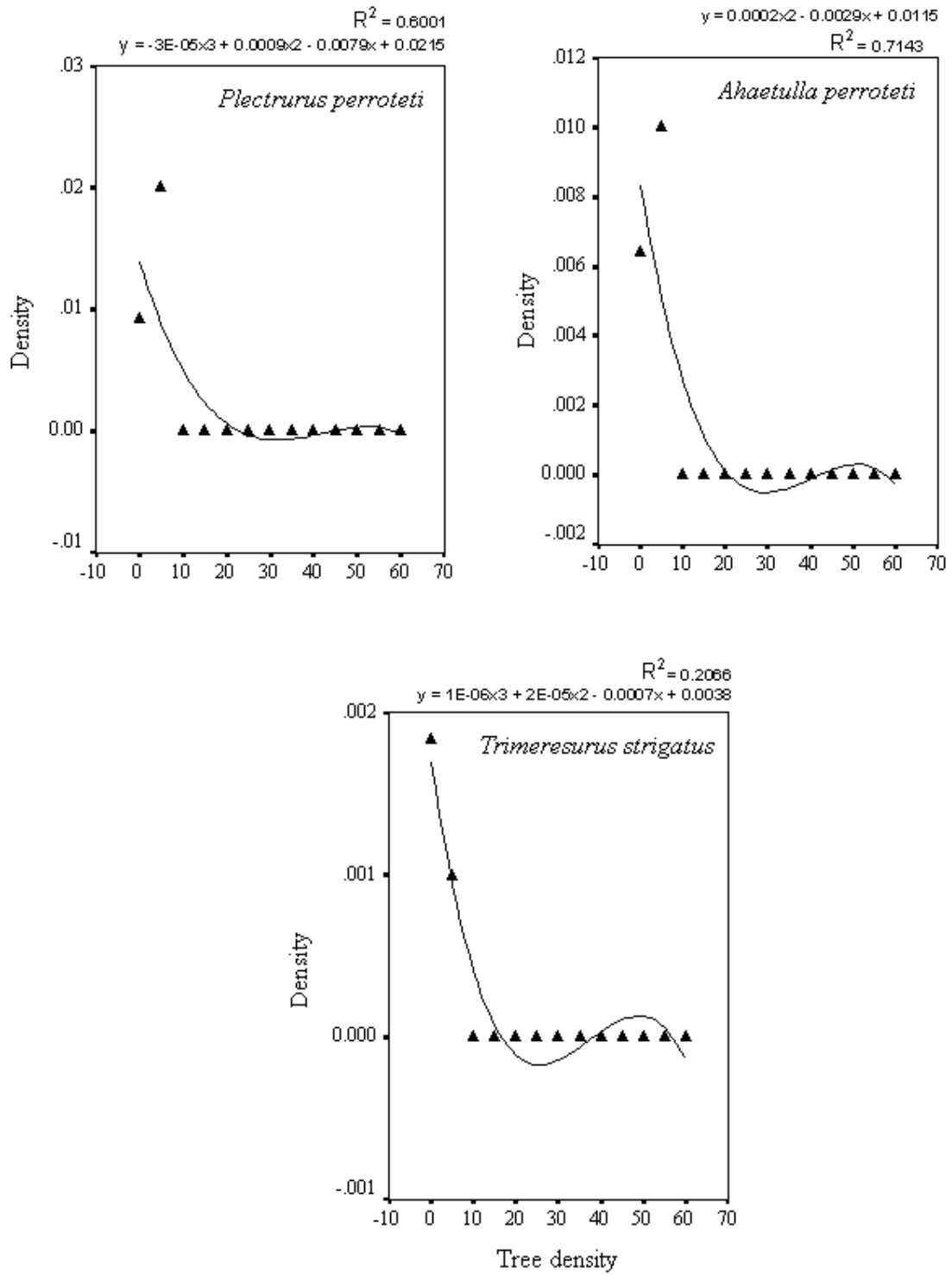


Fig. 4.7b. Relationship between the density of trees and snakes in Upper Nilgiris, Western Ghats.

Salea horsfieldii is a versatile species and used the entire range of habitats. Similarly, *Anolis cristatellus* was found using all habitat types in Puerto Rica (Genet, 2002). Nevertheless, this species has been observed more in vegetated habitats such as Shola compared to other habitats. Present observation on the habitat use of *Salea horsfieldii* is similar to that of *S. anamallayana* (Bhupathy and Kannan, 1997a). Bhupathy and Nixon (2004) reported that this species used the edge of the forest (e.g. Shola and Grasslands edges). Similarly, the Anolis lizard *Norops polylepis* were captured in high frequency along the forest edges than in interior forest (Schlaepfer and Gavin, 2001). Agamid lizard *Calotes nemericola* preferred habitats with small trees (Rao and Rajabai, 1972), which is similar to the habitat use of *Salea horsfieldii*. *Scincella bilineatum* was observed in all five habitats during this study. Duda and Koul (1977) reported that skinks are diverse in habitat and habits. The present observation is similar to the observation on Ground dwelling skinks (Hutchinson and Schwaner, 1991), Tasmanian skink, *Niveoscincus metallicus* (Melville and Swain, 1997) and Himalayan skink, *Scincella himalayanum* (Duda and Koul, 1977).

In general, microhabitat utilisation of reptiles is poorly known. Broadly, reptile microhabitat categories of Upper Nilgiris may be grouped into two: above ground (stem, bark) and ground (boulders, crevices, grass clumps, fallen logs). As the area is nearly temperate (with very low atmospheric temperature and high rainfall), adopting this type of strategy in microhabitat use should be beneficial for their survival. The utilisation of (below) ground microhabitats by uropeltid snakes has already been reported (Smith, 1943; Rajendran, 1985). Similarly, as in the present study, utilisation of rocky areas by geckoes has been reported in the Western Ghats by Ishwar *et al.* (2001).

Reptiles inhabiting colder area by selecting microhabitats in and around boulders or rocky substratum may take advantage of thermal benefits. Bishop and Echternacht (2003) have reported that *Anolis carolinensis* had consistent body temperature throughout the night by selecting rocky

substrate, when the air temperature dropped substantially during night. Inger (1959) found that *Mabuya rudis* use more open canopy and the *Sphenomorphus sadanus* in opposite fashion. Similar to *Mabuya rudis*, *Cnemaspis indica* and *Scincella bilineatum* are found more in open areas. Importance of selecting suitable microhabitats by reptiles for protecting themselves from weather and predators has been recognized (Boykin and Zucker, 1993). Gravelly substrates provide a complex background that makes visual detection of the lizards very difficult for the predators (Beauchamp *et al.* 1998).

Nunez *et al.* (1989) found Iguanids, *Liolaemus fuscus* and *L. lemniscatus* near rocky microhabitats in higher frequencies. In terrestrial poikilotherms (such as reptiles), the thermoregulation is achieved behaviorally by adjusting habitat selection and timing of activities. Huey *et al.* (1989) reported that selection of retreat by reptiles is influenced by the thermal properties of the rock, often selecting those that allow them most for thermoregulation. It is also reported that by selecting appropriate microhabitats, lizards can maintain their body temperature (Greenberg, 1976).

Arboreality of agamid lizards especially the *Calotes* and *Salea* lizards (Sunderesan and Daniels, 1994; Bhupathy and Kannan, 1997a; Daniel, 2002; Ishwar *et al.* 2003; Bhupathy and Nixon, 2004) and *Ahaetulla* spp. (Smith, 1943) has been documented. *Salea horsfieldii* displayed arboreality more than other species of lizard and they predominantly were found at about 80cm from the ground and it the similar perch height used was recorded in Puerto Rican anolis lizard, *Anolis cooki* (Genet, 2002). Similar to *Ahaetulla perroteti*, the Chinese green tree viper mostly used low bushes (0.01 to 1m) on the ground (Tu *et al.* 2000). Foliage structure, microclimate and prey availability may all interact or affect the foraging and perch height of arboreal snakes (Lillywhite and Henderson, 1993). Preference of thickets by species such as *Salea horsfieldii* may protect themselves from avian predators as it has been reported by Fellers and

Drost (1991), who worked on the ecology of the Island night lizard, *Xantusia riversiana* in Santa Barbara Island. Effect of perch diameter on the escape behaviour of Anolis lizards from predators has been documented (Losos and Irschick, 1996).

Many reptiles use trees for foraging, nesting and as refuge from predators. Foliage cover is also an important factor for lizards in selecting arboreal microhabitat for the obvious benefits; may provide cover and reduce the likelihood of detection by predators (Cooper *et al.* 1983; Cooper, 1993). It is reported that to avoid predation, Anolis lizards select short thin branches infrequently used by their primary predator and sleep at the branch extremity (Chandler and Tolson, 1990). Presumably, selecting above ground locations protect them from terrestrial predators and sleeping on terminal plant parts provides them warning when predators approach as those parts move when the stem is disturbed (Martins, 1993). Microhabitat use and vertical distribution of reptiles may also be determined by various ecomorphological traits as recognized in rock inhabiting lacertids (Arnold, 1983) and arboreal Anolis lizards (Losos and Irschick, 1996).

The potential interaction of biotic and abiotic factors influence habitat use and has important implications for ecological consequences (Martin, 2001). However, studies on this line on temperature dependent species community such as reptiles are scanty (Harvey *et al.* 1998). Overall correlation of various habitat parameters such as temperature, boulder availability and tree density and reptile density in the present study shows that they are significantly influenced only by temperature ($P < 0.05$). This view is highly strengthened by strong significant negative correlation ($P < 0.01$) between the density of reptiles and trees. This trend was almost similar at individual species level with respect to temperature. The role of temperature in regulating the distribution and activities of poikilothermic taxa such as reptiles has widely been recognized (Brooks, 1967); however, more studies are needed in tropical countries on this line. The

weak or no correlation between reptile density and other habitat variables could be due to the ill effect of clumping of data.

The relationship of individual species and select habitat parameters such as boulder density and tree density was different. For instance, the correlation between the density of boulders and *Salea horsfieldii* was negative, whereas it was positive with *Cnemaspis indica*, *Plectrurus perroteti* (Fig. 4.6 a, b). Similarly, all species observed in Upper Nilgiris had negative relation with tree density, but *Salea horsfieldii* had no notable relation with this parameter (Fig. 4.7 a, b). Difference in the above trend could be due to differing physiological requirements or tolerance of each species as reported by Martin (2001).

4.5. SUMMARY

- Area (Quadrat) and Time (Visual Encounter Survey) constrained sampling techniques were used for data collection. The forest type was considered as habitat or macrohabitat and location of the species as microhabitat. Location of an individual of a species when first sighted from the ground was considered as its vertical position. Habitat variables assessed in each quadrat include number of trees, fallen logs, boulder and litter cover in each quadrat. Atmospheric temperature at each observation site/ quadrat was recorded using a digital thermometer.
- Higher proportions of *Cnemaspis indica* (82%) and *Scincella bilineatum* (57.1 %) were found in Grasslands. *Salea horsfieldii* was a versatile species in habitat use, as it was found in all habitats in considerable numbers. However, it was found more in Shola forest, mainly on shrubs. Among snakes, *Plectrurus perroteti*, *Ahaetulla perroteti* and *Trimeresurus strigatus* largely used Grasslands. *Ahaetulla perroteti* was versatile among snakes in using various habitats compared to other species. Chi-square analysis showed that all species of reptiles in Upper Nilgiris showed significant

differences in their habitat use.

- Higher proportion (>50%) of the reptiles of Upper Nilgiris has used boulders. About 87.5% of *Cnemaspis indica* was found under boulders. *Salea horsfieldii*, *Ahaetulla perroteti*, *Cnemaspis indica* and *Trimeresurus strigatus* had their mean height from the ground were 79.02, 7.4, 7.4 and 27.1 cm respectively. Due to the prevailing colder conditions, most of the species found in this region largely inhabited ground level microhabitats.
- Density of trees was highest in Wattle 117.5 / 100 m² followed by Shola 20.5 trees/100m². The highest density of boulders was found in Grasslands (6.22/100m²) and the lowest in Pine. Mean temperature recorded at 1200 h showed that Tea plantations and Grasslands were warmer than other habitats. Pine and Shola were colder than other habitats.
- Boulder density had both positive and negative influence on *Cnemaspis indica* and *Salea horsfieldii* respectively. Barring *Plectrurus perroteti* snakes in general showed a negative relation with boulders.

CHAPTER- V

FOOD HABITS

5.1. INTRODUCTION

Food is one of the fundamental factors that directly influence the survival of a species, as energy is required for all activities. Variations in the utilisation of food among species play a major role in community organization. Relative role of species interactions, temporal and spatial variations in resource availability and phylogeny appear to be complexly intertwined in determining diets of sympatric species (Vitt and Zani, 1998a). Animals may adopt various strategies to locate and utilize food resources, some of them being difference in mode of catching prey, morphometric variations and activity period (diurnal/ nocturnal/ seasonal). Shape and size of the body and mouth may also play an important role in the use of different feeding methods adopted by a species. Features such as low energy requirement and prolonged inactive period of reptiles such as aestivation and hibernation make the food habit studies difficult. Energy requirements and food consumption rates of reptiles are an order of magnitude lower than those of similar sized birds and mammals (Diaz, 1995).

A large number of literatures are available pertaining to the food habits of the reptiles of western countries and Australia. Among them, the pioneering and seminal works are that of Pianka (1976, 1978, and 1986). Pianka and colleagues have studied lizard communities for over 20 years in continents such as Australia and Africa. Temporal variations in feeding and difference in prey items have been reported especially among lizards. Other recent works on the food habits of reptiles are by Vitt and his associates (Vitt, 1995; Vitt and Zani, 1998a, b; Vitt *et al.* 2002) in South American tropics. These studies report a variety of food items such as ants, beetles, grasshoppers and crickets, non- ant hymenopterans, insect larvae, pupae, eggs, spiders and termites as important food of reptiles,

especially lizards.

Diet of various species of reptiles have been reported in recent years; scincid species, *Mabuya striata wahlbergii* (Heideman and Bates, 1999), Lacertid lizards, *Psammodromus algirus*, *Podarcis bocagei*, *Lacerta schreiberi*, and *Lacerta monticola* (Diaz, 1995). Dietary composition of legless lizards (Pygopodidae) such as *Pygopus lepidopodus* and *P. nigriceps* and were reportedly very diverse (Patchell and Shine, 1986). Also legless lizards such as *Lialis burtonis* fed on a variety of vertebrate preys such as skinks, geckoes, agamid lizards and elapid snakes. Species such as uropeltid snakes may be specialists feeding on earthworms and other soft-bodied preys (Smith, 1943; Rajendran, 1985). It has been reported that *Vipera berus* fed almost exclusively on a rodent species *Microtus agretis* (Werner, 1994). Thus, the literatures show that reptiles are highly variable in food consumption from specialist (one or two food items) to generalist (consuming a variety of items).

Food habits of Indian reptiles are poorly documented. Information on this aspect is sporadic and sketchy, and is largely based on opportunistic observations (Smith, 1935, 43; Das, 1995; Daniel, 2002). Exceptions being species such as the Bengal monitor lizard, *Varanus bengalensis* (Auffenberg, 1986), Indian flapshell turtle, *Lissemys punctata* (Bhupathy and Vijayan, 1993) and Limbless skink, *Barkudia insularis* (Rao and Rao, 1997). In the present Chapter, aspects such as the dietary composition of reptiles observed in Upper Nilgiris are discussed.

5.2. METHODOLOGY

Various methods are available to study the food habits of reptiles. Among them, the most important and widely used one is the gut content analysis (Pianka, 1969, 1970; Diller and Wallace, 1996; Vitt and Zani, 1998a and b; Vitt *et al.* 2002). This method involves killing of the study animals. Some times preserved specimens in the museums are also examined to study the food habits and reproductive status of herpetofauna (Patchell and

Shine, 1986; Heideman and Bates, 1999; Keogh *et al.* 2000). Harmless methods such as fecal analysis (Bhupathy and Vijayan, 1993; Beaupre, 1995) and stomach flushing (Parmenter, 1980; Seigel *et al.* 1995) were also used to study the food habits of reptiles.

In the present study, reptiles were collected opportunistically from road kills, killed by plantation workers and cattle grazier in close vicinity to the study area. Upon availability, these specimens were stored in 10% formaldehyde during the present study extending over two and half years. No attempt was made to collect live reptiles for gut content analysis as the study area largely comes under National Park. Hence, the results are based on limited samples. Apart from this, opportunistic direct observations were also included in the present analysis. Prior to gut content analysis, morphometric measurements such as Snout-Vent Length, Jaw Length, Head Length and Width were recorded using a Mitutoyo dial vernier calipers (accuracy 0.02 mm). The stomach contents were placed on a petri dish and prey items were separated and identified to the lowest taxonomic order. Length and width of the intact prey items were measured using vernier calipers.

5.2.1. Data Analysis

The following analyses were done.

(1) Individual prey volume was calculated using the formula

$$V = 4/3 \Pi (\text{prey length}/2) * (\text{prey width}/2)^2 \text{ (Vitt and Zani, 1998a, b; Vitt } et al. 1998a).$$

(2) Importance index value (I_x) was calculated following Powell *et al.* (1990) and Anderson and Mathis (1999).

$$I_x = (n_x/N) + (v_x/V) + (f_x/F)$$

Where,

n_x = number of prey taxa, v_x = volume of the prey, and f_x = frequency of prey items, and N, V, and F similarly are summations of the number, volume and frequency of all prey

items. Relative importance of each food item is expressed as an index ranging from 0 to 1.

(3) Linear regression was used to find out the relationship between snout-vent length of the lizard and prey length (SPSS version 10.0).

(4) Mann-Whitney-U test was performed to statistically test the difference in the prey use among species.

5.3. RESULTS

The data presented in this Chapter are based on stomach contents of 27 *Salea horsfieldii*, 18 *Scincella bilineatum*, 24 *Cnemaspis indica*, eight *Plectrurus perroteti*, five *Ahaetulla perroteti* and four *Trimeresurus strigatus*. Apart from this, direct opportunistic feeding observations were also recorded especially for snake, where only a few samples were available. As *Oligodon venusutum* was rare in the present study area, no feeding observation was possible. However, prey items reported in the literatures were considered, and each item was given equal importance in the analysis. Food volume and importance index values were calculated at generic/family level or above. This analysis was restricted to only lizards as sufficient samples were available only for these species.

In all, 18 food categories were identified for three species of lizards. However, only five items were observed with respect to five species of snakes (Appendix 5). As the data is based on small sample size (4 to 27 samples), it is to be noted that the present data shows only the general food spectrum of the species involved.

5.3.1. Dietary Composition

Cnemaspis indica

In all, 24 *Cnemaspis indica* were examined of which only 15 individuals had ten food materials identifiable to taxa. Food items include nine invertebrates and one plant remnants (Table 5.1). About 25.3% geckoes had beetles (Coleoptera), 19 % bees and ants (Hymenoptera) followed by

11.4% grasshoppers (Orthoptera). With respect to percentage frequency of prey items, Hymenopterans (27.3%), Coleopterans (22.1 %) and Hemipterans (15%) were high. However, the total volume of Coleopterans contributed the highest (25.6%) followed by Hemipterans (15.4%) and Hymenopterans (11.9%; Fig.5.1). Plant parts found in only one gut of this species and this may be due to accidental ingestion of the same while swallowing the animal prey.

Salea horsfieldii

In all, 31 *Salea horsfieldii* were examined, of which 27 had identifiable food items. Ten taxa of food were observed including nine invertebrates. Highest percentage of lizards had Hymenopterans (29.8%) followed by Coleopterans (25.9%). Also a significant percentage of this species had Lepidopterans (Table 5.1). Higher frequency of Hymenopterans (45%) prey items was recorded followed by Coleopterans and Lepidopterans. Members of Hymenoptera, Coleoptera and Lepidoptera formed bulk of the volume of the food of this agamid lizard (Fig 5.1). These forms contributed higher quantities of food as well. Plant parts were found in about 10% of the examined lizards.

Scincella bilineatum

Twenty *Scincella bilineatum* were examined of which 18 had identifiable food items. Including plant materials, ten taxa of food items were observed, of which nine were invertebrates. About 30% of the lizards had Coleopteran prey remains in the gut contents. Percentage frequency of prey items found in the gut contents of this species is given in Table 5.1. Similar to *Salea horsfieldii*, plant materials were found in about 10% of the lizards examined. Insects belonging to Lepidoptera, Coleoptera and Hemiptera had higher frequency in the gut contents of this skink. These forms contributed to the total food volume as well, which was dominated by Lepidopterans (Fig. 5.1). Other preys such as Hemipterans, Coleopterans and Araneida also contributed significantly to the food of *Scincella bilineatum*.

Table 5.1. Gut contents of *Salea horsfieldii* recorded in Upper Nilgiris, Western Ghats.

No.	Taxa	% no. of lizards with food items	% Frequency of food items
<i>Cnemaspis indica</i>			
1	Coleoptera	25.3	22.1
2	Hemiptera	10.1	15
3	Hymenoptera	19	27.3
4	Lepidoptera	6.3	3.6
5	Orthoptera	11.4	9.1
6	Diptera	4	2.7
7	Dermaptera	1.3	1
8	Araneida	4	2.7
9	Diplopoda	10.1	9.1
10	Plant parts	1	1
<i>Salea horsfieldii</i>			
1	Coleoptera	25.9	24.8
2	Hemiptera	3.05	1.9
3	Hymenoptera	29.8	45
4	Lepidoptera	16.8	10.1
5	Orthoptera	3.05	1.6
6	Diptera	8.4	6.6
7	Dermaptera	1.5	1.2
8	Araneida	0.8	0.6
9	Diplopoda	6.1	4.1
10	Plant parts	4.6	4.1
<i>Scincella bilineatum</i>			
1	Coleoptera	29.5	30.7
2	Hemiptera	6.4	6
3	Hymenoptera	6.4	7
4	Lepidoptera	19.2	19.8
5	Orthoptera	5.1	5.9
6	Diptera	5.1	3.9
7	Dermaptera	0	0
8	Araneida	7.7	5.9
9	Diplopoda	10.3	9.9
10	Plant parts	10.3	10.9

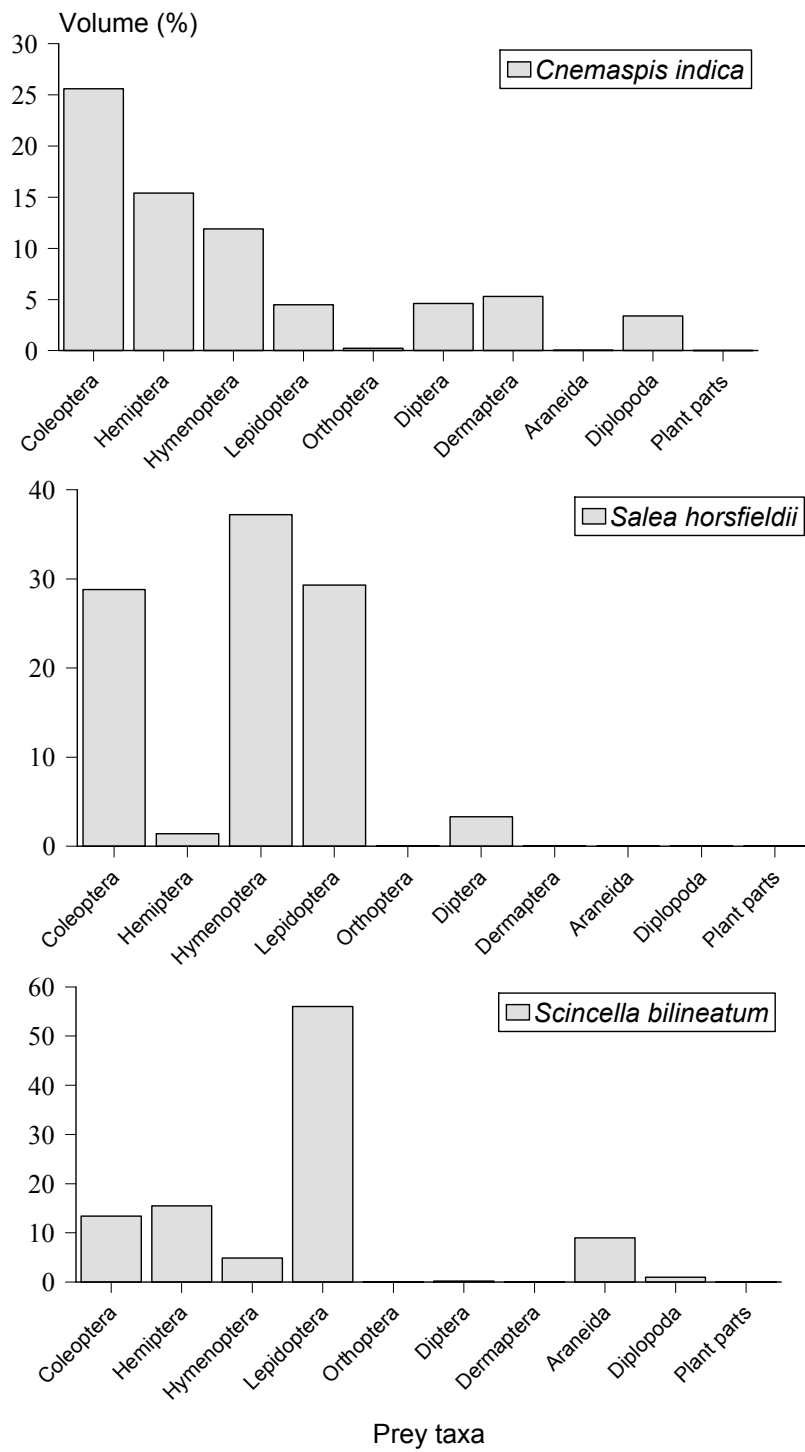


Fig. 5.1. Volume of various prey taxa found in the gut contents of Lizards in Upper Nilgiris.

Snakes

With the limited data set, it is clear that syntopic snakes are different in food consumed compared to lizards. Food items observed in snakes are given in Table 5.2. While *Plectrurus perroteti* fed exclusively on earthworms, other (3) species largely fed on vertebrates; *Ahaetulla perroteti* on amphibians and *Trimeresurus strigatus* on mammalian preys. *Xylophis perroteti* was observed feeding on worms and insects. During the present study, feeding observation on *Oligodon venusutum* was not possible. However, this species is reportedly feeding on amphibians, lizards and mammals (Smith, 1943; Daniel, 2002).

Table 5.2. Food of snake species observed in the Upper Nilgiris, Western Ghats; *Records from literature (Smith, 1943; Daniel, 2002); \$ direct observation.

Prey items	Snakes				
	<i>Plectrurus perroteti</i>	<i>Ahaetulla perroteti</i>	<i>Oligodon venusutum</i>	<i>Xylophis perroteti</i>	<i>Trimeresurus strigatus</i>
Insects	0	0	0	1\$	0
Earthworms	8	0	0	1\$	0
Amphibians	0	5	1*	0	1
Reptiles	0	2	1*	0	0
Rodents	0	0	1*	0	3
No. of observations	8	7	-	2	4

5.3.2. Importance Index (I_x)

Importance index gives an idea on most common and potential prey taxa of a species (Anderson and Mathis, 1999; Sproston *et al.* 1999). This index takes account of number, volume and frequency of prey items consumed. The importance index reduces the bias associated with indices that use fewer measures. The range of this index varies from 0 to 1; zero represents least importance and one for maximum or higher value.

As per the Importance index, Coleopterans were the most important food items of *Cnemaspis indica* (Table 5.3). Hymenopterans were the important prey items of *Salea horsfieldii* followed by Coleopterans and

Lepidopterans. As Hymenopterans obtained index value one (1), this taxon is very important food for *Salea horsfieldii*. Lepidopterans were the most important of all prey items of *Scincella bilineatum* followed by the Coleopterans. The most important prey taxa of lizard species differed from one another (Table 5.3). Important prey items of snake species could not be ascertained owing to small sample size and difficulty in observations. However, it appears that earthworms are the most important food for *Plectrurus perroteti* as all (8) observations were on earthworms. Amphibians and rodents appear to be important food for *Ahaetulla perroteti* and *Trimeresurus strigatus* respectively. Thus, in all, diets of these sympatric species were different from each other.

Table 5.3. Importance index (I_x) of various prey items found in the gut contents of the lizards of Upper Nilgiris, Western Ghats; * most important food taxa.

No	Taxa	<i>Cnemaspis indica</i>	<i>Salea horsfieldii</i>	<i>Scincella bilineatum</i>
1	Coleoptera	0.65*	0.68	0.82
2	Hemiptera	0.36	0.11	0.31
3	Hymenoptera	0.55	1*	0.20
4	Diptera	0.10	0.22	0.10
5	Lepidoptera	0.19	0.56	0.84*
6	Dermoptera	0.44	0.05	0
7	Orthoptera	0.06	0.10	0.12
8	Araneida	0.07	0.03	0.16
9	Diplopoda	0.30	0.21	0.23
10	Insect larvae	0.29	0	0.20

Dietary variability of three lizards was tested using Mann Whitney U test and species pairs were compared to know the difference in the prey items consumed. There is a significant difference in the prey species of the lizards studied. The Mann Whitney U test showed that some of the prey items were significantly different with respect to *Cnemaspis indica* and *Salea horsfieldii* (Table 5.4). In *Cnemaspis indica* and *Scincella bilineatum*, prey species such as Coleopterans, Hymenopterans, insect larvae, and plant materials were significantly different (Table 5.4). The species pair *Scincella bilineatum* and *Salea horsfieldii* also had significantly different

prey species (Table 5.4).

Table 5.4. Mann Whitney- U test showing variations in the prey items consumed by various species pairs of lizards found in Upper Nilgiris, Western Ghats; * significant at $P=0.05$, ** $P= 0.01$, *** $P= 0.001$.

Prey taxa	Species pair		
	Salea-Scincella	Salea-Cnemaspis	Cnemaspis-Scincella
	Mann-Whitney U	Mann-Whitney U	Mann-Whitney U
Coleoptera	709*	886	1224***
Hymenoptera	900*	779.5**	963***
Lepidoptera	947	880	1623
Hemiptera	826**	828.5**	1799.5
Araneida	887.5	918	1741.5
Diptera	805.5	700.75*	1616.75
Dermaptera	944	944	1800
Insect larva	950	725.5**	1405.5**
Arthropod	848*	832*	1772
Plant part	911.5	825**	1647.5*

5.3.3. Body Size and Prey Size

Snout-Vent Length of the lizards and prey length were correlated to find out the relation between body size of the predator (i.e.: lizards) and prey size. A significant correlation was found between the snout-vent length of *Cnemaspis indica* and prey length ($r = 0.544$, $P= 0.01$, $N= 24$; Fig. 5.2). However, in *Salea horsfieldii* and *Scincella bilineatum* the relation was not significant (Fig. 5.3 and 5.4). In *Salea horsfieldii*, the size of the lizard and prey size (length) was not significantly related.

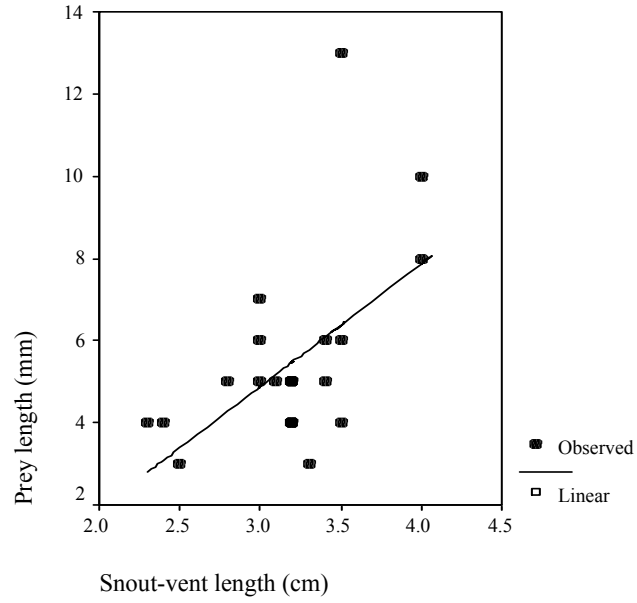


Fig.5.2. Relationship between the Snout-Vent Length of *Cnemaspis indica* and prey length; $r = 0.544$, $P = 0.01$, $N = 24$.

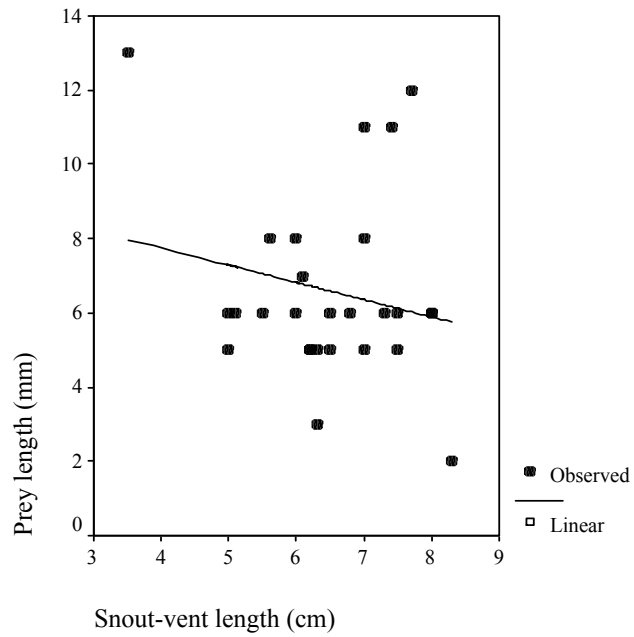


Fig. 5.3. Relationship between the Snout-Vent Length of *Salea horsfieldii* and prey length; $r = -0.200$, $P = 0.318$, $N = 27$.

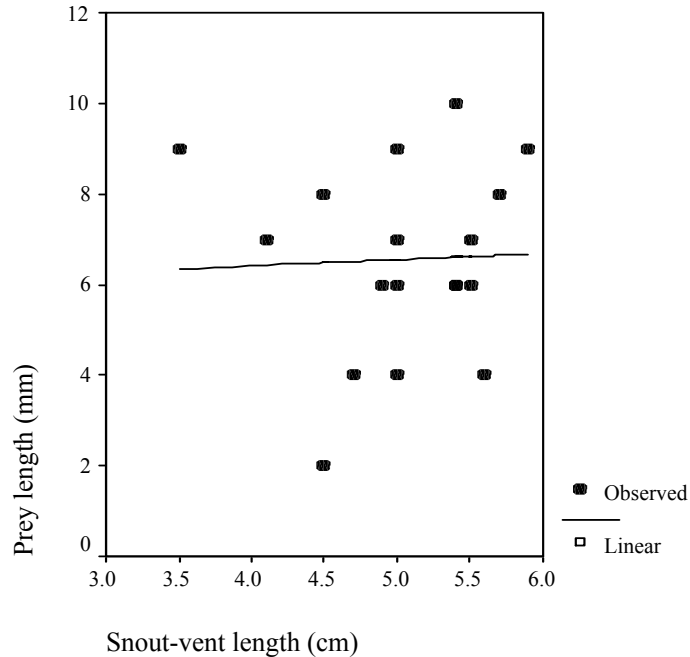


Fig. 5.4. Relationship between the Snout-Vent Length of *Scincella bilineatum* and prey length; $r = 0.040$, $P = 0.876$, $N = 18$.

5. 4. DISCUSSION

In the present study, it was observed that lizards fed on a variety of food items, especially on the invertebrates. It is reported that skinks are largely insectivorous and some large species may devour small vertebrates and a few are partially herbivores (Smith, 1935). The present observations of plant materials in about 10% of the individuals partly augment the above report. Pianka (1969) recorded 22.95% of plant matter in the diets of Australian desert skinks, *Ctenotus*. Insects have been reported as a chief food of geckoes; larger species can devour any thing that they overcome. The present observations support the view of Smith (1935) in this respect as well. Anolis lizards (Iguanid) were reportedly feeding largely on insects. Around thirty different prey items were reported in the diet of the Anolis and among them the predominant ones were Hymenopterans followed by Dipterans (Schoener and Gorman, 1968). Agamids are largely insectivorous and species belonging to the genus such as *Lyriocephalus*,

Agama, *Phrynocephalus*, and *Leiolepis* may be partially herbivorous and *Uromastix* is entirely herbivorous (Smith, 1935). In the present study, the endemic agamid lizard, *Salea horsfieldii* largely fed on insects and a smaller proportion of its food was constituted by vegetation. Similar to the *Salea horsfieldii*, gut contents were dominated numerically by ants followed by fewer large prey items in three closely related Iguanid species such as Anolis lizards (Schoener and Gorman, 1968).

During this study, it was observed that *Plectrurus perroteti* fed on earthworms and other snakes largely fed on vertebrate preys. According to Smith (1943) and Rajendran (1985), Uropeltid snakes mainly consume earthworms and other soft-bodied preys such as insects and larvae. It has been reported that Uropeltid snakes feed on humus and some species may feed on termites (Smith, 1935; Rajendran, 1985). During the present study, *Ahaetulla perroteti* was observed feeding on frogs and reptiles. The closely related Green vine snake (*Ahaetulla nasuta*) has reportedly been feeding on tadpoles (Kunte, 1997). *Ahaetulla perroteti* feeding on vertebrates is similar to that of *Crotaphopeltis hotamboeia* (Family: Colubridae) of South Africa. These snakes chiefly feed on amphibians (97%) and the remaining prey items included skinks, agamid lizards and geckoes (Keogh *et al.* 2000). Most species inhabiting the tropical to subtropical habitats substantially fed on anuran preys (Vitt, 1987; Mushinsky, 1987). Kukri snakes (*Oligodon* spp.) are particularly fond of eggs of both birds and reptiles and spawn of the amphibians (Smith, 1943).

Most of the pit vipers consume a large number of rodents; for instance *Trimeresurus s. stejnegeri* of Northeastern Taiwan Fushan forest fed on small rodents, birds and occasionally lizards (Tu *et al.* 2000). Major prey of *Cerastes cerastes* and *Cerastes gasperetti* of North Africa and southwestern Asia, and *Vipera berus* of Sweden were rodents, particularly the gerbils. *Vipera berus* mainly feeds on *Microtus agrestis* and it has been reported that former two species feed on larger species of rodents

(Werner, 1994). The observations on *Trimeresurus strigatus* feeding on rodents in Upper Nilgiris augment these reports to certain extent.

Pianka (1969) reported that most of the lizards are opportunistic in food habits. Generally, two modes of foraging are recognized; sit and wait and active foraging. Members of most lizard families such as Iguanidae, Agamidae (*Salea horsfieldii*), and geckkonidae (*Cnemaspis indica*) primarily sit and wait for their prey, whereas most of the skinks (*Scincella bilineatum*) forage widely, searching for food. Snakes also adopt both the modes of foraging (Pianka, 1986). For instance, the Pit viper (*Trimeresurus strigatus*) may sit- and- wait for their prey but other species such as *Ahaetulla perroteti* or *Oligodon venusutum* may hunt actively. Hence, there are chances of variation in selecting their food. This may help avoiding competition as they extract food through different ways.

A significant variation was found between species with respect to the utilisation of food categories. For instance, the highest value of Importance index (I_x) obtained varied among species; members of Coleoptera, Hymenoptera and Lepidoptera were most important food for *Cnemaspis indica*, *Salea horsfieldii* and *Scincella bilineatum* respectively. Most of the Coleopterans and a group of butterflies (Lycaenidae) are active at ground level and these taxa were largely found in *Cnemaspis indica* and *Scincella bilineatum* respectively. On the other hand, the Hymenopterans are active at canopy level and the same was important food for arboreal lizard, *Salea horsfieldii*. Major food of the agamid *Agama tuberculata* was reported to be insects but spiders and flower petals were also reported (Bhatnagar, 1967). This is similar to the food of endemic agamid lizard, *Salea horsfieldii*. As in the present study, food of desert lizards by Pianka (1986) reported considerable variations in the food habits among them; some species specialized on scorpions, ants, termites, vertebrates and on plants. Difference in the food consumption was attributed to the habitat or microhabitat occupied by the species. In Upper Nilgiris, *Salea horsfieldii* is largely arboreal compared to *Cnemaspis indica* (gecko) and *Scincella*

bilineatum (skink). The microhabitat use and foraging mode of the species appear to play a major role in food consumed by lizards. Canopy dwelling species such as bees and wasps (Hymenopterans) in the food of *Salea horsfieldii* indicate the importance of microhabitats or position occupied by the species.

Barring *Salea horsfieldii* other two lizards found in the Upper Nilgiris showed a positive relationship with prey size (length). However, this is significant only with respect to *Cnemaspis indica* ($r = 0.544$, $P = 0.01$). Similarly, significant positive relationship was reported between body size and prey size in the Nicaragua rain forest lizards (Vitt and Zani, 1998a; Vitt *et al.* 1998a, 2002). Prey categories and body size relations have been studied in California Mountain Kingsnake, *Lampropeltis zonata* by Greene and Rodri'Guez-Robles (2003). It is reported that correlation between prey size and body size was not significant due to dietary differences among populations of Brazilian species of *Cnemidophorus* lizards (Mesquita and Colli, 2003). Ussher (1999) reported that the length category of the diet of Tuatara, *Sphenodon punctatus* fall over 10 mm, despite an abundance of smaller prey in the area. Significant relationship between the size of the lizard and size of the prey could be due to selection of different size of preys by smaller (e.g. juvenile) and larger (adults) individuals.

5.5. SUMMARY

- Gut contents were analyzed based on availability of specimens opportunistically from road kills, killed by plantation workers and cattle grazier in close vicinity to the study area.

- Percentage frequency of prey, prey volume and Importance index of the same were calculated. The relationship between the size of the lizard (snout-vent length) and prey length has been analyzed. Mann Whitney-U test was performed to know the difference in the prey use among reptile species.

- In all, eighteen food items were identified for three species of lizards. But, only five items were observed with respect to five species of snakes. At broader level, nine taxa of invertebrate food and one plant remains were identified in the gut contents of lizards. Hymenopterans (27.3%); Coleopterans (22.1 %) and Hemipterans (15%) contributed more to the diet of *C. indica*. Hymenopterans (45%) formed the bulk of the prey volume in *Salea horsfieldii* followed by Coleopterans and Lepidopterans. Plant parts were found in about 10% of the examined lizards of *Salea horsfieldii* and *Scincella bilineatum*. Insects belonging to Lepidoptera, Coleoptera and Hemiptera formed higher frequency of food of this skink.

- In comparison with lizards, snakes were different in food consumed; *Plectrurus perroteti* fed exclusively on earthworms and others largely fed on vertebrates.

- As per the Importance index, Coleopterans were the most important food utilized by *Cnemaspis indica*. Hymenopterans and Lepidopterans were the important prey taxa of *Salea horsfieldii* and *Scincella bilineatum* respectively. Dietary variability of three lizard species was significantly different. A significant correlation was found between the snout-vent length of *Cnemaspis indica* and prey length ($r = 0.544$, $P = 0.01$, $N = 24$).

CHAPTER- VI

RESOURCE UTILISATION

6.1. INTRODUCTION

Optimal use of resources is important for the survival of a species. In a competitive environment, optimum resource use is achieved by avoiding competition; in other words different species coexist by avoiding competition (Cody, 1974). Resource may be defined as environmental factors that are directly used by an organism and may potentially influence individual fitness. Aspects of resource include macro and microhabitats, food and daily and seasonal activities (Pianka, 1973; Thorpe and Crawford, 1979). Spatial distribution pattern of animals often reflect the availability and distribution of resource relative to the physiological requirements of organisms (Whiting *et al.* 1997). Microclimates, food, shelter and predators vary spatially and, provide opportunities for resource partitioning, and hence there is niche differentiation among potentially competing species (Melville and Swain, 1997). Resource use can be studied with respect to the three most often recognized niche axes are spatial, trophic and temporal (Pianka, 1986). Community complexity has made comparisons of all species coexisting in a given area difficult (Ricklefs, 1979; Diller and Wallace, 1996). It is reported that habitat is one of the most important niche dimensions partitioned by terrestrial vertebrates (Conroy, 1999). Group of species co-occurring in a given area is termed as community (Whitaker, 1975) and species that use the same type of resources in similar way is called guild (Root, 1967; Farlow and Pianka, 2002).

Temporal variations in activities such as feeding and breeding may be important for a species in using resources differently as demonstrated in coexisting Australian lizards (Pianka, 1975, 1976). Reptiles are prolific breeders and may be seasonal or non-seasonal. Breeding seasonality can affect many aspects of the species biology, and in turn may affect its life history and demography (Lemes-Espinal, 2003). Lizards show seasonality

in reproduction in tropics and it coincides with either dry or wet season (Vitt and Goldberg, 1983; Clerke and Alford, 1993), and in some case this may be continuous (Vitt, 1982, 1991). Extended breeding period has been reported for many tropical lizards (Lichtenbelt and Albers, 1993). Ambient environmental conditions may affect living organisms in many ways. Embryonic development was reported slower for many species of reptiles in colder conditions compared to warmer locations as in *Sceloporus aeneus* and *S. scalaris* (Andrews *et al.* 1999). High temperatures may greatly accelerate embryogenesis and shorten the incubation period. Reduced hatching success and poor quality offspring at cooler incubation conditions have also been recorded in *Sceloporus virgatus* (Qualls and Andrews, 1999).

Various studies are available pertaining to the resource utilisation pattern by different animal communities. Food items and size variations are attributed to the coexistence of several Australian lizards (Pianka, 1975), rodents (Brown, 1975), waterfowl (Poysa, 1983; Armstrong and Nudds, 1985). Vertical and horizontal stratification of species was found to be one of the major strategies in segregation of resources (e.g. MacArthur, 1972; Cody, 1974; Bhupathy, 1991). Variations in morphometry among them are also important mode in resources partitioning (Poysa, 1983; Kehoe and Thomas, 1987; Vitt and Zani, 1998a). Biologists have long appreciated that an animal's morphology reflects its ecology (Pianka, 1986). One way of addressing this issue of evolutionary biology is to compare morphological and ecological characteristics of closely related species (Macrini *et al.* 2003). Quantitative data on the spatio-temporal distributions or resource used by reptiles are scarce (Harvey *et al.* 1998), and comprehensive study on the resource utilisation pattern of Indian reptiles is lacking. In the present Chapter, an attempt is made to analyze various spatio-temporal use patterns of reptiles inhabiting the Upper Nilgiris, Western Ghats.

6.2. METHODOLOGY

Data on morphometry, habitat and microhabitat use, vertical position of each reptile observed and food were drawn from previous Chapters (see for methods: Population, Habitat Use, and Food). Morphometric data, especially head length, head width and jaw length were used to understand the morphology-mediated difference in the resource use by different species. Even though several aspects are there with respect to temporal utilization of animals (e.g. activity pattern), due to logistic difficulties these aspects were not covered during this investigation. We attempted to determine the breeding seasonality with respect to the emergence of hatchlings. Presence of various size class reptiles was recorded during the monthly sampling extended for two years. Individuals with umbilical streaks were considered as hatchlings (couple of weeks old) and the month of observation was included as breeding season. In certain cases, these observations were verified from literature as well (e.g. Smith, 1931-43; Rajendran, 1985; Daniel, 2002).

6.2.1 Data Analysis

The following data analyses were performed.

(1) Three dimensional plotting of head morphometry (head length, head width and jaw length) was done to find out segregation among species (SPSS, Version 10.0, 2000).

(2) Canonical discriminant function analysis was done to find out the variation in head morphometry (head length, head width, jaw length) among species (SPSS version 10.0, 2000).

(3) Niche breadth was calculated following Colwell and Futuyma (1971), which is the inverse of Simpson (1949) index

$$\beta = 1 / \sum P_{ij}^2$$

where, P_{ij} is proportion of individuals of species i occupying food resource state j .

(4) Niche overlap of species pair was calculated using Pianka (1978) overlap index (Φ).

$$\text{Pianka overlap index } \Phi_{in} = \frac{\sum P_{ij}P_{ik}}{\sqrt{\sum P_{ij}^2 P_{ik}^2}}$$

Where, P_{ij} , P_{ik} = Proportion of individual of species j and k occupying in the i^{th} category of the resource category, n = Number of resource category. Niche overlap would give an idea pertaining to the similarity in resource use by various species.

(5) Cluster analysis was done (SPSS, Version 10.0, 2000) to understand the species packing at resource categories separately and together.

6.3. RESULTS

Aspects such as (1) habitat (2) microhabitat and (3) vertical position of the reptiles from the ground were considered for analysis pertaining to spatial use. In addition, measurements of head length and width and jaw length were supplemented to understand the spatial use pattern further. Food consumed by reptiles was considered for resource use at trophic level, and emergence of hatchlings as temporal variations.

6.3.1 Morphometry

Head morphometry (head length, width and jaw length) often provide reasonably accurate information on the quality, quantity and prey size of lizards (Pianka, 1986). It is reported that variation in the consumption of food of an animal may be mainly due to morphological differences such as jaw length and head width.

Three-dimensional plots of head length, head width and jaw length showed that lizard species occupied different position in the multidimensional space (Fig. 6.1). Canonical analysis confirmed the above findings that the morphological differences among species were significantly different ($K = 0.902$, Table 6.1). Values close to 1 indicated a strong correlation between the discriminant scores and the morphometry of the lizard group. This would explain the variation in the food or mode of feeding among these lizards. The highest eigenvalue corresponds to the

eigenvector in the direction of the maximum spread of the mean head length. Small eigenvalues result in eigenvectors of jaw length and head width account for very little dispersion.

Snake species also have largely occupied distinct places in the three dimensional space (Fig. 6.2). Canonical correlation value for head morphometry of snakes showed a significant difference (Table 6.1). The variation of head length and width was significantly different in all species, whereas the variation was weak with respect to jaw length (Table 6.1). 75.8 % of the variation was found in head length, whereas it was only 23.7% in head width. Variation in jaw length was insignificant (0.5%).

Table 6.1. Canonical Discriminant Function analysis with respect to the morphometry of reptiles inhabiting Upper Nilgiris, Western Ghats.

Taxa	Eigenvalue	Variance (%)	Cumulative %	Correlation (K)
Lizards				
Factor 1	4.39	96.9	96.9	0.902
Factor 2	0.14	3.1	100.0	0.349
Snakes				
Factor 1	20.25	75.8	75.8	0.976
Factor 2	6.34	23.7	24.2	0.929
Factor 3	0.14	0.5	100.0	0.345

6.3.2 Temporal Variations in Hatchlings Emergence

Variations in temporal use of resources could be one of the potential ways of avoiding competition in resource partitioning. This may be achieved by fine-tuning in feeding and breeding at various time scales (selective feeding time and seasonality in breeding or emergence of hatchlings). By slightly adjusting the hatchling emergence time, a species may save the offspring from severe predation pressure, competition with other species for food and shelter.

Emergence of the hatchlings during various months is given in Figure 6.3a. *Cnemaspis indica* laid eggs communally at suitable microhabitats such as under stones, boulders and rock crevices. The hatchlings of

Cnemaspis indica started emerging from June and extended up to January. The peak emergence was observed during October (Fig. 6.3a). Similarly, *Salea horsfieldii* hatchlings were observed from September to March with the peak during October.

The hatchlings of *Scincella bilineatum* also emerged during monsoon, and the peak of the same was observed during October followed by November (Fig. 6.3a). The present study showed that the lizards have extended emergence period (breeding season), and the same occurred largely during dry season (non-monsoon).

Emergence pattern of the hatchlings of snakes is given in Figure 6.3 a, b. Hatchlings of snakes were observed during both monsoon and dry seasons. Hatchling emergence was different in the case of snakes compared to lizards, hatchlings of species such as *Oligodon venusutum* and *Trimeresurus strigatus* were observed during pre-monsoon, while others during post monsoon (e.g. *Xylophis perroteti*). Higher number of *Plectrurus perroteti* was observed during northeast monsoon (Fig. 6.3a). Higher number of hatchlings of *Ahaetulla perroteti* was observed during pre-monsoon (March - April). However, considerable number of hatchlings was observed during Northeastern monsoon (October-November) as well (Fig. 6.3b).

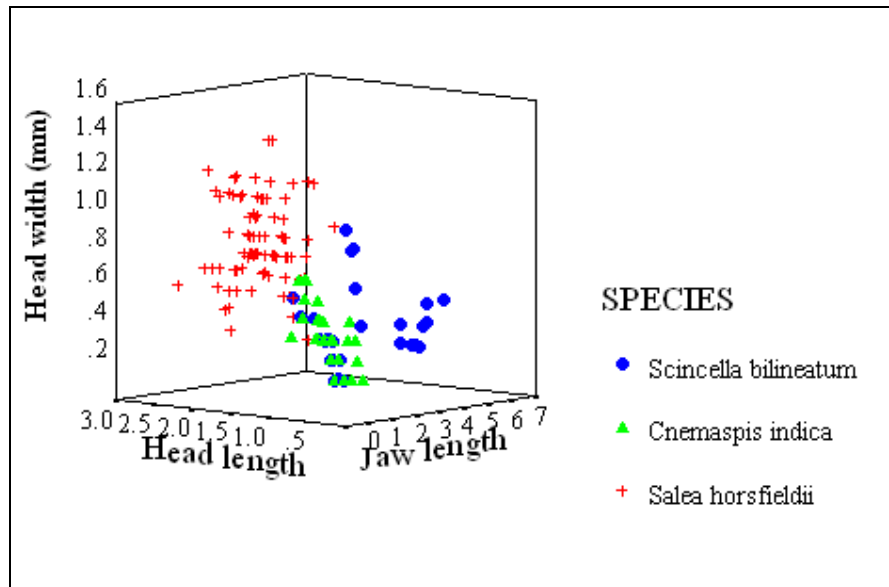


Fig. 6.1 Three-dimensional plot of head morphometry showing variations among lizard species found in Upper Nilgiris, Western Ghats.

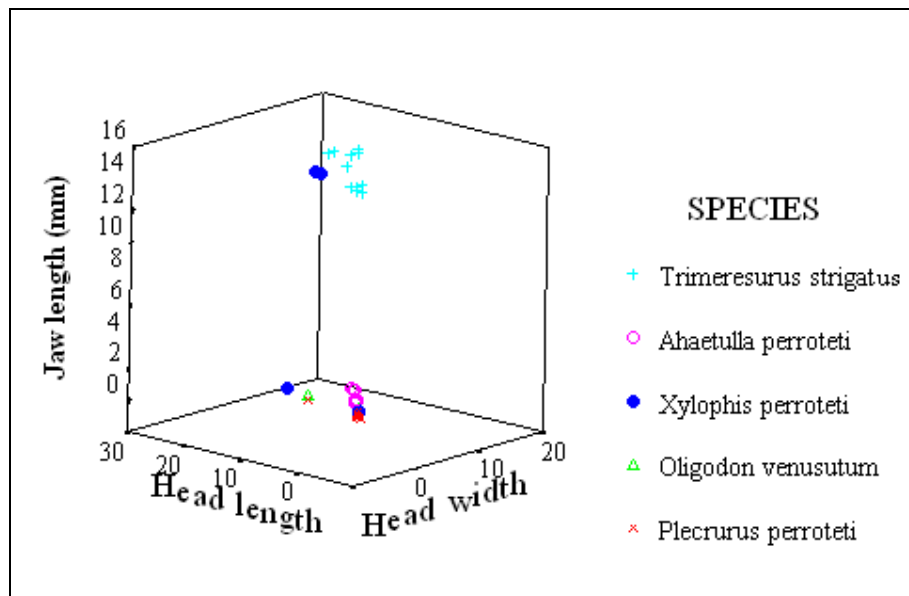


Fig. 6.2 Three-dimensional plot of head morphometry showing variations among snake species observed in Upper Nilgiris.

6.3.3. Niche Utilisation

Niche Breadth

Niche breadth may be defined as a unit of resource utilisation of an organism. The narrower the niche breadth, the species is more specialized and vice-versa in resource use. Niche breadth value (β) varies from 1 (exclusive use of single resource) to n (number of categories, number of food categories consumed). Niche breadth values indicate the adaptability of the species with respect to a particular resource level (e.g. food, microhabitat). In this section, spatial resource such as macro and microhabitat and vertical distribution, and trophic resource (food) of reptiles were considered.

As five habitats (forest types) were studied, the niche breadth (β) value would range from 1 to 5. Present analysis shows that habitat niche breadth of the reptile species of Upper Nilgiris varied from 1.42 to 3.67 (Table 6.2), the lowest value was obtained by *Cnemaspis indica* and highest by *Salea horsfieldii*. Except the agamid lizard (*Salea horsfieldii*), all other species had lower niche breadth values indicating their use of one or two habitats only. Among snakes, the Kukri (*Oligodon venusutum*) had the highest niche breadth (2.67) compared to other snake species (Table 6.2).

From the descriptive records on the microhabitats, 10 categories were short-listed and used for determining niche breadth, which should range from 1 to 10. As in habitats, *Salea horsfieldii* obtained the highest niche breadth value ($\beta= 2.89$), whereas the lowest was obtained for *Scincella bilineatum* (1.08). Among snakes, the Kukri (*Oligodon venusutum*) had the highest niche breadth (2.67) and *Plectrurus perroteti* the lowest (1.19).

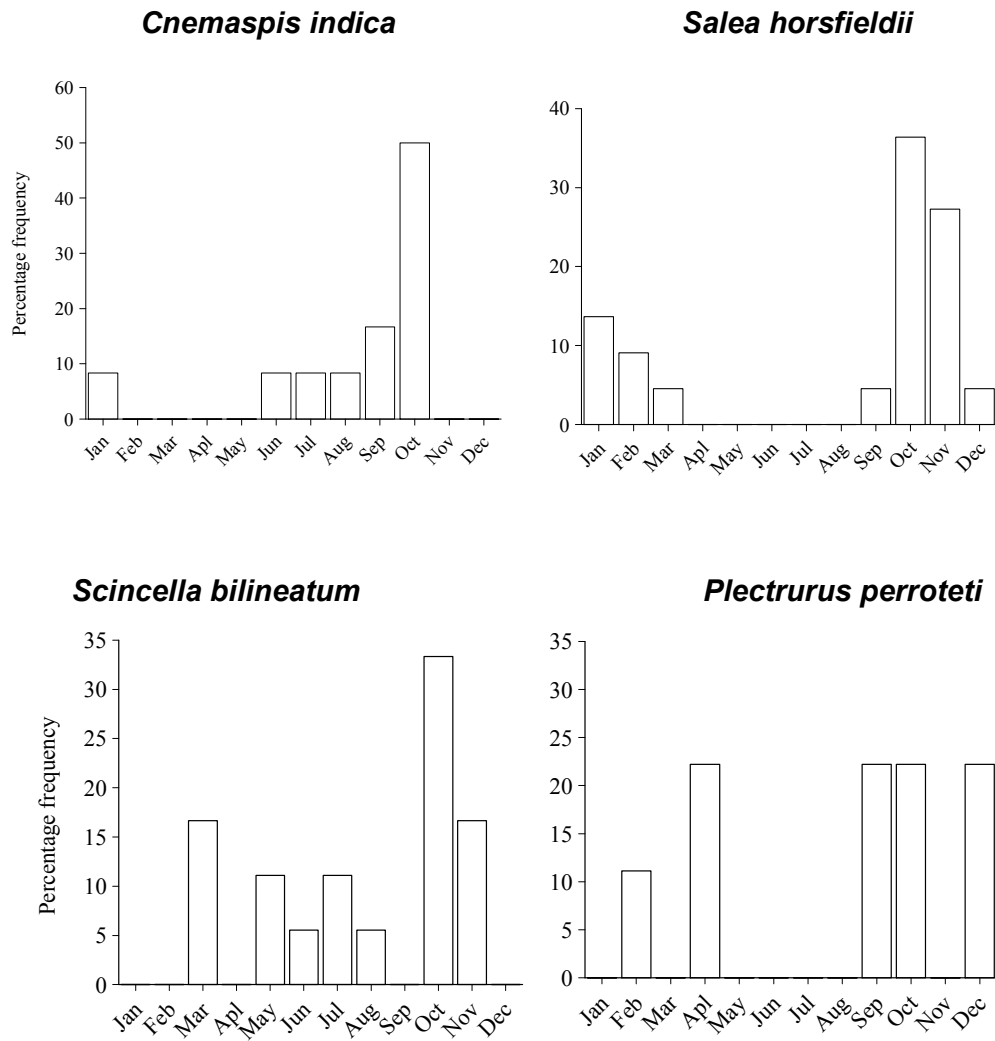
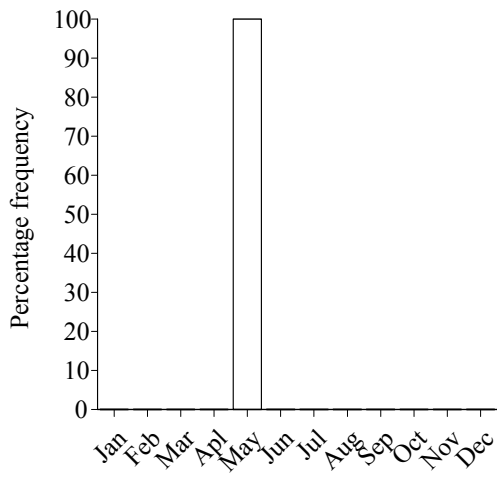
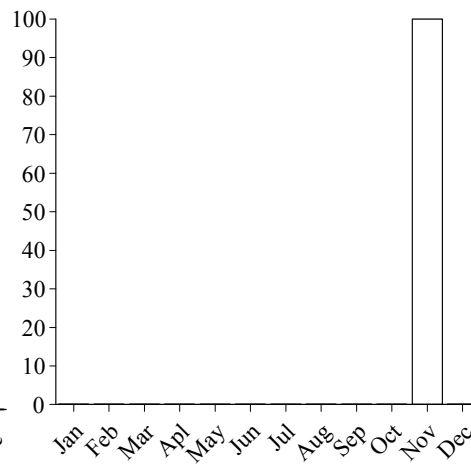


Fig. 6.3a. Emergence of the hatchlings of reptiles in Upper Nilgiris, Western Ghats.

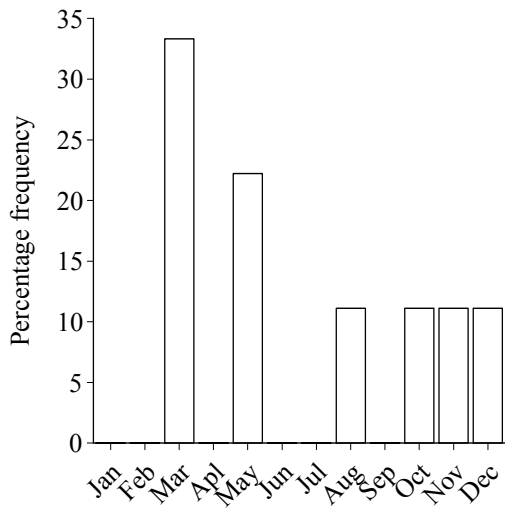
Oligodon venusutum



Xylophis perroteti



Ahaetulla perroteti



Trimeresurus strigatus

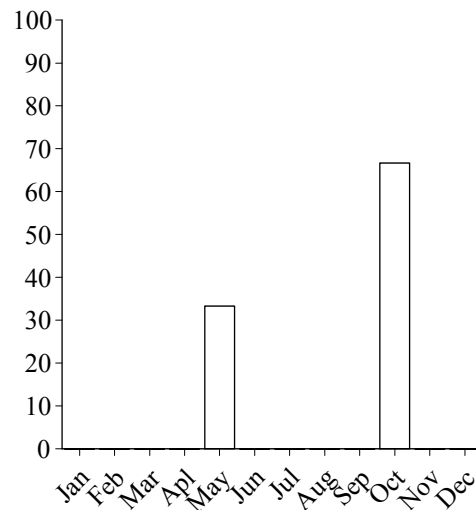


Fig. 6.3b. Emergence of the hatchlings of snakes in Upper Nilgiris, Western Ghats.

Table 6.2. Niche breadth of reptiles in various resource (spatial and trophic) levels in Upper Nilgiris, Western Ghats; * Following Cody, 1974.

Species	Resource category				Average niche breadth *
	Habitat	Microhabitat	Vertical Position	Food	
<i>Cnemaspis indica</i>	1.42	1.3	1.24	5.91	2.47
<i>Salea horsfieldii</i>	3.67	2.89	5.21	5.74	4.38
<i>Scincella bilineatum</i>	2.34	1.08	1	6	2.61
<i>Plectrurus perroteti</i>	1.71	1.19	1	1	1.22
<i>Oligodon venusutum</i>	2.67	2.67	1	3	2.33
<i>Xylophis perroteti</i>	1.8	1.8	1	2	1.65
<i>Ahaetulla perroteti</i>	1.79	1.92	1.33	1.69	1.68
<i>Trimeresurus strigatus</i>	1.92	1.77	2.37	1.6	1.92

In all, the niche breadth was low at microhabitat level compared to habitat indicating sensitivity or specificity of reptiles to microhabitats. Also, the microhabitat niche breadth ranged from 1.08 to 2.89 only when compared to the maximum range of microhabitats (10 categories) available. This shows that all species of reptiles found in MNP are specialist in the use of one or two microhabitats.

Raw data on the vertical position of the animals was sorted at 25cm interval, which resulted in 13 categories (from 0 to 300 cm). The niche breadth (β) at vertical position varied from 1 to 5.21. The minimum niche breadth ($\beta=1$) was obtained for four species namely, *Scincella bilineatum*, *Plectrurus perroteti*, *Oligodon venusutum* and *Xylophis perroteti*, as all these species were found only under stones or below ground. *Salea horsfieldii* had the highest niche breadth ($\beta=5.21$) followed by *Trimeresurus strigatus* ($\beta=2.37$). Among lizards, *Scincella bilineatum* had the lowest niche breadth (1.0). *Cnemaspis indica*, *Ahaetulla perroteti* and *Trimeresurus strigatus* showed some arboreality compared to other species and hence, they obtained niche breadth more than one. Lower niche breadth of many species indicates their specialization in the use of one or two vertical strata.

Number of food categories to the lowest recognizable taxonomic unit in the gut contents of reptiles was 21 (Appendix 5). Hence, the niche breadth

would range from 1 to 21. Niche breadth of species studied varied from 1 to 6 (Table 6.2). The lowest niche breadth was obtained for *Plectrurus perroteti* ($\beta=1$), as this species exclusively fed on earthworms. Niche breadth of *Scincella bilineatum* was the highest ($\beta=6$) compared to all other species. Niche breadth of *Cnemaspis indica* and *Salea horsfieldii* was comparatively higher ($\beta=5.91$ and 5.74 respectively). Overall the niche breadth values were low (1-6) compared to the range of food items consumed by reptiles in the region (ie. 21 categories). This indicates the specialization of each species for certain food items; *Plectrurus perroteti* on earthworm. The study indicates that lizards are generalists compared to snakes as revealed by higher niche breadth.

In all, 49 resource categories; 28 spatial (habitat- 5, microhabitat- 10, vertical position- 13) and 21 trophic were considered for this analysis (Appendix 5). Average niche breadth varied from 1.22 to 4.38 only (Table 6.2). This shows that the reptiles of Upper Nilgiris have low to moderate survival capabilities with respect to the utilisation of spatial and trophic resources. Among the reptiles of Upper Nilgiris, *Salea horsfieldii* was highly generalist in resource use compared to other species as it had obtained the highest total niche breadth value ($\beta= 4.38$), whereas the shield tailed snake, *Plectrurus perroteti* was a specialist ($\beta= 1.22$). All snake species obtained lower niche breadth value compared to lizards and hence, they may be considered as specialists in resource use (Table 6.2).

6.3.4. Niche Overlap

Niche overlap is the degree to which two species share various resources. It is assumed that niche overlap is proportional to the degree of competition. In the absence of competition for a particular resource, niche overlap would be meager. Under intense competition there would be greater overlap. The niche overlap (Φ) values vary from zero (0) to (1), where in zero are no overlap and one is complete overlap. In this section, spatial resource such as macro and microhabitat, vertical distribution and food of reptiles were considered. Temporal variation in the emergence of

hatchlings during various months was considered to find out the overlap among the reptile species. Thus, five parameters were used in the overlap analysis, namely habitat, microhabitat, vertical distribution, food and hatchling emergence.

The highest overlap was found between *Cnemaspis indica* and *Ahaetulla perroteti* ($\Phi = 0.99$) and no overlap ($\Phi = 0$) between *Xylophis perroteti* and *Trimeresurus strigatus* (Table 6.3). In all, lower overlap was observed between *Xylophis perroteti* and other species such as *Ahaetulla perroteti* (0.16), *Cnemaspis indica* (0.19) and *Plectrurus perroteti* (0.21). Altogether, eight species pairs (*Scincella bilineatum*-*Cnemaspis indica*, *Cnemaspis indica*-*Plectrurus perroteti*, *Cnemaspis indica*-*Ahaetulla perroteti*, *Scincella bilineatum*-*Plectrurus perroteti*, *Scincella bilineatum*-*Ahaetulla perroteti*, *Plectrurus perroteti*-*Ahaetulla perroteti*, *Ahaetulla perroteti*-*Oligodon venusutum*, and *Oligodon venusutum*-*Trimeresurus strigatus*) had higher overlap value ($\Phi = 0.9$). *Salea horsfieldii* with *Cnemaspis indica*, *Scincella bilineatum*, *Plectrurus perroteti* and *Ahaetulla perroteti* had niche overlap value below $\Phi = 0.5$ (Table 6.3). Niche overlap analysis at habitat level shows that *Salea horsfieldii* and *Xylophis perroteti* had less overlap with other species (Table 6.3) indicating that the habitat requirement of *Salea* and *Xylophis* was different from other species. The former species used largely the Shola forest and the later species the plantations. All the other species pairs had comparatively higher overlap indicating similarity in habitat use.

Niche overlap on microhabitat components of reptiles showed highest overlap in species pairs *Cnemaspis indica*-*Scincella bilineatum* ($\Phi = 0.99$) followed by *Scincella bilineatum*-*Plectrurus perroteti* (0.91). Lowest overlap was observed between *Salea horsfieldii* and *Plectrurus perroteti* (0). In all 21 out of 28 species pairs had overlap below 0.5 (Table 6.3). This lower overlap indicates that reptiles vary in the microhabitat utilisation to a greater extent. Also, in general, overlap among species pairs at microhabitat level was lower than habitat category.

Niche overlap based on vertical strata or position of the reptiles showed that six species pairs had complete overlap ($\Phi=1$; *Scincella bilineatum*-*Plectrurus perroteti*, *Scincella bilineatum*-*Ahaetulla perroteti*, *Scincella bilineatum*-*Oligodon venusutum*, *Plectrurus perroteti*-*Ahaetulla perroteti*, *Plectrurus perroteti*-*Oligodon venusutum* and *Oligodon venusutum*-*Ahaetulla perroteti*). All the above species largely used the ground layer (Table 6.3). *Salea horsfieldii* had low overlap with other species showing difference in exploiting resources compared to other species. It is to be noted that *Salea horsfieldii* is largely arboreal and was found in various vertical layers.

With respect to food, highest overlap was obtained for species pairs, *Cnemaspis indica*- *Salea horsfieldii* ($\Phi = 0.75$) followed by *Salea horsfieldii* - *Scincella bilineatum* (0.72). Only six species pairs had overlap above 0.5. No overlap was observed in as many as 21 species pairs (Table 6.3). Niche overlap between lizard species pairs showed moderately high overlap in food consumed. Overlap among snake and lizard pairs was negligible. This shows that the food consumed by lizards and snakes were different. Many species were highly specialists or restricted in their food habits. For instance, Uropeltid snake, *Plectrurus perroteti* fed exclusively on earthworms. Other species such as *Ahaetulla perroteti* fed largely on amphibians and *Trimeresurus strigatus* on rodents (Table 5.2; See Chapter: V).

Frequency hatchlings sighted in different months was used to calculate temporal overlap among reptiles. Highest overlap was noticed between *Cnemaspis indica* and *Trimeresurus strigatus* ($\Phi = 0.81$) followed by *Salea horsfieldii* - *Scincella bilineatum* ($\Phi = 0.8$). Seven species pairs had no overlap with respect to the emergence of hatchlings (Table 6.4). Barring six species pairs; *Cnemaspis indica*-*Trimeresurus strigatus*, *Salea horsfieldii*-*Scincella bilineatum*, *Cnemaspis indica*-*Trimeresurus strigatus*, *Salea horsfieldii*-*Cnemaspis indica*, *Scincella bilineatum*-*Cnemaspis indica* and *Scincella bilineatum*-*Trimeresurus strigatus*, all the other species pairs

had comparatively low overlap in the emergence of hatchlings (Table 6.4).

6.3.5. Species Assemblage

Dendrogram using single linkage nearest neighbor method was used to understand species assemblage at spatial, trophic and temporal levels separately and together. This would give an idea of closely related species with respect to the usage of a particular resource.

Cluster analysis at spatial level showed two distinct guilds; one with *Salea* lizards and the rest with all other species (Fig. 6.4). The second group got divided into two sub groups as (1) *Ahaetulla perroteti* and *Trimeresurus strigatus* and (2) remaining species. The second subgroup divided further into two as (1) *Xylophis perroteti* and *Oligodon venusutum* and (2) other by remaining species. Among all reptiles found in Upper Nilgiris, the lizards *Scincella bilineatum* and *Plectrurus perroteti* were closely related with respect to spatial resource use.

At trophic level two distinct guilds were observed; one with *Plectrurus perroteti* and *Xylophis perroteti* and the other with remaining species. The second guild was divided into two subgroups one with *Cnemaspis indica*, *Scincella bilineatum* and *Salea horsfieldii* and the other with rest of the species (Fig. 6.5). Among all reptiles of Upper Nilgiris, *Cnemaspis indica*, *Scincella bilineatum* and *Salea horsfieldii* very similar in food consumed as shown by the Dendrogram.

With respect to the emergence of juveniles, two distinct guilds were observed; one by *Oligodon venusutum* and the other by remaining species (Fig. 6.6). Second guild formed sub groups at an early stage (I-by *Xylophis perroteti* and II by the remaining species).

Table 6.3. Niche overlap between various species pairs of reptiles in various spatial and trophic resource categories in Upper Nilgiris, Western Ghats; for abbreviation of species see Table 6.4.

Habitat								
Species	Cn	Sh	Sb	Pp	Ov	Xp	Ap	Ts
Cn	0	0.3218	0.953	0.98	0.886	0.194	0.99	0.812
Sh		0	0.469	0.34	0.695	0.569	0.404	0.614
Sb			0	0.947	0.909	0.48	0.939	0.739
Pp				0	0.854	0.217	0.973	0.808
Ov					0	0.365	0.919	0.906
Xp						0	0.163	0
Ap							0	0.878
Ts								0
Microhabitat								
Cn	0	0.021	0.996	0.907	0.108	0.596	0.009	0.017
Sh		0	0.004	0	0.043	0.015	0.085	0.088
Sb			0	0.909	0.118	0.602	0.027	0.035
Pp				0	0.093	0.543	0.001	0.005
Ov					0	0.122	0.263	0.293
Xp						0	0.096	0.11
Ap							0	0.462
Ts								0
Vertical position of species								
Cn	0	0.276	0.99	0.99	0.99	0.998	0.99	0.942
Sh		0	0.22	0.22	0.22	0.281	0.22	0.421
Sb			0	1	1	0.997	1	0.923
Pp				0	1	0.997	1	0.923
Ov					0	0.997	1	0.923
Xp						0	0.997	0.934
Ap							0	0.923
Ts								0
Food								
Cn	0	0.749	0.683	0	0	0	0	0
Sh		0	0.721	0	0	0	0	0
Sb			0	0	0	0	0	0
Pp				0	0	0.707	0	0
Ov					0	0	0.657	0.693
Xp						0	0	0
Ap							0	0.484
Ts								0

The later (second) group was intact, which showed that these species were highly similar in the emergence of hatchlings. *Salea horsfieldii* and *Scincella bilineatum* were most similar with respect to the hatchling emergence.

Overall species groupings

In all 61 resources, spatial (28), trophic (21) and (12) in temporal categories (Appendix 5) were used to determine the overall species groupings or assemblages. Unlike species groupings at spatial and temporal levels, species packing was somewhat loose lacking any definite cluster when considered together (overall assemblage). This is indicated by the formation of sub groups by single species at various levels. The analysis shows that *Salea horsfieldii* was totally different from other species observed in Upper Nilgiris with respect to resource use (Fig. 6.7). The nearest neighbors of all species studied were *Cnemaspis indica* with *Scincella bilineatum*, as they are closely packed forming a separate cluster.

Table 6.4. Niche overlap in the emergence of hatchlings of reptiles in Upper Nilgiris, Western Ghats.

Species	Sh	Cn	Sb	Pp	Ov	Xp	Ap	Ts
Sh	-	0.742	0.801	0.495	0	0.557	0.405	0.664
Cn		-	0.754	0.585	0	0	0.256	0.809
Sb			-	0.364	0.25	0.375	0.697	0.783
Pp				-	0	0	0.006	0.096
Ov					-	0	0.485	0.447
Xp						-	0.242	0
Ap							-	0.434
Ts								-
Cn- <i>Cnemaspis indica</i>		Pp- <i>Plectrurus perroteti</i>			Ap- <i>Ahaetulla perroteti</i>			
Sh- <i>Salea horsfieldii</i>		Ov- <i>Oligodon venusutum</i>			Ts- <i>Trimeresurus strigatus</i>			
Sb- <i>Scincella bilineatum</i>		Xp- <i>Xylophis perroteti</i>						

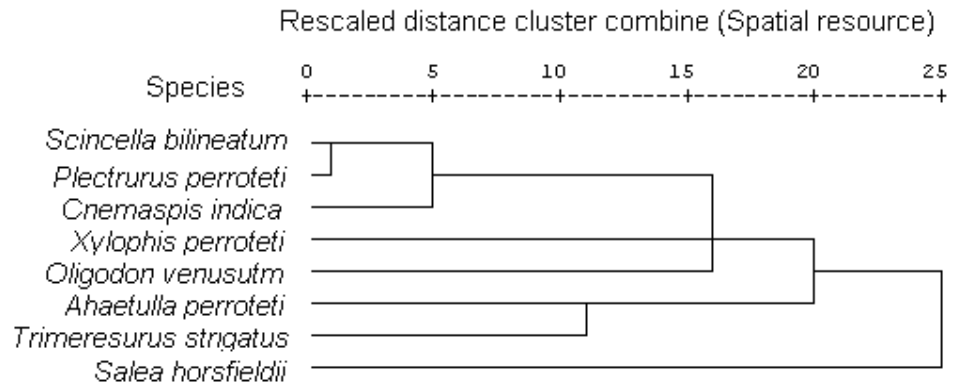


Fig. 6.4. Species assemblages of reptiles found in Upper Nilgiris with respect to spatial use.

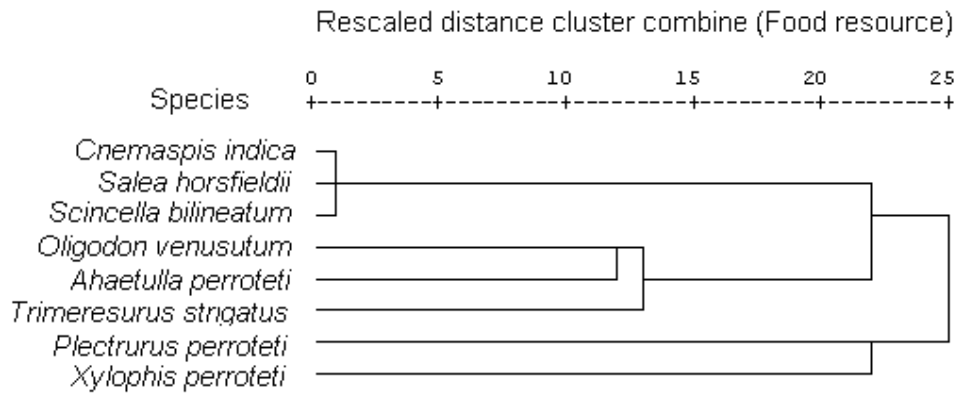


Fig. 6.5. Species assemblages of reptiles observed in Upper Nilgiris with respect to trophic resource (food) use.

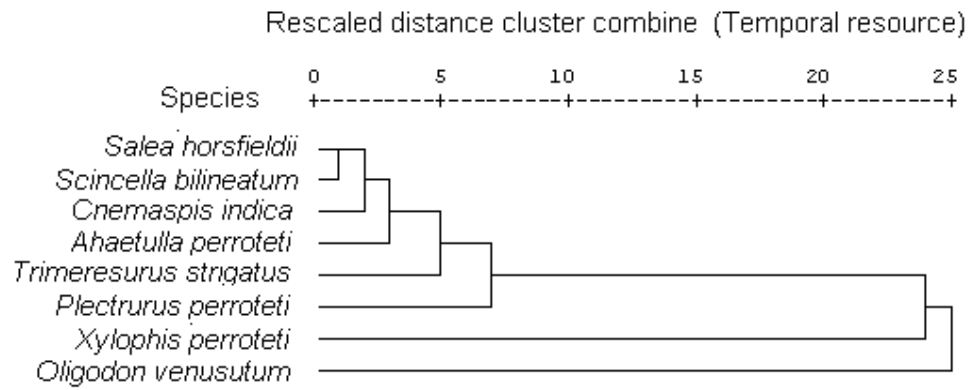


Fig 6.6. Species assemblages of reptiles observed in Upper Nilgiris with respect to the emergence of hatchlings.

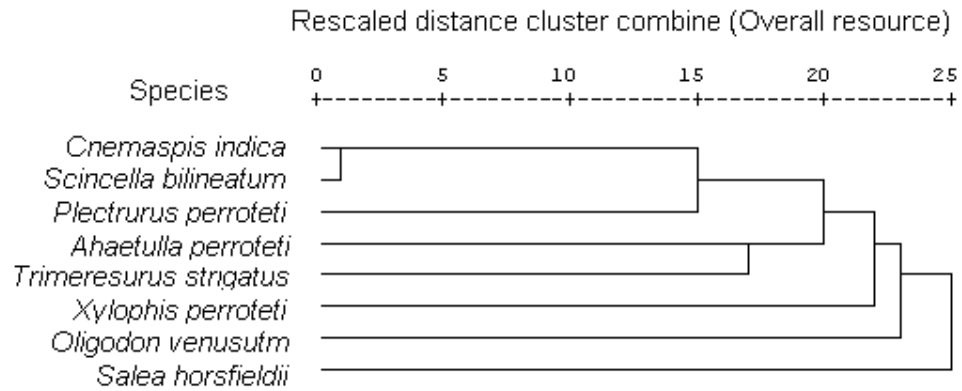


Fig. 6.7. Reptile species assemblages in Upper Nilgiris with respect to various resource categories.

6.4. DISCUSSION

The Upper Nilgiris possesses relatively a simple reptile assemblage with only eight species. This pattern could be due to the prevailing colder conditions and various geophysical constraints (Colwell and Lees, 2000; Grytnes and Vetaas, 2002; Sanders, 2002, Gainsbury, 2003; also see Population Chapter-III). This poor species richness may also be due to relatively simple vegetation structure without many vertical layers. Vegetation complexity promoting a number of herpetofaunal assemblages has been reported (Heatwole, 1982). It is also assumed that habitat complexity is associated with high species diversity (Das and De Silva, 1998) as in other taxa such as birds (MacArthur, 1972, Cody 1974, Holmes *et al.* 1979). Reptile assemblage in the present study area was not randomly distributed as species occupy specific microhabitat and vertical position. Non-random distribution of herpetofaunal species in space has been reported by Heatwole (1982). According to Pianka (1973), animals partition environmental resources in three basic dimensions, namely temporal, spatial and trophic.

Differences in prey selection among intraspecific classes are commonly thought to be reducing resource competition, but other factors, such as behavioral, morphological and physiological differences are also important (Vincent *et al.* 2004). Differences in the shape of feeding apparatus (e.g. beaks in birds, head shape in frogs and snakes) within or among species may be particularly important for prey selection (Houston and Shine, 1993; Forsman, 1996). Ontogenetic changes in the food and feeding mode are also important in resource partitioning. For instance, it was reported that the adult Garter snakes (*Thamnophis atratus hydrophilus*) fed on larger prey, whereas the juveniles fed on small preys (Lind and Welsh, 1994). In the present study, three-dimensional plot of head length, head width and jaw length of reptiles occupied different positions. Canonical analysis also showed high significant correlations in lizards ($K= 0.902$) and snakes ($K= 0.976$). These results indicate the role of morphological difference among species in the differential use of various resources, especially the food in

Upper Nilgiris. Based on the study on sympatric desert lizards in Australia, Pianka (1969) predicted that the body size (SVL) difference would help avoiding competition among species. There was a marked difference in the body size of various species of reptiles found in Upper Nilgiris (See Fig. 3.6, Chapter Population).

Timing of the hatching and emergence are very important for the survival of a species. The emergence time may be due to several factors (Lichtenbelt and Albers, 1993). Seasonal variation in the food availability for the females, variation in soil temperature and moisture during the egg stage and seasonal variation in food availability for hatchlings are a few factors to mention. During this study, hatchlings of lizards were observed almost round the year with the peak in October. A variety of breeding pattern such as fixed breeding period (Lichtenbelt and Albers 1993; Patchell and Shine 1986; Watt, 2002; Bishop and Echternacht, 2003; Lemos-Espinal *et al.* 2003; Enge *et al.* 2004) and extended breeding periods (Fitch, 1970; Duda and Koul, 1977; Shanbhag, 2003) have been reported for reptiles. All the lizards found in Upper Nilgiris had extended breeding period largely in all seasons barring monsoon. Fitch (1970) have reported similar pattern in tropical lizards. Hatchlings of the agamid lizard, *Salea horsfieldii* was not observed during peak monsoon (May - August) and in higher altitude, during peak monsoon the condition may be very cold which may not be suitable for the hatchling survival. The extended breeding season found in the lizards of this area could be due to prevailing mild climatic condition and sufficient food supply throughout the year. Also, multiple clutching of these species may play a role in the extended breeding season. Multiple clutches of many agamid lizards including *Salea anamallayana* have been reported (Kannan and Bhupathy, 1996; Shanbhag, 2003). Duda and Koul (1977) studied the ovarian cycle of *Scincella himalayanum* and reported that skinks are non-seasonal in their breeding behavior. The present study augments the above view with respect to the skink, *Scincella bilineatum*, as it had the extended hatchlings emergence period; from March to December.

Ecologically snakes are poorly known compared to other groups of terrestrial vertebrates and generally are difficult to study in the field (Seigel and Ford, 1987). Similar to the global scenario, studies on the breeding biology of Indian snakes are poorly known. Snakes may also exhibit seasonal and cyclic reproduction and lay eggs ones in few years. Hatchlings of *Ahaetulla perroteti* were observed almost throughout the year, especially during warmer months (March-May, October-December). Limited observations show that *Trimeresurus strigatus* breed during both southwest (May-August) and northeast (September-November) monsoons indicating extended breeding season. Kannan and Bhupathy (1996) recorded a female of this species with five eggs during September in Nilgiris. Keogh *et al.* (2000) reported that egg lying of snakes occur during warmest part of the year. The hatchling emergence of *Ahaetulla perroteti* supports the above view. The emergence of hatchlings during warmer months may be beneficial for the young ones to grow rapidly; enhanced embryonic development. This had been reported in the viviparous snake *Vipera aspis* (Lourdias *et al.* 2004).

Spatially, the agamid, *Salea horsfieldii* had the highest niche breadth score followed by *Scincella bilineatum* (Table 6.2). Agamid lizards are reportedly adaptable to various habitats and microhabitats (Bhupathy and Kannan, 1997a; Daniel, 2002). Duda and Koul (1997) also reported that skinks are adapted to various habits and habitats. The present data augment the above view. It is reported that microhabitats are important in resource partitioning whilst habitat tends to be less important or unimportant (Schoener, 1974, 1977). The narrow niche breadth of reptiles (1.08 - 2.89 out of 10 microhabitats) of the reptiles compared to habitat (1.4 - 3.7 out of 5 habitats) showed that they were more specialists restricted in use with respect to microhabitat (Table 6.2). However, Thorpe and Crawford (1979) reported otherwise with respect to diurnally active Green geckoes (*Phelsuma* spp.). Populations of a single species may also differ in niche characteristics at habitat or landscape levels. For instance, *Neusticurus*

ecpleopus (Gymnophthalmid lizard) had wider niche breadth with respect to food, which ranged from 5.81 to 11.20 in four different populations in Amazon (Vitt *et al.*1998a). In the present study, all lizards had higher trophic niche breadth compared to snakes (Table 6.2) and this could be due to utilisation of specific food items by snakes.

The extent of resource use overlap of one species with another is a measure of possible competition between the species (Jones, 1982). The low values of overlap of various species pairs in one or more categories indicate the niche separation. Brown and Parker (1982) reported that trophic dimension is more important in resource partitioning than is the spatial dimension in resource partitioning in snakes. In the present study, overlap of between or among species pairs was not similar; high in one category and low in others (Table 6.3 and 6.4). *Salea horsfieldii* had low overlap with all other species in all resource categories. *Cnemaspis indica* had high overlap (0.9) with *Scincella bilineatum*, *Plectrurus perroteti*, *Ahaetulla perroteti* and *Oligodon venustum* in habitat, but in microhabitat category, *Cnemaspis indica* had minimum overlap with *Ahaetulla perroteti* and *Oligodon venustum* (>0.1). Overlap at trophic level showed that *Cnemaspis indica* had high overlap with *Salea horsfieldii* and almost minimum overlap with above cited species (Table 6.3). Thus, niche separation among the reptiles of Upper Nilgiris at various resource levels is evident. However, species pair *Scincella bilineatum* and *Cnemaspis indica* had high overlap in all resource levels. This could be one of the reasons for difference in their population density. For instance, in Grasslands the density of *Cnemaspis indica* was 9.4 lizards /ha, whereas it was 1.4/ha in the case of *Scincella bilineatum*.

The competition between these species may be avoided by selecting different size classes of prey items, while the food taxa. This view is supported by the mode of feeding of these lizards (*Cnemaspis indica*- Sit and Wait, and *Scincella bilineatum*- active search). Lizards such as *Liolaemus fuscus* and *Liolaemus lemniscatus* had high similarities in niche

dimensions throughout the year with marginal seasonal difference (Nunez *et al.* 1989). This marginal difference and other variations in resource use may help avoiding competition.

Barring few species such as *Oligodon venusutum* and *Xylophis perroteti*, the overlap in hatchling emergence among species pairs was comparatively high during this study. Hence, it may be considered that temporal variation in the emergence of hatchlings is not an important factor in resource partitioning among reptiles at least in the present case. Activity pattern of various desert lizard species was in general similar, with variations among individuals, and it is suggested that temporal separation of activity reduces intra-specific competition and increases carrying capacity in species for which food is not a limiting resource (Creusere and Whitford, 1982). However, activity pattern and reproductive cycles of different species played an important role in the temporal structure of lizard assemblages of the Dry Chaco of Argentina (Fitzgerald *et al.* 1999). Similarly, Brown and Parker (1982) also 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.

Analysis showed that Mukuruthi National Park did not have distinct species groupings or assemblages in various resource levels. It is suggested that volatile environments tend to prevent the formation of distinct guilds, while the greater species richness of more predictable environments may form a guild (Inger and Colwell, 1977). The species packing also differed in various categories (See Fig. 6.6). Four out of eight (50%) species found in Upper Nilgiris was somewhat arboreal. This is similar to the observations on the lizards of Ponmudi Hills, Western Ghats by Inger *et al.* (1987), where 50% of the lizards were reportedly arboreal.

Overall species assemblage shows that species packing is not distinct; perhaps loosely packed groupings indicate vacant niches. These habitats

are supporting a few species, and this could be due to various geophysical constraints (Colwell and Lee, 2000; Grytnes and Vetaas, 2002; Sanders, 2002, Gainsbury, 2003). The vacant niches may be occupied by invading species such as *Xylophis perroteti* and *Ptyas mucosus*, in due course upon increase in temperature by global warming or by clearing shola forests. Impact of habitat alterations on reptiles in terms of the difference in species richness, diversity and density has recently been demonstrated (Bhupathy and Nixon, 2004; Nixon and Bhupathy, 2004). The endemic species namely, *Salea horsfieldii* formed a separate cluster. It shows that this species is different in resource requirements compared to other species. On the other hand endemic lizards such as *Cnemaspis indica* and *Scincella bilineatum* formed a tight cluster. This shows that these endemic species require similar resource for survival. As discussed earlier, these may avoid competition through factors such as difference in population (e.g. density), mode of feeding and prey size variations.

6.5. SUMMARY

- Aspects such as habitat, microhabitat, vertical position of the animal (spatial), food (trophic) and emergence of hatchlings (temporal) were considered for analyzing resource use pattern of reptiles. Morphometric data, such as head length and width and jaw length were supplemented to understand the spatial use pattern further.
- Three-dimensional plots of head length and width and jaw length showed that lizard species occupied different position in the multidimensional space. Canonical analysis confirmed the above findings that the morphological differences among species were significantly different ($K=0.902$). Snake species also have largely occupied distinct places in the three dimensional space and the same is reflected in the Canonical correlation analysis as well.
- The present study showed that the lizards have extended emergence of hatchlings (breeding season), and the same occurred

largely during dry season (non-monsoon). Hatchlings of snakes were observed during both monsoon and dry seasons.

- Overall niche breadth varied from 1.22 to 4.38 only. This shows that the reptiles of Upper Nilgiris have low to moderate survival capabilities with respect to the utilisation of spatial and trophic resources. Among the reptiles of Upper Nilgiris, *Salea horsfieldii* was a generalist in resource use compared to other species as it had obtained the highest total niche breadth value (4.38), whereas the Shield tail snake, *Plectrurus perroteti* was a specialist ($\beta = 1.22$). All snakes were specialists in resource use compared to lizards.
- Overall high overlap was found at habitat level, which was reduced considerably at microhabitat utilisation. Species such as *Salea horsfieldii* differed from other species at vertical stratification. With respect to food and temporal variation (emergence of juveniles), a few species had less or no overlap. It appears that in one or other resource category, each species were different.
- In all, 61 resources (spatial- 28, trophic-21, and temporal- 12) categories were used to determine the overall species groupings or assemblages. Unlike species cluster at spatial and temporal clusters, species packing was somewhat loose lacking any definite cluster with respect to overall assemblage. The nearest neighbors of all species studied were *Cnemaspis indica* and *Scincella bilineatum*, as they were closely packed forming a separate cluster. The endemic species namely, *Salea horsfieldii* formed a separate cluster indicating difference in resource requirements of this species compared to others. On the other hand, endemic lizards such as *Cnemaspis indica* and *Scincella bilineatum* formed a tight cluster, which indicates similar resource requirements for these species.

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