Taxonomic inventory and ecology of the bats of Silent Valley National Park, Kerala

By

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(2014-17-112)

THESIS

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DECLARATION

I hereby declare that this thesis entitled "**Taxonomic inventory and ecology of the bats of Silent Valley National Park, Kerala**" is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Aswathy Chandran, U. B.

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Introduction

INTRODUCTION

Bats (Order Chiroptera), are the only mammal group capable of powered flight and sophisticated laryngeal echolocation, represent one of the most species-rich and ubiquitous orders of mammals. Laurasia is the place from which bat origin was reported and most probably it was in North America in the early Eocene (Teeling *et al.,* 2005). After rodents they are the second largest group of mammals (Simmons, 2005), with 1,150 species (IUCN, 2015) under two suborders Megachiroptera (Frugivorous bats) and Microchiroptera (Insectivorous bats). Now this unique group of mammals is diversified and distributed all over the world except the Polar regions and a few oceanic islands.

The suborder Microchiroptera consist of 963 species in 17 families and is widespread throughout the range of bats, with the greatest diversity in the tropics (Findley and Wilson, 1983; Simmons, 2005) and the suborder Megachiroptera includes 187 species of bats in a single family Pteropodidae which occurs in the subtropical and tropical regions of the Old World (Rainey and Pierson, 1992; Simmons, 2005). But the recent molecular phylogenetic studies challenged the monophyletic nature of the order Chiroptera and proposed new classification with two suborders, Yinpterochiroptera and Yangochiroptera. The suborder Yinpterochiroptera includes the families Pteropodidae, Rhinolophidae, Megadermatidae, Craseonycteridae and Rhinopomatidae and Yangochiroptera consists of all the remaining families such as Molossidae, Emballonuridae, Nycteridae, Phyllostomidae, Mormoopidae, Noctillonidae, Furipteridae, Thyropteridae, Mystacinidae, Myzopodidae, Natalidae and Vespertilionidae (Teeling *et al*., 2005).

Bats play an important role in pollination, seed dispersion (Marshall, 1985; Fujita and Tuttle, 1991), biological seed treatment and germination (Izhaki *et al.*, 1995), biological pest control (Akbar *et al.*, 1999) and also a good indicator of pollution as they are vulnerable to contaminants (Hickey *et al.*, 2001). Even though bats are extremely important in performing various ecosystem services, very little is known about their ecology and biology. Incidence of overlooked taxa is very high within bats due to its nocturnal habit and cryptic nature, which makes their classification difficult.

The selected study area is also a very special site which holds a plenty of plant and animal diversity. Previous studies are showing that bats are a kind of mammals which we can see in areas with greater biodiversity. Silent Valley National Park is one of the precious ecosystems in the Western Ghats. The watershed of Silent Valley area were first explored and investigated as early as 1847. The forest of the area was notified as reserved forest in 1914. On 15 November 1984 the Silent Valley forests were declared as a National Park with an area of 89.52 sq. km.

Silent Valley National Park (SVNP) is a beautiful representation of the last remaining rainforest of Kerala. Historically it's a paradigm of people's movement to protect the forest. For the last three decades this pristine forests are protected and managed by the Kerala Forest and Wildlife Department and the result is evident from the succession of the secondary grassland in the valley. It has amazing ecosystem diversity from moist deciduous, semi-evergreen, evergreen and shola forests to montane grasslands. Species diversity and endemic value of evergreen and semi-evergreen communities is incomparable with any other forest areas in Kerala.

In the modern society, one of the major crises is the loss and deterioration of biodiversity. This is due the lack of knowledge of global, regional and local biodiversity and actual rate of loss of biodiversity. A majority of biological diversity remains to be under-described or undiscovered (Wilson, 1995). Under estimation of biodiversity may also lead to loss of diversity through mismanagement of geographically or ecologically isolated population. So classification of biodiversity is essential which in turn helps in the management and conservation of our biological heritage. A National Park like Silent Valley can be also listed in the areas or forest lands which are under-described or undiscovered in terms of biodiversity and its ecological importance to our Western Ghats and the whole world itself.

The small mammal studies are very less in Kerala and especially bats, rodents and insectivores are the group of small mammals which are the least studied ones. But most of the people in the world are not well aware about their ecological significances and how they are helping with the ecological functioning and thus the well-being of all creatures including the mankind. This group has received little attention from the scientific community too. This is true in Silent Valley too. The only previous study on the bats of SVNP, was the one by Das (1986), four decades back. And hence the present study, with the following objectives, to study the species diversity, distribution pattern, and habitat preferences of bats in Silent Valley National Park.

Review of literature

REVIEW OF LITERATURE

2.1 BATS IN THE WORLD

Bats, of the order Chiroptera are one of the most fascinating and mysterious creatures because of their specialized abilities and habits. They are the second largest group of mammals after rodents which comprise 1,116 species in 202 genera under 18 families globally (Simmons, 2005). The word Chiroptera was derived from two Latin words '*cheiros*' means 'hand' and '*pteron*' means 'wing'. They are distinguished from other mammals by the unique ability of true flight. The evolution of flight and the unique echolocation of bats have fostered their diversification of feeding and roosting habits, reproductive strategies and social behaviour (Kunz and Kurta, 1988). Out of 5,514 mammal species 1,150 species belongs to the order Chiroptera (IUCN, 2015). This means approximately 21 percent of the total mammals of the world. According to Bates (2013) 123 species are there in South Asia and 149 species if Myanmar is included.

A checklist and dichotomous key by Srinivasulu *et al.* (2010) to 128 species of bats known from South Asia, while according to Nameer (2015), there are 29 species of bats are present in Kerala. While according to Bates and Harrison (1997), there are 119 species of bats in the Indian Subcontinent.

2.1.1 Origin, status and distribution

Bats are considered to be originated in Laurasia, most possibly in North America in the early Eocene (52-50 million years ago [Mya]) (Teeling *et al.,* 2005). The divergence in Oligocene (35 Mya) led to the evolutionary development of two distinct suborders, Megachiroptera which occurs in the subtropical and tropical regions of the Old World from the eastern Mediterranean and the Arabian Peninsula, across Africa to Asia, Australia and the islands in the Pacific (Rainey and Pierson, 1992) and Microchiroptera which are widespread throughout the range of bats, with the greatest diversity in the tropics (Findley and Wilson, 1983). Hence now this group of mammals is diversified and distributed all over the world except the Polar Regions and a few oceanic islands (Mickleburgh *et al*., 2002). Bats are abundant, diverse, and easy to sample, especially in the Neotropical rainforest, they fulfill several of the requirements of indicator species and they were used to study as the indicators of disturbance in Neotropical Rainforests (Medellin *et al*., 2000).

Of the 18 families, nine families such as Pteropodidae, Rhinopomatidae, Nycteridae, Megadermatidae, Rhinolophidae, Hipposideridae, Myzopodidae, Craseonycteridae and Mystacinidae are restricted to the Old World. The six families- Noctilionidae, Phyllostomidae, Mormoopidae, Natalidae, Furipteridae and Thyropteridae are restricted to the New World. The remaining three families- Emballonuridae, Molossidae and Vespertilionidae are found both in the Old and New Worlds (Mickleburgh *et al*., 2002). The families Rhinolophidae, Vespertilionidae and Molossidae have representatives in both hemispheres. There is a very sharp decline in the number of species of bats with increase in distance from the equator (Corbet and Hill, 1986; Koopman, 1993). A decrease in bat density along the gradient is indicated by elevational decrease in sample size and by significant elevation reduction in the number of bats netted per unit effort. Explanations for these patterns are offered based on significant correlations of temperature and foliage height diversity with both overall richness and number of species. The diversity changes in the bat community along the gradient are caused by many factors, both historical and contemporary (Graham, 1983). In Brazil, bats correspond to an order of mammals which is represented by 138 species (Aguiar and Taddei, 1995), approximately one third to a quarter of all 483 Brazilian land mammal species (Fonseca *et al*. 1985). In an another study on the variation in bat diversity and composition in forest areas and open areas of South Brazil lists out 1,111 bats representing 19 species were captured in all sites.

From the forest area they recorded 242 individuals belonging to 15 species were captured and from the open areas they captured 6 species, with 399 individuals with the same effort. This difference in the species number shows the influence of deforestation on the elimination of species (Reis and Muller, 1995).

The bats of the tropical Australia are reviewed with some 51 species recognized, though a few are very poorly known. A new subspecies, *Pipistrellus tenuis westralis* is described and *Rhinolophus megaphyllus ignifer* is synonymized with *R. m. megaphyllus*. The two previously recognized subspecies of *Macroderma gigas* are also synonymized (Koopman, 1984).

2.1.2 Megachiroptera and Microchiroptera

The Megachiroptera or the megabats are commonly known as "fruit bats" because they feed exclusively on flowers, nectar, pollen and fruits. While about 75% of Microchiropterans feed on insects and known as "insectivorous bats", although food sources may include other invertebrates, fishes, amphibians, small mammals (including other bats), blood (Altringham, 1996), fruits, and flowers (Hutson *et al.*, 2001).

As the name indicates, Megachiroptera are larger in size than Microchiroptera (considerable overlap exists). On an average, Megachiroptera weighs between 10g and 1500g and Microchiroptera (micro bats) between 2g and 196g (Mickleburgh *et al.*, 1992). With the exception of genus *Rousettus*, megachiropterans do not echolocate, but have light-sensitive eyes which help in navigation and they also use smell for orientation (Nowak, 1991 and Altringham, 1996) while the microbats have the power of echolocation. Most fruit bats are helpless in total darkness but can see very well in dim light. Megachiropterans have a claw on the second finger of the wing and have longer muzzles than microchiropterans (Gaikwad *et al.,* 2012). Megachiropterans control their body temperature within a tight range of temperatures and they do not hibernate, but many microchiropterans have labile body temperatures, and some hibernate (Hill and Smith, 1984; Nowak, 1991).

2.2 BATS IN INDIA

India, one of the 17 mega diversity countries of the world is renowned for its rich biodiversity. It accounts 2.4% of total world area with 8.86% of the recorded species of the world. Of the 417 known mammal species in India, 117 species are of the order Chiroptera (representatives of eight bat families which includes 39 genera), which means more than a quarter of Indian mammals are bats (Simmons, 2005 and Hedge *et al*., 2013) (Table 1). The current checklist of Indian bats includes 117 species of which fifty-eight occur in the state of Meghalaya (Ruedi *et al*., 2012). Further Ruedi *et al*. (2012), added two species *Murina pluvialis* and *Murina jaintiana* to the country list. They also recorded *Kerivoula kachinensis* for the first time from Meghalaya. Perhaps the first detailed ecological study on the bats of the country was by Brosett (1962a, b, c and 1963). Brosett conducted studies on the bats of central and western India. Bates *et al*. (1994) later resurveyed the location studied by Brosett. Bates and Harrison (1997) brought out a well-illustrated field guide on the bats of the Indian subcontinent. Vanitharani (2006) studied the bats of Agasthiyar hill range in the Western Ghats. Sringaravelan and Marimuthu (2003), reported a mistnet capture of the *Latidens salimalii.*

India support more than 90% of the bat species in the South Asian region, while the other South Asian countries like Bhutan (51%), Nepal (40%), Pakistan (33%), Bangladesh (29%), Afghanistan (28%), Sri Lanka (23%) and Maldives (2%) had only less than 50% of total bat diversity (Srinivasulu and Srinivasulu, 2001).

Table 1. Family wise classification of bats in India (Simmons, 2005)

Sl. No.	Family	Number of Genera	Number of Species
1	Pteropodidae	8	14
2	Rhinolophidae	1	17
3	Hipposideridae	2	13
4	Megadermatidae	1	2
5	Rhinopomatidae	1	3
6	Emballonuridae	2	6
7	Molossidae	3	4
8	Vespertilionidae	21	58
	Total	**39**	**117**

Studies on bats in Western Ghats of India focused mainly on taxonomic identification and listing of species in various locations. Out of 137 species of mammals, 50 species of bats in seven families are reported from the ranges of Western Ghats (Nameer *et al.,* 2001). First report of *Hipposideros ater* from Andra Pradesh, India and description of a new subspecies collected from the Nallamala Hills, Eastern Ghats were published by Srinivasulu and Srinivasulu (2006).

2.3 BATS OF KERALA

A study conducted by Das (1986) in Silent Valley National Park is an important study and he had reported 6 species of bats in 3 families and 5 genera. Recently few studies on the have been done on the bats of Kerala. A study conducted by Madhavan (2000) published an extensive report on study and collection of bat specimens of 24 taxa representing six families and 14 genera from Thrissur District, Kerala. Radhakrishnan (2005) recorded 18 species of bats from Peechi-Vazhani Wildlife

Sanctuary. Abhilash (2005) studied the ecology of the bats of Peechi-Vazhani WLS. Arun (2006) studied the food and feeding habits of fruit bats in Peechi-Vazhani Wildlife Sanctuary and 17 species of trees were found to be dependent by the fruit bats for their food, while Ali (2006) studied the food and feeding habits of insect bats in Peechi-Vazhani Wildlife Sanctuary. The bats of Chimmony Wildlife Sanctuary was studied by Joy (2008) and Fasil (2010) and has reported eight species of bats from the Wildlife Sanctuary, while Ashmi (2011) studied the bats of Parambikulam Tiger Reserve, and reported 11 species of bats from Parambikulam TR.

2.4 ECOLOGICAL IMPORTANCE

2.4.1 Pollination and Seed Dispersal

Chiropterophilly (Pollination by bats) and Chiropterochory (seed dispersal by bats) are two mutualistic population interactions which help in proper ecosystem functions and also to increase forest tree growth and density. Pteropodidae (Old World fruit bats) and Phyllostomidae (New World leaf-nosed bats) are the main two families helps in pollination and seed dispersal. In oceanic islands fruit bats are the single most important pollinator and seed disperser which acts as a key stone species (Cox *et al.,* 1991). Bats play a major role in maintaining genetic continuity of plant population in fragmented and disturbed forest habitats. (Galetti and Morellata, 1994 and Fleming *et al.,* 2009). The mutual relationship between plants and fruit bats in Kerala through food and roost and bats helps plants as disperser and pollinator was studied by Prasad and Sunojkumar in 2014.

2.4.2 Succession

Successional change in the biotic community is the sequential change in the relative abundance of the dominant species in a community (Muscarella and Fleming, 2007). Seed dispersal is the major way that animals contribute to successional change in tropical ecosystems (Muscarella and Fleming, 2007). Frugivorous bats facilitate regeneration in tropical forests, disturbed and fragmented areas through the dispersal of early and late successional species (Medellin and Gaona, 1999; Muscarella and Fleming, 2007).

2.4.3 Insect Pest Suppression

Insectivorous bats play a very major role in suppressing arthropods through biological pest control and also through integrated pest control. In tropics insectivorous bats are consuming species of more than 15 orders of arthropods which includes major agricultural pests and mosquitos. Major arthropod orders which are consumed by bats are Lepidoptera, Coleoptera, Homoptera, Hemiptera,Orthoptera, Odonata, Diptera, Dermoptera, Trichoptera, Neuroptera, Ephemeroptera, Araneae, Blattodea, Mantodea, Hymenoptera, Isoptera (Vanitharani and Chelladurai, 2005).

2.4.4 Soil Fertility and Nutrient Distribution

Bat guano is the main component which can increase the soil fertility and also helps in Nutrient distribution. It acts as a major energy source (Ferreira *et al.,* 2007) and also as a fertilizer (Kuepper, 2003). Source of organic matter, Carbon, Nitrogen, Phosphorous and Potassium indicates the fertility range of guano (Ferreira *et al.,* 2000 and Emerson and Roark, 2007). Physical, chemical and spatial parameters such as pH, percentage of organic matter, percentage of moisture content, distance from the cave entrance, area and shape of the deposits and age of deposits are the main parameters that influence the energy source level and fertility of bat guano.

2.5 ECOLOGY, BIOLOGY AND BEHAVIOUR

2.5.1 Feeding behaviour

Feeding behavior and diet of bats are generally studied through the analysis of bat guano and the fecal analyses revealed that diet of individual bats were diverse. Generally frugivorous bats are having fruits and seeds are the main components in their fecal matter. In the case of insectivores bats insect parts are the main part of their fecal matter. Studies on the feeding habits of insectivores are more than frugivorous bats due to the wide diversity of insects they are having and many researchers are studying bat guano to find out the arthropod diversity in an area. All available insects 3 to 10 mm in body length were accepted as food items by the insectivorous bats. Nematoceran Dipteria were by far the most common insects taken in light-trap samples, and constituted a major portion of the diet throughout the summer. Coleoptera, Trichoptera, Lepidoptera, Ephemeroptera, and Neuroptera were also consumed in appreciable numbers (Anthony and Kunz, 1977). The bats selected alternative, more abundant and/or more profitable prey at certain times of the year, mostly by switching from their traditional feeding habitats to secondary (usually temporary) foraging grounds (Arlettaz, 1996).

In a study related to the Insect pursuit, prey capture and echolocation in pipistrelle bats by Elisabeth (1995) has studied the foraging and echolocation of pipistrelle bats. The study reveals the foraging patterns consisted of four stages, the search flight (before detection of prey), approach flight (pursuit after detection of prey), capture and retrieval of prey. These stages correlated with phases in echolocation behavior, search, approach, and terminal phase followed by a pause.

The common frugivorous bat *Cynopterus sphinx* forages upon fruits, flowers and leaves of a number of wild and a few orchard species of trees in varying proportions. The seasonal variation in its diet is related to both food preference and availability which are determined by annual cycles of flowering and fruiting. It generally plucks the fruits and carries them away from the original tree to feeding perches where it chews the soft parts, swallows the juice and drops seeds and chewed fibers, thus dispersing seeds (Bhat, 1994).

The study on the seasonal dietary variation of the Indian pygmy bat, *Pipistrellus mimus*, from southern India, by the collection of biweekly fecal samples from beneath a maternity roost for 1 year and comparing these samples with insects collected using a light trap on the same dates indicates that *P. mimus* fed on coleopterans (26.3% volume), dipterans (20.4%), homopterans (17.5%), lepidopterans (13.6%), formicids (10.5%), hemipterans (5.7%), and isopterans (5.1%) and thus are generalized feeders (Whitaker *et al*., 1999).

In a study about the diet of *Rhinolophus. rouxii, Hipposideros. speoris* and *Hipposideros ater in* Peechi-Vazhani Wildlife Sanctuary, Kerala shows the consumption of insect families such as Lepidoptera, Coleoptera and Diptera at higher rates (Aravind, 2014).

2.5.2 Breeding behaviour

Bradbury (1977) categorized 120 bat species (about 12% of the order) by social structure, but mating systems were described for only a fraction of these species. He also stated that the existence of monogamous families in any species of bat remains to be proven by year-round studies. Over 90% of the mammal species that have been studied have some form of ploygynous mating system in which one male mate with several females. In contrast birds, where about of all species were thought to be monogamous, a view now refuted by numerous moleculear studies of bird mating systems. Bats conform to the general mammalian pattern. Most bat species are apparently polygynous, while fewer, yet a surprising number, appear to be monogamous. In some bats, females mate in sequence with several males, and paternity outside of apparent mating groups has been documented in a few species. Available evidence suggests that multiple mating by females is common in bats. The structural association categories of bats based on mating are single male or multi-female mating groups, multi-male/multi-female mating groups and single male/single female mating groups (McCracken and Wilkinson, 2000). Many bats are promiscuous in that the individuals that mate have no continuing relationship before or after matting. Promiscous mating can be highly structured and nonrandom (Thomas et al., 1979).

Mating groups that consist of a single male and multiple females are typically called harems. This use of the term 'harem' has been criticized for ambiguity and for carriying anthropocentric connotations of male dominance and female subservience (Lewis, 1992).

While there has been substantial progress in describing bat mating systems, there has been considerably less progress toward understanding the ecological factors responsible for their evolution and maintenance. The conventional view holds that female dispersion patterns are primarily influenced by resource distribution while male dispersion patterns are primarily determined by female dispersion (Bradbury and Vehrencamp, 1977).

Compared to work on other taxa, such as birds, research on bat mating systems has lagged considerably in the use of molecular gene markers. The first molecular analysis of a bat mating system was done by McCracken and Bradbury in 1977.

Female bats store fertile sperm for up to 200 days and the size of social groups varies from single animals to groups of hundreds of thousands. The relative testis mass is positively related to sperm competition risk in bats. Social group size may also influence the level of sperm competition, and one of the costs of living in groups may be decreased confidence of paternity (Hosken, 1997).

Reproductive female bats are more constrained by thermoregulatory and energy needs than are males and non-reproductive females. Constraints imposed on reproductive females may limit their geographic distribution relative to other bats. Such constraints likely increase with latitude and elevation. Males of 11 bat species that inhabit the Black Hills were captured more frequently than females, and reproductive females typically were encountered at low-elevational sites. A mist-net data from 1,197 captures of 7 species revealed that 75% of all captures were males. It is found to be a significant inverse relationship between elevation and relative abundance of reproductive females. Relative abundance of reproductive females decreased as elevation increased. Reproductive females may be constrained from roosting and foraging in high-elevational habitats that impose thermoregulatory costs and decrease foraging efficiency (Racey and Entwistle, 2000).

2.5.3 Roosting behaviour

Bats spend over half of their lives in their roost environments. The condition and events of roosts play a prominent role to their ecology. Roost characteristics play an important role to the success of a species. It provides suitable environment for mating, hibernation, rearing their young ones, protection from adverse weather and predators (Kunz, 1982). The micro-chiropteran bats prefer dark sites for roosting especially in caves, rock cervices, tree cavities and man-made structures. Caves that offer a wide thermal range combined with structural and elevational complexity provide the greatest diversity of roosting sites (Tuttle and Stevenson, 1978). Artifical structures are also used by bats, including a wide range of buildings such as houses and historical monuments, temples, mosque etc. Within such sites they use crevices in walls, attic spaces, chimneys, or under tiles or other roofing materials. Some bats use only one type of roost, for example caves, while others may vary the roost type seasonally.

The Indian flying fox *Pteropus giganteus* roosts usually found in larger trees and for the fulvous fruit bat *Rousettus leshenaulti* they usually found in buildings and caves and for the short-nosed fruit bat *Cynopterus sphinx* are seen in buildings, trees and foliages. The location of majority of bat colonies nearby water bodies suggests that the bats select their day roost to avoid high temperature during day hours. Amongst all the species of insectivorous bats, *Hipposideros lankadiva, H. fulvus, T. nudiventris, T. melanopogon, Myotis lyra, R. microphyllum and R. hardwickii* were observed in a variety of man-made structure in proportionate number. The species was found to roost sites where fresh water in abundance. The diurnal roost of *P. coromandra, P. ceylonicus* include trees, the roof of building, crevices between logs, the ceiling and walls of houses, among the tiles of huts, old buildings. *Hipposideros fulvus* and *H. lankadiva* roosted in cellar of old houses. It favours cool damp places and relies on the proximity of water and shad. The roost of *T. nudiventris* includes crevices of roof, wall and sometime hanging with roof and ceiling of building. The roosting ecology of insectivorous species shows that *H. fulvus, H. lankadiva, T. nudiventris, T. melanopogon, M. lyra, R. microphyllum and R. hardwickii,* found almost exclusively roost in man-made structures. *Rhinopoma hardwickii* shared its roosts with *R. microphyllum, T. nudiventris, T. melanopogan* and *H. lankadiva*. The association of bats with man-made structure appears to vary geographically (Elangovan and Kumar, 2015).

The results of a study based on the roost selection by barbastelle bats (*Barbastella barbastellus*); in beech woodlands of central Italy shows that the trees in unmanaged woodland were favoured as roost trees and woodland subject to limited logging was used in proportion to availability, and areas where open woodland and pasture occurred were avoided. Selection depended on tree conditions, dead trees were preferred and taller trees were selected as roosts. Cavity selection was based on cavity type, height and entrance direction, roost cavities were mainly beneath loose bark, at a greater height above ground and facing south more frequently than random cavities (Russo *et al.,* 2004).

The time of emergence of bats from their roosts at dusk and their return was originally described as a circadian rhythm entrained by the time of sunset and sunrise (Erkert, 1978). Later, various environmental factors such as ambient light conditions, weather (Frick *et al.,* 2012) and moonlight (Elangovan and Marimuthu 2001; Thies *et al*., 2006) were considered to influence bat activity. Bats emerging before dark or during bright moonlight increases their risk of predation by raptorial birds and they avoid such situations (Welbergen, 2006). However insectivorous bats often risk predation to increase foraging opportunities when their prey is available in abundance at dusk (Jones and Rydell, 1994; Rydell *et al.,* 1996).

The short-nosed fruit bat *Cynopterus sphinx* constructs shelters by severing stems of the curtain creeper, *Vernonia scandens*, and stems and leaves of the mast tree, *Polyalthia longifolia*, creating partially enclosed cavities (stem tents) in which to roost. The construction and maintenance of stem tents are primarily, if not exclusively, the behaviour of single males. A stem tent is formed in *V. scandens* when a single male *C. sphinx* severs up to 300 small- to medium-sized stems creating a partially flattened, bell-shaped cavity, and in *P. longifolia* when a male severs a few medium- to small-sized branches and many leaf petioles, creating an entry or exit portal and space in which to roost (Balasingh *et al*., 1995).

The first report about a cave as the day roost of Salim Ali's fruit bat *Latidens salimalii*, was first reported by Singaravelan and Marimuthu in 2003. It was repeatedly mist-netted in the High Wavy Mountains, it roosts in foliage or trees or buildings during daytime, similar to sympatric fruit bats, which was previously unknown. For the first time this species roosts in a cave in the High Wavy Mountains.

Most of the individuals roosted in clusters in the darkest areas of the cave. The distance between the day roost and the only known night roost of *L. salimalii* was less than 1 km.

The stable microclimate in caves provides a relatively constant habitat for many bat species in the Philippines, but human encroachment continues to disrupt this habitat and imperil many of the species roosting in the caves. In most part of the world, the diversity and conservation status of cave bats remain undocumented and unexplored. The declining conservation status of the bats, local disturbance such as bat hunting for bush meat and unregulated tourism are currently taking place in the caves (Tanalgo and Tabora, 2015).

2.5.4 Habitat selection and preference

The primary problem of bats is the conservation of energy. This is achieved through metabolic economy which is made possible through the universal chiropteran characteristic of a "poor" temperature regulating system. When flying, bats behave as homoeothermic animals and can travel long distances, but when resting their body temperatures tend to approximate that of the outside environment. For this reason they have been termed heterothermic mammals. The metabolic demands of bats are much reduced when they are resting. If bats maintained high body temperatures when resting as they do when flying, they would not be able to go for long periods of time without food since food reserves would quickly catabolized despite the decreased surface area volume ratio. If a population of bats is to maintain itself, it appears that one of the most important factors is the selection of proper habitat in which to rest. Conservation of energy then is largely achieved through physiological reactivity in relation to habitat selection (Twente, 1955).

In a study related to the habitat selection by forest bats in relation to mixed-wood stand types and structure in central Ontario, they studied about the multivariate habitat models and it suggested that, between logged and uncut stands, the availability of potential roost sites may be an important determinant of bat *Myotis* species and silver-haired bats. Among uncut stands, habitat models suggested that snag was not an important variable affecting habitat selection in bats. To maintain habitat for bats, forest managers should implement timber harvest strategies that retain remnant old-growth (Jung *et al*., 1999).

Bat activity was significantly and positively related to insect availability and ambient temperature, whereas increased visibility of the moon had a negative influence on flight activity. Together, these factors best explained both total bat activity and activity of bats hunting in open space and edge habitats. The interaction between temperature and light intensity was the best predictor of activity by species foraging in obstacle-rich forest habitats (Meyer *et al*., 2004).

Wetlands are internationally recognized as a crucial habitat type for the conservation of many migratory birds. Despite the fact that many bats are also long-distant migrants, the importance of foraging habitats for sustaining migrant bats has to date received little attention. Habitat selection patterns in the migrant bat, Nathusius pipistrelle (*Pipistrellus nathusii*), in the southernmost part of Iberian Peninsula, an area in which both mating and hibernation of this particular species occurs. The natural wetlands and riparian habitats (*Phragmites* reed beds) were positively selected by *P. nathusii*, whereas human-transformed aquatic habitats (rice paddies) were avoided. Agricultural transformation of the land is likely to be detrimental to this species since it reduces the availability of its preferred foraging habitat (Flaquer *et al.,* 2009).

Out of 50 species recorded from Western Ghats 47% of roost in caves, 31% roost in crevices, 8% roost in logs of dry trees and 13% roost in trees and foliage. Only one species roosts in bamboo thickets. Roosting places for 27 species (52%)

were recorded in man-made structures in forests, rural or urban areas in the vicinity of forests, 17 species (31%) were confined to forests of high altitude, mainly found in natural caves. Most of these species were reported in small groups of a few to about 25 roosting under the same shelter. Only 14 species (27%) are gregarious in the true sense forming a colony of few hundreds to thousands (Korad *et al.,* 2007).

The acoustic and capture data of bats from the study landscape scale habitat suitability modelling of bats in the Western Ghats of India shows for ten species (*Hesperoptenus tickelli*, *Miniopterus fuliginosus*, *Miniopterus pusillus*, *Myotis horsfieldii*, *Pipistrellus ceylonicus*, *Megaderma spasma*, *Hipposideros pomona*, *Rhinolophus beddomei*, *Rhinolophus rouxii* and *Rhinolophus lepidus*) they seen mostly in a tea-dominated landscape. Small scale habitat variables (e.g. percentage tea plantation cover) and distances to habitat features (e.g. distance to water) were the strongest predictors of bat occurrence, likely due to their high mobility, which enables them to exploit even small or isolated foraging areas. Most species showed a positive response to coffee plantations grown under native shade and to forest fragments, but a negative response to more heavily modified tea plantations. Although bats respond negatively to tea plantations, tea-dominated landscapes that also contain forest fragments and shade coffee can nevertheless support many bat species (Wordley *et al.,* 2015).

2.6 THREATS, HABITAT MANAGEMENT AND CONSERVATION OF BATS

In peninsular Malayasia several bat species are limited to the north of the Peninsula (Corbet and Hill, 1992), and their inclusion would lead to an overestimate of inferred species richness. Indeed, inventories for Peninsular Malaysia (Medway, 1983; Lekagul and McNeely, 1988; Koopman, 1989; Corbet and Hill, 1992; Zubaid, 1993; Francis, 1995; Kingston *et al.*, 2003) suggest a decrease in microchiropteran diversity towards the southern end of the Peninsular Malayasia. Recent surveys of the bat fauna of Singapore indicate that of the 24 species of Microchiroptera and six species of Megachiroptera documented for that small equatorial island just 15 and 5, respectively, are still present. These recorded declines in chiropteran species richness almost certainly understate the true losses as extensive land transformation or habitat loss (>95%) and biota loss occurred early in Singapore's colonial history before comprehensive surveys of bats were made (David *et al.,* 2006). In Jordan the uncontrolled use of insecticides was one of the main threats affecting the population of bats. Since the establishment of the Kingdom, extensive amounts of DDT and other organophosphorous insecticides were used for the control of malaria and Leishmania vectors all over the country, especially in the Jordan Valley. Caves were sprayed unintentionally to eradicate resting mosquitoes and sandflies. The Ministry of Agriculture in Jordan was not considered bats as pests and targeted them; yet, several populations of the Egyptian Fruit Bat, R. aegyptiacus, declined sharply due to the use of pesticides. Habitat destruction due to deforestation, urbanization, agricultural expansion, road construction and tourism are other important factors which causes bat population decline. The plans for the education and conservation of bats in Jordan includes, a task force affiliated with the local nature conservation societies should be formed. This task force should consist of nature enthusiasts, academics, and conservation specialists. Adequate training of conservation enthusiasts based on bat conservation in countries with prior experience in this field should be formulated. Educational campaigning in collaboration with the Ministry of Education, targeting public schools in Jordan is another conservation programme. The aim would be to increase awareness of the need for conservation in general, and of bats in particular. Works must be initiated to expand enforcement efforts regarding existing laws and expand the legal framework for bat conservation (Zuhair *et al.*, 2005).

In a study of Neotropical bats in the canopy by Elisabeth *et al*, (2001) studied the differences in capture frequencies of some of the better-sampled species in high and low nets, revealed the vertical stratification and species-specific differences in diet, foraging strategies, roost sites, and sampling bias contributes to this pattern. As a result of the differential use of space among bats, alterations of forest structure are likely to result in changes in structure and function of local bat communities. This information is especially important in view of the need to develop and apply conservation-oriented programs to maintain biodiversity. A review of recent improvements in techniques for inventorying bats shows that a combination of methods, including mist netting and acoustic monitoring, is mandatory for such studies. A study about the reasons of major decline in bat population in southern Belgium shows a strong decrease in the populations of bats such as *Rhinolophus ferrumequinum, R. hipposideros, Barbastella barbastellus, Myotis dasycneme* and *M. myotis*. The bat diversity within these hibernacula has decreased by half over the last fifty years. The fifty percent loss of species diversity observed in this study is both a reflection of the far-reaching ecosystem deterioration in the Walloon Region and the source of considerable change in the way these ecosystems function (Thierry *et al.*, 2009). Roost disturbance, roost loss, hunting, introduced predators and deforestation was cited as the main threats of bats in Fiji islands. Awareness programs, elimination of introduced pests such as domestic cats and establishment of natural orchards are some of the proposed conservation works in the Fiji islands (Palmeirim *et al.*, 2005).

While discussing about the survival of bats in the Indo-Malayan Region, the situation is very crucial. Of the 260 bat species recorded one is extinct and 43 are threatened – six Critically Endangered, nine Endangered and 28 Vulnerable (Hutson *et al.*, 2001). In Pakistan, one species of bat is Endangered, Four are Vulnerable, nine near Threatened, eighteen are Least Concern, seven are Data Deficient and one is Not Evaluated (Walker and Molur, 2003). Main reasons for the threats of bats in Pakistan was the loss of their natural habitat by increased human population and human activities such as deforestation, use of pesticides, industrial activities, loss of buildings or alteration in the design of their roofs and deliberate anthropogenic disturbance are the major causes of their population decline. Even the minor alterations in the habitat such as the loss of key landscape elements for example tree lines, hedgerows, and canals that are used regularly by bats during flight result in the abandonment of their roosts and maternity colonies. Similarly, sufficient is known about some species to indicate that they are not endangered (i.e., those that are abundant), but the status of those that are rarely found is hard to judge. This makes it very difficult to assess which species are threatened or need of special conservation measures in Pakistan (Mahmood-ul-Hassan and Nameer, 2006).

In a study related to the conservation of cave roosts of bats in Yucatan, Mexico, they discussed about the highly nested pattern of species distribution, caves that support great species diversity also harbour large multispecies populations, and provide roosts for several species of concern. The implementation of the conservation strategy was hindered by the fact that the most important sites for the protection of bats are located in the large systems that are so attractive for tourists. Conservation plans for the bats of Yucatan are inevitably linked to the protection of cave environments. Because of the particular social and historical traits of the state, such conservation plans need to be linked also to the protection of archaeological sites, to the use by sport speleologists, and to the management of caves as tourist sites (Arita, 1996).

Materials and methods

MATERIALS AND METHODS

3.1 STUDY AREA

The Silent Valley National Park is a unique preserve of natural rainforests within an area of 237.52 sq. km (Fig 1). It is roughly a rectangular table land extending over 8952 hectares at the south western corner of the Nilgiris (Lat. 11^0 00' & 11^0 15' N and Long. 76^0 15' & 35 E). It is closed on all sides with high and continuous ridges along the entire north, northeast and east with steep escarpments along the western and eastern border. The evolutionary age of the Silent Valley evergreen rain forest is believed to be more than 50 million years. It is perhaps the only remaining un-disturbed tropical rain forest in Kerala State as well as in peninsular India. The flora and fauna of this area are quite unique and 34 mammalian species including three endangered species, *i.e.*, Tiger, Lion-tailed Macaque and Nilgiri Langur have been recorded (Nair, 1999).

The environment of this rainforest is fairly stable, so that the flora and fauna have acquired a highly specific adaptation. The whole valley is shielded from the extremes of climate as well as anthropogenic intervention and so it remained an ecological island with a special microclimate. Along its entire length, the plateau slopes towards Kunthipuzha (Plate 1) which originates at an altitude of about 2,400 m in the over rim of the Nilgiris, descends rapidly to 1,150 m at the northern edge of the plateau and flows thereafter in the north-south direction through the Valley. The highest peaks, Anginda (2,383 m), Sispara (2,206 m) and Kozhippara (1,904 m) are on the northern boundary of the Valley. Both south-west and north-east monsoons are available to the Valley, maximum precipitation being during the south-west monsoons. Average rain fall is 3,180 mm and the highest rain fall is recorded during the month of July (885.8 mm). January, February and March are comparatively drier

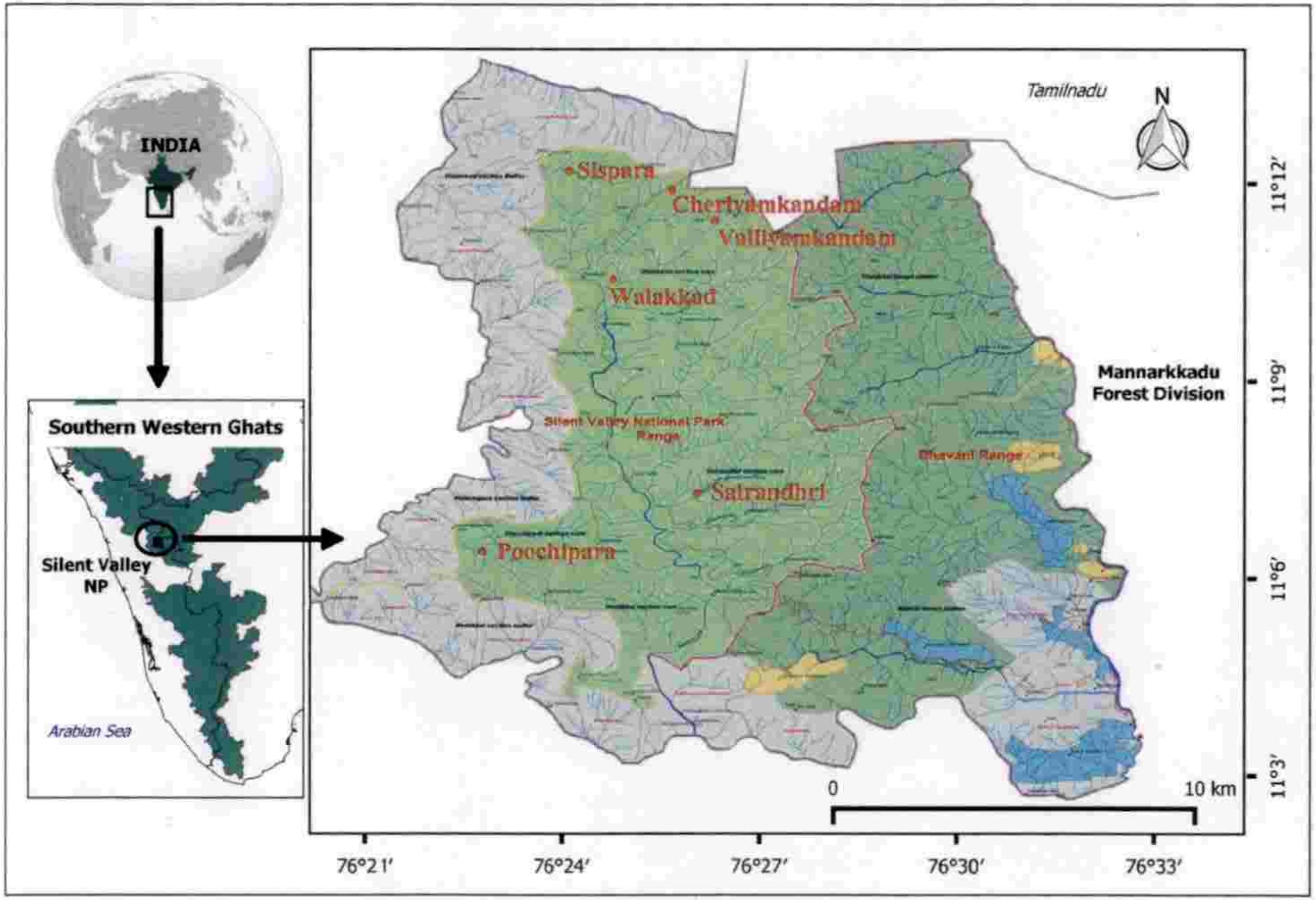

Fig.1: Location map of the study area in Silent Valley National Park

months. The highest temperature is experienced during May (30°C) and the lowest during January (7 °C) (Basha, 1999).

Plate 1: Kunthi River in Silent Valley National Park

The forests of Silent Valley consist mainly of tropical evergreen (Plate 2), grasslands (Plate 3) and shola vegetation, with tremendous complexity as well as floral and faunal diversity. They harbor a large number of threatened and endemic species of flora and fauna. Several new species of flora and fauna including amphibians, fish, insects, lichens, mosses, ferns and flowering plants have been described from Silent Valley. The major vegetation types in this ecological island are the moist deciduous forests, riparian evergreen forests, tropical evergreen forests, subtropical temperate forests (sholas) and grassland of particular significance (Basha, 1999).

Plate 2: Evergreen forests in Silent Valley National Park

Plate3: Grasslands in Silent Valley National Park

3.2 METHODS

3.2.1 Field Study period

The capturing of bats from the study location was carried out during a time span from September 2015 to May 2016. A total of 920 hours of mist netting was done during this period at different selected locations of the Silent Valley National Park. The study was carried out mainly in two seasons such as monsoon (Sept-Nov) and summer (Feb-May) and was also done in two selected habitats such as evergreen and grassland.

3.2.2 Selection of Sites

Representative sample plots were selected from each location based on observations such as habitat, availability of food and water and proximity to the roosting site. Two major habitats in SVNP such as evergreen (Plate 4) and grasslands (Plate 5) were selected for mist-netting.

Plate 4: Mist net set in Evergreen Forest

Plate 5: Mist net set in Grassland

3.2.3 Capturing Technique

Mist-netting was the standard methodology adopted for the capture (Kunz and Kurta, 1988). The mist-nets were placed in sites where bats showed a high rate of activity such as near bat roosts, water bodies, feeding sites of the bats, along flyways such as trails, and openings in the natural forest. The mist-nets are made of monofilament nylon with a usual mesh size of 36mm. For this study mist-net of three different dimensions i.e. 10 x 1.5m, 12 x 3m and 15 x 3m (Plate 6). Mist-nettings were done in selected sites at a height of 3-4m from the ground. The mist-nets should be kept open prior to the dusk, before the bats actually leave the roost, and was kept open for four to five hours. The mist nets were erected across the corridors (gap between rows of trees) to enhance the capture success.

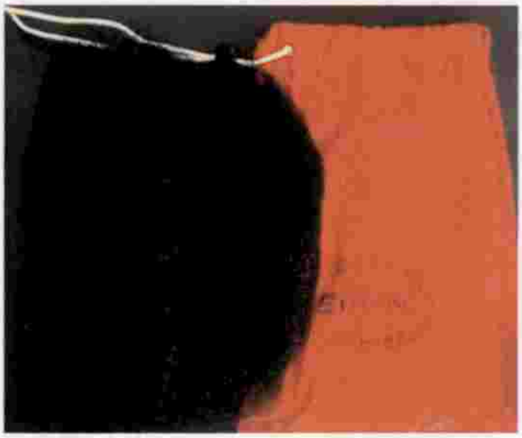

Plate 6: Mist net

Mist-nettings were not done continuously on the same site for more than two days, as it would affect the capture success (Kunz and Kurta, 1988). Nets were watched continuously, if left unattended, the captured bats struggles and become completely entangled that they cannot be removed easily and can also lead injury to bats and damages to nets (Plate 7). It can also result in the small sized bats to chew out of the net if it left unattended for long. For capturing bats from roosts, insect nets were used and mist-nets were also used by spreading it in front of the roost while it's a cave roost or tunnel like structure.

Plate.7: Removing the bat from the mist net

3.2.4 Field Study

The mist nets were kept open for 920h. As soon as the bats were caught in the mistnet, kit was removed immentaely into a cloth bag. On all the captured bats the standard morphological measurements were taken and the sex was also noted. The measurements were taken using the Mitutoyo digital calliper (Plate8) with a precision of 0.01 mm (Plate 9). The major external measurements measured on the bats were head to body length (HB), tail length (T), hind foot length (HF), length of tibia (TIB), forearm length (FA), wing span length (WSP), length of ear (E), Thumb, third metacarpal (3MT), fourth metacarpal (4MT), first (1PH3MT) and second (2PH3MT) phalanx of the third metacarpal and first (1PH4MT) and second (2PH4MT) phalanx of the fourth metacarpal (Fig. 2) (Bates and Harrison, 1997).

Plate 8: Mitutoyo digital calliper

Plate 9: Measuring morphological measurements using Digital Calliper

Fresh weight of each bat was also measured up to 0.01gm precision using Persola balance (Plate 10) of 10gm, 100gm and 1000gm (Plate11). The tissue samples from the bats were preserved in 70 percent ethyl alcohol after fixing using 10 percent formalin for further laboratory studies.

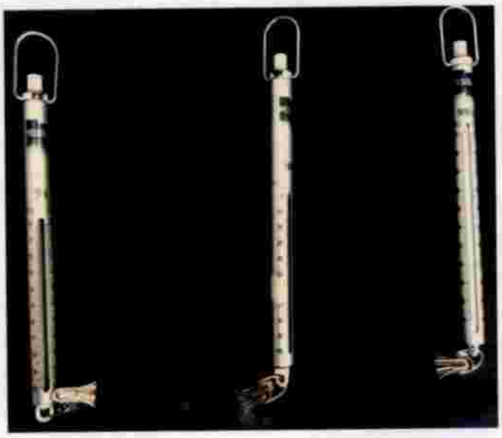

Plate 10: Persola balance (10gm, 100gm and 1000gm)

Plate 11: Weighing bats using Persola balance

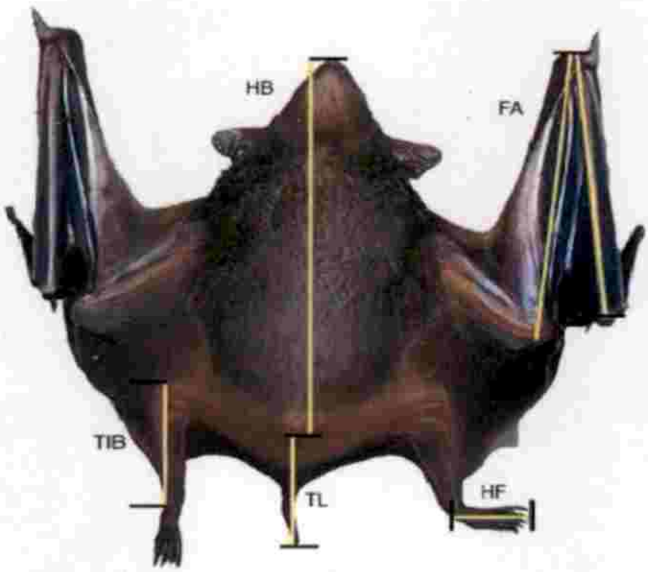

Fig. 2: Morphological measurements in bats

3.2.5 Laboratory study

From each of the collected specimens, the skull was pulled out using the standard procedure, and the skull was processed by boiling it for 2 minutes and treating using hydrogen peroxide (30% solution) through immersing the skull into it and cleaned using forceps and then the standard measurements on the skull were taken (Plate 12). The cranial and dental measurements were taken which included greatest length of the skull (GTL), condylo-basal length (CBL), condylo- canine length (CCL), breadth of braincase (BB), zygomatic breadth (ZB), mandible length (M), maxillary toothrow (C-M^n), mandibular toothrow (C-M_n), posterior palatal width (M^n-M^n) and anterior palatal width (C^1-C^1), (Fig 3) (Bates and Harrison, 1997).

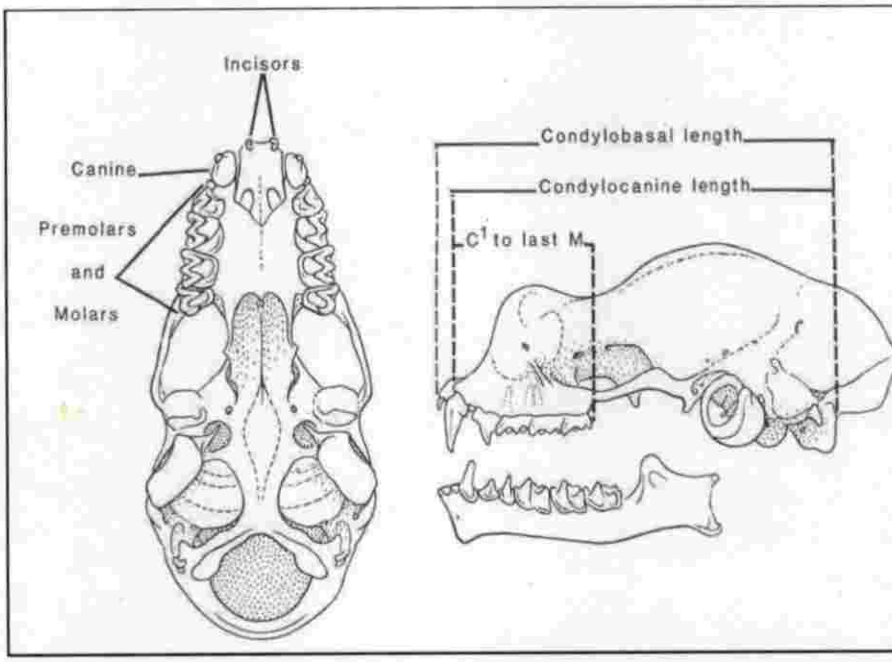

Fig. 3: Cranial measurements in bats (Bates and Harrison, 1997)

Plate 12: Measuring cranial measurements using Digital Calliper

3.2.6 Habitat studies

The macro-habitat parameters such as GPS location, altitude, habitat type, and the micro-habitat parameters like canopy height, canopy cover, density of shrubs, trees, climbers, buttresses and canes, and distance to the nearest large tree (> 60 cm girth), frequency of natural hollow in the trees etc, were recorded from the study locations. These were taken at all the locations whereever the mist net were kept, from within a circular plot having a dimension of 5m radius. A total of 20 such plots were taken for recording the habitat parameters.

3.2.6 Data analysis

Fourteen morphological and 12 cranial and dental dimensions were measured. Role of micro-habitat parameters in the distribution of bats of capturing and non-capturing plots which included the canopy height, canopy cover, densities of shrubs, trees, climbers, buttresses and canes, and distance to the nearest large tree and frequency of natural hollow in the trees were done using the statistical software IBM SPSS statistics 20.

Distribution of bat species based on habitats and seasonal changes was also analyzed and the significance of these ecological parameters and their combined effect was analyzed for the student's t-test using the software PAST.

Diversity indices such as, Dominance-D, Simpson Index, Shannon Index, Evenness, Margalef, Fisher_alpha and Berger Parker were also calculated and analyzed using the statistical software PAST (Jayaraman, 1999; Magurran, 2004).

Discriminant analysis on the effect of micro-habitat parameters in the distribution of bats were analysed using the Xcel Stat software.

Results

RESULTS

4.1 DISTRIBUTION AND SPECIES COMPOSITION OF BATS IN SILENT VALLEY NATIONAL PARK

Bats of eight species belong to five genera and three families were captured from Silent Valley National Park (Table 2). Out of these three species such as *Latidens salimalii*, *Myotis montivagus* and *Cynopterus sphinx* are new reports from Silent Valley. The Salimalii's Fruit Bat (*Latidens salimalii*) is the first report from Kerala. There are four frugivorous bats from the family Pteropodidae were captured which includes *Latidens salimalii, Cynopterus sphinx, C. brachyotis* and *Rousettus leschenaulti* with two, 21, 17 and 2 individuals respectively(Fig 4 and 5). Two species from family Rhinolophidae were captured and it includes *Rhinolopus lepidus* and *Rhinolophus rouxii* with one and two individuals respectively. And two species from family Vespertilionidae includes *Myotis montivagus* and *Myotis horsfieldii* with five and one individuals respectively.

Table 2: Number of species and number of individuals in different families at Silent Valley National Park

Family	Number of species	Number of individuals
Pteropodidae	4	42
Rhinolophidae	2	3
Vespertilionidae	2	6
Total	8	51

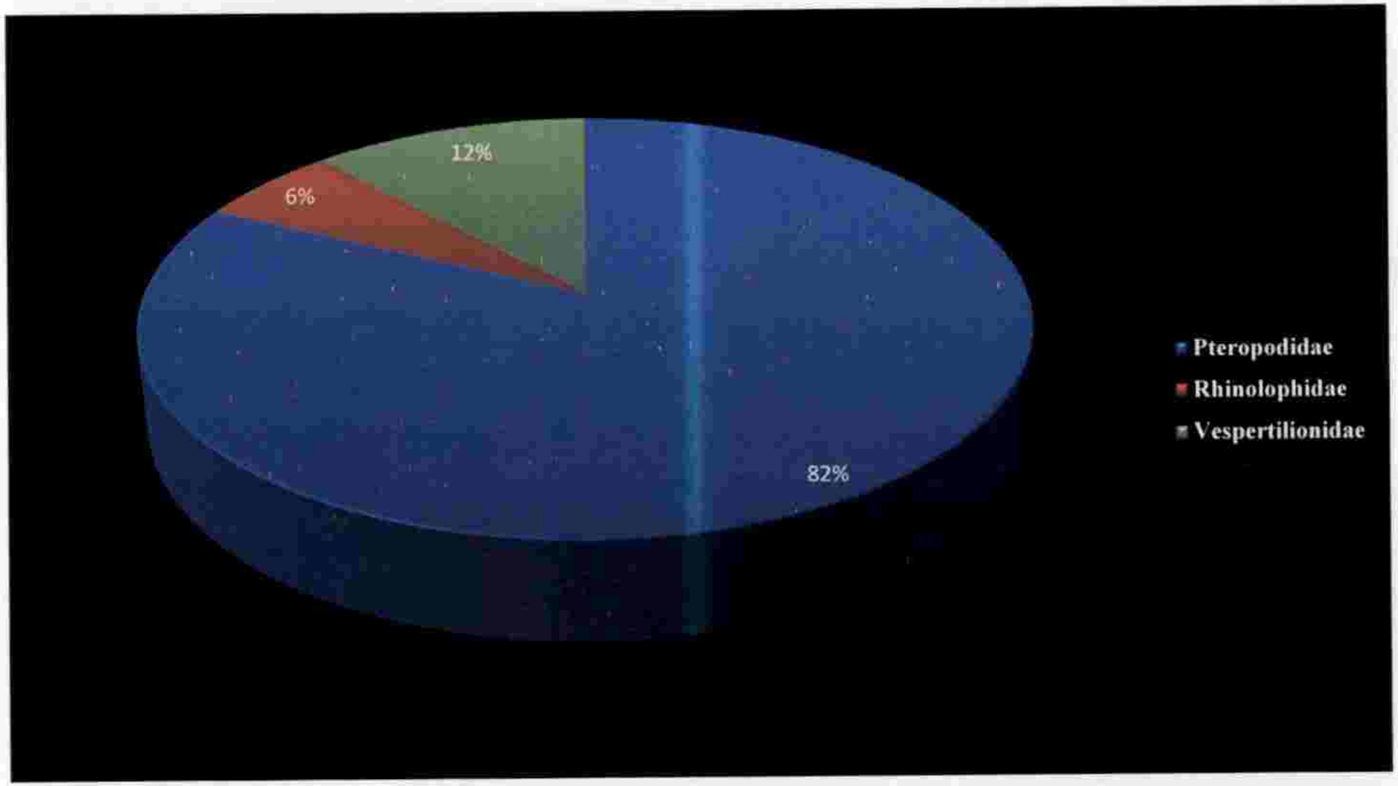

Fig 4: Number of individuals of bats in different families at Silent Valley National Park

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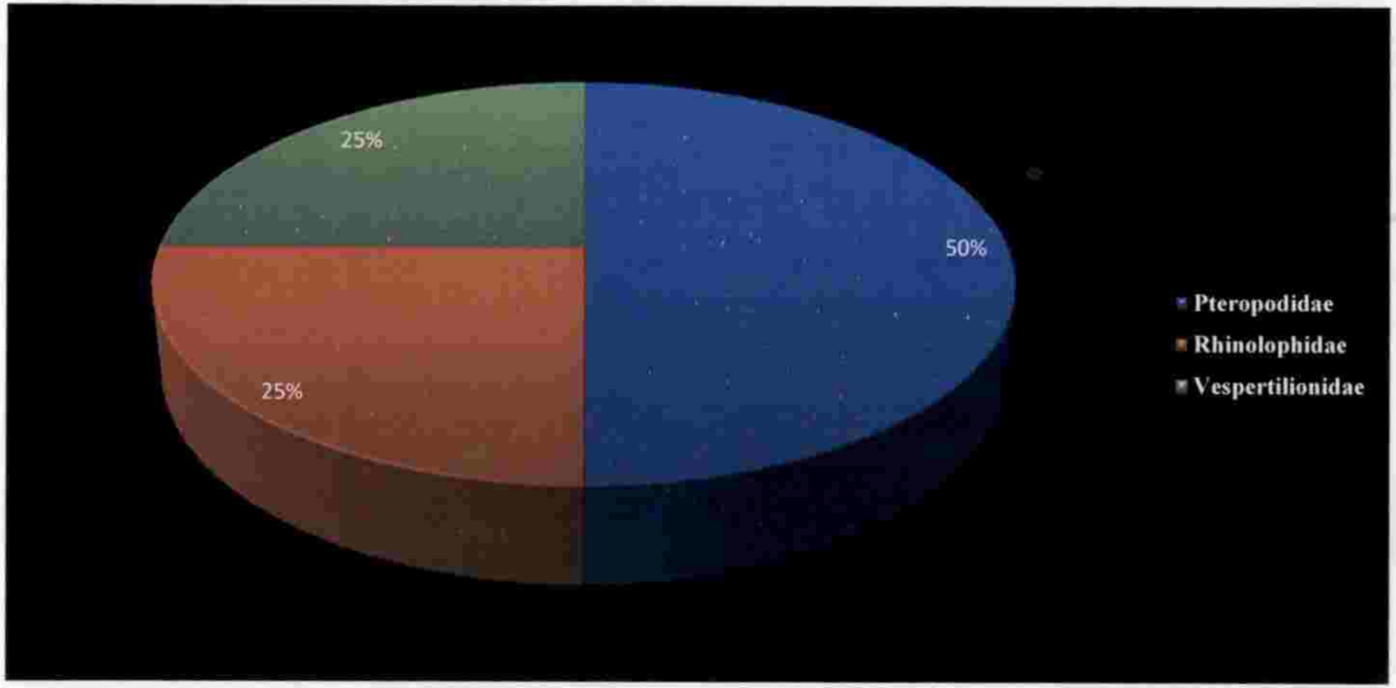

Fig 5: Number of species of bats in different families at Silent Valley National Park

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4.2 MORPHOMETRIC ANALYSIS

The mean morphological and cranial measurements of the eight species of the bats obtained from the Silent Valley NP during the present study are given below.

4.2.1 *Latidens salimalii*

Two individuals, one male and one female, were caught in the mistnet. Both were collected from Sairandhri (Plate 13). One of the striking morphological characters of the *Latidens salimalii* is the absence of tail, which all other pteropodid possess. The forearm length (FA) range from 66.62mm to 70.52mm and hind foot (HF) ranges from 12.44mm to 14.91mm. The main cranial and dental measurements such as the greatest length of the skull (GTL) and mandible length (M) range from 32.99mm to 33.49mm and 24.57mm to 25.5mm respectively (Table 3).

Plate 13: Salimalii's Fruit bat (*Latidens salimalii*)

Table 3. Mean, range and standard deviation of external, cranial and dental measurements of *Latidens salimalii*

Parameter (mm)	Mean (n=2)	Range	SD	Range (Bates and Harrison, 1997)
HB	105.5	102-109	4.95	102.0-109.0
FA	68.57	66.62-70.52	2.76	66.0-69.0
WSP	454	450-458	5.66	434.0-472.0
E	18.01	16.58-19.44	2.02	15.5-18.5
T	Absent	Absent		Absent
HF	13.67	12.44-14.91	1.75	8.0-15.0
3MET	48.56	48.13-49	0.62	45.2-49.3
4MET	45.83	45.63-46.03	0.28	43.3-48.1
GTL	33.24	32.99-33.49	0.35	32.6-34.3
CBL	31.14	31.1-31.18	0.06	31.4-33.0
ZB	20	19.38-20.62	0.88	21.0-22.1
BB	14.52	14.42-14.62	0.14	13.5-14.1
IC	5.36	5.15-5.58	0.30	7.2-8.0
M	25.03	24.57-25.5	0.66	24.8-26.3
$C\text{-}M^1$	11.51	11.28-11.74	0.33	11.3-11.8
$C\text{-}M_2$	12.14	11.89-12.39	0.35	12.4-12.9

4.2.2 *Rousettus leschenaulti*

In this case also two individuals were caught in the mistnet, one each of male and female individuals (Plate 14). One of these individual was considerably smaller in size. However, the forearm lengths fall within the range of that of *Rousettus leschenaulti*. The mean of main morphological measurements such as head to body length (HB), forearm length (FA), ear length (E), tail length (T) and hind foot length (HF) were 101.5 mm, 72.02 mm, 16.97 mm, 11.84 mm and 13.85 mm respectively. The morphological measurements such as the mean of measurements of thumb (27.31 mm) and second phalanx of third metacarpal (38.22 mm) showed values of the two individuals of *Rousettus leschenaulti* the measurement range given by Bates and Harrison (1997). While on the cranial measurements, only the zygomatic breadth (ZB) and breadth of the braincase (BB) showed comparable values with the Bates and Harrison (1997), (Table 4). Since some of the measurements does not come within the range of the *Rousettus leschenaulti* as given by Bates and Harrison (1997), detailed studies including the molecular analysis is warranted in this species to confirm the identity of the species.

Table 4. Mean, range and standard deviation of external, cranial and dental measurements of *Rousettus leschenaulti*

Parameter (mm)	Mean (n=2)	Range	SD	Range (Bates and Harrison, 1997)
HB	101.5	96-107	7.78	111.0-147.0
FA	72.025	67.13-76.92	6.92	75.0-86.0
E	16.975	16.3-17.65	0.95	17.5-24.0
T	11.845	11.23-12.46	0.87	8.0-21.0
HF	13.855	13.82-13.89	0.05	15.0-22.0
THUMB	27.315	25.56-29.07	2.48	24.4-31.1
2ph3mt	38.225	33.89-42.56	6.13	39.6-46.2
GTL	34.005	31.42-36.59	3.66	34.9-39.4
CBL	31.735	29.78-33.69	2.76	33.5-37.7
ZB	19.05	17.13-20.97	2.72	20.2-24.0
BB	14.53	14.04-15.02	0.69	14.4-16.0
IC	4.64	3.46-5.82	1.67	6.9-8.8
M	26.595	24.11-29.08	3.51	27.6-31.1
$C\text{-}M^2$	13.41	12.84-13.98	0.81	13.5-15.2
$C\text{-}M_3$	13.41	11.66-15.16	2.47	14.8-16.7

Plate 14: The Fulvous Fruit bat (*Rousettus leschenaulti*)

4.2.3 *Cynopterus sphinx*

Cynopterus sphinx (Plate 15) and *Cynopterus brachyotis* (Plate 16) are two species closely related with their morphological and cranial measurements. Forearm length is one of the main character which helps to distinguish these two species. Forearm length of *Cynopterus sphinx* and *Cynopterus brachyotis* ranges from 64.0-79.0 mm and 57.3-63.3 mm respectively. The observed range of forearm length of *Cynopterus sphinx* was from 64.11-68.33 mm. The ears are simple and essentially naked. In males, the chin, anterior part of the shoulders, sides of the chest, belly and thighs are characteristically orange tinted. All other morphological and cranial measurements of the species were having values within the range given by Bates and Harrison (1997), (Table 5).

Plate 15: The Short-nosed Fruit bat (*Cynopterus sphinx*)

Table 5. Mean, range and standard deviation of external, cranial and dental measurements of *Cynopterus sphinx*

Parameter (mm)	Mean (n=21)	Range	SD	Range (Bates and Harrison, 1997)
HB	89.33	81-99	4.50	76.0-113.0
FA	65.46	64.11-68.33	1.09	64.0-79.-0
WSP	433.17	418-448	8.31	309.0-436.0
E	14.71	12-18.39	1.56	17.5-24.0
T	9.48	5.11-14.41	2.70	4.5-19.0
HF	12.91	10.13-14.99	1.47	12.6-18.0
3MET	45.39	42.82-48.92	1.63	43.2-53.4
4MET	42.44	40.18-45.62	1.57	40.7-51.1
GTL	30.00	28.91-31.12	0.58	30.2-34.9
CBL	28.80	26.97-29.99	0.77	28.4-33.3
ZB	18.46	17.01-19.66	0.60	18.8-23.1
BB	12.41	11.25-13.33	0.40	11.1-14.8
IC	4.85	4.22-5.28	0.24	5.4-7.7
M	22.65	21.62-23.81	0.64	22.7-27.5
$C\text{-}M^3$	9.92	9.06-10.68	0.43	10.2-12.2

C-M_3	11.10	10.49-11.7	0.38	10.3-13.5

4.2.4 *Cynopterus brachyotis*

This species averages smaller than *Cynopterus sphinx* with a forearm length of 60.3 mm (57.3-63.3 mm). The observed range of forearm length *Cynopterus brachyotis* was from 56.29-63.85 mm. The finger bones of the wing tend to be darker as compared to the pale metacarpals and phalanges of *C. sphinx*. In all other morphological characters, the two species appear to be similar. And all other observed morphological and cranial measurements of the species were having values within the range given by Bates and Harrison (1997), (Table 6).

Plate 16: The Lesser Dog-faced Fruit bat (*Cynopterus brachyotis*)

Table 6. Mean, range and standard deviation of external, cranial and dental measurements of *Cynopterus brachyotis*

Parameter (mm)	Mean (n=17)	Range	SD	Range (Bates and Harrison, 1997)
HB	85.35	73-96	6.96	80.0-96.0
FA	61.51	56.29-63.85	2.50	57.3-63.3
E	14.79	12.31-16.63	1.18	14.5-18.0
T	8.74	4.33-12.86	2.37	4.5-19.0
HF	13.21	11.41-14.87	1.11	12.6-18.0
3MET	42.03	35.19-47.29	3.34	43.2-53.4
4MET	40.06	34.72-46.03	3.09	40.7-51.1
GTL	29.02	26.15-31.01	1.48	27.5-30.5
CBL	27.76	24.22-29.66	1.55	26.0-28.8
ZB	17.68	15.13-19.19	1.22	17.6-19.8
BB	12.44	11.33-12.9	0.40	9.9-13.3
IC	5.18	4.52-7.16	0.63	5.5-6.8
M	21.72	19.57-23.03	1.04	20.5-23.8
$C\text{-}M^3$	9.75	8.94-10.6	0.48	8.9-10.7
$C\text{-}M_3$	10.92	9.91-12	0.49	10.0-11.9

4.2.5 *Myotis montivagus*

These bats were located from a bats roost at Sairandhri. There were about 250-300 in the roost and from where five bats were collected. While comparing the measurements of five specimens of *Myotis montivagus* (Plate 17), the mean of morphological measurements such as forearm length (FA), tibia length (TIB), hind foot length (HF) and length of the third metacarpal (3MET) were 44.63 mm, 18.19 mm, 9.28 mm and 42.32 mm respectively which comes within the range of values given by Bates and Harrison (1997). Similarly in the case of cranial measurements, mandible length (M), mandibular toothrow ($C\text{-}M_n$) and maxillary toothrow ($C\text{-}M^n$)

values were 13.05 mm, 7 mm and 6.54 mm respectively and comes within the range of values given by Bates and Harrison (1997), (Table 7).

Plate 17: The Burmese Whiskered bat (*Myotis montivagus*)

Table 7. Mean, range and standard deviation of external, cranial and dental measurements of *Myotis montivagus*

Parameter (mm)	Mean (n=5)	Range	SD	Range (Bates and Harrison, 1997)
HB	49.7	46.08-54.31	3.39	56.0-62.0
FA	44.63	44.22-45.15	0.37	44.7-46.8
E	16.50	15.25-18.53	1.24	14.2-15.5
T	35.91	32.21-37.85	2.49	42.0-48.0
TIB	18.19	16.75-19.3	0.92	18.0-19.4
HF	9.28	8.55-9.78	0.51	9.0-10.0
3MET	42.32	40.71-44.04	1.57	40.2-43.8
4MET	43.23	41.14-48.7	3.10	39.4-42.5
GTL	16.35	16.18-16.83	0.27	17.0-17.5
CCL	14.76	14.13-15.34	0.44	15.1-15.6
BB	8.48	8.04-8.83	0.37	7.6-8.0

PC	4.08	3.93-4.25	0.12	3.7-4.1
M	13.05	12.66-13.53	0.37	12.9-13.3
$C\text{-}M^3$	6.54	6.35-6.94	0.25	6.5-6.8
$C\text{-}M_3$	7.00	6.63-7.8	0.47	6.9-7.2
$M^3\text{-}M^3$	6.89	6.71-7.13	0.15	7.1-7.3
$C^1\text{-}C^1$	4.23	3.78-4.76	0.39	4.4-4.8

4.2.6 *Myotis horsfieldii*

The morphological and cranial measurements of *Myotis horsfieldii peshwa* (Plate 18) was different than the *Myotis montivagus* as is evidenced from the Table 7 and Table 8. Most of the measurements of *Myotis horsfieldii peshwa* was smaller than that of *Myotis montivagus*. For example, the forearm length, which is a key character to say between the identity of the different species of bats, showed considerable variation between these two species of *Myotis*. In the case of *Myotis horsfieldii peshwa* its forearm length was 37.3 mm, while in the case of the *Myotis montivagus* it was 44.63mm. The morphological measurements such as forearm length (37.3 mm) and ear length (13.64 mm) values falls within the known range for the species (Bates and Harrison, 1997). Similarly in the case of cranial measurements, the greatest length of the skull (GTL), condylocanine length (CCL), zygomatic breadth (ZB), mandibular toothrow ($C\text{-}M_n$), width across the last molars ($M^n\text{-}M^n$) and length between upper canines ($C^1\text{-}C^1$) are 14.99 mm, 14.03 mm, 9.74 mm, 6.06 mm, 5.82 mm and 4.03 mm respectively and values comes within the range that prescribed by Bates and Harrison (1997) (Table 8).

Plate 18: The Horsfield's bat (*Myotis horsfieldii*)

Table 8. Mean, range and standard deviation of external, cranial and dental measurements of *Myotis horsfieldii peshwa*

Parameter (mm)	Mean (n=1)	Range (Bates and Harrison, 1997)
HB	47	49.0-59.0
FA	37.3	36.5-41.5
WSP	292	258.0-284.0
E	13.64	13.0-15.2
T	45.44	34.0-42.0
TIB	19.88	16.8-17.8
HF	5.93	7.0-11.2
3MET	41.23	35.9-39.0
4MET	39.38	34.5-37.7
GTL	14.99	15.6-16.5
CCL	14.03	13.4-14.3
ZB	9.74	9.3-10.2
BB	7.93	7.2-7.7

M	11.61	11.2-11.6
$C\text{-}M^3$	6.03	5.5-5.9
$C\text{-}M_3$	6.06	5.9-6.4
$M^3\text{-}M^3$	5.82	5.8-6.5
$C^1\text{-}C^1$	4.03	4.2-4.3

4.2.7 *Rhinolopus lepidus*

The *Rhinolopus lepidus* (Plate 19) is smaller than *Rhinolophus rouxii rouxii* (Plate 20) and the orange colour on its face is quite charecteristic. The mean of morphological measurements such as head to body length (HB), forearm length (FA), ear length (E), tail length (T), tibia length (TIB), hind foot length (HF), length of third and fourth metacarpal (3MET and 4MET), length of first and second phalanx of third metacarpal (1ph3mt and 2ph3mt) and length of second phalanx of fourth metacarpal (2ph4mt) all corroborate with the figures given by Bates and Harrison (1997). Also in the case of cranial measurements the greatest length of the skull (GTL), condylocanine length (CCL), zygomatic breadth (ZB), Breadth of the braincase (BB), mandible length (M), mandibular toothrow ($C\text{-}M_n$) and maxillary toothrow ($C\text{-}M^n$), width across the last molars ($M^n\text{-}M^n$) and length between upper canines ($C^1\text{-}C^1$) shows values within the range given by Bates and Harrison (1997), (Table 9).

Plate 19: The Blyth's Horseshoe bat (Rhinolophus lepidus)

Table 9. Mean, range and standard deviation of external, cranial and dental measurements of *Rhinolopus lepidus*

Parameter (mm)	Mean (n=1)	Range (Bates and Harrison, 1997)
HB	44	35.0-54.0
FA	40.29	37.0-41.8
WSP	257	232.0-256.0
E	13.25	14.5-20.6
T	19.04	14.0-28.0
TIB	16.02	14.9-18.4
HF	8.74	5.5-10.0
3MET	31.92	28.2-33.3
4MET	30.35	29.6-33.8
1ph3mt	11.83	10.0-13.3
2ph3mt	17.84	16.0-18.9
1ph4mt	11.58	7.6-10.5

2ph4mt	11.13	9.6-12.3
GTL	16.24	16.2-18.4
CCL	13.88	13.8-15.5
ZB	7.98	7.6-8.8
BB	7.15	6.5-7.8
M	10.46	10.0-12.1
$C\text{-}M^3$	5.83	5.6-6.8
$C\text{-}M_3$	6.1	6.0-7.4
$M^3\text{-}M^3$	5.89	5.7-6.3
$C^1\text{-}C^1$	4.01	3.7-4.2

4.2.8 *Rhinolopus rouxii*

In the case of *Rhinolophus rouxii rouxii* (Plate 20) the mean of morphological measurements, the head to body length (HB), forearm length (FA), ear length (E), tail length (T), tibia length (TIB), hind foot length (HF), length of third and fourth metacarpal (3MET and 4MET), length of first and second phalanx of third metacarpal (1ph3mt and 2ph3mt) and length of first and second phalanx of fourth metacarpal (1ph4mt and 2ph4mt) were 60.50 mm, 51.18 mm, 14.74 mm, 27.97 mm, 22.67 mm, 8.68 mm, 38.72 mm, 39.17 mm, 16.34 mm, 23.89 mm, 11.47mm and 13.76 mm respectively. Cranial measurements also show values within the range given by Bates and Harrison (1997), (Table 10).

Plate 20: The Rufous Horseshoe bat (*Rhinolophus rouxii rouxii*)

Table 10. Mean, range and standard deviation of external, cranial and dental measurements of *Rhinolophus rouxii rouxii*

Parameter (mm)	Mean (n=2)	Range	SD	Range (Bates and Harrison, 1997)
HB	60.50	59-62	2.12	42.0-66.0
FA	51.18	50.53-51.82	0.91	46.7-52.3
WSP	337.00	334-340	4.24	290.0-326.0
E	14.74	14.13-15.35	0.86	14.5-22.0
T	27.97	27.55-28.38	0.59	22.0-33.0
TIB	22.67	21.49-23.85	1.67	19.0-24.5
HF	8.68	7.1-10.25	2.23	7.2-12.8
3MET	38.72	36.9-40.53	2.57	34.2-39.5
4MET	39.17	38.17-40.16	1.41	35.6-40.5
1ph3mt	16.34	15.44-17.24	1.27	12.8-16.5
2ph3mt	23.89	23.46-24.32	0.61	20.5-26.0
1ph4mt	11.47	10.97-11.96	0.70	8.5-11.9
2ph4mt	13.76	13.44-14.08	0.45	12.2-16.3
GTL	20.43	20.4-20.45	0.04	21.2-23.5
CCL	19.27	19.1-19.44	0.24	17.5-21.0
ZB	11.27	11.02-11.51	0.35	10.5-11.9
BB	9.61	9-10.22	0.86	8.6-9.9
M	14.66	14.61-14.7	0.06	14.2-16.4

C-M^3	8.62	8.47-8.76	0.21	8.1-9.2
C-M_3	8.97	8.54-9.39	0.60	8.7-10.0

4.3 SPECIES DIVERSITY OF BATS IN SILENT VALLEY NATIONAL PARK

Species diversity of bats in Silent Valley National Park is evaluated using various diversity indices. The Simpson index, Shannon index, Margalef index, Fisher alpha index and Berger parker index are the various diversity indices used for diversity evaluation in this study. The species diversity and richness was calculated and compared based on habitat and seasonal variations. In the case of habitat, values of diversity indices for evergreen and grassland habitats were considered for comparing the species diversity of bats (Fig 6). For comparing the variations in species diversity based on season, values of diversity indices for monsoon and summer seasons were taken for comparison (Fig 7).

The habitat wise species diversity comparison shows, the value of Simpson index is greater for evergreen habitat with a value of 0.61 and for grassland the value is 0.45. Similarly the value of Shannon index is also greater for evergreen habitat with a value of 1.21 and for grassland habitat it is 0.79. The values of diversity indices Margalef index and Fisher alpha index are also greater for evergreen habitat with values of 1.59 and 2.35 respectively. The Margalef and Fisher alpha indices for grassland are 1.03 and 1.99 respectively. The value of Berger Parker index is greater for grassland with a value of 0.71 and for evergreen habitat it is 0.48.

The seasonal wise species diversity comparison shows, the value of Simpson index is greater for monsoon season with a value of 0.69 and for summer season the value is 0.68. The value of Shannon index is greater for summer season with a value of 1.41 and for monsoon season it is 1.29. The values of diversity indices Margalef index and Fisher alpha index are also greater for summer season with values of 1.73 and 3.15 respectively. The Margalef and Fisher alpha indices for monsoon season are 1.14 and 1.64 respectively. The value of Berger Parker index is greater for summer season with a value of 0.5 and for monsoon season it is 0.39 (Table 11).

Table 11: Number of species, number of individuals and various species diversity indices of bats in evergreen, grassland habitats and monsoon, summer seasons in Silent Valley National Park.

Diversity Indices	Grassland	Evergreen	Monsoon	Summer
Species	3	7	6	6
Individuals	7	44	33	18
Simpson Index	0.45	0.61	0.69	0.68
Shannon Index	0.79	1.21	1.29	1.41
Margalef Index	1.03	1.59	1.14	1.73
Fisher-alpha Index	1.99	2.35	1.64	3.15
Berger Parker Index	0.71	0.48	0.39	0.5

4.4 ABUNDANCE OF BATS IN SILENT VALLEY NATIONAL PARK

A total of 51 individuals of bats were captured, out of which 21 individuals belongs to *Cynopterus sphinx* (11 females and 10 males), 17 individuals of *Cynopterus brachyotis* (11 females and 6 males), 5 individuals of *Myotis montivagus* (3 females and 2 males), two individuals of *Latidens salimalii* (1 female and 1 male), two individuals of *Rousettus leschenaulti* (1 female and 1 male), two

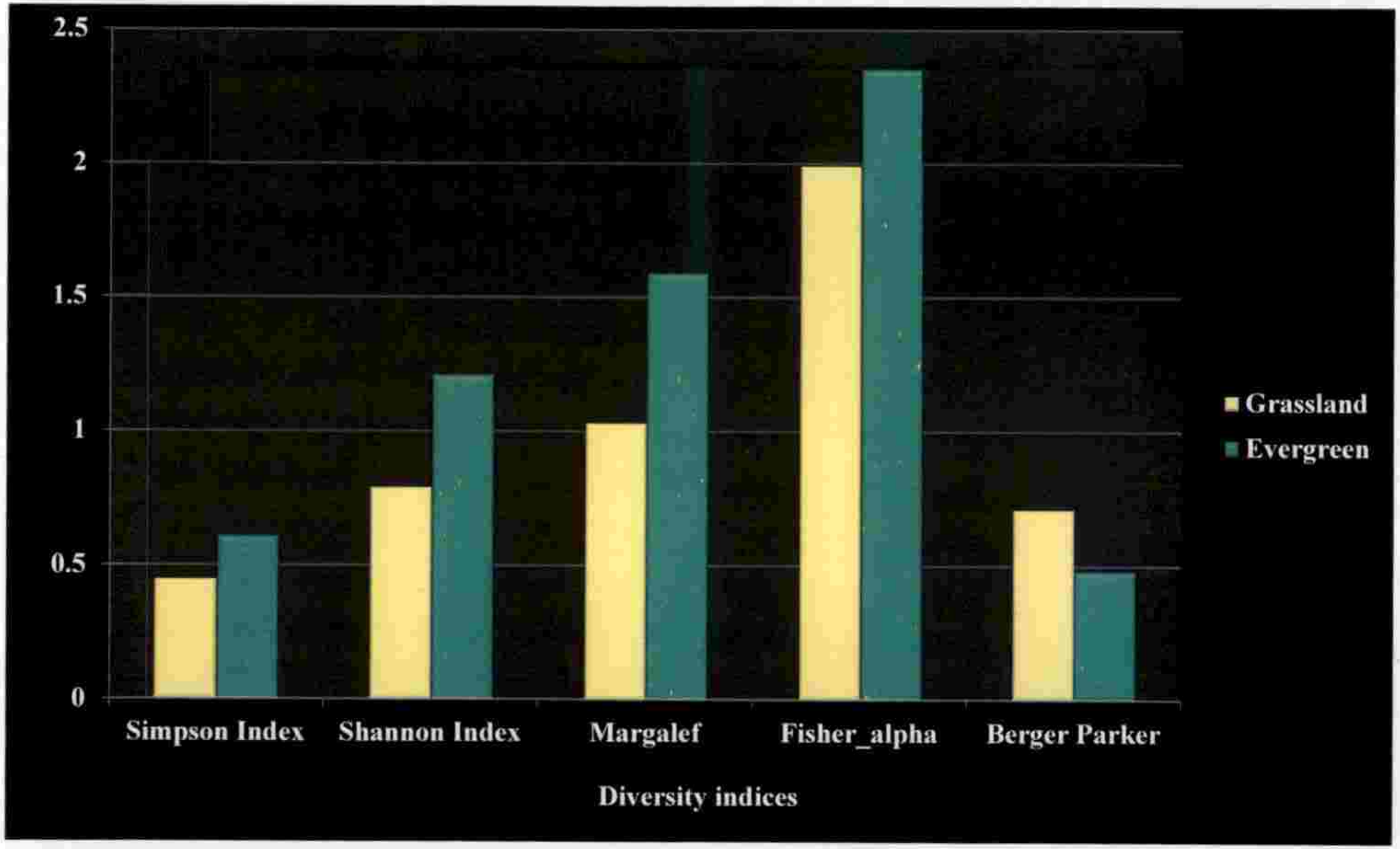

Fig 6: Comparison of species diversity indices of bats in evergreen and grassland habitats of Silent Valley National Park

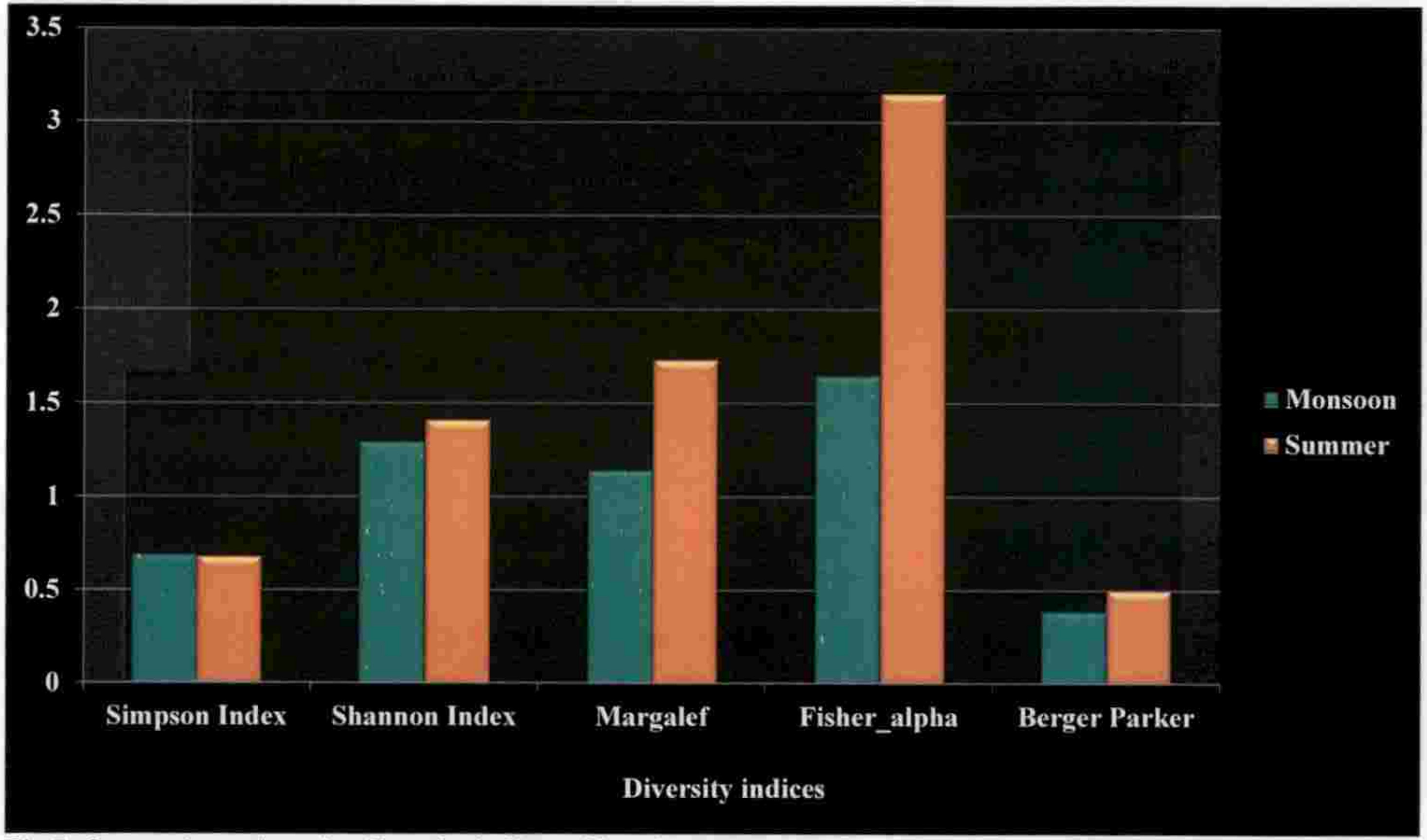

Fig 7: Comparison of species diversity indices of bats in monsoon and summer seasons in Silent Valley National Park

individuals of *Rhinolophus rouxii rouxii* (2 male) and one individual each of *Myotis horsfieldii peshwa* (1 male) and *Rhinolopus lepidus* (1 female) (Table 12). The species *C. sphinx* was captured from all the mist-netting locations. Thus the *C. sphinx* can be regarded as the most abundant bat of Silent Valley NP, followed by *C. brachyotis*, *Myotis montivagus*. In the case of *Latidens salimalii, Rhinolophus rouxii rouxii* and *Rousettus leschenaulti* only two specimens each could be obtained from SVNP (Fig 8).

Table 12: Number of individuals of bats captured from Silent Valley National park

Species	Number of individuals
Cynopterus sphinx	21
Cynopterus brachyotis	17
Myotis montivagus	5
Latidens salimalii	2
Rhinolophus rouxii rouxii	2
Rousettus leschenaulti	2
Myotis horsfieldii peshwa	1
Rhinolophus lepidus	1

4.5 DISTRIBUTION OF BATS IN SILENT VALLEY NATIONAL PARK

4.5.1 Significance of habitats in the distribution of bats in Silent Valley National Park

The significance of habitats in the distribution of bats in Silent Valley National Park was calculated using Student's t-test. Evergreen and grassland are the two types of habitats that used for checking the significance in the distribution of

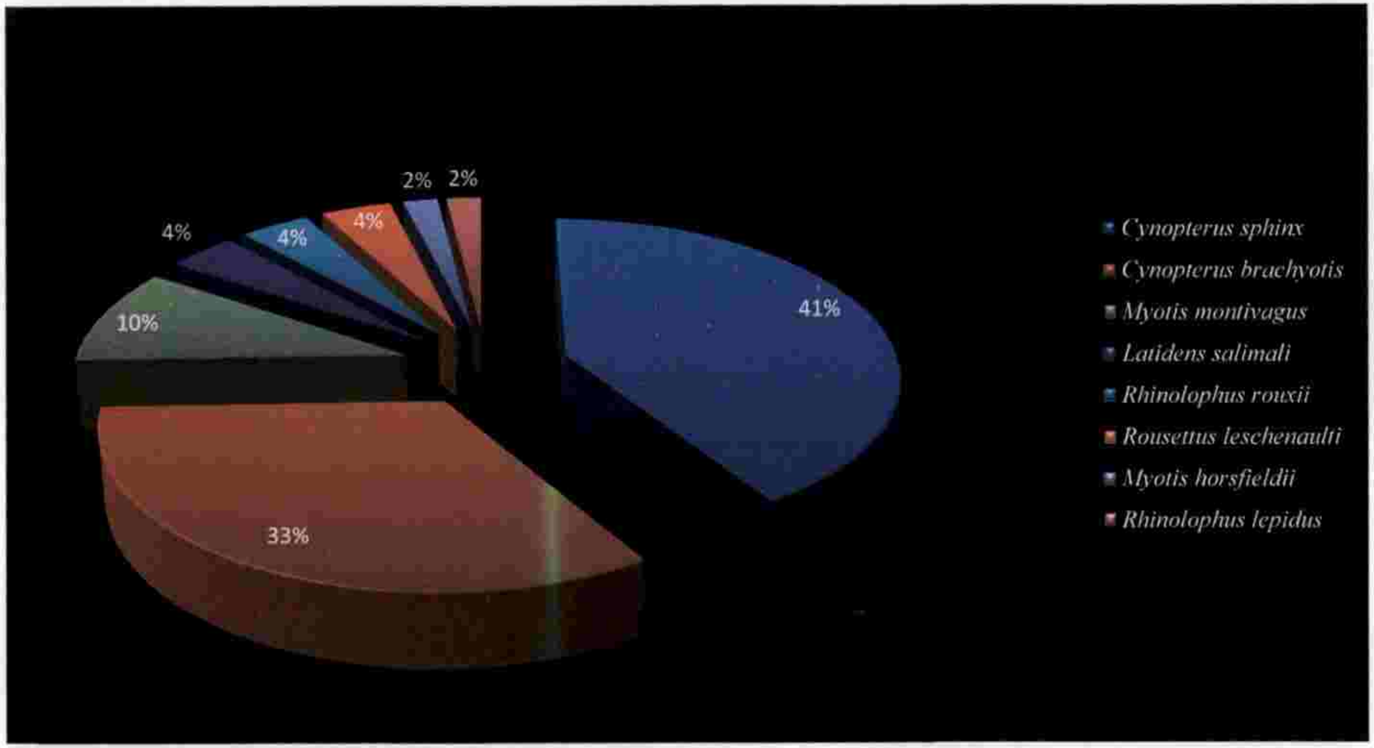

Fig 8: Abundance of different species of bats in Silent Valley National Park

bats. Out of 51 individuals 44 individuals are captured from evergreen and remaining seven individuals are captured from grassland (Fig 9). And out of eight, two species (*Latidens salimalii* and *Rhinolophus rouxii rouxii*) were captured from both habitats and five species (*Rhinolophus lepidus*, *Myotis horsfieldii peshwa*, *Rousettus leschenaulti*, *Cynopterus sphinx* and *Cynopterus brachyotis*) were captured from evergreen only and one species (*Myotis montivagus*) was captured from grassland only.

While checking the significance of two habitats in the distribution of these eight species, the results showing there is no significance for the two habitats in the distribution of bats in the Silent Valley National Park with a value of 1.41 which is greater than the table value (Table 13).

Table 13: Significance of evergreen and grassland habitats in the bat distribution of Silent Valley National Park

Habitat	Grassland	Evergreen
Taxa	3	7
Individuals	7	44
Mean (SE)	0.875 (0.610)	5.50 (2.97)
T-value	**1.41** ^{ns}	

ns: Non-significant

4.5.2 Effect of seasons in bat distribution in Silent Valley National Park

The effect of seasons in the distribution of bats in Silent Valley National Park was calculated using Student's t-test. Monsoon and summer are the seasons that used for checking the significance in the distribution of bats based on seasonal variations. Out of 51 individuals 33 individuals were captured during monsoon season and remaining 18 individuals are captured during summer season. And out of eight, three species (*Rhinolophus rouxii rouxii*, *Cynopterus sphinx* and *Cynopterus brachyotis*) were captured during both seasons and two species (*Latidens salimalii* and *Myotis montivagus*) were captured during monsoon season only and three species (*Rhinolophus lepidus*, *Myotis horsfieldii peshwa* and *Rousettus leschenaulti*) were captured during summer only (Fig 10).

While checking the significance of two seasons in the distribution of these eight species, the results showing there is no significance for the seasonal variations in the distribution of bats in the Silent Valley National Park (Table 14).

Similarly the significance of monsoon and summer seasons in evergreen and grassland habitats in the distribution of bats were also tested using Student's t-test. Both monsoon and summer seasons were considered for checking the significance of distribution of bats in each of the two habitats that studied in Silent Valley National Park (Fig 11 and 12). There are no significant differences in the distribution of bats during the two seasons in the two habitats (Table 15).

Table 14: Effect of monsoon and summer seasons in the bat distribution of Silent Valley National Park

Season	Monsoon	Summer
Taxa	5	6
Individuals	33	18
Mean (SE)	4.12 (1.92)	2.25 (1.06)
T-value	**0.12** ^{ns}	

ns:Non-significant

Table 15: The effect of monsoon and summer seasons in evergreen and grassland habitats in the distribution of bats in Silent Valley National Park.

Habitat	Grassland		Evergreen	
Season	Monsoon	Summer	Monsoon	Summer
Taxa	2	1	4	5
Individuals	6	1	27	17
T-value	**1.35** ns		**0.99** ns	

ns:Non-significant

4.5.3 Effect of micro-habitat parameters in the distribution of bats in Silent Valley National Park

The micro-habitat parameters are the most important factors that effectively influences in the distribution of most of the animals in different ecosystems. In the case of bats also their distribution is mostly related with the micro-habitat parameters of the habitats in which their activity is maximum.

In the case of distribution of bats in Silent Valley National Park, nine micro-habitat parameters were analyzed to find out their effect in the distribution of bats. The nine micro-habitat parameters include altitude, canopy height, canopy cover, tree number, climber number, cane number, buttress number, distance to the large tree and the frequency of natural hollows in the trees. All these micro-habitat parameters were recorded for the captured and non-captured plots and mean of these two plots were used for the independent t-test.

It has been observed that the following micro-habitat parameters such as the density of trees, density of canes and the presence of natural hollow were found to be of influencing the distribution of the bats at five percentage significance level (Table 16).

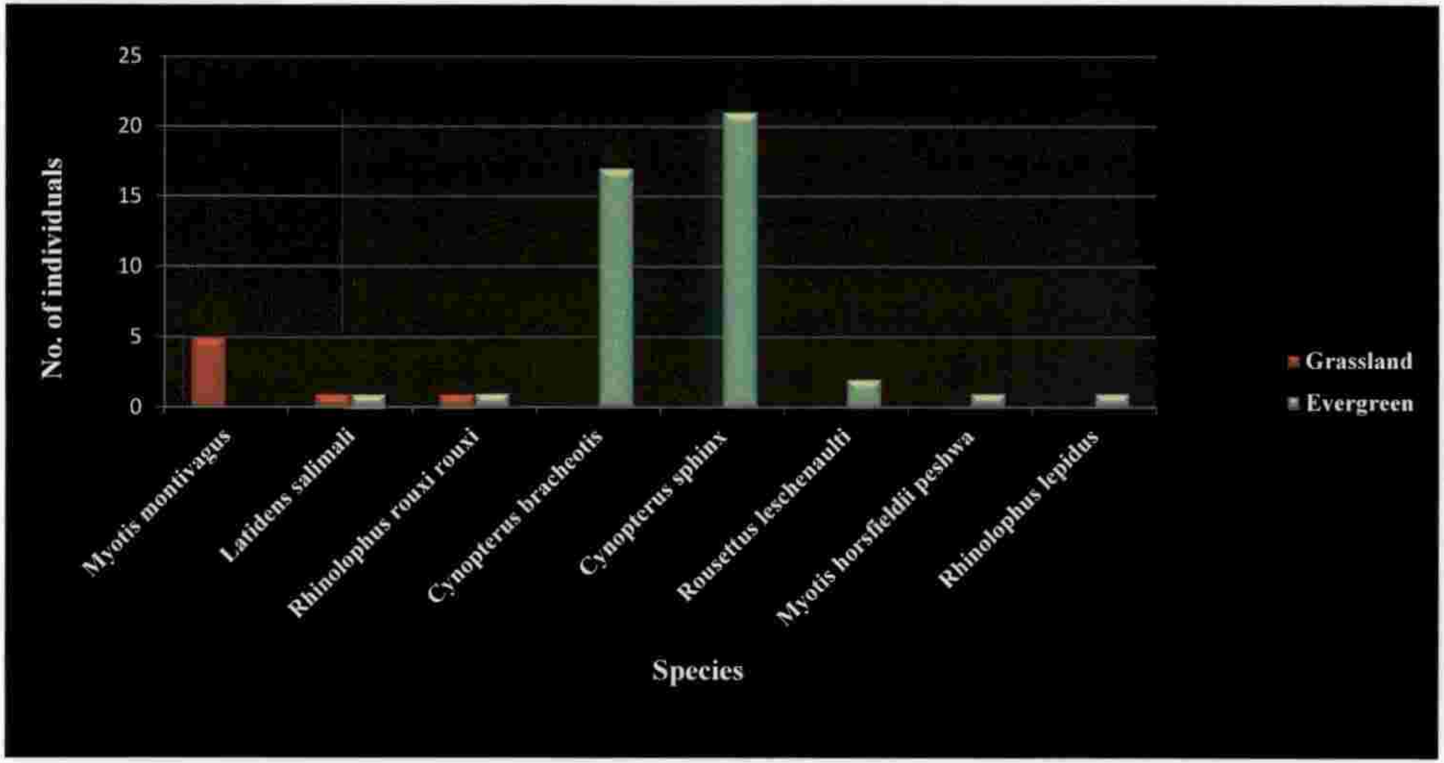

Fig 9: Number of different species of bats captured from grassland and evergreen habitats in Silent Valley National Park

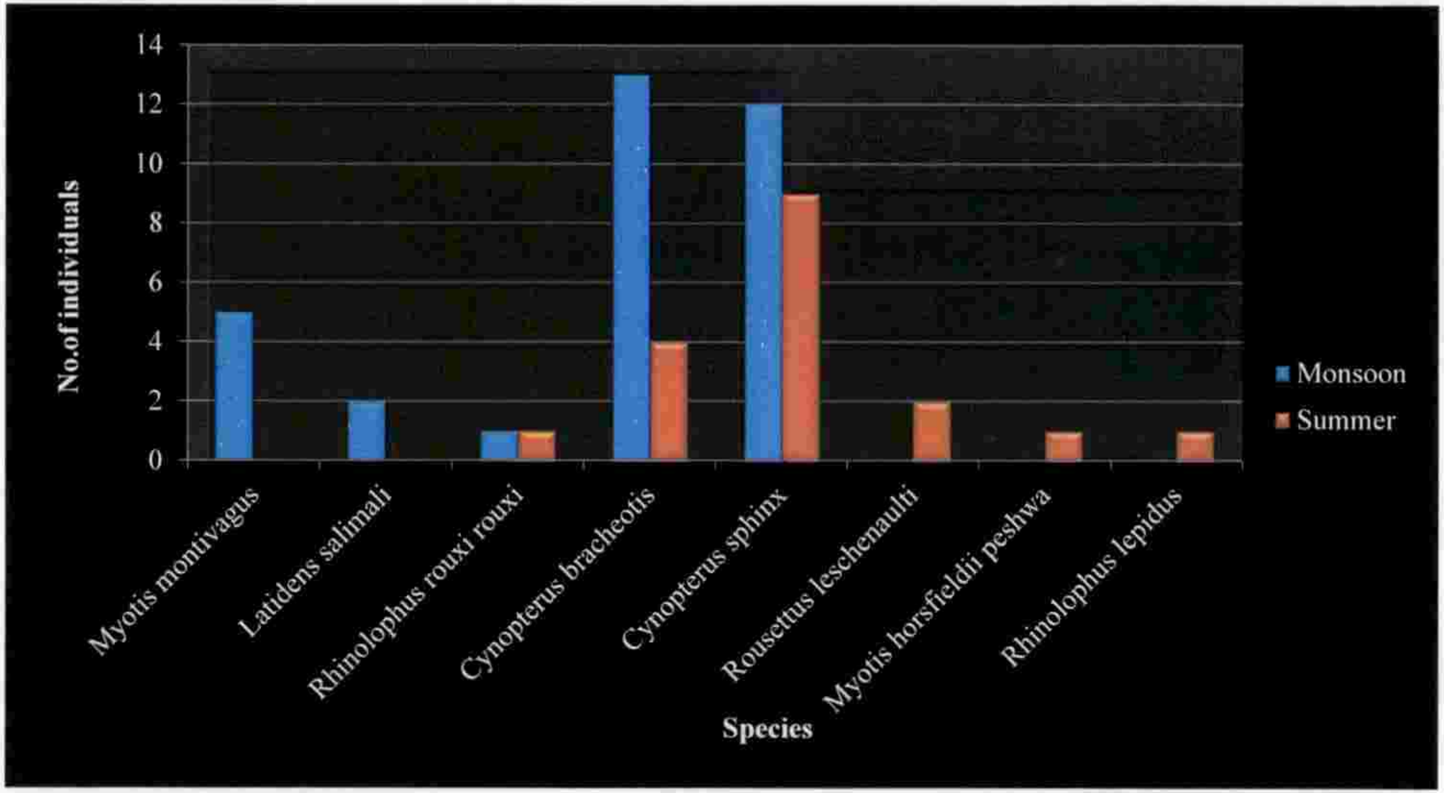

Fig 10: Number of different species of bats captured during monsoon and summer seasons in Silent Valley National Park

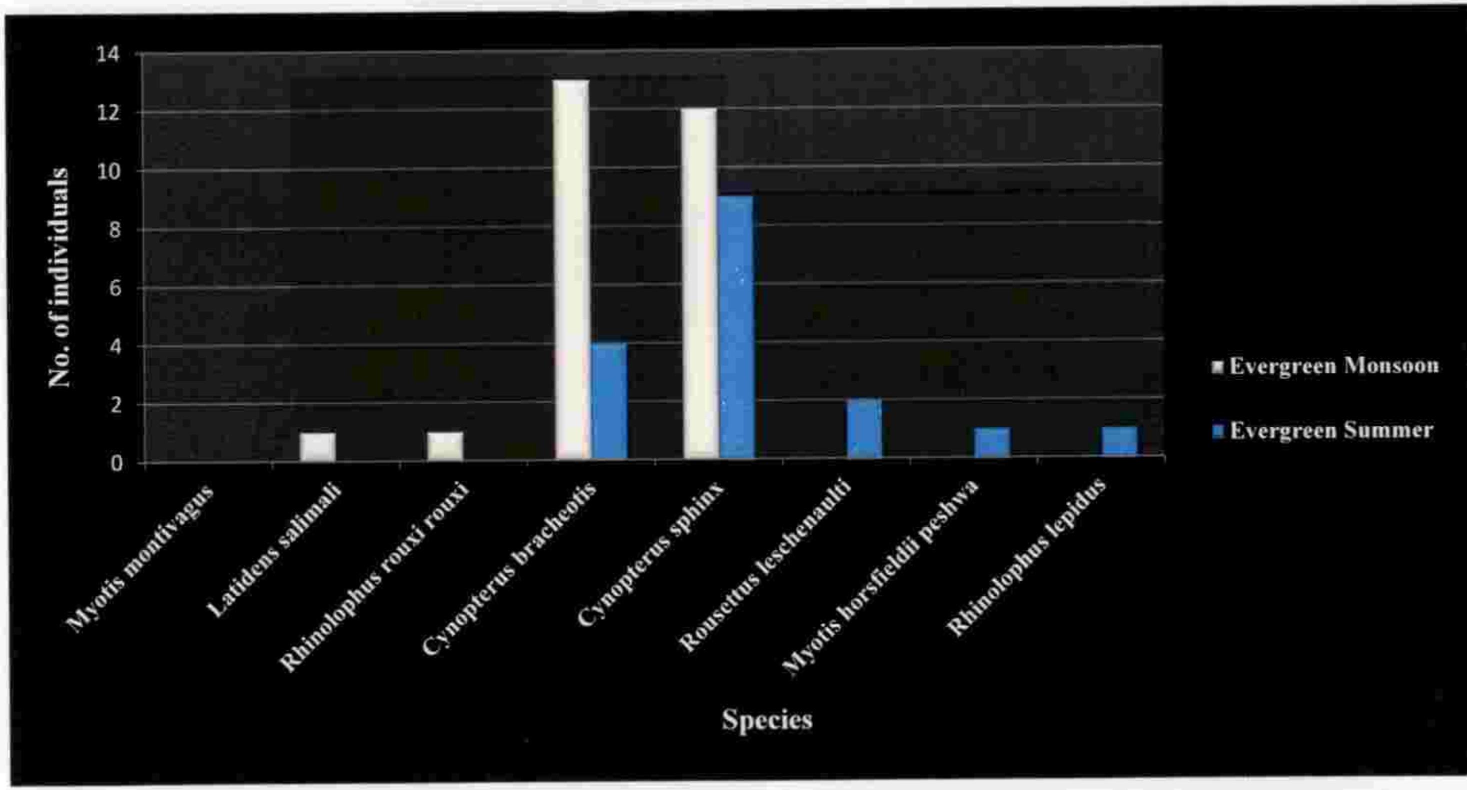

Fig 11: Number of different species of bats captured during monsoon and summer seasons from evergreen habitat in Silent Valley National Park

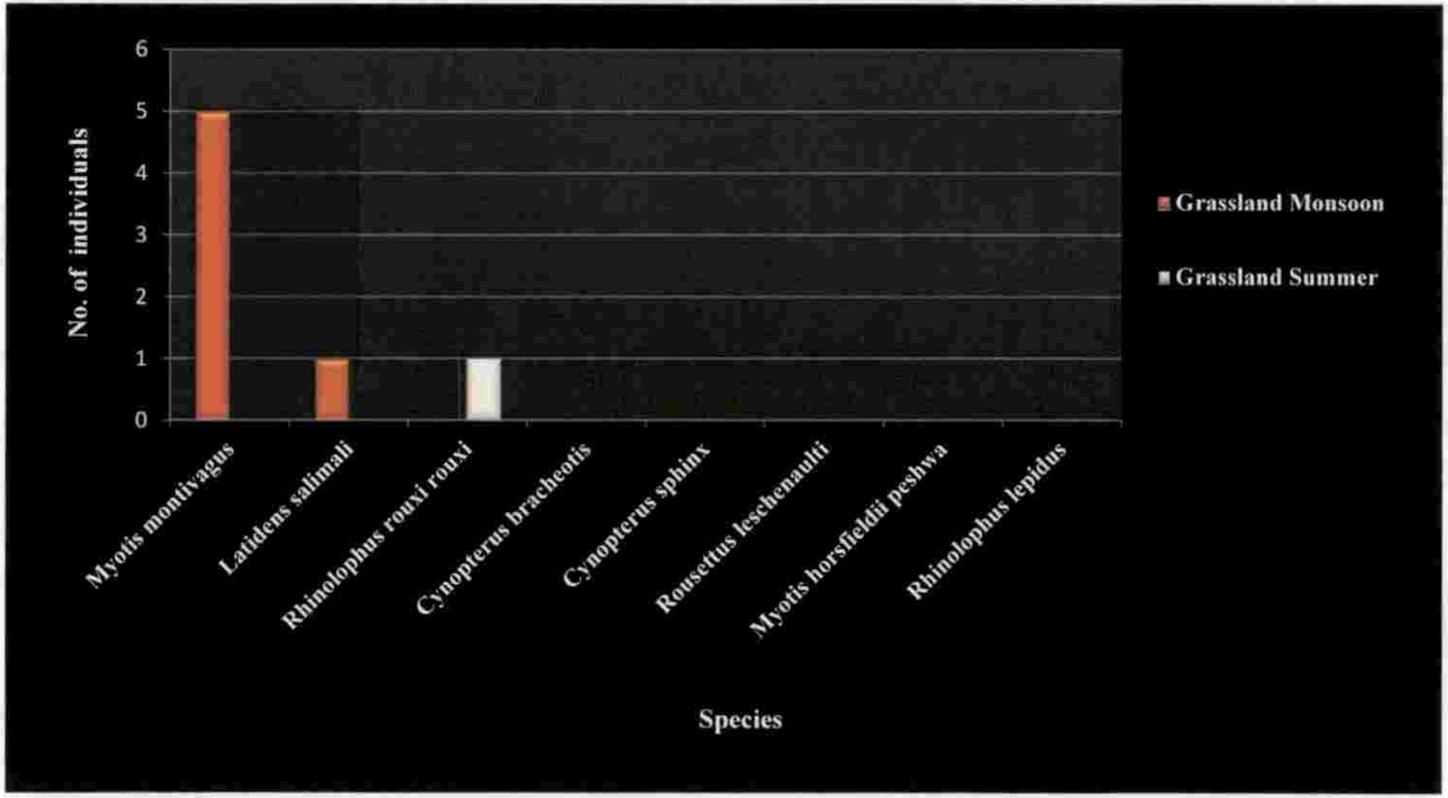

Fig 12: Number of different species of bats captured during monsoon and summer seasons from grassland habitat in Silent Valley National Park

Table 16: The effect of micro-habitat parameters in capture plots and non-capture plots in the distribution of bats in Silent Valley National Park

Variable	Capture Plot (N=16) Mean (SE)	Non-capture plot (N=4) Mean (SE)	T-value
Altitude (m)	1023.31(10.13)	1018.5(20.80)	0.212^{ns}
Canopy height (m)	22.11(1.39)	15.25(1.92)	2.30^{ns}
Canopy cover (%)	66(0.05)	28(0.05)	3.97^{ns}
Tree number (#/plot)	5.00(0.58)	1.75(0.25)	**2.74***
Climber number (#/plot)	1.19(0.38)	0.75(0.48)	0.54^{ns}
Cane number (#/plot)	0.38(0.15)	0	**1.18***
Buttress number (#/plot)	1.00(0.30)	0.25(0.25)	1.19^{ns}
Distance to large tree (m)	3.50(0.32)	2.25(0.63)	1.76^{ns}
Frequency of natural hollow in the trees (#/plot)	3.13(0.54)	0.5(0.29)	**2.36***

ns; Non-significant, *: 5% significance, **: 1% significance

4.5.4 Discriminant analysis on the effect of micro-habitat parameters in the distribution of bats in Silent Valley National Park

The discriminant analysis is doing for find out the effect of micro-habitat parameters in the niche partitioning of the bats in the Silent Valley National Park. It is analyzed using to variables, the pairwise Fisher's distances and the associated P values. The significance of Fisher's distances were compared with the corresponding P values (Table 17). For each species there is a corresponding Fisher's distance and P value with the other species.

While checking the significance, the species *Cynopterus sphinx*, *Cynopterus brachyotis* and *Rousettus leschenaulti* are showing niche sharing and showing niche partioning with the species *Latidens salimalii*, *Myotis montivagus* and *Rhinolophus rouxii*. *Rhinolophus rouxii* was showing niche sharing with *Latidens salimalii* and *Rousettus leschenaulti*. *Latidens salimalii* was showing niche sharing only with *Rhinolophus rouxii* and it showing the niche partioning of *Latidens salimalii* with all the other species. *Myotis montivagus* was the only species which does not showing any niche sharing with any of the other species. Thus it is the only one species which represents a completely partitioned niche (Fig 13).

Table 17: The pairwise Fisher's distances (blue cells) and associated P values (red cells) for the discriminant analysis on the effect of micro-habitat parameters in the distribution of bats in Silent Valley National Park

	CB	CS	LS	MM	RR	RL
Cynopterus brachyotis (CB)		0.032 ns	3.736**	32.764 **	2.729 *	0.615 ns
Cynopterus sphinx (CS)	0.990		3.833 **	34.134 **	2.752*	0.656 ns
Latidens salimalii (LS)	0.003	0.002		15.524**	0.240 ns	2.412 *
Myotis montivagus (MM)	< 0.0001	< 0.0001	< 0.0001		13.802 **	14.428 **
Rhinolophus rouxii rouxii (RR)	0.018	0.018	0.980	< 0.0001		1.896 ns
Rousettus leschenaulti (RL)	0.759	0.726	0.034	< 0.0001	0.091	

ns; Non-significant, *: 5% significance, **: 1% significance

4.5.5 Sex ratio of bats collected from Silent Valley National Park

From the 51 individuals of bats, there are 28 females and 23 males were captured. It is clear that female ratio is higher than male ratio (Fig 13). Breeding season and activity time are the two factors which can influence in the sex ratio of captured bats. In the 28 female bats 11 belongs to *Cynopterus sphinx*, 11 belongs to

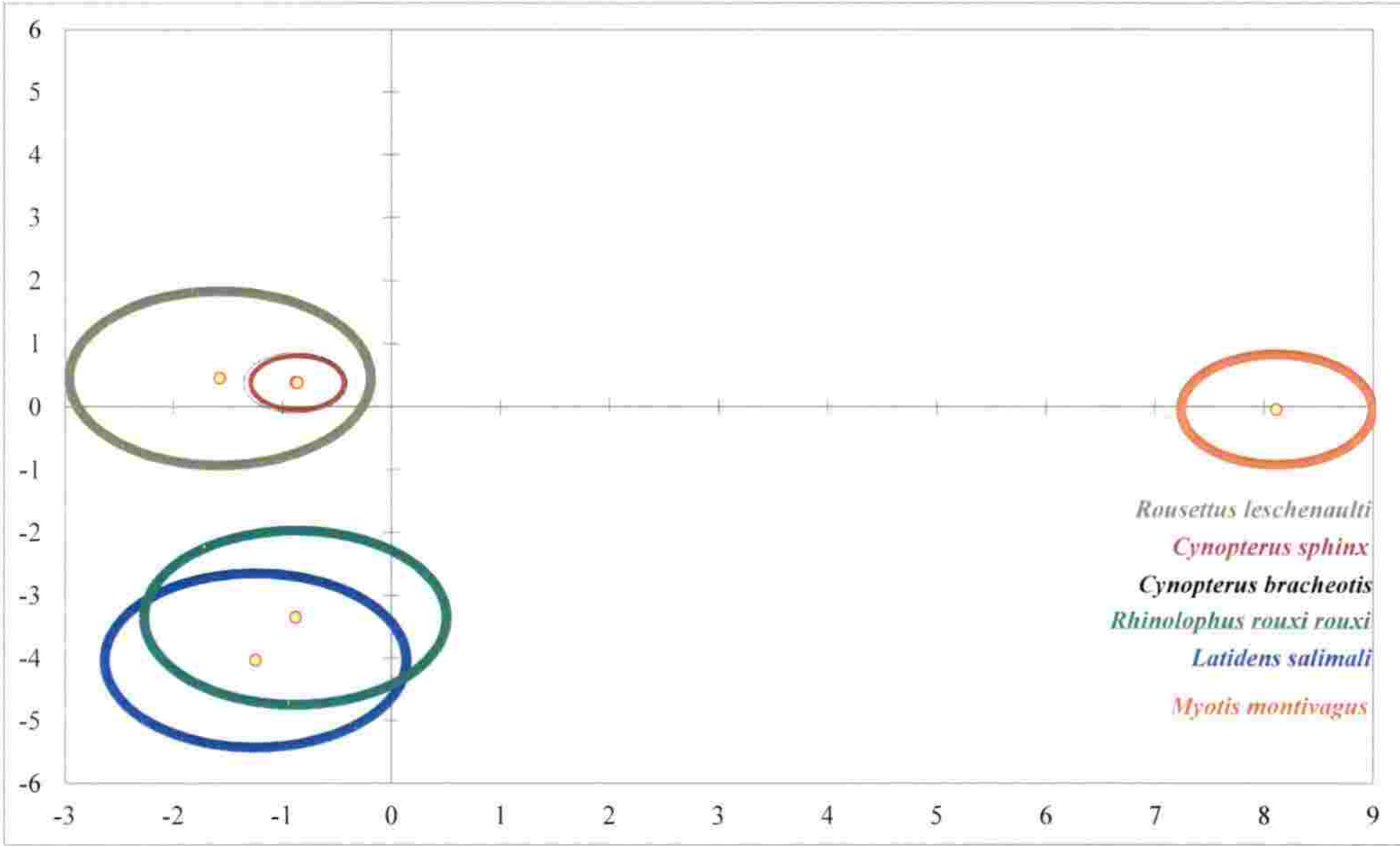

Fig 13: Distribution and niche partitioning of different species of bats in Silent Valley National Park

Cynopterus brachyotis, three belongs to *Myotis montivagus* and one each to *Latidens salimalii*, *Rousettus leschenaulti* and *Rhinolopus lepidus* respectively. Out of the 23 male bats 10 belongs to *Cynopterus sphinx*, six belongs to *Cynopterus brachyotis*, two each to *Myotis montivagus* and *Rhinolophus rouxii rouxii* and one each to *Latidens salimalii, Myotis horsfieldii peshwa* and *Rousettus leschenaulti* respectively (Table 18).

Table 18: Number male and female bats in each species captured from the Silent Valley National Park

Species	**Male**	**Female**
Cynopterus sphinx	10	11
Cynopterus brachyotis	6	11
Myotis montivagus	2	3
Rhinolophus rouxii rouxii	2	0
Latidens salimalii	1	1
Rousettus leschenaulti	1	1
Myotis horsfieldii peshwa	1	0
Rhinolophus lepidus	0	1

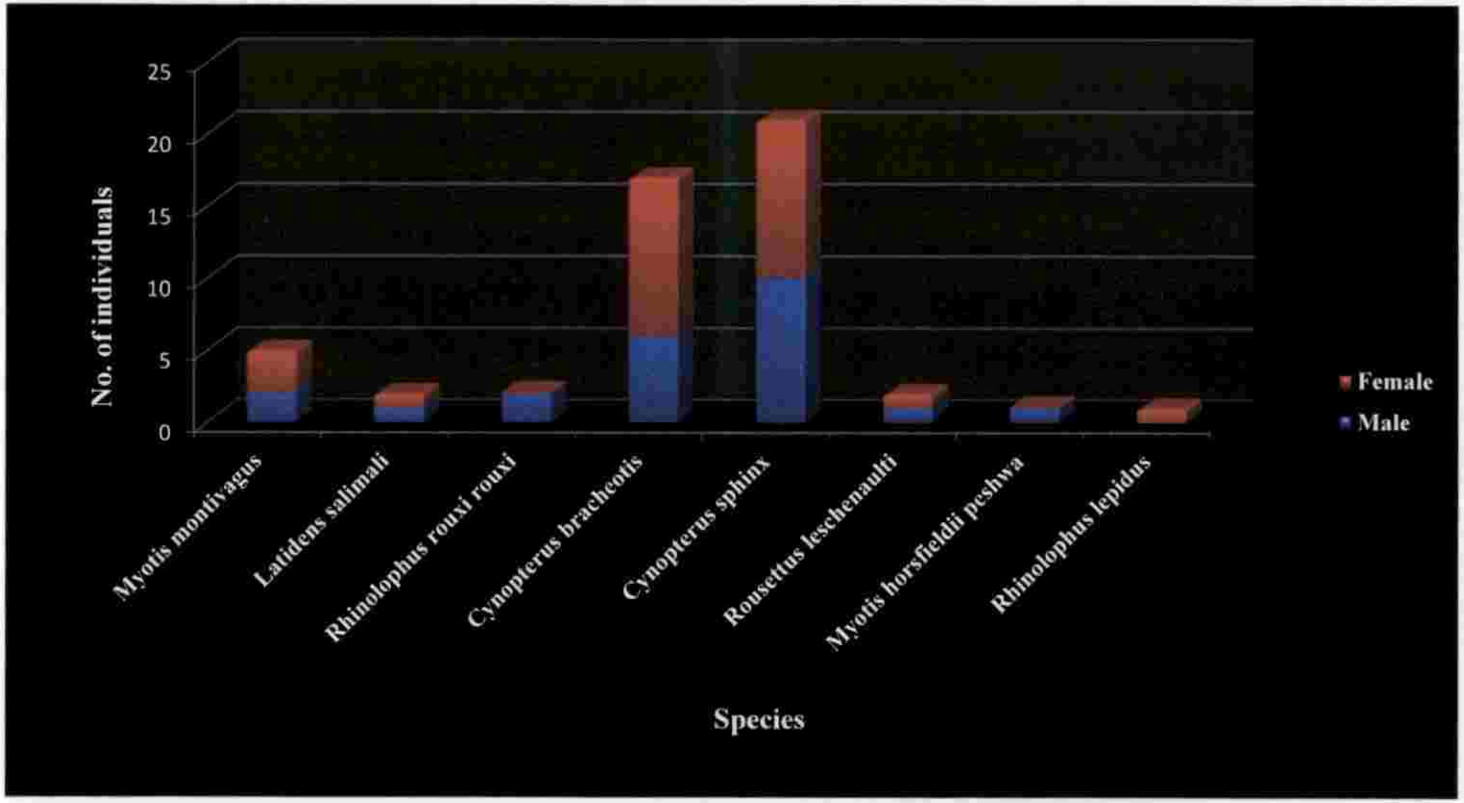

Fig 14: Sex ratio of different species of bats collected from Silent Valley National Park

4.6 ROOST DETAILS OF THE BATS OF SILENT VALLEY NATIONAL PARK

A roost of the *Myotis montivagus* was located among a rocky patch on the banks of Kunthi river at Silent Valley. It is a tunnel with a length of 35m, width of 3m and a height of 2m. The rock is located within a secondary grassland with sparse trees here and there. The roost is on about 250m from the Kunthi River. The roost is situated at an altitude of 903m. The roost was having an approximate number of 250 to 300 bats which are hanging on the ceiling crevices of the tunnel (Plate 21). They are hanging in groups of 10 to 20 in each spots on the ceiling of the tunnel. The ground of the tunnel was covered with thick mat of bat guano. The interior of the cave was very damp.

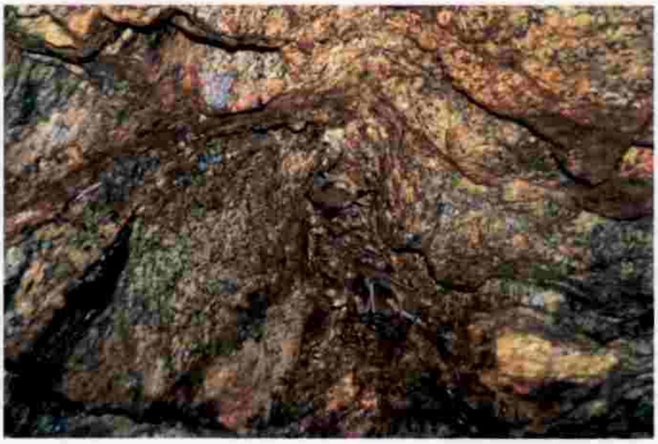

Plate 21: Roost of *Myotis montivagus*

4.7 CUMULATIVE TRAP HOURS OF MIST-NETTING IN SILENT VALLEY NATIONAL PARK

A total of 920 mistnet hours were done in the Silent Valley National Park for studying the taxonomy, distribution and habitat preference of bats. From these 920 trap hours 46 individuals were captured by mist-netting. The cumulative trap nights and cumulative frequency number of species of all four fields were calculated and plotted in a graph (Fig 15).

A minimum of 175 trap hours was necessary for the capturing of 4 species which is the maximum number of species captured from the first field. In the case of second field, the overall mist-net hours was less than the other fields but the analysis of cumulative frequency of trap nights and number of species shows, a minimum of 50 trap hours was necessary for the capturing of one species which is the maximum number of species captured from the second field. Likewise in the third field, a minimum of 125 trap hours was necessary for the capturing of four species which is the maximum number of species from the third field. A minimum of 300 trap hours resulted in the capturing of seven species which is the maximum number of species captured from the fourth field.

4.8 TRAP SUCCESS OF MIST-NETTING IN SILENT VALLEY NATIONAL PARK.

The trap success of mist-netting in SVNP was done for all the four fields using total mist netting hours in each field and number of individuals captured during mist-netting (Table 19). The first field is the site with greater trap success with a value of 10.64 with a total of 235 mist net hours and 25 individuals of bats captured. The first and second fields have greater trap success values than other two fields, this may be due to the monsoon season and the activity time of the bats (Fig 16).

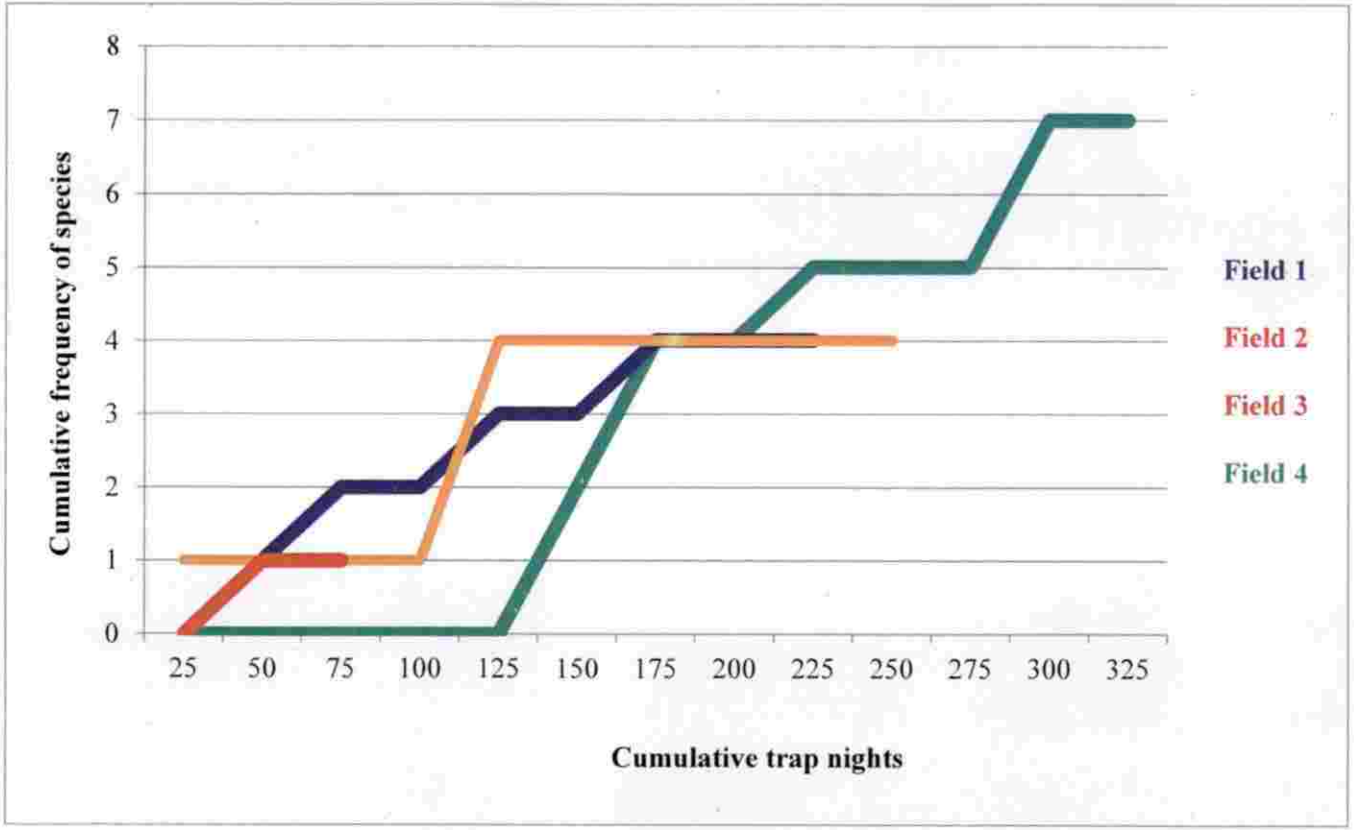

Fig 15: Cumulative trap nights of mist-netting in different fields of study in Silent Valley National Park

Table 19: Trap success of mist-netting with total mist net effort and number of bats captured in each field

Field Number	Total mist net effort	Number of bats captured	Trap success
Field 1	235	25	10.64
Field 2	75	3	4.00
Field 3	235	7	2.98
Field 4	375	11	2.93

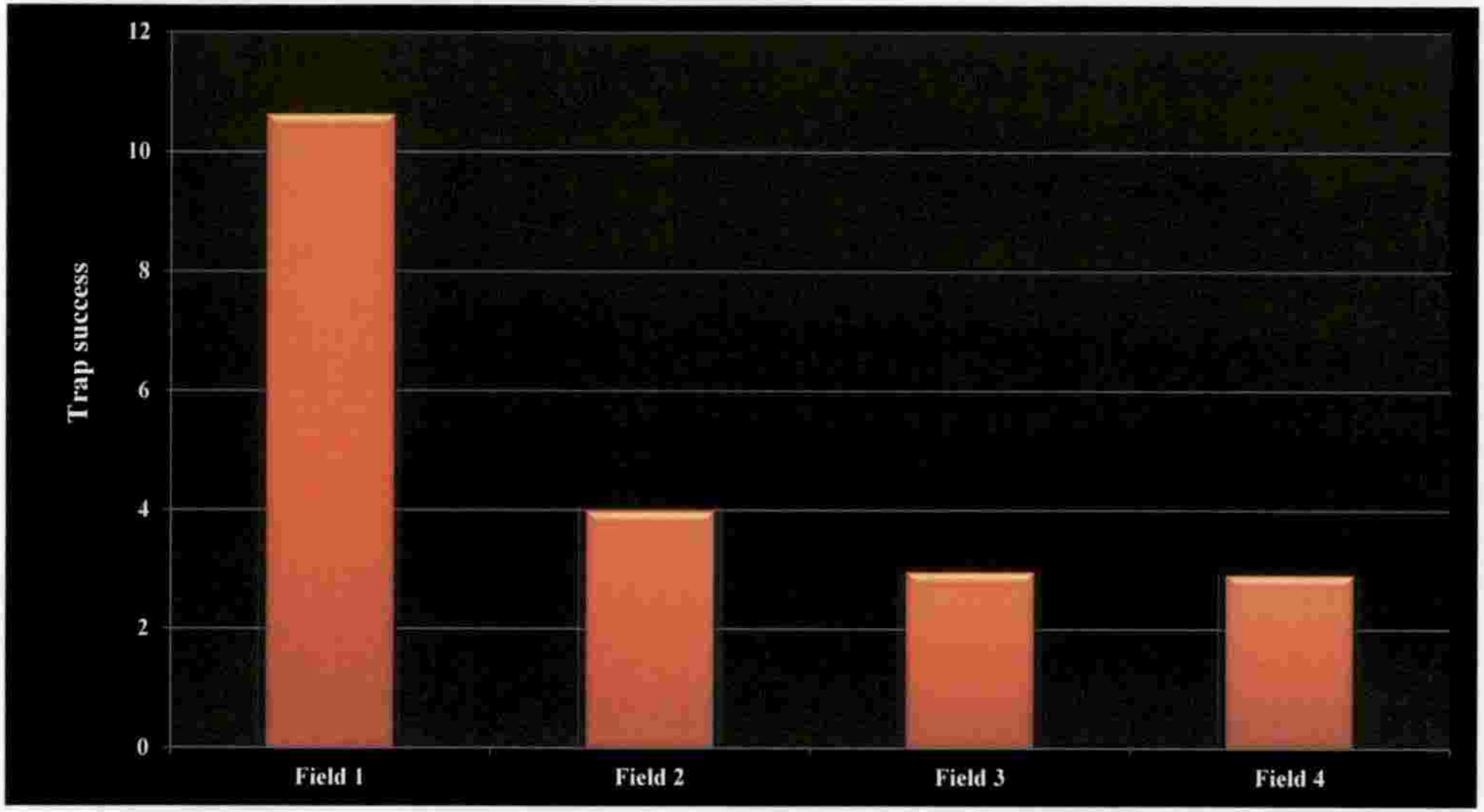

Fig 16: Trap success in different fields of study in Silent Valley National Park

Discussion

DISCUSSION

5.1 DIVERSITY OF BATS OF SILENT VALLEY NATIONAL PARK

The present study revealed the presence of eight species of bats in Silent Valley National Park (SVNP). A total of 920 mist net hours using five mist nets per day for three to five hours for 38 days were carried out for the present study. The eight species of bats identified from SVNP include four fruit bats viz. *Latidens salimalii, Cynopterus sphinx, C. brachyotis* and *Rousettus leschenaulti,* and four species of insectivorous bats namely *Rhinolopus lepidus*, *Rhinolophus rouxii rouxii*, *Myotis montivagus* and *Myotis horsfieldii peshwa*.

5.1.1 Family Pteropodidae

5.1.1.1 *Cynopterus sphinx* Vahl, 1797 (The Short-nosed Fruit bat)

This is a medium sized fruit bat with an average forearm length of 70.2 mm (64-79 mm) (Bates and Harrison, 1997). Individuals captured from SilentValley were observed with an average forearm length of 65.46 mm (64.11-68.33 mm). The wings arise from the flanks and therefore there is no narrowing of dorsal pelage. The membranes are dark brown throughout, but with pale fingers on the wings. The medial part of interfemoral membarane is hairy. The muzzle is short, broad and with nostrils which projects well forwards. The ears are simple and essentially naked. In males, the chin, anterior part of the shoulders, sides of the chest, belly and thighs are characteristically orange tinted (Bates and Harrison, 1997). All these morphological characters are observed in the *Cynopterus sphinx* individuals captured from Silent Valley National Park.

In the case of cranial and dental measurements the skull has an average condylobasal length of 30.9 mm (28.4-33.3 mm) (Bates and Harrison, 1997). The specimens captured during the study have an average condylobasal length of 28.80 mm (26.97-29.99 mm). The brain case is ovoid with a weak sagittal crest. The upper toothrow length averages 11.1 mm (10.2-12.2 mm). The first and second upper incisors are small, peg-like and situated close to another in a straight line. The upper canine is relatively broad and without any grooves on its anterior surface but has a secondary cusp on its inner side (Bates and Harrison, 1997).

From a total of 920 mist net hours 21 individuals of *Cynopterus sphinx* were captured with 10 males and 11 females. It was captured from all the four fields of study in SVNP. This incidentally is the first report of *Cynopterus sphinx* from SVNP.

It is a widely distributed species ranges from Pakistan, India, Sri Lanka, China, Malayasia, Java, Lesser Sunda Island, Borneo and Sulawesi (Bates and Harrison, 1997). In India the species distribution ranges from Jammu & Kashmir (Chakraborty, 1983), Rajasthan (Advani, 1982), Gujarat (Ryley, 1914; Brosset, 1962; Sinha, 1981), Maharashtra (Anderson, 1912; Wroughton and Davidson, 1920; Das and Sinha, 1971), Goa (Agarwal, 1973), Karnataka (Das and Sinha, 1971; Ryley 1913; Brosset, 1962), Kerala (Anderson, 1912; Wroughton, 1921), Tamil Nadu (Wroughton, 1921; Lindsay, 1927; Balasubramanian, 1988; Balasingh *et al.*, 1995), Andhra Pradesh (Khajuria, 1953), Orissa (Das *et al.*, 1993), Madhya Pradesh (Brosset, 1962; Khajuria, 1979; Khajuria, 1984) Uttar Pradesh (Khajuria, 1953; Bhat, 1974), Bihar (Sinha, 1986), West Bengal (Agarwal *et al.*, 1992), Assam (Hinton and Lindsay, 1926), Arunachal Pradesh (Saha, 1985), Meghalaya (Das *et al.*, 1995; Hinton and

Lindsay, 1926), Tripura (Agarwal and Bhattacharyya, 1977), Nagaland (Sinha, 1980) and Andaman and Nicobar Islands (Chaturvedi, 1969).

5.1.1.2 *Cynopterus brachyotis* Muller, 1838 (The Lesser Dog-faced Fruit bat)

This species averages smaller than *Cynopterus sphinx* with a forearm length of 60.3 mm (57.3-63.3 mm) (Bates and Harrison, 1997). The *Cynopterus brachyotis* specimens collected from Silent Valley have an average forearm length of 61.51 mm (56.29-63.85 mm). It can be distinguished by its smaller ears which do not exceed 18 mm in length. The specimens captured during this study also have ear length range from 12.31 to 16.63 mm. The finger bones of the wing tend to be darker as compared to the pale metacarpals and phalanges of *C. sphinx* (Plate 16). In all other external characters, the two species appear to be similar.

The skull of *C. brachyotis* averages smaller than that of *C. sphinx* with a condylobasal length of 27.76 mm (24.22-29.66 mm). The upper toothrow length averages 9.75 mm (8.94-10.6 mm). The dentition cannot be distinguished from that of *C. sphinx* except by its average smaller size.

From a total of 920 mistnet hours 17 individuals of *Cynopterus brachyotis* were captured with 6 males and 11 females. It was captured from three fields of study in SVNP. *Cynopterus brachyotis* has a distribution that extends from southern India and Sri Lanka to Myanmar, Thailand, Malaysia, Sumatra, Borneo, Sulawesi and Philippines (Bates and Harrison, 1997). In India it was reported from Goa (Agarwal, 1973), Kerala (Das, 1986), West Bengal, Assam and Andamans (Sinha, 1986a). There is a former record of this species from SVNP (Das, 1986).

5.1.1.3 *Latidens salimalii* Thonglongya, 1972 (The Salim Ali's Fruit bat)

According to Bates and Harrison (1997) this is a medium sized fruit bat, with an average forearm length of 67.3 mm (66-69 mm). The specimens captured from Silent Valley were observed with an average forearm length of 68.57 mm (66.62-70.52 mm). It is similar to *Cynopterus sphinx* in size but without an external tail. The muzzle portion is typically like the members of genus *Cynopterus* with a deep emargination between the two projecting nostrils (Plate 13).

The skull is longer, but less robust than that of *C. sphinx*. It has an average condylobasal length of 32.6 mm (31.4-33.0 mm) according to Bates and Harrison, (1997). The average condylobasal length of the specimens captured in this study is 31.14 mm (31.1-31.18 mm). The braincase is elongated with a relatively broad postorbital constriction. The upper toothrow length averages 11.6 mm (11.3-11.8 mm) (Bates and Harrison, 1997). The average upper toothrow length of specimens captured in this study is 11.51 mm (11.28-11.74 mm). Unlike all the other species of fruit bat from the Indian subcontinent, there is only one pair of upper incisors for this particular fruit bat and this is one of the main species identification key for this species.

From a total of 920 mist net hours two individuals of *Latidens salimalii* were captured with one male and one female. It was captured from only one field of study in SVNP.

The *Latidens salimalii* is endemic to Western Ghats. This species was considered as only known to be from the High Wavy Mountains in Tamil Nadu which is the type locality of this species (Bates *et al.*, 1994). It was considered as *Cynopterus sphinx*, when it was collected by Angus Hutton from the High Wavy Mountains in the Madurai district of Tamil Nadu in 1948. It was re-examined by

Kitty Thonglongya in 1970 and found to be a different species. That specimen was considered as the only holotype, skin and skull until six more specimens were collected from Yeni Kodai Cave on the Kardama Coffee Estate in the High Wavy Mountains during a survey of the bat fauna by the Harrison institute. Until 1999, the High Wavy Mountains were considered as the only distributional record of this species and its presence was reported from the Kalakkad-Mundanthurai Tiger Reserve, Tamil Nadu (Ghosh *et al.*, 1999). Sringaravelan and Marimuthu (2003) reported *Latidens salimalii* from the Agasthiyamalai hill complex. It was then reported from Therkumalai Estate in the Courtallum Hills, Nagapodigai and Vudumbukal caves in the Agasthiyar Hills and from the Sengaltheri Cave in the Kalakkad Hills in western Tamil Nadu by Vanitharani (2004).

5.1.1.4 *Rousettus leschenaulti* Desmarest, 1820 (The Fulvous Fruit bat)

The pelage of the Fulvous Fruit bat is soft, fine and silky. It is fulvous brown on the crown of the head, back, flanks and throat. The belly is more greyish in the median area. The Fulvous fruit bats have an average forearm length of 80.6 mm (75-86 mm) (Bates and Harrison, 1997). But the individuals captured from Silent Valley National Park have an average forearm length of 72.03 mm (67.13-76.92 mm). This because of the variation in size between the male and female bats captured during the study. Only two individuals were captured during this study and all the morphological, cranial and dental measurements are greater for the male individual than the female individual. This resulted in the lower average values of taxonomic measurements while compared to the expected values by Bates and Harrison (1997). The muzzle is relatively short and slender (Plate 14). The skull is measured with a condylobasal length of 31.73 mm (29.78-33.69 mm) which comes within range given by Bates and Harrison (1997) and is usually delicate than other fruit bats. The mandible is also relatively more slender and delicate. Normally the dentition is with an average upper toothrow length of 14.2 mm (13.5-15.2 mm) will be smaller and more delicate (Bates and Harrison, 1997). The studied individuals have an average upper canine length of 13.41 mm (12.84-13.98 mm). The cheek teeth are relatively narrow in relation to their length. From a total of 920 mist net hours two individuals of *Rousettus leschenaulti* were captured with one male and one female. It was also captured from only one field of study in SVNP.

Rousettus leschenaulti has a wide spread distribution extending from India, Sri Lanka and Pakistan to Myanmar, Vietnam, southern China, Java and Bali (Bates and Harrison, 1997). From India it was reported from Jammu & Kashmir (Chakraborty, 1983), Himachal Pradesh (Bhat *et al*., 1983), Rajasthan (Wroughton, 1918), Gujarat (Brosset, 1962; Sinha, 1981a), Maharashtra (Karim and Gupta, 1986; Bates *et al*., 1994), Goa (Agarwal, 1973), Karnataka (Brosset, 1962; Sreenivasan and Bhat, 1974), Kerala (Sinha, 1980: Das, 1986), Tamil Nadu (Sinha, 1980), Orissa (Das *et al*., 1993), Madhya Pradesh (Brosset, 1962; Khajuria, 1979), Uttar Pradesh (Bhat, 1974), Bihar (Sinha, 1986), West Bengal (Agarwal *et al*., 1992), Sikkim (Ghose and Ghosal, 1984), Arunachal Pradesh (Rookmaaker and Bergmans, 1981), Meghalaya (Das *et al*., 1995) and Tripura (Rookmaaker and Bergmans, 1981).

5.1.2 Family Rhinolophidae

5.1.2.1 *Rhinolophus rouxii rouxii* Temminck, 1835 (The Rufous Horseshoe bat)

The Rufous Horseshoe bat is Rhinolophidae member with a forearm length average of 49.3 mm (44.4-52.3 mm) (Bates and Harrison, 1997). Two individuals are captured during this study with a foream length average of 51.18 mm (50.53-51.82 mm). The noseleaf is broader than other members in the Rhinolophidae family (Plate

20). The first phalanx of the third metacarpal (16.34 mm) is less than half the length of the metacarpal (38.72 mm). The pelage is soft and silky. There is a considerable variation in pelage ranging from orange, to russet brown to buffy brown to grey.

The skull size varies considerably with the condyle-canine length ranging from 17.4 to 21.0 mm (Bates and Harrison, 1997). The individuals captured during this study have the condyle-canine length ranging from 19.1 to 19.44 mm. The upper canine is not in contact with the second upper premolar and the first upper premolar is usually situated in the toothrow.

From a total of 920 mist net hours two individuals of *Rhinolophus rouxii rouxii* were captured with two males. It was captured from two fields of study in SVNP.

The distribution of *Rhinolophus rouxii rouxii* ranges from India and Sri Lanka to southern China and Vietnam (Bates and Harrison, 1997). In India it is reported from Himachal Pradesh (Das, 1986), Maharashtra (Muni *et al.*, 1994), Goa (Agarwal, 1973; Sinha, 1973), Karnataka (Gopalakrishna and Rao, 1977), Kerala (Das, 1986), Tamil Nadu (Sinha, 1973), Andhra Pradesh (Sinha, 1973), Orissa (Das *et al.*, 1993), Madhya Pradesh (Das, 1986), Uttar Pradesh (Wroughton, 1914), West Bengal (Das, 1986), Sikkim (Bhat, 1974) and Arunachal Pradesh (Lal, 1982).

5.1.2.2 *Rhinolophus lepidus* Blyth, 1844 (The Blyth's Horseshoe bat)

It is a small Rhinolophid with an average forearm length of 39.8 mm (37.0-41.8 mm) (Bates and Harrison, 1997). There is only one individual was captured from Silent Valley National Park with a forearm length of 40.29 mm. The tip of the triangular shaped connecting in the noseleaf is more broadly rounded off. The anterior surface of the sella is also less emarginated (Plate 19). The pelage colour is typically grey-brown dorsally and slightly paler ventrally with a bright orange shade in the face.

The skull is characterized with the condyle-canine length which averages 14.6 mm (13.8-15.5 mm) (Bates and Harrison, 1997). The captured individual have a condyle-canine length of 13.88 mm which comes within the range above mentioned. The upper canine is well developed. It is almost twice the height of the second upper premolar.

From a total of 920 mist net hours only one individual of *Rhinolophus lepidus* was captured and it was a breeding female with well-developed mammary glands.

The distribution of *Rhinolophus lepidus* ranges from Afghanistan, India, Myanmar and Thailand to southern China, Malaysia and Sumatra (Bates and Harrison, 1997). In India the species distribution ranges from Rajasthan (Prakash, 1961), Maharashtra (Tiwari *et al.*, 1971), Karnataka (Wroughton, 1913), Kerala (Das, 1986), Tamil Nadu (Das, 1986), Andhra Pradesh (Das, 1986), Orissa (Das *et al.*, 1993), Madhya Pradesh (Khajuria, 1980), Delhi (Brosset, 1962), Uttar Pradesh (Wroughton, 1914), Bihar (Sinha, 1986), West Bengal (Lal and Biswas, 1985), Assam (Kurup, 1968) and Meghalaya (Hinton and Lindsay, 1926).

5.1.3 Family Vespertilionidae

5.1.3.1 *Myotis montivagus* Dobson, 1874 (The Burmese Whiskered bat)

This is a vespertilionidae member with an average forearm length of 45.3 mm (44.7-46.8 mm) (Bates and Harrison, 1997). Five individuals were captured from its roost during this study and have an average forearm length of 44.63 mm (44.2-45.15

mm). The dorsal pelage is medium short in length and soft with dark brown and chocolate brown hair tips and blackish roots (Plate 17). The ears are relatively short and bluntly pointed with anterior surface smoothly convex. The tragus is short, less than half the height of the pinna. The wings are attached to the base of the outer phalanx of each foot.

The skull is robust with an average condyle-canine length of 15.3 mm (15.1-15.6 mm) (Bates and Harrison, 1997). The average value for the individuals captured is 14.76 mm (14.13-15.34 mm). The zygomata are broadly flattened. The braincase is elevated above the rostrum but without a marked post natal depression. The upper toothrow averages 6.54 mm (6.35-6.94 mm) which comes within the range of 6.5 to 6.8 mm given by Bates and Harrison (1997). The upper canine is relatively short and broad. The first and second lower incisors have three cusps and the third incisor has four.

It was not captured through mist netting and was captured from its natural roost. The roost was a tunnel near to the Kunthi River with an approximate number of 250 to 300 individuals in it. A total of five individuals were captured using insect net with two males and three females.

The distribution of *Myotis montivagus* is ranges from China to India, Myanmar, western Malaysia and Indonesia (Bates and Harrison, 1997). In India it is reported from Karnataka (Wroughton, 1913), Andhra Pradesh (Ghosh, 1989). There is a single record of this species from Anakkampoyil (11°26′0″N 76°3′0″E), which is located in the hill side valley of Vellarimala in Kozhikode district, Kerala (Bates and Harrison, 1997).

5.1.3.2 *Myotis horsfieldii* Temminck, 1840 (The Horsfield's bat)

This is a medium-small sized *Myotis* with an average forearm length of 38.5 mm (36.5-41.5 mm) (Bates and Harrison, 1997). There is only one individual was captured during this study with a forearm length of 37.3 mm. The ears are naked, dark and with rounded tips (Plate 18). The tragus is short, less than half the height of the pinna and relatively broad. The pelage is dark brown almost black on the dorsal surface. On the ventral surface, it is deep brown with greyish tints near the base of the tail. The wings are attached to the outer metatarsal of each foot.

The skull has an average condylo-canine length of 13.9 mm (13.4-14.3 mm) (Bates and Harrison, 1997). For the individual captured the condyle-canine length is 14.03 mm which comes within the range mentioned above. The zygomata are well developed. The upper canine is having nearly twice the height of the third upper premolar. The upper and lower molars are unremarkable.

From a total of 920 mist net hours only one individual of *Myotis horsfieldii peshwa* was captured and it was a male. The distribution of *Myotis horsfieldii peshwa* ranges from south eastern China, Thailand, India, and west Malaysia to Indonesia and Philippines (Bates and Harrison, 1997). In India the species distribution is reported from Maharashtra (Brosset, 1962; Hill, 1976), Goa (Das, 1986), Karnataka (Hill, 1976), Kerala (Das, 1986), Tamil Nadu, Madhya Pradesh (Hill, 1976) and Andaman Islands (Anderson, 1907). The only previous record of this species from Kerala was from Silent Valley (Das, 1986).

5.2 SPECIES RICHNESS AND ABUNDANCE OF BATS IN SILENT VALLEY NATIONAL PARK

At SVNP, seven species of bats have been captured from 920 mist net hours and one species from its natural roost using insect net. Thus a total of 51 individuals from these eight species were captured from SVNP. A study conducted by Das (1986) in Silent Valley National Park is an important study and he had reported 6 species of bats in 3 families and 5 genera. Ashmi (2011) reported 11 species of bats from Parambikulam TR through mistnet effort of 23h and direct collection from the roost. Joy (2008) and Fasil (2010) reported eight species from Chimmony Wildlife Sanctuary with a mistnet efforts of 87.5h. Radhakrishnan (2005) recorded 18 species of bats from Peechi-Vazhani Wildlife Sanctuary with a mist net effort of 384h. Vanitharani (2006) studied the bats of Agasthiyar hill range in the Western Ghats and have reported 33 species of bats. Vanitharani and Chelladurai (2005) have also reported nine species of bats from Kalakad-Mundanthurai Wildlife Sanctuary.

In a study by Webala *et al.* (2004) in Meru National Park, Kenya has reported 15 species of bats from 48 trap nights. While in this study it is 38 trap nights and eight species. Rahman *et al*. (2010) studied the bats in Niah National Park and Wind Cave Nature Reserve in Sarawak and has reported 36 species of bats with accumulated effort of 572 trap-nights. In Kayan Mentarang National Park (KMNP), East Kalimantan, Indonesia, a total of nine species were reported with 16 sampling nights. A total of seven species of pteropodid bat species, accounting for 91.6% of the total capture was reported. The *Cynopterus brachyotis* followed by *Aethalops alecto*, which comprised 58.9% and 16% of the total capture respectively from KMNP.

While for this study four species of pteropodod bat species, accounting for 50% of the total capture was captured from SVNP. And in this study *Cynopterus sphinx* followed by *Cynopterus brachyotis* which comprised 41% and 33% of the total capture respectively from SVNP. A low relative abundance was observed for *Myotis* *horsfieldii peshwa* and *Rhinolopus lepidus* with the capture of only one individual each.

5.3 STATUS AND DISTRIBUTIONOF BATS IN SILENT VALLEY NATIONAL PARK

Out of eight species of bats recorded from SVNP, five species were previously reported by Das (1986) and three were newly recorded from SVNP. The *Cynopterus brachyotis*, *Rousettus leschenaulti, Rhinolopus lepidus*, *Rhinolophus rouxii rouxii* and *Myotis horsfieldii peshwa* are the five species reported by the previous study. *Latidens salimalii, Cynopterus sphinx* and *Myotis montivagus* are the three species which are newly recorded from SVNP during this study. Hairy-winged bat (*Harpiocephalus harpia*), one of the species of bat that was previously reported by Das (1986), could not be located during the present study.

Of the pteropodids, *Cynopterus sphinx* and *Cynopterus brachyotis* are the most common bats which are recorded from almost all the study fields. While *Latidens salimalii* and *Rousettus leschenaulti* are the two pteropodids which are very rare and was recorded from each study fields only.

The capturing of *Latidens salimalii* which is an endemic bat to the Western Ghats is the most important finding during this study and it is the first report from Kerala and first report north of the Palghat Gap and is of interest. Silent Valley NP thus has the honor of being the only protected area in the State that support a population of *Latidens salimalii*. This further signifies the importance of SVNP being a repository of extremely high biodiversity.

The sighting of the *Myotis montivagus* from its natural roost is also an interesting finding of this study. This is also the first report of this species from Kerala, the previous one being from Anakkampoyle, near Kozhikode.

5.4 SPECIES RICHNESS, DIVERSITY INDICES AND EVENNESS BASED ON HABITAT PREFERENCE OF BATS IN SILENT VALLEY NATIONAL PARK

The major applications of diversity management are in nature conservation and environmental monitoring. In both cases diversity is held to be synonymous with ecological quality. Diversity measures are used extensively to gauge the adverse effects of pollution and environmental disturbances (Magurran, 2004).

The values of the Shannon diversity index are usually found to fall between 1.5 and 3.5 (Magurran, 2004). In the present study, evergreen habitat showed higher diversity (1.21) of bats than the grassland habitat (0.79). Margalef index also followed similar pattern for the two habitats. Evergreen habitat showed higher species richness than the grassland habitat. Similar studies conducted in area of regenerated forest at Atlantic forest, south eastern Brazil (Bergallo *et al.*, 2003), showed Shannon diversity index varied from H'= 1.87 and H'= 2.19.

Evenness index has a range of 0-1and the maximum when all the species have same number of individuals. This occurs when the environment is equally favourable for all the species resulting in higher species diversity (Magurran, 2004). Grassland habitat of the SVNP showed higher value for evenness index (0.74) than the evergreen habitat (0.48). Even though higher number of species and individuals were obtained from the evergreen habitat compared to the grassland habitat, the evenness indices were lower.

The Berger-Parker index is a diversity index which is calculated to see the dominance factor prevalent in a trail due to higher abundance by fewer species (Molur and Singh, 2009). In this study the Berger-Parker index value is greater for grassland habitat (0.71) than the evergreen habitat (0.48).

5.5 THE BURMESE WHISKERED BAT ROOST AT SILENT VALLEY

The Burmese Whiskered bat (*Myotis montivagus*) is an insectivorous species belongs to the family Vespertilionidae. Tanalgo and Tabora (2015) recorded bats from the caves with large openings and near to water. In this case also the roost is a tunnel with wide opening and near to water. Tanalgo and Tabora (2015) also reported that the roosts were located near to areas with high vegetation because they were attracted to insects and other creatures in that area. Furey and Racey (2016) studied about the role of caves as roost for bats and they find out that the inside temperature and less disturbances inside a cave roost is very favourable for the breeding and well-being of the bats. This roost also shows the symbols of a good roost with greater number of individuals (250-300) may be due to its warmer inside temperature and less human disturbances. The insectivorous bats can consume insects up to 30-100 % of their body weight each night and can act as a major predator of nocturnal insects and helps as a natural pest and insect control agent (Leelapaibul *et al.*, 2005).

5.6 CONSERVATION STATUS OF BATS IN SILENT VALLEY NATIONAL PARK

Among the eight species recorded from SVNP, the *Latidens salimalii* the species which is enlisted as the Endangered (Molur and Vanitharani, 2008) and included in the Schedule I of the Wildlife (Protection) Act, 1972. It is also a species endemic to Western Ghats. While all other three fruit bats, *Cynopterus sphinx* (Bates *et al.,* 2008), *Cynopterus brachyotis* (Csorba *et al.,* 2008) and *Rousettus leschenaulti* (Bates and Helgen, 2008) are enlisted as Least Concern. All the four insectivorous bats, *Rhinolopus lepidus* (Bumrungsri *et al.,* 2008), *Rhinolophus rouxii rouxii* (Bates *et al.,* 2008), *Myotis montivagus* (Francis *et al.,* 2008) and *Myotis horsfieldii* (Rosell-Ambal *et al.,* 2008) are also enlisted in the Least Concern.

Although many Indian bats are assessed as Least Concern are still safe to some extent and we have to understand that the assessments have been done only at the species level and not at subspecies or population level. The status of many species is safe for now, but we do not know is there any pressure or threats at the population or subspecies level. Only through proper conservation activities at the population and subspecies level the genetic diversity could also be conserved forever.

Habitat destruction due to deforestation, urbanization, agricultural expansion, road construction and tourism are the important factors which causes bat population decline. The plans for the education and conservation of bats in Jordan includes, a task force affiliated with the local nature conservation societies should be formed. This task force should consist of nature enthusiasts, academics, and conservation specialists. Adequate training of conservation enthusiasts based on bat conservation in countries with prior experience in this field should be formulated (Zuhair *et al.*, 2005). Roost disturbance, roost loss, hunting, introduced predators and deforestation were cited as the main threats of bats in Fiji islands. Awareness programs, elimination of introduced pests such as domestic cats and establishment of natural orchards are some of the proposed conservation works in the Fiji islands (Palmeirim *et al.,* 2005).

The South Asian countries are not that much interested in protecting bats. For example, in Pakistan the bats are exempted from the CITES (Mickleburgh *et al.*, 1992).

In India, except the Salimalii's Fruit bat all other bats are listed still under Schedule V of the Wildlife (Protection) Act, 1972, where they are defined as "vermin" and can be captured or killed with impunity. Insectivorous bats are not listed in any schedule and can be similarly killed with impunity if they are happening to be a nuisance to human beings. For the bats not listed in any schedule in the Wildlife (Protection) Act, 1972, the only situation under which anyone can be charged and persecuted for harming them is within a Protected Area, where every living creature comes under the protection of the Chief Wildlife Warden of the state.

Summary

SUMMARY

Bats of the Order Chiroptera are the second largest and most widely distributed group of mammals with 1,116 species in the world. They are divided into two sub orders, Megachiroptera (frugivorous bats) and Microchiroptera (insectivorous bats). There is only a single, very brief study done on the bats of Silent Valley National Park (Das, 1986), and other than that there is nothing is known on the bats of Silent Valley and hence the present study. The present study on "Taxonomic inventory and ecology of the bats of Silent Valley National Park, Kerala" will help to improve the ecological and taxonomical information on the bats of Silent Valley, which will be useful for deriving a conservation action plan on the bats of Silent Valley. The important findings of this study are summarized below.

1. Bats of eight species belong to five genera and three families were captured from Silent Valley National Park.

2. In these eight species three species such as *Latidens salimalii*, *Myotis montivagus* and *Cynopterus sphinx* are new reports from Silent Valley.

3. The Salimalii's fruit bat (*Latidens salimalii*) is the first report from Kerala.

4. Four frugivorous bats from the family Pteropodidae were captured which includes *Latidens salimalii, Cynopterus sphinx, C. brachyotis* and *Rousettus leschenaulti*.

5. Two species from family Rhinolophidae were captured and it includes *Rhinolopus lepidus* and *Rhinolophus rouxi rouxi*.

6. Two species from family Vespertilionidae were also captured and it includes *Myotis montivagus* and *Myotis horsfieldii peshwa*.

7. The value of Simpson index is greater for evergreen habitat than grassland.

8. Shannon index is also greater for evergreen habitat than grassland.

9. The values of diversity indices Margalef index and Fisher alpha index are also greater for evergreen habitat than grassland habitat.

10. The value of Berger Parker index is greater for grassland than evergreen habitat.
11. The value of Simpson index is greater for monsoon season than summer season.

12. The value of Shannon index is greater for summer season than monsoon season.

13. The values of diversity indices Margalef index and Fisher alpha index are also greater for summer season.

14. The value of Berger Parker index is also greater for summer season with a than monsoon season.

15. From the 51 individuals of bats captured, 21 individuals belongs to *Cynopterus sphinx*, 17 individuals of *Cynopterus brachyotis,* 5 individuals of *Myotis montivagus*, two individuals of *Latidens salimalii*, two individuals of *Rousettus leschenaulti*, two individuals of *Rhinolophus rouxii rouxii* and one individual each of *Myotis horsfieldii peshwa* and *Rhinolopus lepidus*.

16. The species *C. sphinx* was captured from all the mist-netting locations. Thus the *C. sphinx* can be regarded as the most abundant bat of SVNP.

17. The results for checking the significance of two habitats in the distribution of these eight species, showing no significance in the two habitats in the distribution of bats in the SVNP.

18. The results for checking the significance of two seasons in the distribution of these eight species, showing no significance in the seasonal variations in the distribution of bats in the SVNP.

19. The results for checking the effect of two seasons in the two habitats in the distribution of these eight species, showing no significant differences in the distribution of bats during the two seasons in the two habitats.

20. The micro-habitat parameters such as the density of trees, density of canes and the presence of natural hollow were found to be of influencing the distribution of the bats at five percentage significance level.

21. The discriminant analysis for checking the niche partitioning between the species shows, *Cynopterus sphinx*, *Cynopterus brachyotis* and *Rousettus leschenaulti* are showing niche sharing

22. *Latidens salimalii* showing niche sharing only with *Rhinolophus rouxii*

23. *Myotis montivagus,* the only species which does not showing any niche sharing with any of the other species (represents a completely partitioned niche)

24. The female ratio is higher with a number of 28 bats than male ratio with a number of 23 bats in SVNP.

25. In the 28 female bats 11 belongs to *Cynopterus sphinx*, 11 belongs to *Cynopterus brachyotis*, three belongs to *Myotis montivagus* and one each to *Latidens salimalii*, *Rousettus leschenaulti* and *Rhinolopus lepidus* respectively.

26. Out of the 23 male bats 10 belongs to *Cynopterus sphinx*, six belongs to *Cynopterus brachyotis*, two each to *Myotis montivagus* and *Rhinolophus rouxii rouxii* and one each to *Latidens salimalii, Myotis horsfieldii peshwa* and *Rousettus leschenaulti* respectively.

27. A minimum of 175 trap hours was necessary for the capturing of 4 species which is the maximum number of species captured from the first field.

28. Minimum of 50 trap hours was necessary for the capturing of one species which is the maximum number of species captured from the second field.

29. A minimum of 125 trap hours was necessary for the capturing of four species which is the maximum number of species from the third field.

30. A minimum of 300 trap hours resulted in the capturing of seven species which is the maximum number of species captured from the fourth field.

31. In the case of trap success, the first field is the site with greater trap success with 235 mist net hours and 25 individuals of bats captured.

32. The capturing of *Latidens salimalii* is a very important finding of this study which helps in the addition of Kerala in the distribution of this bat.

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33. This study will help in the widening up of the ecological and taxonomical information of bats in SVNP thus in the Western Ghats and Kerala also.

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Taxonomic inventory and ecology of the bats of Silent Valley National Park, Kerala.

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ABSTRACT

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ABSTRACT

Bats are the only group of mammals with the true ability of flight. Bats play a very crucial role in the ecosystem functioning of a region. Very little is known about the taxonomy, ecology and the biology of the bats. Most of the protected areas of the country in general and Kerala in particular, do not have comprehensive inventory of the mammals including bats present there. This is true with the Silent Valley National Park (SVNP) also and hence the present study.

The study was conducted at different selected locations within the Silent Valley and the study was held from September 2015 to May 2016. The bats were studied using mist-net technique. A total of 920 hours of mist netting was done during this period at different selected locations of the SVNP. The study was carried out mainly in two seasons such as monsoon and summer and was also done in two selected habitats viz., evergreen and grassland.

Bats of eight species belong to five genera and three families were observed from SVNP. In these eight species three species *Latidens salimalii*, *Myotis montivagus* and *Cynopterus sphinx* are new reports from Silent Valley. Moreover this is the first report of the Salimalii's fruit bat (*Latidens salimalii*) from Kerala and is a significant discovery. Four frugivorous bats from the family Pteropodidae were recorded from SVNP, which include *Latidens salimalii, Cynopterus sphinx, C. brachyotis* and *Rousettus leschenaulti*. Two species from family Rhinolophidae were also recorded and it includes *Rhinolopus Lepidus* and *Rhinolophus rouxi*. While the Vespertilionidae members such as *Myotis montivagus* and *Myotis horsfieldii* were the other two bats seen at SVNP.

Though the species diversity of the bats were more at evergreen forests than the grasslands, there were no significant difference in the species diversity. Neither there were any significant differences in the species diversity between the seasons too.

The species *C. sphinx* was located at all the study locations at SVNP and may be considered as the most common bat at SVNP. The sex ratio of the bats were more skewed towards the females.

The microhabitat parameters that were found to be influencing the distribution of the bats of SVNP were tree density, cane density and the frequency of the natural hole in the trees.

The discovery of *Latidens salimalii*, which is an endangered and Western Ghats endemic species of bats, is a significant and it once again highlights the value of the rainforests of SVNP.