DIVERSITY OF BATS IN PEECHI - VAZHANI WILDLIFE SANCTUARY, WESTERN GHATS, KERALA

By

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THESIS

Submitted in partial fulfillment of the requirement for the degree of

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DECLARATION

I hereby declare that the thesis entitled **"Diversity of bats in Peechi-Vazhani Wildlife Sanctuary, Western Ghats, Kerala"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that the thesis, entitled **"Diversity of bats in Peechi-Vazhani Wildlife Sanctuary, Western Ghats, Kerala"** is a record of research work done independently by **Mr. Radhakrishnan S.R.**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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EXTERNAL EXAMINER

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Dedicated to

my

Amma and Achan

Introduction

INTRODUCTION

Bats are among the most diverse and widely distributed group of mammals and can be found on all continents, except Antarctica. Bats are the second largest group of mammals after rodents. The diversity and abundance of bats is probably attributable to a number of features of their biology that are unique. Bats are the only true flying mammals. Many species echolocate and they have a wide range of feeding and roosting habits, social behaviour and reproductive strategies. Their nocturnal habits and their diversity in biology make bats, not only a fascinating group of animals to study but also a difficult one.

Most bats are predominantly insectivorous but many are frugivorous or nectarivorous, eating flowers and flower products. Approximately twenty nine per cent of the known species of bat, Old World fruit bats and many species of the family Phyllostomidae, are partially or wholly dependent on plants as a source of food (Gardner, 1976). Some are carnivorous, capturing small invertebrates, frogs, lizards, small rodents or even other bats, and few catch small fish. It is clear that bats are in a position to exploit many of the food sources available to them through the evolution of feeding specializations.

Preferred roosts vary widely and include trees, foliage, tree hollows or holes, under bark or shale, caves, rock shelters, ruins of other man made structures such as mines, culverts and buildings. Some species are gregarious and strongly colonial, others form small groups, are semi solitary or rarely solitary.

Bats belong to the order Chiroptera, which represents an important and diverse component of the mammalian fauna in the world. Of all the known species of mammals one in five is a bat (Yalden and Morris, 1975). The order Chiroptera is divided into two sub orders, the Megachiroptera or Old World fruit bats containing a single family. The second suborder the Microchiroptera, predominantly insect eating bats, constitute the remaining sixteen families.

At present there are about more than 900 species of bats in the world in seventeen families. In India, 113 species of bats are present in seven families (Bates and Harrison, 1997, Nameer, 2000). About 50 species of bats are seen in Western Ghats. Kerala has a rich diversity of bats which includes 31 species in seven families (Nameer *et al.*, 2001) (Table. 1).

Table 1. Families and number of bat species in the world, India and Kerala (Koopman, 1993; Bates and Harrison, 1997; Nameer, *et al.* 2001).

Sl. No.	Family / Group name	Number of species		
		World	India	Kerala
1	Pteropodidae (Old World fruit bats)	166	13	4
2	Rhinopomatidae (Mouse-tailed bats)	3	2	1
3	Emballonuridae (Sheath-tailed bats)	47	6	3
4	Craseonycteridae (Hog nosed/ Bumble bee bats)	1	-	-
5	Nycteridae (Slit-faced bats)	12	-	-
6	Megadermatidae (False Vampire bats)	5	2	2
7	Rhinolophidae (Leaf-nosed and Horseshoe bats)	130	27	8
8	Noctilionidae (Bulldog bats/ Fisherman bats)	2	-	-
9	Mormoophidae (Moustached bats/ Ghost faced bats)	8	-	-
10	Phyllostomidae (New World Leaf-nosed bats)	143	-	-
11	Natalidae (Funnel-eared bats)	5	-	-
12	Furipteridae (Smoky bats)	2	-	-
13	Thyropteridae (Disk-winged bats / New World Sucker-footed bats)	2	-	-
14	Myzopodidae (Old World Sucker-footed bats)	1	-	-
15	Vespertilionidae (Evening bats)	318	59	12
16	Mystacinidae (Short-tailed bats)	2	-	-
17	Molossidae (Free-tailed bats)	80	4	1
	Total	**927**	**113**	**31**

Of all the species of bats in the world, almost three-fourths are insectivorous. These bats consume many types of insects including common crop pests such as many species of moths, beetles, corn borers, bugs and even mosquitoes. The majority of bats in South Asia feed upon insects, yet we know very little about the beneficial economic impacts they might have on agricultural systems.

Many people think fruit bats are found primarily in fruit orchards and contribute nothing but hard time to struggling farmers. In fact fruit bats play an important role in the regeneration of forests. There are numerous species of forest dwelling bats which feed on fruits or husks which are not agricultural produce but are associated with a variety of economically important trees and their products such as dyes, tannin, medicine, fibre, fuel, lumber etc. which depend on fruit bats for their propagation. Fruit bats are major pollinators of plants and also dispersers of seeds which have been noted to have a very high rate of germination (Fujitha and Tuttle, 1991).

Bats in India face catastrophic loss of habitat, which decreases foraging areas, reduces prey populations and often forces bats to live in around human habitations. This proximity to human, especially such structures as temples, tunnels and archaeological ruins are used as roosts, often create the gravest threats to bat populations (Mistry, 2003).

Knowledge of the ecology of bats and their habitats and roosting requirements is needed in many areas in order that land management policies may allow for the protection of roosts and foraging areas (Nowak, 1994). Field work carried out on bats can contribute to the information that is required for their conservation through out the world. Even in the most basic form, data on species present, altitudinal range and habitat use, for example, from any area that has been poorly studied is worth collecting.

The present study envisages understanding the different species of bats present in Peechi-Vazhani Wildlife Sanctuary. The information brought in would be of immense use for the managers of the protected areas, so that at the time of planning and implementation of the management strategies of the protected areas, they can take into consideration these group of animals too. Such basic information on the status and distribution of bats can also ensure conservation of this group of mammals.

Review of Literature

REVIEW OF LITERATURE

Bats are the only true flying mammals that mastered flight. These hand winged flying machines are the most fascinating animals of the world because they "see" with their ears, hangs upside down to sleep by day and they can catch insects while flying even in the darkest of nights (Vanitharani, 1998).

Bat fossils date back approximately fifty million years but surprisingly, the bats of the ancient period very closely resembled those we know today. The earliest known fossil record of the order Chiroptera is from an early Eocene site in the South West Wyoming, USA. Here an almost complete skeleton of a bat (*Icaronycteris index*) was found in marble stone from the Green river formation (Jespen, 1966).

Kunz (1982) stated that the evolution of flight and echolocation in bats was undoubtedly a prime factor in the diversification of feeding and roosting habitats, reproductive strategies and social behaviors and they have successfully colonized almost every continental region on earth, except Antarctica, as well as many oceanic islands and archipelagos.

2.1 BATS OF THE WORLD

The Order Chiroptera is divided into two suborders: the Megachiroptera and Microchiroptera. The Megachiropterans are all found in the old world tropics and subtropics, feed on fruits, nectar, pollen and roost mainly in trees (Hill and Smith, 1984). There is only one family in the suborder Megachiropetra, the Pteropodidae, containing 42 genera. The 57 species of the largest genus, Pteropus are mainly island species and levels of endemism are extremely high, 35 species out of this are found on only one, or on a small group of islands (Koopman, 1993).

Mickleburgh *et al.* (1992) observed that the megachiropterans do not use high frequency echolocation but have large eyes and good vision, and use sight and smell as their major locational senses. Bates and Harrison (1997) reported that one megachiropteran genus, *Rousettus* has developed a crude form of echolocation, by producing clicks with the back of the tongue.

Microchiropterans use high frequency echolocation and rely on hearing as their major locational sense. According to Hill and Smith (1984) insectivorous bats feed on insects, fruits, nectar, pollen, fish, other vertebrates or blood and they roost in a great variety of sites including caves, buildings and trees. The largest family, the Vespertilionidae has around 300 species and an almost global distribution. The microchiropterans are found world wide and there are 16 families and 135 genera (Koopman, 1993).

Around 88 per cent of bat species are exclusively tropical. In the Old World tropics, the pteropodids are the main fruit eating bats where as in the New World tropics, the super family Phyllostomidae dominates (Findley, 1993).

The largest bat in the world belongs to Pteropodidae family. Heaney and Heideman (1987) reported that *Acerodon jubatus*, an endemic species to Philippines, weighs up to 1.1 Kg, although it is second to, *Pteropus vampyrus* in wing span which reaches to six feet. They also reported that the smallest bat is *Haplonycteris fischeri* which weighs only about 16 g.

Haematophagous bats, popularly known as vampires exist only in Latin America, from Mexico to the Northern provinces of Argentina. They are represented by three species, Common Vampire bat (*Desmodus rotundus*), Hairy-legged Vampire bat (*Diphylla ecaudata*) and White-winged Vampire bat (*Diaemus youngii*). While two species feed only on blood of wild birds, one species, *Desmodus rotundus*, causes losses feeding on livestock and could be a vector for rabies virus (Mayen, 2003).

2.2 ROOSTING BEAVIOUR

Bats spend over half their lives subjected to the selective pressures of their roost environment. Roosts provide sites for hibernation, mating, and rearing young; they promote social interaction and the digestion of food; and they offer protection from adverse weather and predators (Kunz, 1982).

Gaisler (1979) reported that many bat species roost gregariously in hollow trees, buildings, caves or foliage. He also stated that the relative number of species using external shelters generally decreases with distance away from the equator, and there is a general tendency for bats that roost in caves and man-made structures to be highly gregarious. According to Kunz (1982) the roosting habits of bats may be influenced by roost abundance and availability, risks of predation, the distribution and abundance of food resources, social organization, and an energy economy imposed by body size and the physical environment. He also reported that because of their ability to echolocate, the Microchiroptera have successfully exploited a variety of internal shelters like caves, rock crevices, tree cavities and man made structures. The Megachiroptera have virtually excluded from most internal shelters because of their inability to echolocate and have been successfully adapted to a variety of external roosts. Roosts of some species of Megachiroptera may be more easily located than those of Microchiroptera as the bats are often noisy when they are in the roost and are sometimes visible as they leave and return to the roost.

Humphrey (1975) has shown that species richness and diversity of colonial bats are strongly correlated with an index of physical structure of environment which includes contribution from topographic complexity, presence of trees and human constructions. High bat diversity characterises areas where all kind of roost structures occur, whereas places with low bat diversity are lacking one or more roost types. Many tropical forest bats roost in caves, but many others utilize tree hollows or foliage.

Usman (1988) reported that light and temperature of the area is affecting the roosting behaviour of bats. Granek (2000) stated that out of the total forty one genera in India, twenty nine roosts in trees, eleven roosts in caves and six in other sites whereas members of the genus *Pteropus* often form large aggregation on exposed tree branches.

According to Jung and Thompson (1999) bats use wide variety of habitats and many taxa are dependent to a great extent to the primary forest, whereas some species are very common in urban areas also. Different species of bats are known to occupy different altitudes (Hayes and Gruver, 2000).

Roost site fidelity is generally high in those genera that roost communally. Thus, cave roosts of *Eonycteris*, *Notopteris* and *Rousettus* may be occupied for many years as may tree roosts of *Eiodolon, Epomophorus* and *Pteropus*. Those genera roosting singly or in small groups show less site fidelity but may use same perch for considerable periods. For some taxa, there can be dramatic seasonal changes in roost composition. Most colonies of *Eidolon helvum helvum* use same roosts for many years, but because of local fluctuations in food availability, some colonies make regular seasonal migrations, returning after a few months to their former roosting sites (Marshall, 1983).

2.2.1 Day roosts

2.2.1.1 Bats roosting in caves

The distribution of cave dwelling bats varies geographically with the distribution of caves and their physical dimensions, topography and microclimate (Brosset, 1966, Tuttle and Stevenson, 1978).. Tuttle (1979) has reported that caves with cold, descending chambers are not occupied in summer and seldom in winter, and many cold caves in temperate regions are unsuitable for bats during maternity periods.

According to Brosset (1966), cave environment in tropical regions are typically more stable, more uniformly inhabited than in temperate regions and bats are often distributed internally along gradients of light intensity.

The presence of crevices and cavities in cave ceilings and walls provide roosting site for a variety of bats (Dalquest and Walton, 1970), they serve as heat traps that enhance metabolic economy (Dwyer and Smith, 1965, Tuttle, 1975); and facilitate group sub structuring and the defense of roosts or female groups against incursions of conspecifics (Bradbury, 1977, McCracken and Bradbury, 1981).

2.2.1.2 Bats roosting in crevices

According to Kunz (1982), rock crevices provide relatively permanent roost sites, but spaces beneath loose bark are temporary and thermally more variable and often require bats to make frequent relocations.

Vaughan (1959) found that *Eumops perotis* prefers crevices in vertical or near vertical cliffs, situated in deep slopes. Barbour and Davis (1969) have observed that crevice dwelling appears to be prevalent feature of molossids and vespertilionids in arid and semi-arid regions. Humphrey *et al.* (1977) have reported that crevices beneath loose and exfoliating bark of trees provide shelter for small maternity colonies of *Myotis sodalis*.

2.2.1.3 Bats roosting in tree cavities

Ryberg (1947) stated that tree cavities provide roost sites for several species of Palearctic bats, where individuals typically hang from the upper parts of these cavities. In the Old World tropics, tree cavities are most commonly used by members of the Nycteridae, Rhinolophidae, Hipposideridae (Rosevear, 1965, Brosset, 1966 and Kingdon, 1974).

The hollow trees that are prevalent in nutrient-poor soils in the tropical regions prompted Janzen (1976) to postulate that rotted hollow cores may be an adaptive trait selected as a mechanism for nitrogen and mineral trapping resulting from the accumulation of animal feces and subsequent microbial metabolism.

Studies by Hutchinson (1950) revealed that tree-roosting bats that deposit large quantities of nitrogen-rich guano may play an important nutrient role in forest ecosystems, favouring Janzen's hypothesis. Tuttle (1976) has reported that, in the Neotropics tree cavities are used predominantly by phyllostomids, of which fifteen genera, representing twenty eight species, are known to regularly or occasionally use such cavities as day roosts.

2.2.1.4 Bats roosting in foliage and other external sites

Bradbury (1977) has stated that foliage roosts promote nomadic populations and roost fidelity and provide minimal protection from variations in temperature and humidity. Morrison (1980) has recorded that large groups of *Artibeus lituratus* and *Vampyrodes caraccioli* commonly roost high in the tree canopy, where they may be conspicuous from the ground, but those that seek lower sites roost in smaller groups well concealed in understorey foliage and vine-entangled sub canopy trees.

According to Ayensu (1974), the roosts of most megachiropterans vary from being located in dense foliage in the darkest parts of trees to open, conspicuous areas. The concealment of many foliage roosting mega-chiropterans is enhanced by mottled and broken colour patterns and sometimes by motionless postures. In some pteropodids hues of yellow, orange and resemble fruits and dry leaves, contrasting lighter colours around the head and neck suggest a type of counter- shading and motionless postures engulfed in folded wings, gives the appearance of dead leaves (Dobson, 1877, Nelson, 1965, Jones, 1972, Walker, 1975 and Novick,1977). A fundamental similarity among foliage-roosting bats is that their roost sites are temporary (Kunz, 1982).

Medway and Marshall (1970) have reported that *Tylonycteris pachypus* and *Tylonycteris robustula* roost in the interior of bamboo culms. Studies conducted by Brosset (1974 and 1976) in north eastern Gabon has shown that *Myotis bocagei* regularly roosts singly or in small harem groups in unfurled banana leaves.

A number of neotropical and paleotropical bats known to modify leaves of plants as "tents" for use as day-time roosts (Barbour, 1932). Direct evidence for tent making behaviour in Old World Megachiroptera appears to be restricted to the genus *Cynopterus* (Kunz *et al.*, 1994). Bhat and Kunz (1994) have reported that *Cynopterus sphinx* creates bell shaped cavities of flower and fruit clusters of the kitul palm (*Caryota urens*) by chewing and severing flower and fruit strings. Kunz *et al.* (1994) have referred this type of shelter as 'stem tents'.

2.2.2 Night roosts

Night roosts include places used to ingest food transported from nearby feeding areas, resting places for bats following one or more feeding bouts, feeding perches used by sit-and-wait predators, and calling roosts as part of leks. They may promote digestion and energy conservation, offer retreat from predators, serve as centres for information transfer about the location of food patches, and facilitate social interactions (Kunz, 1982).

Night roosts occur in a variety of places, including areas beneath bridges (Krutzsch, 1954, Dalquest, 1957, Davis and Cockrum, 1963 and Hirshfeld *et al.*, 1977), on rock surfaces (Nyholm, 1965, Howell, 1979), in rock crevices (Cross,1965, Hayward and Cross, 1979), in caves and mine tunnels (Sanborn and Nicholson, 1950, Davis *et al.*, 1968, Kunz,1974 & O'Shea and Vaughan,1977), in abandoned and occupied buildings (Krutzsch,1954, Schowalter *et al.*, 1979 and Anthony *et al.*, 1981), in porches, breezeways, and garages (Barbour and Davis, 1969), in barns (Orr, 1954, Hoffmeister and Goodpaster, 1954), park shelters (Kunz, 1973), thatch houses (Hall and Dalquest, 1963, O'Shea, 1980), on the walls of buildings (Fenton *et al.*, 1977), on branches in small trees and shrubs (Nyholm, 1965), and on desert plants (Howell, 1979).

2.3 FEEDING BEHAVIOUR

Marshall (1985) observed that fruit bats feed exclusively on plants, taking floral resources (largely nectar and pollen but also petals and bracts), fruits and often the seeds themselves and leaves.

Specialist seed eaters have not evolved as in the case of birds (Snow, 1971). The studies conducted by Fleming *et al.* (1972) and Bonaccorso (1979) showed that both frugivorous and insectivorous bats adjust their reproductive cycle so that the young are born during the periods of food abundance. Studies conducted by Luft *et al.* (2003) revealed that fruit bats are able to assess the ripeness of a fruit by its odour.

Insect remains have been found in the alimentary canal or intestine of megachiropteran bats, but their ingestion is perhaps accidental (Lim, 1973, Start and Marshall, 1976). Fruit bats may also require extra water and have been observed drinking, sometimes taking sea water (Kock, 1972, Kingdon, 1974 and Bergmans, 1978).

Marshall (1983) recorded *Eidolon helvum* feed on flowers of 10 genera, fruits of 34 and leaves of four. Similarly, the genus *Pteropus* used flowers of 26 genera, fruits of 62 and leaves of three (Marshall, 1985). According to Mickleburgh *et al.* (1992) fruit bats may show preferences to different plants of trees during different seasons.

A few flowers of fruit species are largely associated with a single bats species. Although both *Cynopterus* and *Rousettus* have also been reported as visitors to the flowers (McCann, 1940), Gould (1978) has shown that *Oroxylum* flowers are morphologically adapted for pollination by *Eonycteris spelaea*.

For the nectarivorous *Macroglossus sobrinus* weighing about 18 to 26 g, Start (1974) estimated that one individual required the nectar produced by the inflorescences of *Musa malaccensis* each night as each inflorescence produced at least 1.8 ml of nectar which was consumed per bat per night.

The food of megachiropteran bats tend to be conspicuous, often clumped and generally abundant and easily harvested with in the clumps. Inter-specific competition may be limited by spatial and temporal separation (Thomas, 1984).

The distribution of bats is largely dependent on the spatial and temporal variation of their food resources. Certain plants play a major role in bat nutrition. The most obvious are the *Ficus* species because of their unusual fruiting phenology, fruiting occurring asynchronously, and each tree fruiting every six to twelve months (Medway, 1972). Folivory has been reported for at least 17 species of Old World Megachiroptera and four species of New World Microchiroptera. Leaves eaten by bats include at least 44 species of plants represented by 23 different families. It is suggested that liquid fractions derived from leaves may provide females with an important source of protein, especially during periods of pregnancy and lactation. Folivory, once thought to be rare among plant visiting bats, may in fact be quite common and widespread, especially among species that feed largely on fruits which are low in protein (Kunz and Diaz, 1995).

2.4 ECOLOGICAL IMPORTANCE

2.4.1 Pollination and dispersal of seeds

Seed dispersal and pollination by animals play a crucial role in the maintenance of forest ecosystem worldwide. Frugivorous bats are important pollen and seed dispersers in the Paleotropics and at least 300 plant species are known to be relying on Old World fruit bats for their propagation. Old World fruit bats have the potential to disperse small seeds to hundreds of kilometers (Fleming, 1986, Fleming *et al.*, 1987 and Shilton *et al.*, 1999). Flying foxes of the genus *Pteropus* play important roles as pollinators and seed dispersers in oceanic-island forest communities (Banack, 1998).

Marshall (1985) has stated that the visits by Megachiroptera to flowers for food may result in pollination of those flowers. This is known to be the case for 31 genera in 14 families, with members of the Bignoniaceae (eight genera) and Bombacaceae (six genera) being particularly prominent. Many so called 'bat flowers' are notably well adapted for bat pollination.

Megachiropteran bats feed upon at least 145 genera of fruit in 30 families of plants widely distributed throughout the angiosperms. The most important families are the Palmae (sixteen genera), Anacardiaceae (ten genera) and Sapotaceae (eight genera) (Marshall, 1985).

Many of the plants that benefit from pollination or seed dispersal by bats are economically important to man. At least 443 products useful to man are derived from 163 plant species that rely to some degree on bats for pollination or seed dispersal. These products include timber, fruits fibres and tannins that contribute significantly to world markets as well as lesser known products such as medicines and food items important in local economies (Fujitha and Tuttle, 1991).

Frugivorous bats are important agents in the regeneration of tropical forests (Gonzalez, 1998). According to Law *et al.* (1999) bats carry six times more pollen than birds.

Studies conducted in four habitats represented a disturbance gradient, in Selva Lacandona tropical rain forest region, Mexico, revealed that in all the habitats, bats dispersed more seeds than the birds and fifty per cent of the species represented in the dispersed seeds in all habitats were pioneer species and hence bats are likely to play an important role in succession and restoration process among habitats as structurally and vegetationally different as corn fields, old fields, cacao plantations and forest (Medellin and Gaona, 1999).

Studies on seed dispersal by mammals at Point Calimere Wildlife Sanctuary, Tamil Nadu have shown that 36 plant species are dispersed by bats (Balasubramanian and Bole, 1993). A comparison of the quality of dispersion of *Ficus exima* (Moraceae) by birds and bats in south eastern Brazil showed that the drupelets defecated by bats germinated more than those defecated by birds. The placements of bat feces were done in more suitable places for drupelets' germination than bird ones (de Figueiredo, 1999).

Studies carried out in La Selva, Costa Rica revealed that mammal seed dispersal is high but only three species of primates help in seed dispersal and the greater proportion are dispersed by bats (Levey *et al.*, 1993). A similar study conducted on dispersal modes of tree species in the wet evergreen forests of southern Western Ghats revealed that bird dispersed fruits were usually small and fleshy with colour ranging from purple to orange, while mammal dispersed fruits were large, fleshy, and mostly green to brown in colour. The study also revealed that the seed dispersal by mammals is accounted largely by civets and bats since primates are seed predators (Ganesh and Davidar, 2001). Hodgkison *et al.* (2003) had the same observation that, in contrast to primates and squirrels, which were major seed predators for several of the plant species under investigation, fruit bats had no negative impact on seed viability.

Arizaga *et al.* (2000) during the study in pollination ecology of *Agave macrocantha* showed that it is extremely dependent on nocturnal pollinators for its reproductive success and that bats are especially important for successful pollination.

Shapcott (1999) has observed that seed dispersal by frugivores especially, bats have acted to expand the effective population size of *Syzygium nervosum* beyond the individual rain forest patch, and thus has prevented the substantial loss of genetic diversity that otherwise would have been observed. Godinez *et al.* (2002) found that the bat *Leptonycteris curasoae* is a legitimate agent of the columnar cactus *Neobuxbaumia tetezo* dispersing seeds directly to safe sites, and thus representing a key species in the ecology of this columnar cactus. Nassar *et al.* (2003) have stated that bat mediated gene dispersal confers high levels of genetic exchange among populations of the three Venezuelan columnar cacti, a process that enhances levels of genetic diversity with in their populations.

According to Gonzalez (1998) frugivorous bats play a crucial role in dispersal of seeds of *Brosimum alicastrum*, *Cecropia* sp., *Eugenia* sp., *Ficus* sp, *Piper* sp., *Solanum* sp. and *Spondias* sp. Elangovan *et al.* (1999) have reported that *Cynopterus sphinx* helps in the distribution of seeds of species like *Annona squamosa*, *Polyalthia longifolia*, *Polyalthia pendula*, *Achrus sapota*, *Calophyllum* *inophyllum, Coccinia indica, Terminalia catappa, Ficus religiosa, Ficus bengalensis* and *Ficus benjamina*. Rajan *et al.* (1999) have recorded that *Cynopterus sphinx* feed on 23 plant species (Table. 2).

Table 2. Food plants of *Cynopterus sphinx* (Rajan *et al.*, 1999)

Sl. No.	Species	Family	Food type
1	*Polyalthia longifolia* Thw.	Annonaceae	Fruit
2	*Annona squamosa* Linn.		Fruit
3	*Ficus bengalensis* Linn.	Moraceae	Fruit
4	*Ficus religiosa* Linn.		Fruit
5	*Morus alba* Linn.		Fruit
6	*Enterolobium saman*	Mimosaceae	Fruit
7	*Pithecellobium dulce* Benth.		Fruit
8	*Acacia nilotica* Linn.		Fruit
9	*Achras sapota* Linn.	Sapotaceae	Fruit
10	*Bassia latifolia* Roxb.		Fruits and Flowers
11	*Mimusops elengi* Linn.		Fruit
12	*Psidium guajava* Linn.	Myrtaceae	Fruit
13	*Eugenia jambolana* Lam.		Fruit
14	*Terminalia catappa* Linn.	Combretaceae	Fruit
15	*Cassia fistula* Linn.	Caesalpiniaceae	Leaves
16	*Mangifera indica* Linn.	Anacardiaceae	Fruit & Flowers
17	*Murraya koenigii* Sperg.	Rutaceae	Fruit
18	*Calophyllum inophyllum* Linn.	Clusiaceae	Fruit
19	*Punica granatum* Linn.	Punicaceae	Fruit
20	*Azadirachta indica* A. Juss.	Meliaceae	Fruit
21	*Cephalandra indica* Naud.	Cucurbitaceae	Fruit
22	*Solanum torvum* Sw.	Solanaceae	Fruit
23	*Ziziphus jujube* Mill.	Rhamnaceae	Fruit

Cynopterus brachyotis are found to be an important seed disperser with wide selection of fruits of more than 54 species (Tan *et al.*, 1998). *Cynopterus brachyotis* preferentially feeds in the forest rather than in nearby urban areas, indicating that this species has distinct food preferences when nearby, alternative food sources are available. These results also support the hypothesis that Old World fruit bats, including *Cynopterus brachyotis* are 'sequential specialists'. The tendency for *Cynopterus brachyotis* to consume fruits away from source trees, at both feeding and day roosts, has important consequences for seed dispersal (Tan *et al.*, 2000).

The distance a seed is carried will depend on its size and the size of the bat; tiny seeds which pass through the alimentary canal of a large bat will be carried furthest. *Cynopterus brachyotis* which weighs about 30 g can carry a fruit of up to 75 g but it will seldom carry it more than two hundred meters (van der Pijl, 1957). On the other hand *Pteropus vampyrus* which weighs about 800 g can carry fruits over 200 g. *Pteropus vampyrus* can travel about 50 km each night to feed so that long distance dispersal may sometimes occur (van der Pijl, 1957, Marshall and Mc William, 1982).

Southerton *et al.* (2004) have observed that bats have the capacity to carry viable pollen over greater distances than birds and the effect of the pollen transfer by birds and bats on the genetic structure of widespread eucalyptus species is potentially greatest in fragmented forests where these animals can traverse gaps of several kilometers between discontinuous stands.

von Helversen and Voigt (2002) have found that the bat *Glossophaga soricina* is the main pollinator of *Helicteres baruensis*, a common shrub of the tropical dry forest in the Pacific low land of Costa Rica.

The studies conducted by Thies and Kalko (2004) have revealed that neotropical pepper plants (Piperaceae) are having a narrow spectrum of dispersal consisting mainly of two species of fruigivorous bats *Carollia perspicillata* and *Carollia castenea* (Phyllostomidae).

Investigations by Sazima *et al.* (2003) revealed that *Dyssochroma viridiflorum* (Solanaceae), an epiphyte endemic to Atlantic rainforest in south-eastern Brazil, is visited by phyllostomid bats for nectar as well as for fruits, with the pollination and seed dispersal of the plant ensured by these flying mammals.

A review of bat plant dispersal interactions done by Lobona *et al.* (2003) revealed that 15 species of *Cecropia*, a neotropical genus of pioneer plants are consumed by 32 species of bats and bat dispersal is not necessary for seed germination but it increases seed survival and subsequent germination.

Quesada *et al.* (2003) have observed that two of the bat species (*Glossophaga soricina* and *Musonycteris harrisons*) that functioning as effective pollinators for *Ceiba grandiflora* in the tropical dry forest of the central pacific cost of Mexico.

Varassin *et al.* (2001) have reported that two species of Passiflora (*Passiflora galbana* and *Passiflora mucronata*) are pollinated by bats. Liu *et al.* (2002) found that long-tongued fruit bat (*Macroglossus sobrinus*) is an effective pollinator of *Musa itinerans*.

The increasingly popular durian fruit (*Durio zebethinus*) depends on bats for pollination, as does petai (*Parkia speciosa* and *Parkia javanica*) whose seeds are popular food item in South East Asia (Fujitha and Tuttle, 1991).

Twelve tree species dependant on fruit bats for dispersal are major timber species in Malaysia, one of the largest timber exporters in the world. The kapok or silk cotton tree (*Cieba pentandra*), the fibre, bark and seeds of which are economically important, is pollinated by a large number of bat species in Africa and

South America but pollinated solely by *Pteropus tonganus* in Samoa (Baker and Harris, 1959).

Studies carried out by Molina and Eguiarte (2003) have revealed that paniculate agaves from tropical deserts depend on nectar- feeding bats for successful pollination.

Beside pollination and dispersal of seeds, bats are also important in germination of certain seeds. Seed retention time in digestive tract is one factor affecting seed germination. In Philippines, an increased germination rate was recorded for *Ficus chrysolepis* taken from bat fecal masses (Utzurrum and Heideman, 1991).

In island ecosystems in the south west Pacific, fruit bats are considered to be 'key stone species', because significant declines in forest regeneration rates and diversity would accompany their extinction (Cox *et al.*, 1991). Many Pacific plant species are assumed to be exclusively dependent on fruit bats for successful pollination (Marshall, 1983 and 1985). In Samoa during the dry season, 80 to 100 per cent of the seeds deposited on the ground in the lowland forests are transported by fruit bats (Cox *et al.*, 1991).

Evelyn and Stiles (2003) have stated that maintaining healthy bat population is critical to natural forest regeneration because they play a vital role as the primary seed dispersers in cleared areas.

Bernard and Fenton (2003) have suggested that a persistent biological flow may be maintained among isolated fragments, with bats acting as pollinators and seed dispersers.

Changes in the frugivorous bat community may have indirect consequences on both the demographic and the genetic structure of plant population inside forest fragments (Cosson *et al.*, 1999). According to Gonzalez *et al.* (2000) and Shanahanz *et al.* (2001) bats are important seed dispersers in pastures, dispersing seeds of pioneer and primary species connecting forest fragments and maintaining plant diversity. They also may contribute to the recovery of woody vegetation in distributed areas in tropical humid forests.

The study conducted in the Piracicata river basin, south east Brazil, to identify the plant species in the diet of bats collected at site has revealed that bats are acting as dispersers for plants of early secondary succession and contribute to diversity in disturbed areas such as abandoned plantations (Garcia *et al.*, 2000).

2.4.2 Natural predators of insect pests

Microchiroptera (Insectivorous bats) play an important role in maintaining the insect pest population in agricultural as well as forest lands. According to Gelusa *et al.* (1976) five hundred bats each weigh around 15 g will harvest one metric ton of insects per year. This involves a major quota of noxious insects such as mosquitoes, other vectors and pests (Usman, 1981). It has been found that insectivorous bats on an average consume the equivalent of their own body weight of insects each night (Akbar *et al.*, 1999).

Sinha (1986) has described the Indian False Vampire (*Megaderma lyra*) as "good friend of farmers" in the state of Bihar. Colonies of this species, ranging from 25 to 240 individuals, consume rats and mice, which destroy different grains, stored in bags and are rewarded with protection by farmers.

Studies on seasonal variation in the diet of the Indian pygmy bat, *Pipistrellus mimus*, in southern India revealed that they feed on coleopterans (26.3%), dipterans (20.4%), homopterans (17.5%), lepidopterans (13.6%), hemipterans (5.7%) and isopterans (5.1%) and were classified as generalist feeders (Whitaker *et al.*, 1999).

The insect biological control exerted by an urban colony consisting of 64000 individuals of *Tadarida brasiliensis* was estimated as it would be of 209 kg to 385 kg of insects nightly between September and late February, demonstrating the important role they play in the urban ecosystem (Romano *et al.*, 2000).

Whitaker and Weeks (2001) have found that Big brown bats (*Eptesicus fuscus*) in Indiana (USA) feed heavily on agricultural pest insects and their includes scarabaeid beetles, spotted cucumber beetles, green stink bugs, carabid beetles, other beetles, cicadellid bugs and lepidopterans.

2.4.3 Indicators of habitat destruction

Diversity and abundance of bats can be regarded as an indicator of disturbance in neotropical rain forests (Medellin *et al.*, 2000). A comparison of the phyllostomid bat assemblages in undisturbed Neotropical forest and in forests fragments of the slash and burn farming mosaic in Guatemala prove that the relative abundance of large frugivores which feed on small- fruited plants occurring in early successors are an indicator of forest disturbance (Schulze *et al.*, 2000).

A study conducted by Wikramasinghe *et al.* (2003) highlights that the position of bats as bio-indicators and victims of agricultural change. They found that greater habitat quality in terms of prey availability and better water quality on organic farm favoured higher foraging activity by bats.

2.5 THREATS

Bat populations appear to be in general decline for a number of reasons, including loss or disturbance of roosting sites (Tuttle, 1979); loss of feeding habitats, particularly due to the deforestation of the rain forests (Carroll, 1984, Fujitha and Tuttle, 1991); conflict between bats and fruit growers and over exploitation for trade (Fujitha and Tuttle, 1991). According to Fenton (2003) misleading information about bats may adversely affect their survival.

Thomas (1984) has stated that the role of fruit bats in more complex ecosystems has been the subject of limited attention. Bats became a target of control activities by farming communities and local governments. Indiscriminate actions such as poisoning bats and destroying their roosts put the lives of bats, which are extremely important for the ecologic balance, at risk (Mayen, 2003).

According to Evelyn and Stiles (2003) loss of mature forests could impair the ability of frugivorous bats to locate suitable roost sites and this could have a negative impact on bat populations, which in turn could decrease forest regeneration in impacted areas.

Varghese (1998) has suggested a non destructive and cheap method for protecting grapes from fruit bats by erecting nylon netting. Based on the studies conducted in Egyptian fruit bat *Rousettus aegyptiacus*, Korine *et al.* (1999) have stated that the definition of the fruit bat as a major agricultural pest should be reexamined because only four fruit species, consisting fifteen per cent of the bat's diet, are commercially grown in the field.

It is a pity that a number of bat species are dwindling on account of the action of man. Several countries, including Britain, realizing the crucial role that bats play in maintaining an ecological balance, have placed bats on their list of protected species (Kumar, 1984).

2.6 IMPORTANCE OF HABITAT MANAGEMENT AND CONSERVATION OF BATS

Habitat fragmentation can be described as having two components, habitat loss and insularisation, both of which contribute to decline in biodiversity. Even if survival of relatively few species is relatively jeopardized by fragmentation, the loss of those species may precipitate multiple extinctions through community level effects (Wilcox, 1980). Habitat fragmentation is rapidly becoming a central issue in conservation policy; prompting legislative and regulatory action aimed at mitigating its impact on biotic diversity was well as prompting long term research on its effects (Harris, 1984).

Terborgh (1975) has raised this point much earlier, arguing that some primary extinction may represent the loss of species in 'keystone' position in communities. Large range and the degree of individual spacing implies that conservation areas for bats should be large and that protection of roosting areas alone would not be sufficient to protect bat populations (O' Donnell, 2001).

Mikich (2002) has emphasized the importance of keeping habitat diversity, especially in small isolated resources. Erickson and West (2003) suggested that management of forest dwelling bats should focus primarily on structural attributes at the stand level and the effects of these features on feeding and roosting opportunities. Patriquin and Barclay (2003) have stated that a mosaic of patches with different tree densities that may influence habitat use by foraging bats. They have suggested that management for forest-dwelling bats must take species-specific effects into consideration.

Warren *et al.* (2000) have suggested that in upland river systems, the maintenance and enhancement of bank side vegetation and tree cover in association with the maintenance and enhancement of a mosaic of water surface increases the value of the riverine habitat to bats. Weller and Zabel (2001) have observed that management of day roost habitat requires large number of tall snags in early to medium stages of decay. According to Jaberg and Guisan (2003) the community composition in bats is related to landscape structure through species-specific relationships to resources. Aguirre *et al.* (2003) have found that resource partitioning of roosts and food is considered a key element in shaping bat communities.

Conservation of bat populations in rural environments needs to be considered at the landscape scales, with particular attention to identifying landscape elements that provide key resources. de Jong (1994) has stated that forestry and agriculture had a definite influence on the bat fauna, mainly through changes in vegetation structure and drainage operation. Russ and Montgomery (2002) have recommended that habitat management should focus on improving those habitats which are selected by bats, including the maintenance and enhancement of connecting linear habitats. Russo and Jones (2003) have suggested that the negative impact of urbanization on bats might be counteracted by fostering trees, gardens and small cultivated patches. They also pointed out that farm land practices should encourage landscape complexity and limit the use of pesticides.

According to Wickramasinghe *et al.* (2003), less intensive farming benefits bats, and as the number of organic enterprises increases, it may help to reverse declines in bat populations. Jay and Tupinier (2003) observed that the presence of large trees and water are important factors in the distribution of bats in orchards.

Evelyn *et al.* (2004) have stated that protection of roosting habitats is essential to the conservation of bats in human dominated landscapes and recommend the preservation of large trees and forested park land, particularly along stream corridors, to help maintain bat populations in urbanizing landscapes.

2.7 BAT STUDIES IN INDIA

2.7.1 Ecological studies

Studies on the bats of the Indian subcontinent are far and in between. Perhaps the only detailed ecological study on the bats of the country was by Brosset (1962a, b, and c). He conducted extensive studies on the bats of the subcontinent, though it covered only the central and western region of India. Bhat (1968a, 1968b, and 1974) studied the bats of Uttar Pradesh and West Bengal. Bates *et al.* (1994a, b and c) did a follow up study on bats of the same region. Bates and Harrison (1997) brought out a well illustrated field guide on the bats of the Indian subcontinent.

2.7.2 Breeding Habit Studies

Gopalakrishna (1947, 1954, 1969, 1986), Gopalakrishna and Badwaick (1989), Gopalakrishna and Bhatia (1982), Gopalakrishna and Chari (1983), Gopalakrishna and Choudhari (1977), Gopalakrishna and Karim (1972), Gopalakrishna and Madhavan (1970, 1971, 1977, 1978), Gopalakrishna *et al.* (1970), Gopalakrishna *et al.* (1985, 1992), Gopalakrishna *et al.* (1976), Gopalakrishna *et al.* (1992), Gopalakrishna *et al.* (1991), Gopalakrishna and Rao (1977), Krishna and Dominic (1980, 1981, 1982, 1983 and 1985), Madhavan (1971, 1978 and 1980), Madhavan *et al.* (1978), were among the pioneers who carried out studies on breeding habits of many of the Indian bat species. Sinha (1980, 1981 and 1999) studied the bats of Rajasthan, Gujarat and North East Hills.

2.7.3 Behavioural Studies

Chandrashekaran (1992, 1994), Marimuthu (1984, 1988, 1991 and 1997), Marimuthu and Selvanayagam (1981), Marimuthu and Chandrashekaran (1983a, 1983b and 1985), Marimuthu and Neuweiler (1987), (Marimuthu *et al.* (1978, 1981, 1998 and 1995), Subbaraj (1981), Subbaraj and Balasingh (1996), Subbaraj and Chandrashekaran (1977 and 1978), Subbaraj *et al,* 1997 studied the various behavioural aspects of the bats of the Indian subcontinent.

2.7.4 Bat studies in South India

Bhat (1994) studied the bats of Pune, Bhat and Jacob (1990), studied the bats of Karnataka, Das (1986) has done studies on taxonomy and geographical distribution of species of bat obtained in Silent Valley National Park, Kerala. Bhat and Sreenivasan (1972 and 1990) and Bhat *et al.* (1980) studied the bats of Karnataka.

Bats though constitute the largest mammalian order in India; very little studies have been done on them. Most of the studies and researches on the fauna of India are concentrated around charismatic species, viz. tiger, lion, leopard, elephant, rhinoceros and other big mammals. Little attention has given to the small mammals of the order such as insectivores, chiropterans and rodents, which account for sixty per cent of Indian mammals. This has resulted in a gap in our knowledge about the very basic information about the distribution pattern and status of these mammals. This is true for the bats of Kerala also. This inadequacy of the knowledge and information on bats of Western Ghats in general, and Kerala in particular warrants immediate attention on the studies of bat in the region and hence the present study.

Study Area and Methods

STUDY AREA AND METHODS

3.1 STUDY AREA

3.1.1 Name, Location and Extent

Peechi-Vazhani Wildlife Sanctuary, lies within the geographical extremes of latitudes 10° 26'N and 10° 40'N longitudes 76° 15'E and 76° 28'E in Thrissur District, Kerala State (Fig. 1). The sanctuary was established in 1958. It consists of 125 sq km and is contiguous with the forest areas of Nelliampathy and Palappilly reserves. On south, the sanctuary has a common boundary with Chimmony Wildlife Sanctuary (George, 2002).

3.1.2 Terrain

The terrain of the sanctuary is undulating and is hilly and the altitude range varies between 45 m to 900 m above MSL (George, 2002).

3.1.3 Climate

The sanctuary is blessed with copious rains, typical of the state, good sunlight and hot and humid weather (George, 2002).

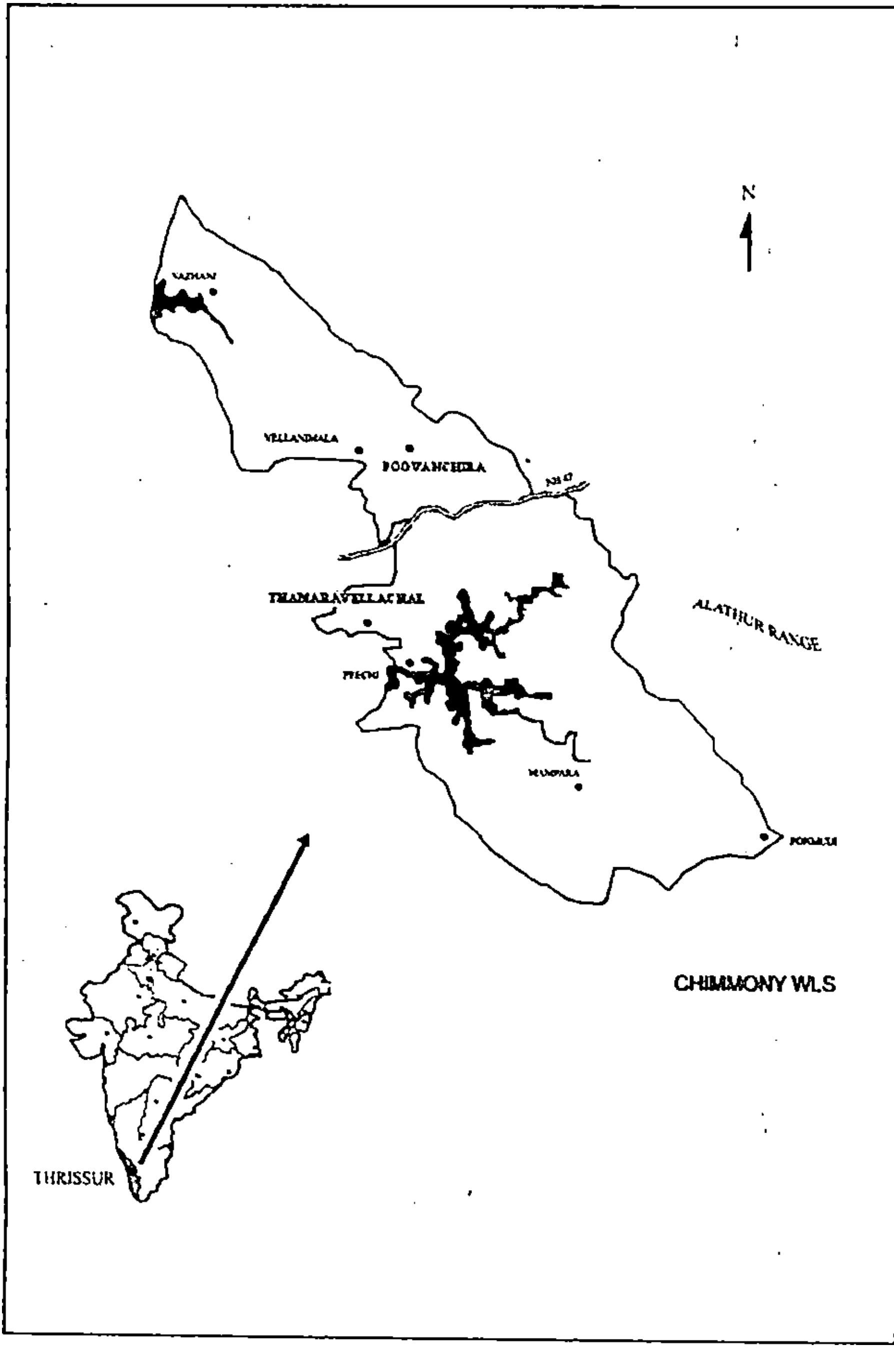

Fig.1. Map of Peechi-Vazhani Wildlife Sanctuary indicating the study areas.

3.1.3.1 Rainfall

The sanctuary receives showers from both northeast and southwest monsoons. Pre-monsoon showers are often received in the month of April. Southwest monsoons bring in precipitation from June till September. Heavy showers associated with thunderstorms are common. Northeast monsoons bring reasonable rains during October -November. Average precipitation in the sanctuary is 3000 mm (George, 2002).

3.1.3.2 Temperature

The sanctuary enjoys salubrious weather with cooler months during November to January and hotter days between February to May. The hilltops are relatively cooler when compared to plains owing to altitudinal effects. Mean maximum temperature recorded in the year 2001 is 39.4°C with a mean minimum temperature of 18.9 °C (George, 2002).

3.1.3.3Relative Humidity

Relative humidity is always greater than 55% and attains 100% during the rainy season (George, 2002).

3.1.3.4 Winds

North-East winds blowing through Palakkad gap of the Western Ghats have desiccating effect and cause heavy leaf fall, resulting in accumulation of combustible organic debris on the forest floor inducing forest fires (George, 2002).

3.1.4 Water Source

There are numerous streams small and big, flowing over the entire sanctuary, most of which join the three main rivers Kurumali, Manali and Wadakkanchery. Majority of these streams dry up during summer. There are two reservoirs, Peechi and Vazhani formed by construction of two dams across the rivers Manali and Wadakkanchery. The water-spread area of the two reservoirs is 14.793 sq km (George, 2002).

3.1.5 Habitat and vegetation

Zoo-geographically the area is classified as Indo-Malayan Region. The sanctuary provides a mosaic habitat for the bats by the presence of moist deciduous forests, semi-evergreen forests, riparian forests as well as evergreen forests. Major portion of the sanctuary, nearly 80 per cent is moist deciduous forest, 15 per cent is evergreen and semi-evergreen forests and the balance 5 per cent is under plantations of teak and softwood species.

Evergreen forests are found in higher slopes of the sanctuary and in patches at some places amidst moist deciduous forests. The dominant species found are *Palaquium ellipticum, Cullenia exarillata, Mesua ferrea, Canarium strictum* with canes and reeds.

Semi-evergreen type of forests is restricted to valleys and moist pockets. The dominant species are *Artocarpus hirsutus, Toona ciliata, Hopea parviflora, Mangifera indica* and *Vitex altissima.*

Moist deciduous type of forests is an intermediary stage between semi evergreen and dry deciduous type of forests. These forests are predominated by tree species like *Dalbergia latifolia*, *Xylia xylocarpa*, *Terminalia tomentosa* and *Lagerstroemia lanceolata* (George, 2002).

The mosaic pattern of the vegetation helps the bats to exploit the area efficiently (Verboom and Speoelstra, 1999). The rich abundance of the fruit trees like *Dillenia pentagyna*, *Ficus* sp., *Spondias mangifera, Ziziphus* sp. etc makes the sanctuary an abode of fruit bats.

Other main peculiarity of the sanctuary is the presence of large number of *Tetrameles nudiflora* tree, whose trunk bears large hollows, which offers the bats a comfortable roosting house. The sanctuary also provides large dead and standing trees with holes and rocky patches with large caves which are all ideal for bats (Akbar *et al.*, 1999 and Grindal, 1999).

3. 2 SELECTION OF SITE

The major portion of the Peechi-Vazhani Wildlife Sanctuary, nearly 80 per cent is most deciduous forests, 15 per cent is evergreen and semi-evergreen forests and the remaining five per cent is under teak and softwood plantations. Hence locations coming under evergreen habitat and moist deciduous habitat were selected according to the proportional area of the two habitats in the sanctuary.

3.3 METHODS

3.3.1 Field study

Mist nets are used most commonly for the small, volant mammals, because they are easily deployable and suitable in a variety of situations (Greenhall and Paradiso, 1968; Nagorson and Peterson, 1980; Kunz and Kurta, 1988). Mist nets made of monofilament nylon with a mesh size of 36 mm and an overall size of 10 x 1.5 m were used to capture bats during the study. Mist netting was done in different locations of evergreen and moist deciduous habitats during summer and rainy season. A total of 384 mist net hours were spent, out of which 307 mist net hours in moist deciduous and 77 mist net hours in evergreen habitats, in accordance with the proportional area under the two habitats in the sanctuary. The study period was from May, 2002 to April, 2003.

Mist nets were erected up to the height where bat activity is high. For decreasing the chance of bats avoiding the net across the water body, mist net was raised such that the lowest edge of the net is as near to the water surface as possible (Kunz and Kurta, 1988). Nettings were not done continuously on the same site more than two days, as it would affect the capture success (Laval and Fitch, 1977). When the mist netting was done in dense vegetation, they were mostly erected across the corridors (gap between rows of trees) so that the capture success was high.

The net was erected about half an hour before dusk and was kept open for two to four hours after dusk. Light intensity is important in controlling the time of emergence of bat species in both temperate and tropical region (Prakash, 1962; Herreid and Davis, 1966; Funakoshi and Uchida, 1975; Erket, 1978). The time of bats leaving the roosts varies from species to species and hence dusk is the best time to capture bats.

Nets were watched continuously. The bats, which were trapped in the mist net were removed immediately with gloved hands and placed in cloth bags, measured and released. Measurements such as head to body length (HBL), fore arm length (FL), ear length (EL), tail length (TL), were taken using digital calliper (Mitutoyo) (Fig. 2). For each of the species of bat captured, one or two voucher specimens were taken and deposited in the Museum of the Department of Wildlife Sciences, College of Forestry.

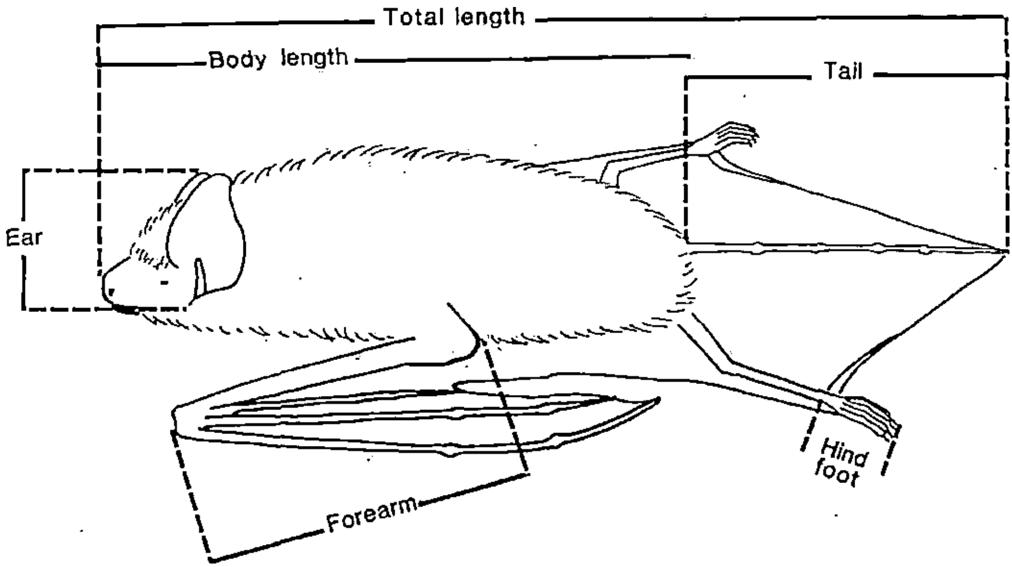

Fig 2 External measurements of bats

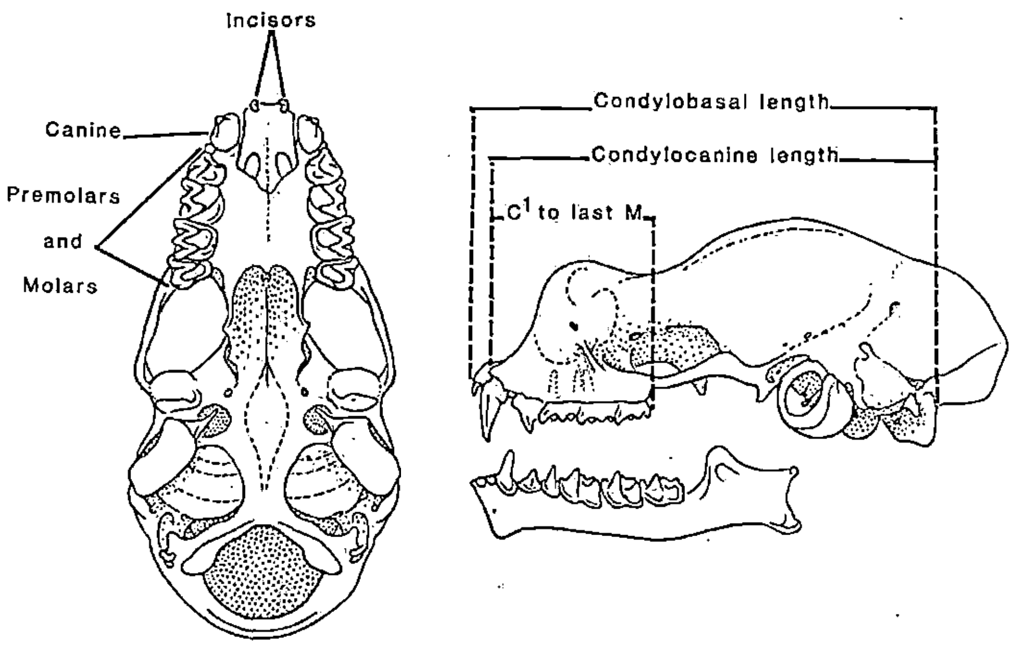

Fig 3. Bat skull with teeth and cranial measurements indicated

3.3.2 Roost habitat study

3.3.2.1 Tree roost

For each of the tree roost located in the study area, the following characters were recorded. The roost tree species, habitat type, roost type, the proximity of the roost tree to water and human habitation, bat species and number of individuals present in the roost.

3.3.2.2 Cave roost

With regard to cave roosts, habitat type, proximity to water and human habitation, bat species and number of individuals present in the roost were recorded.

3.3.3 Laboratory studies

The captured specimens from the field were carefully taken out of the nets. Standard morphological measurements were taken on all the specimens collected. For many species, cranial and dental measurements are needed to be taken for the correct and positive identification of species. For all the species voucher specimen was retained. The voucher specimens were taken to the laboratory for identification. They were euthanised using diethyl ether. The specimens were then skinned and skull was extracted. The skull was then boiled for 5 minutes, then the flesh was removed and then the skull was kept immersed in formic acid for half a day so that the skull is completely cleaned off the flesh and is ready for the further studies and examination. Measurements of skulls (Fig. 3) such as greatest length of skull (GTL), mandible length (M), breadth of brain case (BB), were taken. All these measurements were used for identifying the species. The skull and the specimens are then labelled and preserved in the museum of Department of Wildlife Sciences, College of Forestry, Kerala Agricultural University.

3.4. DATA ANALYSIS

Measures of diversity are frequently seen as indicators of the well being of ecological system. Species diversity may be thought of as being of two components. The first is the number of species in the community, which ecologist often refers to as species richness, and the second component is species evenness or equitability. Evenness refers to how the species abundance is distributed among species (Magurran, 1988).

Over the years, a number of indices have been proposed for characterising species richness and evenness. Such indices are termed richness indices and evenness indices. Indices that combine both species richness and evenness into a single value are referred to as diversity indices (Ludwig and Reynolds, 1988).

3.4.1. Richness indices

The following indices were used for measuring species richness

3.4.1.1. Margalef index

$$R1 = (S-1) / \ln N$$

where, S is the total number of species recorded and N is the total number of individuals summed over all S species (Magurran, 1988).

3.4.2. Diversity indices

3.4.2.1 Simpson's index, λ

Simpson (1949) proposed the first diversity index used in ecology as

$$\lambda = \sum p_i^2$$

where, pi is the proportional abundance of the 'i'th species given by

$$p_i = n_i / N$$

where, i = 1, 2, 3, 4, ...S , n_i is the number of individual of the i th species and N is the known total number of individuals for all S species in the population. Simpson's index, which varies from 0-1, gives the probability that two individuals drawn at random from a population belong to the same species. Simply stated if the probability is high that both individual belong to the same species, then the diversity of the community sample is low (Ludwig and Reynolds, 1988).

3.4.2.2. Shannon-Wiener index, H'

The Shannon-Wiener index (Shannon and Wiener, 1963) is a measure of the average degree of "uncertainty" in predicting to what species an individual chosen at random from a collection of S species and N individuals will belong. This average uncertainty increases as the number of species increases and as the distribution of individuals among the species becomes even. Thus, H' has two properties that have made it a popular measure of species diversity: (1) H' = 0 if and only if there is one species in the sample, and (2) H' is maximum only when all S species are represented by the same number of individuals, that is, a perfectly even distribution of abundance (Ludwig and Reynolds, 1988).

The equation of the Shannon function, which uses natural logarithm (ln), is

$$H' = - \sum_{i=1}^{S} (p_i . \ln p_i)$$

where H' is the average uncertainty per species in the infinite community made up of S species with known proportional abundance $p_1, p_2, p_3, \ldots\ldots\ldots p_S$.

3.4.3. Evenness index

To quantify evenness, five indices are used, each of which expressed as a ratio of Hill's (1973) numbers. In the present study evenness index was calculated using the equation given below.

$$E1 = H' / \ln(S)$$

E1 expresses H' relative to the maximum value that H' can obtain when all of the species in the sample are perfectly even with one individual per species.

3.4.4. Similarity indices

The similarity of the bats between the three study sites were worked out using Jaccard's and Sorensen's indices (Smith, 1983).

3.4.4.1 Jaccard's index

$$S_j = a / (a + b + c)$$

where,

a = number of species common in both sites 1 and 2

b = number of species in site 1 but not in site 2

c = number of species in site 2 but not in site 1

3.4.4.2 Sorensen's index

$$S_s = 2a / (2a + b + c)$$

where,

a = number of species common in both sites 1 and 2

b = number of species in site 1 but not in site 2

c = number of species in site 2 but not in site 1

3.4.4.3 Sorensen quantitative index

$$CN = 2jN / (aN + bN)$$

Where,

aN = the number of individuals in site A

bN = the number of individuals in site B

jN = the sum of the lower of the two abundances of species which occur in the two sites (Bray and Curtis, 1957).

3.5 STATISTICAL ANALYSIS

The data collected from the field were subjected to statistical analysis using standard statistical package (MSTAT) as suggested by Freed (1986).

Results

RESULTS

4.1 SPECIES COMPOSITION OF BATS IN PEECHI-VAZHANI WILDLIFE SANCTUARY

During the study period, a total of 184 individuals of bats were collected through mist netting from Peechi-Vazhani Wildlife Sanctuary. Out of the 31 species of bats in seven families recorded from Kerala, 18 bat species belonging to four families were recorded from the sanctuary during the present study. This constitutes about 58.07 per cent of the bat species in Kerala and 15.93 per cent of the total bat species in India. The bat families identified were Pteropodidae, Megadermatidae, Rhinolophidae and Vespertilionidae. All the four species of the members of Pteropodidae found in Kerala were recorded from Peechi-Vazahni Wildlife Sanctuary. So also, both the species of the False Vampire bats (Megadermatidae) present in Kerala were obtained from the study area. Of the other families maximum number of species (seven) was obtained for Vespertilionidae followed by Rhinolophidae (five). The bat species collected from the sanctuary along with their taxonomic positions are given in Table 3.

Table 3. Different species of bats recorded from Peechi-Vazhani Wildlife Sanctuary

Sl. No.	Common Name	Scientific name	Family
1	Indian Flying Fox	Pteropus giganteus (Brünnich, 1782)	Pteropodidae
2	Short-nosed Fruit bat	*Cynopterus sphinx* (Vahl, 1797)	
3	Lesser Dog- faced Fruit bat	*Cynopterus brachyotis* (Müller, 1838)	
4	Fulvous Fruit bat	*Rousettus leschenaultia* (Desmarest, 1820)	
5	Greater False Vampire	*Megaderma lyra* E Geoffroy, 1810	Megadermatidae
6	Lesser False Vampire	*Megaderma spasma* (Linnaeus, 1758)	
7	Rufous Horseshoe bat	*Rhinolophus rouxii* Temminck, 1835	Rhinolophidae
8	Blyth's Horseshoe bat	*Rhinolophus lepidus* Blyth, 1844	
9	Fulvous Leaf nosed bat	*Hipposideros fulvus* Gray, 1838	
10	Schneider's Leaf nosed bat	*Hipposideros speoris* (Schneider, 1800)	
11	Dusky Leaf nosed bat	*Hipposideros ater* Templeton, 1848	
12	Asiatic Greater Yellow House bat	*Scotophilus heathii* (Horsfield, 1831)	Vespertilionidae
13	Asiatic Lesser Yellow House bat	*Scotophilus kuhlii* Leach, 1821	
14	Indian Pipistrelle	*Pipistrellus coromandra* (Gray, 1838)	
15	Indian Pygmy bat	*Pipistrellus tenuis* (Temminck, 1840))	
16	Kelaart's Pipistrelle	*Pipistrellus ceylonicus* (Kelaart, 1852)	
17	Chocolate Pipistrelle	*Pipistrellus affinis* (Dobson, 1871)	
18	Painted bat	*Kerivoula picta* (Pallas, 1767)	

4.1.1 Pteropodidae

4.1.1.1 Pteropus giganteus (Brunnich, 1782)

This is a very large fruit bat (Plate 1) with an average forearm length of 168.4mm (152-183mm). It exceeds in size all other species known from Kerala. The snout is long and hairy throughout. The ears are black, virtually hairless, tall and pointed. The wings are massive. The first digit (thumb) has a large claw; the claw of the second digit is small. The feet are large and have very robust claws. The pelage is moderately long and coarse over the head, upper shoulder and ventral aspect. It is a rich chestnut brown on the crown of the head. On the nape of the neck and mantle, it varies from a light yellowish tan to a deep chestnut brown. The pelage is relatively darker around the eyes and mouth. The pelage on the posterior shoulders and mid dorsal region is short, sparse and black with some paler hair tips. There is a clear line of demarcation on the shoulders between the chestnut hairs of the head, neck and mantle and the dark hairs of the dorsum. The interfemoral membrane is little developed and there is no external tail. *Pteropus giganteus* were not caught in the mist net. However, two dead individuals were obtained from Peechi dam site area that is a moist deciduous habitat.

4.1.1.2 Cynopterus sphinx (Vahl, 1797)

This is a medium sized fruit bat (Plate 1) with an average forearm length of 70.2mm (64-79mm). The membrane is dark brown throughout, but with pale fingers on the wing. The medial part of interfemoral membrane is hairy, above and below. The muzzle is short, broad and covered with hairs as far as the nostrils, which project well forwards. The ears are simple and essentially naked; mocha brown in colour but with well defined pale anterior and posterior borders. The pelage is soft and silky in texture. A total of 76 individuals captured from the sanctuary, majority of which (92.11%) were from moist deciduous habitat.

4.1.1.3 Cynopterus brachyotis (Muller, 1838)

This species (Plate 1) averages smaller than *Cynopterus sphinx* with a forearm length of 60.3mm (57.3-63.3mm). It can be distinguished by its smaller ears, which do not exceed 18mm in length. In comparison with *Cynopterus sphinx* the pale borders of the ears are narrow or absent. Two individuals were obtained during the study period both from evergreen at an altitude of 543m MSL.

4.1.1.4 Rousettus leschenaulti (Desmarest, 1820)

This species (Plate 1) is having an average forearm length of 80.6mm (75-86mm). The muzzle is relatively short and slender. The pelage 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. Eleven individuals were captured from two sites, both moist-deciduous habitat. A large roost of *Rousettus leschenaulti* comprising of more than fifteen thousand individuals was found in a rocky cave at Mampara.

4.1.2 Megadermatidae

4.1.2.1 Megaderma lyra E. Geoffroy, 1810

This is robust species (Plate 1) with an average forearm length of 66.4mm (56.0-71.5mm). The head is characterized by its large, oval ears, which have a fringe of white hairs on their inner margins. The ears are joined medially for between one third and half their length. Each ear has a bifid tragus, the posterior process of which is taller. The face is hairy on the forehead and upper cheeks. The snout is naked, flesh coloured but with some well defined papillae. The lower jaw projects beyond the upper. The nose leaf is erect, straight-sided and some 10mm in height; it has a longitudinal ridge and a simple rounded horizontal base. The pelage is fine, soft and moderately long. It extends on to the forearms for half their length dorsally. The upper surface of the body is a uniform mouse grey faintly washed with brown. The ventral surface is paler, with the hair tips on the throat and belly white; the hair bases are grey. The membranes and ears are greyish black and semi translucent. The wings are broad. Five individuals were captured from two different locations of moist deciduous habitat.

4.1.2.2 Megaderma spasma **(Linnaeus, 1758)**

A smaller species (Plate 1) than *Megaderma lyra* with an average forearm length of 56.9mm (54.0-62.0mm). The interfemoral membrane larger than *Megaderma lyra*. The face differs in the shape of the vertical nose-leaf, which is shorter than that of *Megaderma lyra*; it has convex rather than straight sides and its longitudinal ridge has a characteristic heart shaped base. The pelage is deep grey on the upper surface; it is paler grey on the belly. A total of thirteen individuals were captured from five different locations moist deciduous habitat.

4.1.3 Rhinolophidae

4.1.3.1 Rhinolophus rouxii **Temminck, 1835**

The forearm length of this species (Plate 2) varies from 44.4-52.3mm. The pelage is soft and silky. There is a considerable variation in pelage colour ranging from orange, to russet brown to buffy brown to grey. This is the second most

Plate 1 Different species of bats at Peechi-Vazhani Wildlife sanctuary

Pteropus giganteus

Rousetteus leschenaulti

Cynopterus sphinx

Cynopterus brachyotis

Megaderma lyra

Megaderma spasma

abundant bat species in the sanctuary. Out of the 41 individuals collected from the sanctuary, 34 (82.93%) were from moist deciduous habitat.

4.1.3.2 Rhinolophus lepidus **Blyth, 1844**

This is a small Rhinolophid with an average forearm length of 39.8mm (37.0-41.8mm). The pelage colour is typically grey-brown dorsally and slightly paler ventrally. Two individuals were captured both from moist deciduous habitat.

4.1.3.3 Hipposideros fulvus **Gray,1838**

This is a medium-small species (Plate 2) of *Hipposideros* with characteristically very large ears, the tips of which are broadly rounded off. The forearm length averages 40.4mm (38.4-44.0mm). The structure of the wings is essentially similar to *Hipposideros ater* with the third metacarpal significantly shorter than the fourth. The feet are small. The nose leaf has a greatest width of about 5mm. The pelage is variable in colour including dull yellow, pale grey, dull brown and golden orange. Two individuals were captured from the same site of a moist deciduous habitat.

4.1.3.4 Hipposideros speoris **(Schneider, 1800)**

Although the forearm length averages 50.7mm (45.6-54.0mm), which significantly exceeds that of *Hipposideros fulvus*, the ears are markedly smaller (Plate 2). The nose leaf has three supplementary leaflets, of which the outer is distinctly smaller than the other two. The narial lappets are well developed. The intermediate leaf has a slightly concave upper edge. The posterior leaf is divided into four cells by three vertical septa, its upper edge is slightly thickened and without processes. A frontal sac is present in males where as in females it is represented by a tuft of hairs.

The pelage colour is variable. Some individuals are grey, palest on the ventral surface, and between the shoulders on the upper back; they are darker on the flanks. Others are yellowish brown or bright orange colour. Twelve individuals were captured from a single site known as Poovanchira. A cave roost of more than five hundred individuals was also found in Poovanchira which comes under moist deciduous habitat.

4.1.3.5. Hipposideros ater Templeton, 1848

This is a small species of Hipposideros (Plate 2) superficially similar to *Hipposideros fulvus* with a significantly shorter forearm (average 36.3mm; 34.9-38mm) and smaller ears. The breadth of the ears is sub equal to their height and the tips are broadly rounded off; each ear has a well-defined antitragus. The nose-leaf has a greatest width of about 4.0-4.5mm. Its anterior leaf is without supplementary lateral leaflets or a median emargination. The feet are small. In the wing, the fourth metacarpal exceeds the fifth in length whilst the third is the shortest. The tail is long and is enclosed, all except the extreme tip, with in the well-developed interfemoral membrane. The wings and the interfemoral membrane are naked, above and below, and are a uniform dark brown or black. The pelage is variable in colour ranging from dull yellow, golden orange or pale grey to dark brown on the dorsal aspect. The hair bases are paler than the tips. The ventral aspect is also variable in colour but is usually paler than the back. Two individuals were captured from moist deciduous habitat.

4.1.4 Vespertilionidae

4.1.4.1 Scotophilus heathii Horsfield, 1831

This is a robust bat (Plate 2) with an average forearm length of 60.7 mm (55.4-65.8mm). The tail is long, with only the terminal 2 to 3 mm. projecting free from the interfemoral membrane. The muzzle is broad and blunt; it is swollen on the sides, dark in colour and mostly naked. The nostrils are simple in form, round and slightly outward facing. The ears are small in relation to the size of the head; they are naked and have a number of transverse ridges. The antitragus of each ear is well formed and separated form the posterior margin of the pinna by a distinct notch. The tragus is half the height of the pinna and crescent shaped. The pelage is fine and short; it is longer on the nape of the neck and throat. The head and back have pale buffy brown hair roots and darker olive-grey-brown tips; the nape of the neck is paler. The throat, chest and belly are pale yellow-buff throughout. The inter-femoral membrane and wings are uniformly dark brown and essentially naked, except for some hairs adjacent to the body and forearm on the ventral surface of each wing. In the wing, the third metacarpal slightly exceeds the fourth and fifth in length. The feet are about half the length of the tibiae. Five individuals were collected from moist deciduous habitat of the sanctuary.

4.1.4.2 Scotophilus kuhlii Leach, 1821

This species (Plate 2), with an average forearm length of 49.0mm. (44.0-56.4mm), can only be distinguished with certainly from *Scotophilus heathii* by its smaller size. In all other structures it is essentially similar. The pelage is chestnut

Plate 2 Different species of bats at Peechi-Vazhani Wildlife sanctuary

Rhinolophus rouxii

Hipposideros fulvus

Hipposideros speoris

Hipposideros ater

Scotophilus heathii

Scotophilus kuhlii

brown above; paler below usually without the characteristic yellowish tinge of *Scotophilus heathii.* Five individuals were collected from moist deciduous habitat of the sanctuary.

***4.1.4.3 Pipistrellus coromandra* (Gray, 1838)**

This is a small pipistrelle (Plate 3) with an average forearm length of 30.0mm. (25.5-34.3mm). It is uniform brown on the dorsal surface, ranging from chestnut to dark clove brown. The ventral surface is conspicuously paler, with beige brown or cinnamon brown tips to the hairs, depending on the individual; the hair roots are dark. The ears and membrane are mid to dark brown and essentially naked, although there are some hairs on the inter-femoral membrane adjacent to the body and the tail, above and below. Only one individual was collected from a moist deciduous habitat.

***4.1.4.4 Pipistrellus tenuis* (Temmminck, 1840)**

This is the smallest pipistrelle (Plate 3) found within the Indian subcontinent with an average forearm length of 27.7mm (25.0-30.2mm). Since it is not possible to discriminate between this species and smaller individuals of *Pipistrellus coromandra* using external characters, cranial characters were used for the identification of this species. The skull is significantly smaller than that of *Pipistrellus coromandra.* One individual each were obtained from both evergreen and moist deciduous habitats.

4.1.4.5 Pipistrellus ceylonicus (Kelaart, 1852)

This is a relatively large *Pipistrellus* (Plate 3) with an average forearm length of 37.2mm (33.0-42.0mm). The ears, naked areas of the face, wings and interfemoral membrane are uniform dark brown. There are some hairs on the interfemoral membrane, above and below, adjacent to the body, tail and femora. The dorsal pelage is variable in color ranging from grey- brown to chestnut, reddish or golden brown. The ventral surface has dark hair bases and pale grey tips. Only one individual was collected from evergreen habitat.

4.1.4.6 Pipistrellus affinis (Dobson, 1871)

This is a large species of pipistrelle with an average forearm length of 40.2mm (38.4-41.4mm). The pelage is soft, dense and relatively long. It is essentially dark brown above, although the extreme tips of some of the hairs are pale grey, giving a slightly grizzled effect. The ventral surface is also dark, only slightly paler than the back. The membranes, ears and naked parts of the face are uniform blackish brown. Only one individual was collected from evergreen habitat.

4.1.4.7 Kerivoula picta (Pallas, 1767)

This is a relatively small bat (Plate 3) with an average forearm length of 34.7mm (31.5-37.9mm). The muzzle is very hairy but the nostrils are naked, which are slightly protuberant and face outwards and slightly downwards. The upper and lower lips are also hairy. The ears are relatively large; the anterior border of each is smoothly concave; the tip rounded off; there is a distinct concavity just below the tip on the posterior border. The tragus is tall and narrow. The pelage is long, dense and woolly. On the dorsal surface, it is bright orange, to tawny-red from the tips to the

Plate 3 Different species of bats at Peechi-Vazhani Wildlife sanctuary


Pipistrellus ceylonicus


Pipistrellus coromandra


Pipistrellus tenuis


Kerivoula picta

roots. On the ventral surface, it is buff coloured, with a distinct orange hue on the flanks. The wings are bright orange adjacent to the body and on either side of the metacarpals, above and below; the reminder is black. The interfemoral membrane is orange to scarlet. The feet are hairy. The wings are attached to the bases of the outer toes. Only one individual was collected from the sanctuary boundary region near the dam site, which is a moist deciduous habitat.

4.2 ABUNDANCE OF BATS IN PEECHI-VAZHANI WILDLIFE SANCTUARY

The abundance of bats from different locations in Peechi-Vazhani Wildlife Sanctuary is given in Table 4. Out of the twenty locations selected for the study, *Cynopterus sphinx* and *Rhinolophus rouxii* were found in nine locations each. Maximum number of species was collected from Peechi dam (eight) representing all the four families recorded during the present study. Maximum numbers of individuals were obtained from Thamaravellachal and were belonging to three different families. The species obtained were *Cynopterus sphinx* (Pteropodiade), *Rhinolophus rouxii* (Rhinolophidae), *Rhinolophus fulvus* (Rhinolophidae) and *Megaderma spasma* (Megadermatidae).

Table 4. Diversity of Bats in different locations of Peechi-Vazhani Wildlife Sanctuary

Habitat	Location	Altitude (m)	Species	Abundance
Evergreen	Ponmudi	543	*Cynopterus sphinx*	2
	Vellanipacha	327	*Rhinolophus rouxii*	4
	Olakara	255	*Cynopterus sphinx*	6
			Pipistrellus tenuis	1
			Pipistrellus affinis	1
			Pipistrellus ceylonicus	1
	Odakkundu	230	*Rhinolophus rouxii*	3
Moist deciduous	Mamparakuthu	223	*Rousettus leschenaulti*	8

Moist deciduous	Mampara	190	*Megaderma spasma*	1
	Poovanchira	154	*Hipposideros speoris*	12
	Thamaravellachal	140	*Cynopterus sphinx*	17
			Rhinolophus rouxii	6
			Hipposideros fulvus	2
			Megaderma spasma	2
	Kompazha	137	*Cynopterus sphinx*	13
			Rhinolophus rouxii	3
			Pipistrellus coromandra	1
	Kachithodu	135	*Cynopterus sphinx*	14
			Rousettus leschenaulti	3
	Kuthiran	128	*Cynopterus sphinx*	8
	Irumbupalam	125	*Cynopterus sphinx*	8
	Pattikkadu	108	*Hipposideros ater*	2
	Pattathipara	105	*Rhinolophus rouxii*	14
			Megaderma spasma	7
			Rhinolophus lepidus	1
	Peechi dam	103	*Cynopterus sphinx*	4
			Pipistrellus tenuis	1
			Scotophilus heathii	2
			Scotophilus kuhlii	5
			Megaderma spasma	2
			Rhinolophus rouxii	4
			Pteropus giganteus	2
			Kerivoula picta	1
	Pullumkandam	98	*Rhinolophus rouxii*	2
	Karadipara	97	*Rhinolophus lepidus*	1
	Vazhani dam	90	*Cynopterus sphinx*	3
			Scotophilus heathii	3
			Rhinolophus rouxii	1
			Megaderma lyra	3
	Vazhani	84	*Rhinolophus rouxii*	4
			Megaderma lyra	2
			Megaderma spasma	1

The abundance and proportional abundance of bats in Peechi-Vazhani Wildlife Sanctuary is given in Table 5. *Cynopterus sphinx* was found to be the most abundant species in the Peechi-Vazhani Wildlife Sanctuary followed by *Rhinolophus rouxii, Megaderma spasma, Hipposideros speoris* and *Rousettus leschenaulti.* The bat species *Pipistrellus ceylonicus, Pipistrellus affinis, Pipistrellus coromandra,* and *Kerivoula picta* were collected only once.

Table 5. Abundance and proportional abundance of bats in Peechi-Vazhani Wildlife Sanctuary

Sl. No.	Species	Abundance (n_i)	Proportional abundance ($Pi = n_i / N$)
1	*Cynopterus sphinx*	76	0.41
2	*Rhinolophus rouxii*	41	0.22
3	*Megaderma spasma*	13	0.07
4	*Hipposideros speoris*	12	0.07
5	*Rousettus leschenaulti*	11	0.06
6	*Megaderma lyra*	5	0.03
7	*Scotophilus heathii*	5	0.03
8	*Scotophilus kuhlii*	5	0.03
9	*Pteropus giganteus*	2	0.01
10	*Cynopterus brachyotis*	2	0.01
11	*Hipposideros fulvus*	2	0.01
12	*Hipposideros ater*	2	0.01
13	*Rhinolophus lepidus*	2	0.01
14	*Pipistrellus tenuis*	2	0.01
15	*Pipistrellus affinis*	1	0.01
16	*Pipistrellus ceylonicus*	1	0.01
17	*Pipistrellus coromandra*	1	0.01
18	*Kerivoula picta*	1	0.01

n_i = number of individuals of i^{th} species; N= Total number of individuals of all the species

The abundance and proportional abundance of bats in two different habitats viz. evergreen and moist deciduous are given in Table 6 and 7.

Table 6. Abundance and proportional abundance of bats in evergreen habitat of Peechi-Vazhani Wildlife Sanctuary

Sl. No	Species	Abundance (n_i)	Proportional abundance ($p_i = n_i / N$)
1	*Rhinolophus rouxii*	7	0.39
2	*Cynopterus sphinx*	6	0.33
3	*Cynopterus brachyotis*	2	0.11
4	*Pipistrellus tenuis*	1	0.06
5	*Pipistrellus affinis*	1	0.06
6	*Pipistrellus ceylonicus*	1	0.06
		N = 18	

n_i = number of individuals of i^{th} species; N= Total number of individuals of all the species

Table 7. Abundance and proportional abundance of bats in moist deciduous habitat of Peechi-Vazhani Wildlife Sanctuary

Sl. No.	Species	Abundance (n_i)	Proportional abundance ($p_i = n_i / N$)
1	*Cynopterus sphinx*	70	0.42
2	*Rhinolophus rouxii*	34	0.20
3	*Megaderma spasma*	13	0.08
4	*Hipposideros speoris*	12	0.07
5	*Rousettus leschenaulti*	11	0.07
6	*Megaderma lyra*	5	0.03
7	*Scotophilus heathii*	5	0.03
8	*Scotophilus kuhlii*	5	0.03
9	*Pteropus giganteus*	2	0.01
10	*Rhinolophus lepidus*	2	0.01
11	*Hipposideros fulvus*	2	0.01
12	*Hipposideros ater*	2	0.01
13	*Pipistrellus tenuis*	1	0.01
14	*Pipistrellus coromandra*	1	0.01
15	*Kerivoula picta*	1	0.01
		N = 166	

n_i = number of individuals of i^{th} species; N= Total number of individuals of all the species

Evergreen habitat recorded 18 individuals in six species where as moist deciduous habitat recorded 166 individuals in 15 species. *Cynopterus brachyotis*, *Pipistrellus affinis* and *Pipistrellus ceylonicus* were recorded from evergreen habitat only.

Distribution of bats in Peechi-Vazhani Wildlife sanctuary according to various altitudes is given in Fig. 4. Maximum number of individuals (67.9 percent) of bats was obtained from the lower altitudinal range of 100 to 150 m above M.S.L. This is five to six times higher than the number of individuals of bats at higher elevation.

4.3 SPECIES RICHNESS, DIVERSITY, EVENNESS AND SIMILARITY INDICES OF BATS IN PEECHI-VAZHANI WILDLIFE SANCTUARY

4.3.1 Species richness

Species richness, diversity and evenness indices are given in Table 8. Species richness index was calculated for moist deciduous and evergreen habitats of the sanctuary. Margalef's index showed higher value for moist deciduous habitat than the evergreen.

4.3.2 Species diversity

Simpson's diversity index and Shannon diversity index for moist deciduous habitat showed higher values (0.32 and 1.63 respectively) than the evergreen (0.28 and 1.46). Evenness index was higher for the evergreen habitat (0.82) when compared to the moist deciduous habitat (0.60) (Table 8).

Fig. 4 Altitudinal variation of bats in Peechi-Vazhani Wildlife Sanctuary

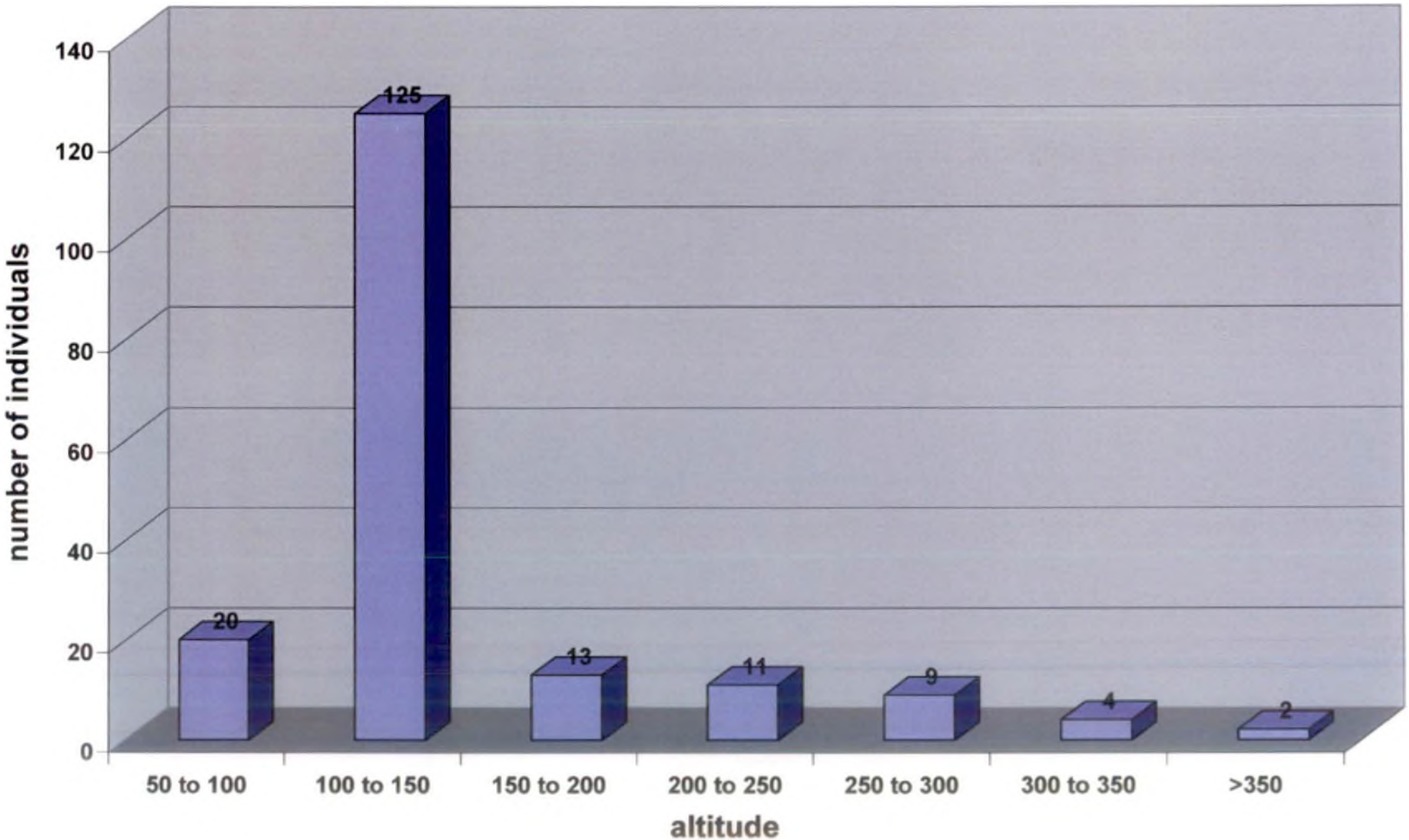

Table 8: Diversity indices of bats in different habitats of Peechi-Vazhani Wildlife Sanctuary

Sl.No.	Measures of Diversity	Evergreen	Moist deciduous	For the whole sanctuary
1	Margalef's index	1.73	2.74	3.26
2	Simpson's diversity index	0.28	0.32	0.24
3	Shannon diversity index	1.46	1.63	1.94
4	Evenness index	0.82	0.60	0.66

4.3.3 Species similarity

Similarity indices of the different habitats of the sanctuary are given in Table 9. Lower values were calculated for three indices showing the dissimilarity in species composition in the two habitats of the sanctuary.

Table 9. Similarity of bat species between moist deciduous and evergreen habitats of Peechi-Vazhani Wildlife Sanctuary

Similarity indices	Evergreen v/s Moist deciduous
Jaccard's index	0.17
Sorensen's index (Qualitative data)	0.29
Sorensen's index (Quantitative data)	0.14

4.4 FIELD AND LABORATORY OBSERVATIONS

4.4.1 Morphological measurements

The data regarding the morphological measurements of the bat specimens collected from Peechi-Vazhani Wildlife Sanctuary are given in Table 10. The measurements were compared with that of Bates and Harrison (1997).

Table 10. The morphological measurement of bat specimens collected from Peechi- Vazhani Wildlife Sanctuary

Species	Present study			Bates and Harrison (1997)		
	FAL	EL	TL	FAL	EL	TL
Pteropus giganteus (n= 2)	160.2	37.4	-	168.4	39.8	-
Cynopterus sphinx (n= 76)	68.92	16.94	13.17	70.2	20.6	10.9
Cynopterus brachyotis (n= 2)	65.0	13.1	12.5	60.3	16.7	7.2
Rousettus leschenaulti (n= 11)	87.5	17.9	12.3	80.6	20.8	15.6
Megaderma lyra (n= 5)	67.35	35.85	-	66.4	37.9	-
Megaderma spasma (n= 13)	58.4	37.2	-	56.9	36.9	-
Rhinolophus rouxii (n= 41)	49.53	17.43	25.67	49.3	19.0	27.1
Rhinolophus lepidus (n= 2)	40.05	15.3	17.35	39.8	16.9	20.4
Hipposideros fulvus (n= 2)	40.7,5	16.55	21.5	40.4	22.0	29.5
Hipposideros speoris (n= 12)	54.3	10.05	30.5	50.7	16.9	25.2
Hipposideros ater (n= 2)	35.3	16.0	23.6	36.3	17.6	24.7
Scotophilus heathii (n= 5)	59.0	13.1	46.2	60.7	16.9	59.1
Scotophilus kuhlii (n= 5)	47.1	14.0	44.0	49.0	13.5	47.5
Pipistrellus coromandra (n= 1)	25.9	9.8	27.5	30.0	10.3	32.0
Pipistrellus tenuis (n= 2)	28.3	8.9	27.9	27.7	9.7	28.8
Pipistrellus ceylonicus (n= 1)	39.98	11.58	43.45	37.2	12.2	38.2
Pipistrellus affinis (n= 1)	39.6	9.0	49.2	40.2	13.7	36.3
Kerivoula picta (n= 1)	33.8	14.7	43.1	34.7	15.0	45.4

<u>Legend:</u> FAL = Fore arm length, EL = ear length; TL = tail length

4.4.2 Roost characteristics

The bat roost characteristics of the sanctuary are given in Table 11. For the *Rhinolophus rouxii, Megaderma spasma* and *Megaderma lyra* were found roosting in the trees, while the *Rousettus leschenaulti, Hipposideros speoris* and *Hipposideros fulvus* were found roosting in the caves.

Table11. Bat roost types in moist deciduous habitats of Peechi-Vazhani Wildlife Sanctuary

Sl. No.	Roost type	Roosting tree	Bat species	NI	PW (m)	PH (km)
1	Hollow living tree	*Tetrameles nudiflora*	*Rhinolophus rouxii*	< 100	150	1.0
2	Hollow living tree	*Terminalia bellirica*	*Megaderma spasma*	16	50	9.0
3	Hollow living tree	*Tetrameles nudiflora*	*Megaderma spasma*	4	10	0.0
4	Hollow living tree	*Tetrameles nudiflora*	*Megaderma lyra*	12	35	0.0
5	Cave	–	*Rousettus leschenaulti*	>15,000	0	12.0
6	Cave	–	*Hipposideros speoris* *Hipposideros fulvus*	> 150	0	0.0
7	Cave	–	*Hipposideros speoris*	> 500	25	0.25
8	Foliage	*Polyalthia longifolia*	*Cynopterus sphinx*	9	10	0.30

Legend: NI= Number of individuals, PW=Proximity to water, PH=Proximity to human inhabitation

Eight roosts of seven different species were found during the present study. *Rhinolophus rouxii, Megaderma spasma* and *Megaderma lyra* were found to be roosting in hollow living trees. *Tetrameles nudiflora* and *Terminalia bellirica* were the roosting trees. *Cynopterus sphinx* was found to be roosting in the foliage of *Polyalthia longifolia*.

Rousettus leschenaulti, Hipposideros speoris and *Hipposideros fulvus* were found to be roosting in caves. A large colony, comprising more than fifteen thousand individuals of *Rousettus leschenaulti* was found in a cave at Mampara, deep inside the moist deciduous habitat of the sanctuary. More than five hundred individuals of *Hipposideros speoris* was found at Poovanchira which is also a moist deciduous habitat. At another moist deciduous site called Thamaravellachal, *Hipposideros speoris* was found to be sharing its cave roost with *Hipposideros fulvus*. Proximity to water found to be an important factor in roost characteristics. All the bat roosts found during the present study were within 150m from water source.

4.4.3 Cranial and dental measurements

The data regarding the cranial and dental measurements of the bat specimens collected from Peechi-Vazhani Wildlife Sanctuary are given in Table 12.

Table12. Cranial and dental measurements of various bat species recorded from Peechi-Vazhani Wildlife Sanctuary

Sl. No	Species	GTL (mm)	$C\text{-}M_3$ (mm)	$C\text{-}M^3$ (mm)	M (mm)	ZB (mm)	BB (mm)
1	*Pteropus giganteus (n=1)*	75.83	28.83	-	58.96	40.24	25.26
2	*Cynopterus sphinx* (n=4)	33.26.	-	-	23.53	22.86	13.72
3	*Cynopterus brachyotis* (n=1)	29.26	-	-	22.56	18.91	10.82
4	*Rousettus leschenaulti* (n=3)	35.96	15.50	-	28.41	23.37	15.72
5	*Megaderma spasma* (n=3)	25.41	10.52	9.46	17.10	14.28	10.35
6	*Megaderma lyra* (n=3)	26.23	11.27	10.81	18.92	16.22	11.93
7	*Rhinolophus lepidus* (n=1)	17.98	6.51	5.83	11.54	8.31	7.52
8	*Rhinolophus rouxii* (n=4)	23.23	9.12	9.07	14.85	11.52	9.01
9	*Hipposideros ater* (n=1)	16.51	5.98	5.56	10.15	7.92	7.80
10	*Hipposideros speoris* (n=3)	19.4	7.62	7.35	12.51	10.75	8.43
11	*Hipposideros fulvus*,(n=1)	17.54	7.13	6.58	11.95	9.54	8.92
12	*Scotophilus heathii* (n=2)	24.68	9.26	7.84	17.23	15.31	10.62
13	*Scotophilus kuhlii* (n=2)	20.1	7.20	6.60	14.01	12.84	9.23
14	*Pipistrellus ceylonicus(n=1)*	15.03	5.86	5.63	10.92	10.01	7.22
15	*Pipistrellus tenuis* (n=1)	11.07	3.83	3.64	7.83	7.57	6.15
16	*Pipistrellus coromandra* (n=1)	12.85	4.61	4.23	9.24	7.82	6.56
17	*Pipistrellus affinis* (n=1)	15.62	5.63	5.56	11.25	9.10	7.16
18	*Kerivoula picta* (n=1)	14.62	5.68	5.96	10.43	8.54	6.76

Legend: GTL = The greatest antero-posterior diameter of the skull; $C\text{-}M_3$ = Length from the front of the lower canine to back of the crown of the third lower molar; $C\text{-}M^3$ = Length from the front of the upper canine to back of the crown of the third upper molar; M = Mandible length; ZB = Zygomatic Breadth; BB = Breadth of Brain case.

4.5 CONSERVATION STATUS OF BATS IN PEECHI-VAZHANI WILDLIFE SANCTUARY

The conservation status of the bat species that have been recorded from the sanctuary is given in Table 13. Among the eighteen species, *Pipistrellus affinis* and *Rhinolophus rouxii* are near threatened species as per the IUCN red list criteria (Walker and Molur, 2003).

Table 13. Conservation status of bats in Peechi-Vazhani Wildlife Sanctuary

Sl. No.	Species	Conservation status
1.	*Cynopterus brachyotis*	Least Concern
2.	*Cynopterus sphinx*	Least Concern
3.	*Hipposideros ater*	Least Concern
4.	*Hipposideros fulvus*	Least Concern
5.	*Hipposideros speoris*	Least Concern
6.	*Kerivoula picta*	Least Concern
7.	*Megaderma lyra*	Least Concern
8.	*Megaderma spasma*	Least Concern
9.	*Pipistrellus affinis*	Near Threatened
10.	*Pipistrellus ceylonicus*	Least Concern
11.	*Pipistrellus coromandra*	Least Concern
12.	*Pipistrellus tenuis*	Least Concern
13.	*Pteropus giganteus*	Least Concern
14.	*Rhinolophus lepidus*	Least Concern
15.	*Rhinolophus rouxii*	Near Threatened
16.	*Rousettus leschenaulti*	Least Concern
17.	*Scotophilus heathii*	Least Concern
18.	*Scotophilus kuhlii*	Least Concern

Discussion

DISCUSSION

Bats are one of the least studied mammalian groups in the region. There is an obvious dearth of information on bats in the wild. Information for many species is based only on museum or literature references, with no recent distribution information in the wild. Paucity of information is so dramatic that there could be a few species that may be locally extinct already, but these possible extinctions can not be ascertained for want of systematic surveys. Mammal surveys in protected areas have a very strong bias towards larger, more conspicuous forms. Ecological studies are critical for better understanding of the status of the species as well as the very much needed documentation of the ecological value of bats. Hence, the present study was taken up to study the diversity of bats in Peechi-Vazhani Wildlife Sanctuary, Western Ghats, Kerala.

5.1 SPECIES COMPOSITION OF BATS IN PEECHI-VAZHANI WILDLIFE SANCTUARY

During the present study period 18 species belonging to four families were collected through mist netting from Peechi-Vazhani Wildlife Sanctuary. This constitutes about 58.07 per cent of the bat species of Kerala and 15.93 per cent of the total bat species in India. A total of 384 mist net hours were spent, out of which 307 (79.95%) mist net hours in moist deciduous and 77 (20.05%) mist net hours in evergreen habitats, in accordance with the proportional area under the two habitats in the sanctuary.

5.2 ABUNDANCE OF BATS IN PEECHI-VAZHANI WILDLIFE SANCTUARY

Mist netting was done in four sites of evergreen and sixteen sites of moist deciduous habitat. Among the evergreen sites, maximum number of species (four) and maximum number of individuals (nine) were obtained from Olakara. Six species of bats were recorded from the evergreen habitat of the sanctuary of which three belongs to Vespertilionidae, two from Pteropodidae family and the remaining one belongs to Rhinolophidae. *Rhinolophus rouxii* was found to be the most abundant species in evergreen habitat followed by *Cynopterus sphinx*. Even though there was no significant difference between the two habitats, maximum number of species (15) and maximum number of individuals (166) were recorded from moist deciduous habitat. Maximum number of species was collected from the moist deciduous habitat near the Peechi dam (eight) representing all the four families recorded during the present study. *Cynopterus sphinx* was found to be the most abundant species in the moist deciduous habitat of Peechi-Vazhani Wildlife Sanctuary followed by *Rhinolophus rouxii.*

Cynopterus brachyotis was collected only from the evergreen habitat of the sanctuary at an altitude of 543 m above M.S.L. This sighting of the species during the present study is of interest because the only earlier sighting of the species from Kerala, was by Das (1986) from Silent Valley National Park at an altitude of 900 m.

Maximum number of individuals (67.9 percent) of bats was obtained from the lower altitudinal range of 100 to 150 m above M.S.L. This is five to six times higher than the number of individuals of bats at higher elevation. Erickson and Adams (2003) also reported a similar pattern of higher bat abundance at lower altitudes from Black Hills of Washington.

5.3 SPECIES RICHNESS, DIVERSITY, EVENNESS AND SIMILARITY INDICES OF BATS IN PEECHI-VAZHANI WILDLIFE SANCTUARY

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, 1988).

The Simpson's index is an index of the diversity of the bats and as the value of the index increases, the diversity increases and dominance decreases. Even though moist deciduous habitat recorded maximum number of species and maximum number of individuals, Simpson's index value is not much higher (0.32) compared to evergreen (0.28). The lower values of Simpson's index for both the habitat could be due to predominance of *Cynopterus sphinx* and *Rhinolophus rouxii.*

A study conducted in French Guiana at different ecological units viz. primary forest, secondary forest, coastal savanna woodland, coastal marshes and urban areas has shown that habitats altered by humans harbour over four times as many individual bats as primary rainforest. This rise in both frugivorous and insectivorous bat population in areas of degraded vegetation appears linked to the abundance of bat dispersed pioneer fruiting plant species available to fruit bats and the multiplication of roosting sites for insectivorous bats in human habitats. The species richness of local bat communities is positively influenced by the presence of forest corridors or the immediate proximity of a forest block (Brosset *et al.*, 1996). The spatial complexity of a habitat, in combination with insect availability, influences habitat use by foraging bats (Grindal and Brighan, 1999). Similar factors might have been contributed to the higher value of Simpson's index for moist deciduous habitat in Peechi-Vazhani Wildlife Sanctuary. Study conducted by Tibbles and Kurta (2003) revealed that bat activity was more than twenty times greater in small openings within thinned and unthinned stands than within the stands themselves, and bat activity was associated with greater insect abundance in openings. This could be the reason for the higher abundance of insectivorous bats in moist deciduous habitat.

The values of the Shannon diversity index are usually found to fall between 1.5 and 3.5. In the present study, moist deciduous habitat showed higher value (1.63) than evergreen (1.46). Margalef index also followed a similar pattern for the two habitats. Moist deciduous habitat showed higher species richness than the evergreen habitat. Similar studies conducted in area of regenerated forest at Atlantic forest, south eastern Brazil (Esberard, 2003), showed Shannon diversity index varied from H'= 1.87 and H'= 2.19. In the present study a decrease in value of Shannon index (H') indicates an increase in the magnitude of environmental stress favouring the dominance of a few adapted species.

Evenness index has a range of 0-1 and the value is 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. Evergreen habitat of the sanctuary showed higher value for evenness index (0.82) than the moist deciduous (0.6). Here, in evergreen habitat, the magnitude of differences in the population between the few species of bats present are not very high as in moist deciduous, and thus, resulted in fairly high value for evenness index. Even though higher number of species and individuals were obtained from moist deciduous habitat compared to evergreen habitat, the evenness indices were lower. When the environmental stress occur, only a few adapted species are favoured, the population of which will dominate over the other species. In both evergreen and deciduous habitats, two species of bats, *Cynopterus sphinx* and *Rhinolophus rouxii* were the most abundant species. This condition resulted in low evenness index.

5.4 FIELD AND LABORATORY OBSERVATIONS

The morphological as well as cranial measurements were similar to that of the measurement ranges given by Bates and Harrison (1997).

Eight roosts were found during the present study. All the roosts were found to be within less than 150 m to some kind of water sources. This indicate that water is an important factor for selection of roost site for bats. Jay and Tupinier (2003) have observed that the presence of large trees and water are important factors in the distribution of bats. Large hollow trees especially *Tetrameles nudiflora* were found as favourable roost sites for *Rhinolophus rouxii* which is a near threatened species.

The large colony, comprising of more than fifteen thousand individuals of *Rousettus leschenaulti* was found in a cave at Mampara. This cave site should be given special protection from fire and human interference.

5.5 CONSERVATION STATUS OF BATS IN PEECHI-VAZHANI WILDLIFE SANCTUARY

Among the eighteen species recorded from the sanctuary, *Pipistrellus affinis* and *Rhinolophus rouxii* are near threatened species as per the IUCN criteria. *Rhinolophus rouxii* is the second most abundant species in the sanctuary. *Hipposideros speoris* is endemic to south Asia (Walker and Molur, 2003)

Although it may seem that many Indian bats, having been assessed Least Concern, are still relatively safe, it is very important to understand that the assessments have been done only at the species level and not at subspecies or population level. Even though the status of many species is safe for now, individual populations or subspecies may be under tremendous pressure. If appropriate measures are not taken to conserve such subspecies and populations, genetic diversity could be lost forever. The loss of even non endemic species population and subspecies is actually a danger to the country due to the loss of myriad benefits to ecosystem and human needs.

Bats are protected in many parts of the world due to their demonstrated ecological value. Ironically, temperate countries of the western world are far more organized in this aspect than the tropics, where the diversity of bats is enormous. Several countries, including Britain, realizing the crucial role that bat play in maintaining an ecological balance, have placed bats on their list of protected species (Kumar, 1984). In the tropics, Australia, Mexico and some states in Malaysia have strong protective legislation for bats while most other tropical countries and continents have no or actually negative legislation. Mexico's legislation includes full protection of caves partly because of their role as bat roosts. Many countries are currently updating wildlife legislation as a result of the Rio Convention. In this, it is not really sensible to sign the Convention on Biological Diversity and continue to treat pollinating and seed dispersing animals as 'noxious'.

No South Asian country protects bats in principle. Sri Lankan legislation gives full protection to one subspecies, *Rousettus leschenaulti seminudus*. Other countries, such as Pakistan go to the other extreme of exempting bats from wildlife legislation. Bats are exempted from the regulation of international trade in Pakistan (Mickleburgh *et al.*, 1992).

Protection legislation for bats is a vexed subject in India where fruit bats are caught and eaten as food by some local people, and used for medicines to cure headache and female ailments by others. They can be trapped for zoos and laboratory work in any numbers with impunity. Fruit bats are killed in great numbers from time to time due to what is considered as their nuisance value to farmers when they damage crops. On 30th September 2002, the Central government listed two species of bats (*Otomops wroughtonii*, Wroughton's Free-tailed bat, and *Latidens salimalii*, Salim Ali's Fruit bat) on Schedule I of the Wildlife (Protection) Act, 1972, according the highest degree of protection to these threatened species. No other species of Indian bats are protected; in fact, the remaining twelve fruit 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 persecuted with impunity if they prove to be a nuisance to human beings. As insectivorous bats are not listed anywhere in the Wildlife (Protection) Act, 1972, the only circumstance under which anyone can be charged and prosecuted for harming them is within a Protected Area, where every living creature comes under the protection of the Chief Wildlife Warden of the state.

5.5.1 Recommendations

Bats are one of the least studied mammalian groups in the region. Information for many species is based only on museum or literature references, with no recent population or distributional information. So surveys should be carried out, incorporating population and habitat viability analysis especially in Protected Areas. For a thorough understanding of the species status in the wild, it is imperative that surveys are followed by period monitoring. Lack of monitoring will hinder the information about population structure and dynamics of bats of the region.

The role of bats in the regeneration of forests, dispersing seeds and pollen and in consumption of harmful insects has been well documented in scientific paper from around the world. Such biological studies are sparse in Kerala. So such ecological studies should be carried out.

Habitat management is crucial from not only conserving roost areas but also in conserving its source of food. Education should form a part of management as man is the only genuine threat to bats.

Small mammals with smaller area requirements would have been the last one to be affected due to the changes in the landscape and habitat degradation. Smaller mammals are susceptible to the alterations in the habitat and thus could be a good indicator of the habitat health. In general, the development of comprehensive inventories of key vertebrate taxa such as bats derived from a combination of several standardized sampling procedures is essential to develop meaningful, conservation oriented plans for land use and management for protected areas (Sampaio, *et al.*, 2003). Conservation strategies may be improved if information on species abundance pattern is taken into account.

Summary

SUMMARY

Bats are among the most diverse and widely distributed group of mammals and can be found on all continents, and are the second largest group of mammals after rodents. The diversity and abundance of bats is probably attributable to a number of features of their biology that are unique. Bats are the only flying mammals. Bats play a crucial role in the ecosystem, a very simplistic example being fruit bats' task as flower pollinators and in seed dispersal, and that of insectivorous bats in controlling much of the insect pest population.

The present study was carried out to understand the different species of bats present in Peechi-Vazhani Wildlife sanctuary and their habitat preferences. The salient findings of the experiment are summarized below.

1. During the present study period from May 2002 to April 2003, eighteen species belonging to four different families and 184 individuals of bats were collected through mist netting from Peechi-Vazhani Wildlife Sanctuary. This constitutes about 58.07 per cent of the bat species in Kerala and 15.93 per cent of the total bat species in India.

2. A total of 384 mist net hours were spent, out of which 307 mist net hours in moist deciduous and 77 mist net hours in evergreen habitats, in accordance with the proportional area under the two habitats in the sanctuary.

3. Six species of bats were recorded from the evergreen habitat of the sanctuary of which three belongs to Vespertilionidae, two from Pteropodidae family and the remaining one belongs to Rhinolophidae. *Rhinolophus rouxii* was found to be the most abundant species in evergreen habitat followed by *Cynopterus sphinx*.

4. Even though the analysis of data revealed that there was no significant difference between the two habitats, maximum number of species (15) and maximum number of individuals (166) were recorded from moist deciduous habitat. *Cynopterus sphinx* was found to be the most abundant species in the moist deciduous habitat followed by *Rhinolophus rouxii.*

5. Even though moist deciduous habitat recorded maximum number of species and maximum number of individuals, Simpson's index is not much higher (0.32) compared to evergreen (0.28) habitat. The lower value of Simpson's index for both the habitats could be due to predominance of *Cynopterus sphinx* and *Rhinolophus rouxii.*

6. The values of the Shannon diversity index are usually found to fall between 1.5 and 3.5. In the present study, moist deciduous habitat showed higher value (1.63) than evergreen (1.46).

7. Evergreen habitat of the sanctuary showed maximum value for evenness index (0.82) compared to moist deciduous (0.6).

8. Maximum number of individuals (67.9 percent) of bats was obtained from the lower altitudinal range of 100 to 150m above M.S.L. This is five to six times higher than the number of individuals of bats at higher elevation.

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DIVERSITY OF BATS IN PEECHI - VAZHANI WILDLIFE SANCTUARY, WESTERN GHATS, KERALA

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ABSTRACT OF THE THESIS

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ABSTRACT

Bats though constitute the largest mammalian order in India; very little studies have been done on them. This has resulted in a gap in our knowledge about the very basic information about the distribution pattern and status of these mammals. This is true for the bats of Kerala also. The present study to generate information on diversity of bats in Peechi-Vazhani Wildlife Sanctuary was carried out during the period May 2002 to April 2003.

A total of 384 mist net hours were spent, out of which 307 mist net hours in moist deciduous and 77 mist net hours in evergreen habitats, in accordance with the proportional area under the two habitats in the sanctuary.

The result of the study revealed that during the study period a total of 184 individuals of bats were collected through mist netting from Peechi-Vazhani Wildlife Sanctuary. 18 bat species belonging to four families were obtained. This constitutes about 58.07 per cent of the bat species in Kerala and 15.93 per cent of the total bat species in India. The bat families identified were Pteropodidae, Megadermatidae, Rhinolophidae and Vespertilionidae. All the four species of the Kerala fruit bats (Pteropodidae) were recorded from Peechi-Vazahni Wildlife Sanctuary. So also, both the species of the False Vampire bats (Megadermatidae) present in Kerala were also obtained from the study area. Of the other families maximum number of species (seven) was obtained for Vespertilionidae followed by Rhinolophidae (five).

Out of the twenty locations selected for the study, *Cynopterus sphinx* and *Rhinolophus rouxii* were found in nine locations each. Maximum number of species representing all the four families was recorded during the present study from premises of Peechi dam (eight) which is a moist deciduous area. Maximum numbers of individuals were obtained from another moist deciduous habitat, Thamaravellachal and were belonging to three different families. The species obtained were *Cynopterus sphinx*

(Pteropodiade), *Rhinolophus rouxii* (Rhinolophidae), *Rhinolophus fulvus* (Rhinolophidae) and *Megaderma spasma* (Megadermatidae).

Cynopterus sphinx was found to be the most abundant species in the Peechi-Vazhani Wildlife Sanctuary followed by *Rhinolophus rouxii*, *Megaderma spasma*, *Hipposideros speoris* and *Rousettus leschenaulti*. The bat species *Pipistrellus ceylonicus*, *Pipistrellus affinis*, *Pipistrellus coromandra*, and *Kerivoula picta* were showing the minimum abundance (1).

The analysis of the data revealed that there is no significant variation in bat diversity between the two habitats in Peechi-Vazhani Wildlife Sanctuary. Even though there was no significant difference between the two habitats, a close perusal of the data showed that maximum number of species was obtained from moist-deciduous habitat (15). Moist deciduous habitat recorded 166 individuals. Evergreen habitat recorded 18 individuals in six species.

Among the 18 species recorded from the sanctuary, *Pipistrellus affinis* and *Rhinolophus rouxii* are near threatened species as per the IUCN criteria. The remaining sixteen species are coming under the category least concern. *Rhinolophus rouxii* is the second most abundant species in the sanctuary. *Hipposideros speoris* is endemic to south Asia.

Small mammals with smaller area requirements would have been the last one to be affected due to the changes in the landscape and habitat degradation. Smaller mammals are susceptible to the alterations in the habitat and thus could be a good indicator of the habitat health. The development of comprehensive inventories of key vertebrate taxa such as bats derived from a combination of several standardized sampling procedures is essential to develop meaningful, conservation oriented plans for land use and management for protected areas. Conservation strategies may be improved if information on species abundance pattern is taken into account.