Ecology and Biology of Sri Lankan Bats

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Abstract

Although bats represent the largest order of mammals in terms of the number of species, they are one of the least studied in Sri Lanka. The Department of Zoology of the University of Colombo undertook pioneering investigations on the ecology and biology of Sri Lankan bats, which included studies on their distribution, population dynamics, roost characteristics, breeding patterns, diet, social behaviour and parasitological studies. Our results show that the status of bats has considerably changed during the last few decades. In general the numbers of fruit bats (Megachiroptera) has increased, whilst some species of insectivorous bats (Microchiroptera) have become rare. Some of the species recorded in previous studies were not recorded in our survey, which was extended over a period of 5 years. We have identified and described five main types of day roosts of Sri Lankan bats (Tree tops, foliage including tents, caves, buildings and crevices). Some species show the generalist roosting pattern where as some have strict affinity to a particular kind of roost. During the course of our investigations we recorded maternity roosts of several species, details of which were hitherto unknown. Our observations show that Wavul pena cave is occupied by six species of bats making it probably the largest sympatric roost of bats in the world. By banding bats we have shown that bats from other caves (Wavulgalge) migrate to this cave, most probably because of its unique microclimatic conditions. Breeding patterns of Sri Lankan bats were poorly documented and our studies show that the majority of Sri Lankan bat species have well defined annual cycle of reproduction, which may either take place between March ï April or September ï December. Further, breeding periods of bats were closely associated with the rainfall. We investigated the diet of carnivorous bats in Sri Lanka revealed that they feed on vertebrates from all classes. Early studies on chiropteran Parasitology at the turn of the century in Sri Lanka were limited to taxonomic descriptions of bat ecto parasites. An island-wide ecto-parasitic survey including parasite ecology, was initiated in 1995 and is ongoing. The number of bat ecto parasites recorded from Sri Lanka currently stands at 27 genera representing 45 species that embody all major bat ecto-parasitic groups. Our studies show that neonatal mortality is higher in species which form large nursery roosts. We also recorded the cannibalistic behaviour of the Indian false vampire bat, *Megaderma lyra* a phenomenon which was not observed in any species of bats in the world. Bat roosts serve as potential hunting sites for many avain, reptile and mammalian predators. Regrettably, man appeared to be the most vicious predator of bats, at times accounting for the loss of bat colonies in several locations. In addition, indirect activities of man may also be the reason for the decline of bat population in Sri Lanka. In conclusion, our work has contributed significantly to the understanding of the Biology of Sri Lankan bats. We have collected base line data for bats in several fields and some of these were first time records for Sri Lankan bat species.

Key words: Sri Lankan bats, Chiroptera, eco-biology, species diversity, cave dwelling, migration

Introduction

Bats are a group of placental mammals and like us they too are warm blooded, furry, give birth to young, nurse them with milk and groom to stay clean. In fact bats are closer to us than many species of other mammals. The skeletal architecture of a bat's wings show essentially the same design as those in human arms and hands. The brains of flying foxes (Mawavula in Sinhala) have more in common with primates (the order to which humans belong) than they do with other group of mammals. Despite this similarity, bats show some remarkable specializations, which are not seen among any other mammals. Bats are the only group of mammals that are capable of true flight. For this their fore limbs are modified to form a wing, and each wing is composed of a thin layer of heavily vascularised skin, stretched between the batǿs forearm, all fingers of the hand, except the thumb, the sides of the body and the ankle of the hind limb. Contrary to the normal upright posture of other mammals, bats hang by their feet up side down, while at rest. The articulation of the bones in the knee joint of bats is completely different from all other mammals, so that the knee bends forward, the opposite direction to that of all other mammals.

They are nocturnal (active at night) when vision is of little use. Bats have solved the problems of avoiding obstacles and finding their food in the dark by evolving an intricate system of echolocation or sonar. Echolocation is a system of orientation where animals use echos of the sounds (acoustic signals) produced by the animal itself to perceive the environment. Although echolocation is found in few other animal groups such as cetaceans (whales and dolphins), some birds and insctivores (shrews) (Fenton, 1984), the echolocation system of bats is far more superior than in any of these groups and even the sophisticated man made devices such as radar system. The sounds produced by bats during echolocation are extremely short in duration (range: 0.1-200 ms), sometimes 1/1000th of a second (Fenton, 1984, Neuweiler, 1980). These are high pitched (ultrasounds in the range of 20-20,000 Hz) and thus are inaudible to humans. The echolocation sounds produced by bats are of very high intensity and some times as loud as 80 decibels (as intense as the sound produced by a siren of an ambulance). The power of perception of an echolocating bats is comparable, if not superior, to human vision. A bat (even if blinded) can detect wire obstacles, which are thinner than human hair (80 micrometers) in complete darkness. A single brown bat can capture as many as 600 mosquitoes within an hour simply by echolocation. Today, man has copied the principles of the echolocation system (sonar) in the areas of medicine, navigation and fishing, to name a few.

Most probably due to these two unique specialisations - echolocation and flight, bats have become one of the most successful groups of mammals living today. Bats belong to the order Chiroptera and they are the sole members of this order. Over 1000 species of bats have been recorded (Mickelborough et al., 2002) which is almost 1/4th of the total number of mammalian species recorded so far. Chiroptera is the second largest order of mammals in terms of number of species and probably exceed all other such groups in overall abundance. It is divided in to two suborders; Microchiroptera and Megachiroptera. The Megachiroptera (so called fruit bats) are represented by only one family, the Pteropodidae, which are restricted to the Old World tropics of Africa and Asia (Smith,1977). There are over 170 species of Megachiropterans. The modern Microchiroptera are divided into four living super families, Emballonuroidea, Rhinolophoidea, Phyllostomoidea and Vespertilionoidea which indicate the evolutionary affinities among the 17 families. Microchiropterans are a highly diverse group having over 850 species.

Bats, specially the microchiroptrans, have successfully occupied all ecological niches in almost every habitat. Bats are distributed in deserts, rainforests, cities, oceanic islands and many other places except the polar regions. Their widespread distribution and the unique specialisation in morphology, physiology and behaviour have led to a variety of life styles among bats.

Bats exhibit a remarkable diversity in their dietary habits and there are frugivores (fruit eating), nectarivores (nectar feeding), folivores (leaf eating), feeding on flowers & pollen, insectivores (insect eaters), picivores (fish eaters), carnivores (flesh eaters) and sangunivores (those feed on blood). Many Microhiropterans are exclusively insectivorous. 79 out of a total of 169 genera of bats are specialized for feeding on insects. Approximately 29% of the known species of bats, the old world fruit bats (Pteropodidae) and many species of the family Phyllostomidae, are partially or wholly dependant on plants as a source of fruits

Bats are a group of highly sociable animals. Generally bats are gregarious (live in groups) and in fact they form the largest known mammalian congregations, some of which exceed several millions of individuals (eg. Davis cave in Mexico: 20 million bats). Although, highly variable in size, bats are not large animals. Generally megachiropterans are larger and the largest species (*Acerodon jubatus)* weigh about 1.5 kg and has a wing span of 2m.

Microchiropterans are smaller in body size and smallest bat, Kittis hog nosed bat or bumble bee bat (*Craseonycteris thonglongai*) does not weigh more than 2g (body length: 3cm and the wing span 13cm). Incidentally, this is the smallest living mammal in the world.

Despite this remarkable diversity and long evolutionary history, today, bats are considered to be one of the most threatened group of mammals. Since bats cluster in large colonies a million bats can be wiped out in less than five minutes because of easy access and vulnerability. Recent investigations have shown that 60% of bats do not survive infancy; a female has only one infant a year so population recovery is quite slow. It can be well illustrated with the following example. If a pair of meadow mice (also a mammal like a bat) survived a year, they and their progeny could leave a million offspring in a year. An average pair of bats will total three in one year: mother, father, and baby. Since bats play and important role in many eco systems and some are considered to be key stone species, loss of bats could seriously threaten the survival of tropical rain forests. Bats are the major seed dispersers of many tropical plants and trees. The elimination of these bats may cause seed dispersal and tree reproduction to cease. Bats also play an innumerable role in controlling the nocturnal aerial insects many of which are pests of agricultural crops.

Sri Lankan Bats

Historical background

Bats (Order: Chiroptera) represent one of the most successful groups of mammals living In Sri Lanka. Kelaart (1852) recorded 19 species of bats with details on their places of inhabitance and some morphological measurements. The subsequent work on bats carried out by W.W. A Phillips in the 1920ês was far more detailed. This gives an excellent account on the number of species, their general habits, identification features, locations where bat populations were found and important morphometric (body) measurements (Phillips, 1935). However, this study lacks quantitative information on the population sizes of bats. Phillips (1935) work shows that there are 28 species of bats belonging to eight families. This is approximately about 1/3 of the total number of mammalian species recorded by Phillips and as such Chiroptera represents the highest number of species for any mammalian order in the island.

The second revised edition of Phillipôs work was published as ôManual of the Mammals of Sri Lankaö in the early 1980´s in three volumes,(parts. I,II&III) of which part I was exclusively devoted to bats. In the second edition some inaccuracies were corrected by Phillips and changes in the classification and in nomenclature have been incorporated, but otherwise the information given in the second edition remains very much the same as it was in the first edition.

Almost 60 years later, the next survey on the bats was initiated by Rubsamen and coworkers in 1981. However, compared with Phillipôs survey, this was much restricted to species which roost strictly in caves (cave dwelling species) which included a single megachiropteran species *Rousettus leschenaulti,* and 9 species of microchiropterans. Yapa (1992), gives a detailed description on population size of five species of cave dwelling bats, their seasonal variation and daily activity patterns in a single cave at Wellawaya. The studies made by others in the subsequent era (Corbet and Hill , 1992 , Wilson and Reeder, 1993) were entirely based on museum specimens. In 1997, Bates and Harrison re-evaluated the taxonomic status of bats in Sri Lanka, with available museum specimens and these data were backed by some field collections. This work, which can be considered as the latest up date of Sri Lankan bats. shows that there are 30 species of bats in Sri Lanka.

Foregoing overview indicates that after Phillips (1935), distribution of bats in Sri Lanka was not properly documented. The loss of natural habitats, increase in human population and environmental pollution (specially wanton use of insecticides) must undoubtedly have had a serious impact on the bats. Therefore, the validity of the existing records of bats, most of which are based on data collected many decades ago, appeared to be doubtful. Further, no quantitative information is available on the population sizes of different species of bats or their distribution in different climatic zones, which are prime requirements for identifying species which are threatened and need to be conserved and for inclusion in the Red Data Book of the World Conservation Union (IUCN).

Present status

Therefore we (of the Department of Zoology, University of Colombo) initiated a comprehensive research program on the Ecology and Biology of Sri Lankan bats, which is still on going. Our recent investigations, extended for a period of for a period of five years (Yapa *et al*. 2000;Yapa et al. 1996, Digana *et al*. 2001), provides comprehensive data on the status of bat fauna in Sri Lanka for the first time, after Phillips original work carried out in the early 1920´s. A total of 20 species belonging to six families were recorded in this study. The Megachiropterans (Family - Pteropodidae) in the island comprise of four species, *P. giganteus*, two species in the genus *Cynopterus* and the cave dwelling bat *R. leschenaulti*. All four species were rather common species found in many parts of the island. In contrast, it appears that the status of the microchiropterans had changed markedly since the 1920´s. as only, 16 species of microchiropterans were captured during this study. These include single species in families Rhinolophidae (*Rhinolophus rouxii*) and Emballonuridae (*Taphozous melanopogon*), two species in the Family Megadermatidae (*Megaderma spasma, M. lyra*), five species in the Family Hipposideridae (*Hipposideros speoris, H. lankadiva, H. galeritus, H. fulvus, H. ater*) and seven species in the family Vespertilionidae (*Miniopterus schreibersii, Scotophilus heathi, Pipistrellus tenuis, P. ceylonicus, P. coromanda, M. cyclotis, K. picta*).

All three species of Megachiropterans recorded by Phillips (1935) were recorded in this study. Two species in the genus *Cynopterus* are reported to be found in the Indian subcontinent *C. sphinx* and *C. brachyotus*. Phillips (1935) included both of these species in *C. sphinx*. As there were some differences as to body size and the colour of the pelage he classified the larger (fore arm length 64-72 mm), lightly coloured individuals as *C. sphinx sphinx* and the smaller individuals (forearm length: 56 ï 64) as *C. sphinx ceylonensis.* Bates and Harrsion (1997) looking at the character matrix, reported that these two subspecies are in fact two different species and classified them as *C. sphinx* and *C. brachyotus*. Mapatuna et al. (2002) by using advanced taxonomic techniques such as DNA finger printing techniques (a multi-disciplinary study between Department of Zoology & Department of Chemistry, University of Colombo) have now confirmed that these are indeed two different species.

Among the 16 species recorded by Yapa *et al.* (1996, 2000) both species of false vampire bats and all hipposiderids recorded by Phillips (1980) were captured. However, only a single species in horseshoe bats and also in sheath tailed bat are found in the present study, although Phillips had recorded two species in both families. Thus they have not recorded *Rhinolophus bedomei* and *Taphozous longimanus*. In addition, *Pipistrellus affinis,* *Kerivoula harwickei*, bats in the genera, *Hesperoptenus, Myotis* and *Tadarida* were also not recorded in this study.

By comparing the colony sizes of identified colonies Yapa et al (2000) have stated that the number of fruit bats, specially *R .leschenaulti,* in the island are increasing rapidly. Thus, it is clear that the change in the environment by loss of habitat and suitable roosts have accounted for considerable change in the status of bats in the island. On one side the species which rely on forests for food and roosting sites are diminishing while those who are able to co exist in human settlements are increasing in numbers. It is not only the loss of forests that resulted in change in the population sizes of bats. Many species of bats roost in old buildings, specially in kovils (eg.Sri Ponnambalavaneswarar Devasthawam Kovil in Kotahena) and in temples (eg. Isurumuniya, Thalaguli Viharaya, Hasthikuchchiya). It was evident that with the renovation of these buildings, bats were excluded from these places (Yapa et al. 2000). Regrettably bats are hunted in many parts of the island as a cheap source of meat or believing that meat of bats is good medication against some diseases such as asthma.

In our view it appears that numbers of bats recoded in Sri Lanka is under estimated and a higher species diversity in Chiropterans can be expected in Sri Lanka. This is quite evident when we compare the bat fauna of the island with that of the Indian sub continent. Although six of the seven families found in the Indian Subcontinent (except family: Rhinopomatidae) are found in Sri Lanka, the representative species found are far less. In the indian subcontinent a total of 119 species were found in 35 genera. In contrast only 30 species (15 genera) were recorded in the island, including work of Philips (1935, 1980), Corbet and Hill (1995), Bates and Harrison (1997). Specially families Pteropodidae (4 vs 14), Rhinolophidae (2 vs 16) Hipposideridae (5 vs 15) and Vespertilionidae (12 vs 59) are under represented compared to their overall presence in the subcontinent. In addition, none of these species are endemic to Sri Lanka, which itself is surprising when compared with the number of endemic bird species, which are also equally mobile. Thus further island wide investigations and surveys, are essential to inventories the bat population in Sri Lanka.

Size and shape

In general, megachiropterans (Mawavula) are larger compared to microchiropteran (Kiriwavula) The common flying fox is the largest bat living in Sri Lanka (body weight: around 1.5 kg: body length: approximately 25cm). where as the Indian pigmy bat (*Pipistrellus tenuis)* is the smallest bat (Length: 4cm; body weight: 4-5g*)*. In the eyes of the many bats are not colourful animals and general notion is that bats are dark coloured animals. Although this is true in most cases, there are some brightly coloured bats, such as the painted bat *(Kerivoula picta*) which usually haunts banana plantations in several parts of Sri Lanka. The entire body apart from the parts of the wing, is bright orange or tawny red in colour, where as middle parts of the wing is conspicuously black. Thus this bat appears more like a brightly coloured moth and often referred to as ðkehel wavulaò by the villagers since it often roosts among dried leaves of banana plants. In Wavulgalge we recorded an albino bat of the species *H. lankadiva*, which was seen in this cave for a period over a year. Albinism in bats is rather rare and this is the first record of an albino bat in Sri Lanka (Yapa et al.2000b).

Diet

In general, Bats show a remarkable diversity in diet which include fruit eating, nectar feeding, carnivory and also highly specialised forms such as sanguinivory (taking a meal of blood) as observed in the vampire bats. Phillips have recorded the food habits of many of the species studeis by him, but most of these are casual references. In a recent study Yapa et al. (1999) at the Department of Zoology, University of Colombo, have investigated the food preferences of a fruit eating bat *Cynopterus sphinx* in semi-natural conditions. In these experiments they have given the choice of three types of fruits, Mango (commercially cultivated), guava typical home garden fruit and almond (a wild fruit) to the bats and the results showed that although the bats consumed all three types of fruits, guava was the most preferred where as the mango was the least preferred fruit. Their observations also showed that bats prefer ripe fruits over raw and the authors claimed that loss to the commercial cultivations can be minimised by plucking the fruits raw. They also of the view that presence of wild fruit varieties such as almond would reduce the damage to the economically important fruits.

In recent investigation (Nandasena *et al*. 2000; Goonatilake *et al.* in press) of the Department of Zoology, University of Colombo, examined the food habits of the false vampire bats, *Megaderma lyra* and *M. spasma* which are claimed to be semi carnivorous species. In a detailed investigation which includes collection of prey remainings below the feeding perches and faecal analysis, they have shown that both of these species have a wide dietary spectrum. *M. lyra* feeds on larger insects (mainly Colepterans) and vertebrates which includes amphibians, smaller reptiles such as house geckos, birds and smaller rodents such *Mus* species. (Nandasena et al., 2000, 2002a). One of the most interesting findings in this study was their observations on the cannibalistic behaviour of adult *M. lyra*. Although *M. lyra* is known to feed on other species of bat this is the first record of cannibalistic behaviour of any species of bats in natural conditions. In addition, we have recorded that *M. lyra* also feed on fish which was not observed in Sri Lanka up to now. *M. lyra* also feed on array of invertebrate prey. Colepterans (beetles) were the most abundant prey item in faecal pellets. However, parts of the other arthropods such as Arachnids (spiders) also recorded in the faecal pellets,

In contrast the diet of *M. spasma* mainly consists of invertebrates. All invertebrates recorded were insects (class: Insecta), which includes the species from orders Coleptera, Encifera, Calsifera and Hemiptera (unpublished personal observation).

Roosting

Although bats are found to roost in bizarre of places, the main types of day roosts of Sri Lankan bats include i. Tree tops, ii. Foliage & tents, iii. Caves iv. Buildings and v. crevices/cracks/ tree holes.

The observations on the roost selection of the Sri Lankan bats suggest that some bats species were highly selective in their roosting preference where as some could be termed as "generalists" which may roost in several types of day roosts. *P. giganteus* was always found on exposed branches; i.e. open tree roosts (Digana et al. 2000a; Yapa et al. 2003). *M. schreibersii, R. rouxi, H. lankadiva* and *R. leschenaulti* can be described as species which showed a clear affinity to caves (Yapa et al. 2000) and some (*M. lyra*) were always found in buildings. *Pipistrellus* spp. were usually found in crevices or cracks. In contrast, *H. speoris* and *T. melanopogon* were found in several types of day roosts which consisted of caves, culverts, buildings etc.

Out of the 19 species recorded, only common flying fox, *P. giganteus* formed large communal roosts on branches of trees, in the open. It appears that the open day roosts are the norm for this species in Sri Lanka (Phillips 1980, Yapa *et al.* 2003) as well as elsewhere (Neuweiler, 1969; Pierson & Rainey, 1992). Day roosts of the common flying foxes are a familiar sight in many parts of the country, both in the urban areas (Mawanella, Viharamaha Devi Park, Colombo, Royal Botanical Garden, Peradeniya, Pinnawala) as well as in the rural areas. Phllips (1935) reports a colony of the Common flying foxes in Warakapola. Even today a large colony of flying foxes can be seen in Warakapola, along Kandy Road and most probably this may be the roost described by Phillips.

However, the day roosts of the other species appeared to be quite different from those of the common flying foxes. For example the day roosts of *Cynopterus* is unique in that they quite often actively constructed a "tent" like structure. In Sri Lanka this is the only genus which construct tents and these tents were always found on the talipot palm (Digana *et al.* 2003). Most probably because of this habit, thy are referred to as "*thala wavula*" by the villagers. The tent construction is closely related with the social organisation of this species and the tents were constructed by males in anticipation to attract females to form harems. Thus a tent population consists of one adult male, several females and their offspring.

Cavities in the tree trunks and branches also offer favourable shelter for many species. According to Yapa (2000) only *M. spasma* and *Pipistrellus ceylonicus* were found in tree holes in Sri Lanka. However, there are many reports on the species which roost in this type of environment, both in the new world and old world (Kunz, 1982 and references therein). In the old world tropics, Rhinolophidae and Hipposideridae are reported to roost in tree cavities (Brosset, 1962 in Kunz 1982) but in Sri Lanka the members of these genera were never found in tree holes. Most probably several other species, specially smaller vespertilionids such as *P. tenuis* which form smaller colonies may roost in tree cavities, but the difficulty in locating these roosts may be the reason for under representation of species that occupy this type of roost.

Most of the caves, which are totally dark, serve as roost sites for many species of bats and it can be said that bats are the only group of vertebrates that have successfully exploited such caves as permanent roosts. Large numbers of species are reported to be cave dwelling. In temperate countries, caves provide ideal roost for hibernating bats, as often the cave environment is very stable. This stability in the micro habitat of caves are favoured for raising the young. Often, not only the resident bats use caves with satble microclimate, but also for some migrating bats that may roost in smaller satellite caves (Brosset, 1962; Van der Merwe 1975). In Sri Lanka, s*everal species such as H. lankadiva, Miniopterus schreibersii* and *Rhinolopus rouxi* can be described as strictly cave dwelling species. None of these species were found in any other type of day roost. In addition, some species were (*T. melanopogon*, *H. speoris*, *H. fulvus, H. ater* and *R. leschenaulti)* were also found predominantly in caves, but they were also found, some times, in buildings.

The cave populations of bats can be described as the largest known mammalian congregations as some times the numbers run in to many hundred thousands (Brosset, 1966, Kunz 1982). In Sri Lanka two large populations were found in Wavul Galge (in Koslanda) and Wavulpena cave (Ambilipitiya). Wavulgalge is an underground cave with 4 entrances, which provide shelter for five species (*R. rouxii, H. lankadiva, H. speoris, M. schreibersii, R. leschenaulti*) of sympatric bats and the overall population size was about 100,000 individuals. It is a maternity cave for all occupying bats except *M. schreibersii* (Yapa, 1992). Wavul pena cave is a lime stone cave which has a tunnel like appearance with two main entrances. A river flows through the cave so that cave floor is permanently covered with water through out the year. The cave roof is highly porous with large number of cavities which serve as roosting chamber for the bats. Because of these unique features the microclimate inside the cave is completely different from many other caves in Sri Lanka. In certain areas of the cave, the relative humidity is as high as 90 ï 100% and the ambient temperature is around 24 C. These unique specializations have made this a very favourable roost for bats, specially for raising pups. Thus nurseries of all roosting species were found in this cave. It is the only cave in Sri Lanka where a nursery *M. schreibersii* was found. This cave also harbours the largest bat roost in Sri Lanka with over a population of 200,000 individuals.

For several species, buildings and other similar anthropogenic structures serve as favourable roosts. Some species such as *Megaderma lyra* has only been found in buildings. Phillips (1935) describing the roosting habits of this species, indicated that it is predominantly found in buildings, though occasionally found in caves or plumbago pits. In contrast to cave dwelling, there is no definite advantage in roosting in a building. On the contrary if the building is occupied by humans, it can cause a lot of disturbance to the roosting bats. Several other species such as *R.. .leschenaulti, H. speoris, H. ater, H. galeritus, T. melanopogon* have been found in buildings. But all these species have been found in some other type of day roosts, often in caves. Thus it is apparent that these species have no strict affinity to a particular day roosts and may occupy any, which provide them adequate shelter. This type of multi roosting ability of these species may be an advantage over a strict cave dweller, as this enables them in colonizing in many areas where variety of roosts are available.

Most probably their roost selection of *Pipistrellus tenuis* and *Pipistrellus ceylonicus* was influenced by their body size (body weight: 4-5 g) and these usually do not hang freely as many of the other species. They roost in smaller crevices, usually in buildings. The presence of several individuals in such a roost may increase the roost temperature which is advantages for a smaller mammal like *Pipistrellus*. Once we found that several Pipistrels in a torpid condition in the early evening although ambient temperature was around 26°C. Phillips (1980) also reported a similar observation. Thus it can be said, with respect to thermoregulation and accompanied problems associated with smaller body size, crevices offer them best roosting conditions.

Generally Pipistrells are known as generalists in terms of their roosting habits as they were not selective in their choice of roost with respect to the characteristic of the building where they roost This is illustrated by the variety of roosts found during this study. Bats were found in many types of crevices (between roof tiles, inside the wooden frames of a light meter, cracks wooden pillars of temples etc.). Thus it is likely that these two species will generally not be limited by the availability of buildings and may occupy smaller crevices of any type of structure. However, since the colony size is comparatively small and as they are nocturnal these colonies may often go unnoticed.

A close relationship has been observed between the roost type and the colony size of the bats. Always the larger colonies were formed by species which roost in caves. In addition open roosts of flying foxes are also massive in sizes. The colonies found within buildings are of medium size. Finally smaller roosts were formed in tents, tree holes and crevices.

A population in a roost may consist of a single species or in certain cases several species may be roosting together in a single roost. Such mixed species assemblages are known as sympatric associations. In Sri Lanka many caves are sympatric associations. In Wavulpena cave seven species are roosting sympartically (*R. rouxii, H. lankadiva, H. speoris, H. fulvus, H. galeritus, M. schreibersii, R. leschenaulti*) and this is the highest number of sympatric species recorded in Sri Lanka and probably in the world. Sympatric association may be a resulting from lack of proper roosting sites and possible among only a particular combination of species which do not compete with each other for food. However, this type of mixed species associations should not be viewed as a forceful conditions as sharing a day roost has several advantages. Improved energy economy (as presence of large number of individual may increase the roost temperature) may be one definite advantage. (Kunz 1987) indicated that postnatal growth rates and post flight survival of *Myotis grisescens* is severely reduced if the colony size is too small to sufficiently increase roost temperature. In addition another potential benefit derived from interspecific roost association is reduced predation (see Novick, 1977, Kunz 1982). Some disadvantages in sharing a roost with other species are the misdirected social behaviour, increased competition for food and roosting sites, increased incidence of parasites and disease. Thus sympatric roosting is possible only among a particular combination of bats.

Ecto Parasites of Sri Lankan Bats

Early studies on Chiropteran Parasitology in Sri Lanka are sparse, confined to a few in the early 20th century. These were limited to taxonomic description of bat ecto parasites mostly on a few specimens of preserved bats (Scott, 1908, 1914,1925; Phillips, 1924,1980; Thompson, 1937). Scott in his work (1908, 1914, 1925) reported twelve species of Nycteribiid bat flies on 21 different bat hosts. In Phillipsõs subsequent study (1924), in addition to Scottõs findings, he reported 3 genera of Streblid bat flies including one endo-parasitic fly, a polyctenid bug and 8 forms of unidentified mites. Thomsponõs (1937) work revealed the presence of 8 nycteribiid species previously recorded (Scott, 1925), Streblids of 3 genera, a flea and a mite. He also attempted to record the microhabitat of these ecto-parasites. Both Scott (1925) and Thompson (1937) based their work on a few specimens provided from the systematic collection of bats made by Phillips in 1922 and 1923. A catalogue of nycteibiid flies of the Rothschild collection (Theodore, 1967) lists 67 species, of which some were from Scottõs material from Ceylon. In 1950, Turk reported several new species of bat mites from Sri Lankan fruit bats. More recently, Uchikawa (1985) studied mite species from specimens of *Miniopterus schreibersi* that are deposited in the European museums, some which were taken from Sri Lanka.

The paucity of information for approximately 70 years, led to the undertaking of a detailed island-wide ecto-parasitic survey from 1995 to 1998 on both mega and microchiropterans. This revealed 14 species of bat flies, 2 speceis of bugs, 2 species of fleas, a tick species and 5 species of mites (Randeniya et al, unpublished; Weerakkody *et al*., 1999). More recently Seneviratne *et al* (2002a) reported, thirty-three species of ecto parasites collected from six species of cave-dwelling chiropteran hosts, including 8 nycteriibid bat flies, 8 streblid bat flies, a single bat flea, 4 ticks and 14 mites. This study increased the number of bat ecto parasite genera known from Sri Lanka from 19 to 27. These include new records of a streblid genus *Megastrebla*, a hard tick genus *Haemaphysalis*, two genera of soft ticks *Argus and Ornithodoros*, a spinturnicid mite *Spinturnix* and three genera of trombiculid mites *Whatonia, Chiroptella* and *Rudnicula*. This lead to the description of two new species of mites, *Whatonia ratnasooriyai* and *Chiroptella kanneliya* (Brown et al, 2003). The rest of the genera (n= 14) confirmed previous records.

Foremost studies on bat parasite population and community characteristics were made by Randeniya and co-workers (unpublished) and Weerakkody *et al.* (1999). The latter reported the incidence, prevalence and density of parasite fauna harboured by three species of cave-dwelling microchiropterans. Of the recorded ecto-parasites, with the exception of two streblids and individuals of the three mite families, the others were host specific. This study concluded that the prevalence of ecto-parasites is neither dependant on the gender of the host nor the climatic zones of their roosting sites. In a subsequent study, the host specificity of bat ecto-parasites showed a monoxenous trend in the island (Seneviratne *et al*, 2002b). All Nycteribiids and the Ischnopsyllid bat flea, 85% of Streblids, 77% of mites and 75% of ticks were strictly host specific among a large sample of ecto parasites collected from six species of cave dwelling bats. The endo-parasitic Streblid fly also showed strict specificity to its host and to the microhabitat on it. The less specific (polyxenous) ecto parasites depicted two types of host preferences supported by statistical analysis.

Reproduction

Breeding pattern of Sri Lankan bats have not been well documented - apart from the observations made by Phillips (1980) - until recently (Digana et al. 1997; Yapa et al. 1989). According to Phillips (1980) majority of bats give birth either between February and April (*R. luctus, R. rouxii, H. galeritus, H. ater, M. lyra)* or from September to December *(P. mordax, S. heathi, M. cyclotis, T. melanopogon).* However, there were some species of which the breeding pattern did not conform to this pattern and gave birth at the different times of the year (*P. tenuis, C. sphinx*). Phillip had never attempted in a prolonged study of breeding of Sri Lankan bats and all the observations were based on the status of the individuals at the time of capture (whether they were carrying a young or pregnant etc.). Thus it is not possible to get an accurate picture about the breeding pattern (whether these species are mono oestrous or polyoestrous) of these species. Moreover, he had not observed the breeding periods of some species *(K. picta, M. schreibersii, H. lankadiva*).

Yapa (1992; Yapa et al. 1989) examined the reproductive behaviour of five species of sympatric cave dwelling bats. These observations indicated two peaks of reproduction between February to April (*H lankadiva*) and September to December (*R. rouxi, H. speoris* *and R. seminudus*). Thus, all four species of microchiropterans had a single annual peak of reproduction where as *R. leschenaulti* showed a bi modal pattern of reproduction. This study also showed that the breeding periods of bats were closely linked to the prominent rainy seasons of the area.

However, there are some discrepancies with regard to the breeding periods of bats between these two studies. Although Phillips (1980) reported that *R. rouxii* gave birth in April May season, according to Yapa (1992) this species has a very well defined breeding period, which takes place between September and November. His observations are in agreement with the breeding periods recorded for this species in India (Sreenivasan et al. 1973). Thus it was not clear whether the breeding period of *R. rouxii* has changed since the 1920´s or whether there exists more than one breeding cycle for *R. rouxii* in Sri Lanka. In a recent investigation, we have recorded two breeding cycles of *R. rouxii* (Yapa et al. 2000). In many locations (Wavul Galge, Wavul Pena cave, Ridee Viharaya) the breeding took place at the latter part of the year (between September & November). However, in a few colonies (Sthripura cave in welimada) the breeding took place between April and May.

In a recent study, made by Yapa et al (2000) breeding periods of different species, their cyclicity and associated behaviour was studied in detail, which describes the breeding periods of two species of Megachiropterans and majority of microchiropterans. This is the first study, after Phillips observation in the early 1920´s, which attempted to record the breeding periods Sri Lankan bats. Further, it records the breeding periods of *M. schreibersii* and *K. picta* for the first time in Sri Lanka.

According to them *Cynopterus sphinx* (Megachiroptera) and two species of Microchiropterans, *Pipistrellus tenuis* and *P. ceylonicus* have aseasonal reproductive cycles, without well defined breeding periods. In contrast, a majority of microchiropterans inhabiting in Sri Lanka showed a highly seasonal monoestrus reproductive cycle with a very strict parturition. In all seasonal breeding bats, the breeding cycle closely followed the prominent rainy seasons of the island, either from February to April or from September to December. Thus this study provides further evidence to the widely held view that rainfall is the major determinant of the timing of the reproduction among the tropical bats through its effect on the food supply (Usman 1981, Mc William, 1997, Mc William 1998a, Mc William, 1998b, Miller et al. 1988). The breeding cycle of *Hipposideros ater, H. fulvus, H. galeritus, H. lankadiva, Megaderma lyra* and *M. spasma* were closely related with the first rainy season of the year from (March - April). The breeding cycles of *R. rouxii* and *H. speoris* coincided with the second rainy season of the year between September to December. In all cases parturition of all pregnant females is highly synchronised and all the pups were born within 2-3 weeks.

This type of reproductive synchronization also has a definite advantage. In many species of bats the young are born in a rather immature state, without fur, eyes closed and they first hear after the 1st postnatal week (Rübsamen 1987). These young bats are poikilothermic in their early postnatal age and as such are unable to control the body temperature by themselves. Being completely naked (without fur) the young bats are subjected to bigger losses of body heat. According to Kunz (1987) neonates behave in various ways to minimize this heat loss such as clustering, facultative torpor and selection of more suitable hanging places. We have observed in several species (*R. rouxii, M. schreibersii*) the young bats form densely packed nursery colonies and thus maintain a higher body temperature than the ambient temperature in the roost.

We also believe this may be one of the reasons for the migration observed during the breeding period. A selection of a day roost that is very stable is highly advantages for bats in terms of thermoregulation. However, many smaller roosts do not provide such stable environment and as such are not suitable for raising the young. Thus it is advantageous for many of these bats to migrate to a suitable roost (maternity roost) for parturition. Another advantage is that since the births are highly synchronized mere presence of large number of neonates facilitate formation of a large cluster, which is useful in effectively elevating the temperature within the cluster. Migration however may have several functions as will be addressed in the next section, bats may also be migrating to rainy areas, which are rich in food, particularly if the areas where they are roosting experience severe weather conditions.

Migration

In many of the maternity caves, fluctuations of the population size were observed during the breeding periods (Yapa 1992, Yapa et al. 2000). These fluctuations have resulted in the significant change in the sex ratio favouring females. During this period around 90% of the population consists of pregnant females. Based on these observations the authors were of the view that pregnant females are migrating into the maternity caves from other smaller caves in the area. In this context during the investigations in Wavul Galge since 1986 some interesting observations, which were not observed for any other bat species in Sri Lanka, have been made by Yapa (1992). According to him the onset of the breeding period was marked by a significant increase (by about 4 fold) of the colony size of *M. schreibersii* due to migration of bats into the cave. During this time the colony of *M. schreibersii* mainly consisted of pregnant females. However, the population sizes gradually decreased by the latter part of the pregnancy period and after a few weeks from the initial migration, *M. schreibersii* were absent in the cave. Based on this information Yapa (1992) was of the view that Wavul Galge resembles a pre-maternity cave as specified by van der Merwe (1975). Although the site of the parturition (maternity cave) was not known, he predicted that these bats may be migrating to Wavul Pena cave where a large colony of *M. scheribersii* was inhabiting. In subsequent observations they (Yapa et al. 2000) have recorded the same pattern of behaviour in Wavulgalge. Since they already have recorded a nursery colony of *M. schreibersii* in Wavulpena cave they hypothesized that bats from some smaller colonies migrate to Wavulpena for parturition and that these bats temporally roost in Wavul Galge on their way to Wavulpena where parturition takes place. In order to test this hypothesis they have banded and released over 650 bats in Wavulgalge and subsequently sampled the colony of bats in Wavulpena cave (Yapa et al. 1998, Yapa et al. submitted). During this process they have captured over 1700 *M. schreibersii* in the Wavulpena cave and among them 6 were those banded at Wavulpena cave. This work clearly show that bats from Wavul Galge migrate to Wavulpena cave for parturition.

This study presents the details of the breeding pattern of *M. schreibersii*, for the first time in Sri Lanka. The marked (four fold) increase of the population size in Wavul Galge indicates that many bats first migrate to Wavul Galge probably from other smaller caves. Since a significant number of banded bats were caught in Wavulpena cave it can be presumed that these bats migrate to Wavulpena cave from Wavul Galge for parturition. Further, it also indicates that for bats of several colonies, the site of parturition is Wavulpena cave. The fact that bats banded at Wavul Galge were found in Wavulpena (during this time they were absent in Wavul Galge) and subsequently these marked bats were found again in Wavul Galge, indicating that these bats migrate from Wavul Galge to Wavulpena and are returning to Wavul Galge after parturition. Thus, this confirms the hypothesis that bats from unknown locations first come to Wavul Galge on their way to Wavulpena cave and pass again through Wavul Galge during their journey back.

This is a clear indication that Wavul Galge is a pre-maternity cave and that Wavulpena is a maternity cave as described by Van der Merwe (1975) for South African species. Bats first migrate to Wavul Galge probably from smaller colonies and use it as a temporary roost until they migrate to Wavulpena cave (which is about 50 km away from Wavul Galge) for parturition. Sex ratio at Wavul Galge during the breeding period is heavily female biased and as such the majority of invading bats to Wavul Galge are pregnant females. However, when migrating to the maternity cave, even the males migrated with the females as marked males were caught at Wavulpena. Moreover, we did not capture any males in Wavul Galge after August.

The factors that draw bats first to Wavul Galge and then to Wavulpena or their preference to Wavulpena cave over Wavul Galge for parturition are not clear. However, Yapa et al (submitted) attribute two factors which may be related this pattern of migration *of M. scheibersii,* the microclimate in the Wavulpena cave and the overall abundance of the inset prey fro the mothers. In Wavulpena caves the temperature was about 24 °C, i.e. 4 °C less than that of Wavul Galge, and also this was the lowest temperature recorded in a cave in Sri Lanka. Further the humidity in the nursery roost (in Wavulpena cave) was about 95 percent, an increase of 15percent compared to Wavul Galge and also to many other caves. Another important factor which determines the site and the time of parturition is the relative abundance of prey items for lactating mothers and newly weaned pups. The breeding period of *M. schreibersii* (June to August) coincides with the South - West monsoon, which brings the largest amount of rainfall to the South Western low lands around Wavulpena area (Baldwin 1991).

This study provides strong scientific evidence for the proposed hypothesis that bats from Wavul Galge are migrating to Wavulpena cave for parturition. Thus it is clear that Wavul Galge is a pre-maternity cave and Wavulpena cave is a maternity cave. The parturition of *M. schreibersii* is highly synchronous as all young were born within three weeks. The migratory behavior observed in South Africa was identical to the observation made in this study. This shows even with latitude and other geographic differences, the migratory behavior of *M. schreibersii* with respect to breeding remains unaltered.

Mother infant relationship

Like many other mammalian species, bats also take meticulous care of the young. In many species (*R. rouxii, M. schreibersii)* the pups are naked (without body fur), blind and deaf during the early post natal stage. They are poikilothermic (unable to control their temperature) during this period. Because of this, in certain species, the mothers carry the pups even when they leave the day roosts in the evening for foraging (e.g. most of fruit eating bats and some microchiropteran such as *H. speoris, Pipistrelus tenuis)*. In contrast, many species of microchiroptera, specially those roost in caves, leave their pups before they leave the day roosts for foraging. In the absence of their mothers, the neonates (young pups) form densely packed clusters and Yapa (1990) reports that over 150 pups aggregate in an area of 400cm$^{2.}$ This form of clustering is described a strategy used by young bats to reduce the thermoregulatory cost (Kunz, 1987). However, Yapa (1992) reports that there is a constant movement of the pups in the clusters and as a consequent to this movement a lot of young pups are dropped to the ground. Although some of these dropped pups are retrieved by the mothers, when they returned to the roost in the morning, this causes the highest neonatal mortality of this species. In an interesting observation Brosset (1962) reports that other than the mothers, other females in a colony of *M. schreibersii* also engage in retrieval activity of the dropped pups. In many cases the young bats are cabable of flying when they are about 2 months old and they are nursed by mothers with milk until such time

Several species are known to carry pups with them in the evening flight, but do not carry them when they are foraging (hunting) as this would reduce their movement (manuerability). These species hang the pups in a location close to their respective foraging areas and return periodically to nurse the pup. On one occasion we have observed that *M. lyra* adopted this strategy and hung its pup in an isolated area in the day roosts before leaving the roost for foraging. In the absence of the mother the pup remained motionless, however this pup was detected by another adult *M. lyra* and was immediately captured and eaten (Nandasena *et al*. 2001, 2002b). Our observations showed that *M. lyra* indeed cannibalised on pups of the conspecifics (not the mother) and in fact about 30% of pups are eaten by the adults. Interestingly this is the first observation of the cannibalistic behaviour of a bat species in natural condition.

Mortality

As in many other species, the mortality is highest in the early postnatal age. As described in a preceding section in the horseshoe bats, there is a high neonatal mortality because of the falling of the pups from the nursery colony. Many of these pups are unable to crawl back to the nursery sites and become victims of many ground dwelling predators such as rats and some times even to the cockroaches which infest the caves in large numbers. Even if they are not preyed, still the fallen pups may die because of the starvation unless they are retrieved by the mothers. Digana et al. (1997) estimated that as much as 33% of the pups of the horse bats die this way before weaning. In many instances, the young bats become easy prey for predators. In a recent study we have observed that a rat snake regularly hunting pups of a cave dwelling species of bat, *Miniopterus schreibersii,* and a single rat snake consume over 20 pups during a visit (a day). Then in a very rare incident, we have observed that adult *M. lyra* feed on its pup. Cannibalism is not observed in bats and in our observations the pups were eaten by an adult member of the group (not the mother) and in this colony over 30 percents of pups were eaten by the adults.

Most probably because of their nocturnal habit and mode of locomotion, the adult mortality rate of bats are comparatively low. Consequently there is very little information on the predation of adults. In a recent study Digana et al. (2000b) of the Department of Zoology, University of Colombo, reported 9 vertebrate predators of Sri Lankan bats which includes reptiles (rat snake & cobra), birds of prey (crested hawk eagle and Brown hawk eagle) and mammals (domestic cats, dogs, golden civet cat and the black palm civet cat). All of these predators sit and wait in the vicinity of the day roosts of bats and quite often capture out flying bats. However, surprisingly the most vicious predator of the bats is the man himself. To our astonishment and utter dismay, we have found that bats are regularly hunted in large numbers at several locations. Bats are hunted either as a chief source of meat or because of the belief that consumption of bat meat is a remedy to cure many respiratory. This wanton killing of bats has indeed a reduce the bat populations in many areas. For example Rubsamen *et al.* (1989) has recorded bats in Rawana Ella cave and Batadombalena in 1989. However, when we visited this cave in 1996 the cave was completely devoid of bats. In Bogala mine in Avissawella, a population of over 200 *H. lankadiva* was once disappeared from it due to hunting bats. However, now the cave is again occupied by bats.

Apart from hunting indirect activities of humans have caused a serious decline in bat population in Sri Lanka. The numbers of many insectivorous species are in the decline due to use of pesticides and loss of foraging habitats (forest) and day roosts. This decline is not restricted to a single location and populations of bats are declining all over the world. For example in the Eagle Crack Cave in Arizona, which was once considered as the largest known bat population of the world, has a population of 30 million bats in 1960. This was a decline by 99% just in 6 years. In certain locations 100% decline has been reported (e.g. Durango, El Olmo) and already 4 species of bats are known to be extinct.

Bats are slow breeding animals and usually produce only a single pup per year. For a example a pair of meadow mouse would leave a population of half a million offspring in a year, but at the end of the same year a pair of bats would leave only a single pup. Thus recovery of bat population is very slow. Sri Lanka is endowed with the highest numbers of plant and animal species per unit area in the world. One of the Sri Lanka richest natural resource is undoubtedly its biological diversity (Baldwin, 1991) and bats account for a high degree of species richness. At the beginning of the last century bats were the largest mammalian order accounting for 1/3rd of the mammals of the island. Bats play a very important role in the control of nocturnal insects, most of which are pest. For example *S. heathi*i in Sri Lanka was known to be exclusively feeding on the coconut beetle. Many other species feed on pests of cotton, potatoes etc. They fly as high as 3000m to intercept high altitude migrations of agricultural pests. Our estimates show that the bats in Wavulpena cave along consume over 150 kg of insects within a single night. They also play an Innumerable service in pollination of economical important plants and seed dispersal. Thus today it has become a prime necessity to conserve the remaining species of bats and this can only be achieved by understanding their biology and ecology, which are necessary for developing management plans for conservation of bats. Consorted effort of the public, researchers and policy makes is required to conserve this important group of animal, which are so close to us phylogentitically and a friend in need.

In conclusion we at the Department of Zoology, University of Colombo have contributed immensely in understanding the biology of the Sri Lankan bats and some of the observations we have made are novel findings for this important group of mammals.

References

Baldwin, M. F. 1991. Natural Resources of Sri Lanka: Conditions and Trends. Keels Business System Ltd. 280p.

Bates, P. J., D. L. Harrison. 1997. Bats of the Indian Subcontinent. Harrison Zoological Museum Publication. 258p.

Bradbury, J.W. 1979. Behavioural aspects of reproduction in Chiroptera. J Reprod. Fer.56:431-438.

Brosset, A. 1962. The bats of central and western India. . J. Bombay Nat. Hist. Soc. 59: 707-746.

Brown, W. A., Udagama-Randeniya, P. V. and Seneviratne, S. S. (2003) Two new species of Chiggers (Acari: Leeuwenhoekiidae and Trombiculidae) from bats(Chiroptera) collected in the Kanneliya forest reserve of Sri Lanka, *Internat. J. Acarol*.,**29**, No. 1, 69-73.

Corbet, G. B. and J. E. Hill. 1992. The mammals of the Indomalayan Region; A systematic review. Natural History Museum Publications, Oxford University Press. 156 ï 160.

Digana, P M C B, Yapa,W.B. , Randeniya, P V ., Ratnasooriya,W D. 2000a. Roost selection of Sri Lankan bats. *Proceeding of the .1st Annual .Sessions, University of Colombo, Sri Lanka,* 39pp.

Digana, P M C B., Yapa,W.B. , Randeniya, P V., Ratnasooriya,W D. 2001 Present status of Sri Lankan bats. Proceedings of IOB 21st Annual Sessions. P21.

Digana, P.M.C.B., Yapa, W.B., Randeniya, P.V, Ratnasooriya, W. D. 1997a. Neonatal mortality of rufous horse shoe bat *Rhinolophus rouxii,* (Chiroptera) in a maternity colony Wavul-Galge in Sri Lanka. Proceedings of IOB 17th Annual Sessions. P. 17.

Digana, P.M.C.B., Yapa, W.B., Randeniya, P.V., Ratnasooriya, W. D. 1997b. Breeding pattern of Schneiders Leaf nosed bat *Hipposideros speoris* (Microchiroptera) in Sri Lanka. Proceedings of the SLAAS 53rd Sessions. P 243.

Digana, P.M.C.B., Yapa, W.B., Randeniya, P.V., Ratnasooriya, W. D. 2000b. Predators of Sri Lankan bats. *Loris*. 22 (4):46-48

Digana, P.M.C.B., Yapa, W.B., Randeniya, P.V., Ratnasooriya, W. D Roost 2003 (in press) Selection of the short nosed fruit bat, *Cynopterus sp.* (Pteropodidae: Chiroptera) in Sri Lanka. J of Science, University of Kelaniya (in press).

Digana, P.M.C.B., Yapa, W.B.,Randeniya, P.V.,Ratnasooriya, W. D. 1996. Roosting pattern of some Sri Lankan bats. Proceedings of SLAAS 52nd Sessions. P 149

Fenton, B. 1984. Echolocation: Implication for ecology and evolution of bats. The Quaterly Review of Biology.59: 33-53.

Goonatilake, MRNP, Schmidt, S, Ratnasooriya, W. D, Yapa, W.B. Frog composition in the diet of the Indian False vampire bat *Megaderma lyra*: Observations in a natural population in Sri Lanka. (*Lyriocephalus*- accepted for publication

Kelaart, E.F. 1852. Prodromus Faunae Zeylanicae. Colombo. 197.

Kunz, T. H. 1987. Post-natal growth and energetics of suckling bats . In Fenton, M.B., Racey, P. and Rayner J.M.V. (Edts.). Recent Advances in the study of bats. 395-420. Cambridge University of Press. Cambridge.

Mapatuna, Y., Gunasekera. M., Ratnasooriya W.D., Goonesekere N.C.W. Bates PJJ. 2003. Unravelling the taxonomic status of the genus *Cynopterus* (Vhiroptera:Pteropodidae) in Sri Lanka by multivariate morphometrics and mitrochondrial DNA sequence analysis.Mamm. Biol.67:321-337.

Mc Willliam, A. N 1990. Mating system of the Bat *Miniopterus minor* (Chiroptra: Vespertilionidae) in Kenya, East Africa: a Lek? Ethology. 85: 302-312.

Mc Willliam, A. N. 1988. The reproductive cycle of male long fingered bat *Miniopterus minor* (Chiroptera: Vespertilionidae) in an seasonal environment in African tropics. J. Zool. Lond. 216: 119-129.

Mickleburgh, S.P., Hutson, A.M., Racey P.A. 2002. A review of the global conservation status of bats. Oryx.36(1):18-34.

Nandasena M N.P., Yapa, W.B. , Schmidt, S., Ratnasooriya, W.D.. 2002a. Diet of the Greater False Vampire bat, *M. lyra* Geoffrey, 1810, (Chiroptera; Megadermatidae) in Sri Lanka determined by fecal analysis. . Proceedings of IOB 22nd Annual Sessions. P21.

Nandasena M N.P., Yapa, W.B. ., Ratnasooriya W D. ,Schmidt S. 2002. Evidence for infanticide in A Sri Lankan colony of Indian false vampire bats. Proc 1st European Behavioural Biology, 41.

Nandasena, M.N.P, Yapa, W.B. , Schmidt, S., Ratnasooriya, W.D.. 2002b. Are bats cannibalistic? Evidence from the Indian False Vampire bat, *Megaderma lyra*. Proceedings of IOB 21st Annual Sessions. P 19.

Nandasena, M.N.P., Yapa, W.B. , Schmidt, S., Ratnasooriya, W.D. 2000. Diet composition of greater false vampire bat, *Megaderma lyra* at Baddegama, Sri Lanka. Proceedings of IOB 20th Annual Sessions. P38.

Neuweiler, G. 1980. How bats detect flying insetcs. Physics Today. 34-40.

Novick A (1987). Acoustic Orientation. In Wimsat W.A. (ed) Biology of bats. Academic Press, New York, San Francisco, London pp. 73-287.

Phillips, W W A (1924) , Ectoparasites of Ceylon Bats, Ceylon Journal of Science, **13**, 65-70.

Phillips, W W A (1980), *Manual of the mammals of Sri Lanka* (2nd revised ed.),Wildlife and Nature Protection Sociaty of Sri Lanka

Phillips, W. W. A. 1935. Manual of the Mammals of Ceylon. Ceylon Journal of Science. 363p.

Phillips, W. W. A. 1980. Manual of the Mammals of Ceylon. Wild Life and Nature Protection Society of Sri Lanka. (2nd Rev. edition) 23-116.

Scott H (1908), On a large series of *Nycteribiidae*, parasitic Diptera, from Ceylon, Trans. Ent. Soc. Lond., Part iv: 421-429

Scott H (1914), On some oriental Nycteribiidae (Diptera, Pupipera), The Annals and Magazine of Natural History, **14,**209-235

Scott H (1924) Zoo geographical and systematic notes on the Nycteribiidae (Diptera Pupipera) of India, Ceylon and Burma., *Rec. Ind. Mus.*, **27**,351-383

Seneviratne, S. S. and Udagama-Randeniya, P. V. (2002a), Ecto parasites of cave dwelling chiropterans in selected roosts of the wet and intermediate zones of Sri Lanka, Proceedings of the 22nd Annual Sessions of the Institute of Biology, Sri Lanka, p 41-42.

Seneviratne, S. S., Fernando, C. and Udagama-Randeniya, P. V. (2002b), Specificity of Ecto parasites of three cave dwelling Chiroptera (*Rousettus leschenaulti, Rhinolophus rouxii,* and *Hipposideros speoris)* in selected cave roosts of Sri Lanka, 58th Annual Sessions of the Sri Lanka Association for the Advancement of Science, p. 166.

Smith, J. D. 1977. Comments on flight and evolution of bats. In Hecht, M.K., P.C. Goody & B.M. Hecht. (eds). Major pattern of vertebrate evolution. NATO Advanced study institute series. Series A. Life Science. 14, New York: Plenum Press.

Srinivasan, M.A. , Bhat, H. R., Geevarphese, 1973. Breeding cycle of *Rhinolophus rouxii* . Temmick 1835. (Chiroptera:Rhinolophidae)., in India Journal Mamml.54(4):1013-1017.

Theodore, O (1967), *An illustrated Catalogue of the Rothschild collection of Nycteribiidae (Diptera) in the British Museum (Natural History),* Trustee of the British Museum (Natural History) London.

Thompson, G B 1937), A census of the Ectoprasites of some Ceylon Bats, J*. Anim. Ecol***., 6,**337-339.

Turk, F.A. (1950), Parasitic Mites from mammalian host obtained in Ceylon, Parasitology*.,* **40**,63-76.

Uchikawa, K. (1985), Mites of the Genus *Calcarmyobia* (Acarina, Myobiidae) with information of the Taxonomy of their host bats of the Genus *Miniopterus* (Chiroptera, Miniopteridae), *Bull. Br. Mus. Nat. Hist. (Zool),* **48(1)**,15-25

Van der Merwe, M. 1973. Aspects of social behaviour of the Natal clinging bat *Miniopterus schreibersii natalensis*. Mammalia. 37:379-389.

Van der Merwe, M. 1975. Preliminary study on the Annual Movements of the Natal Clinging Bat. S. Afri. J. Sci. 71:237-241.

Van der Merwe, M. 1987. Adaptive breeding strategies in some South African bats between 22°S and 28°S. Suid-Afrkaanse Tydsrif vir. Wetenskap. 83:607-609.

Weerakkody, A S A, Randeniya, P V and Ratnasooriya, W D (1999), Ecology of Ecto Parasites of Some Cave Dwelling Microchiropterans of Sri Lanka, Vidyodaya J Sci, **8**:198-210.

Yapa W.B., Randeniya, P.V. Ratnasooriya W.D. 2002, Ecology and Biology of Bats in Sri Lanka. A suyver on the dIstributin of bats in Sri Lanka. Final Report. NSF (RG/95?B/5)

Yapa, W.B., Digana, P.M.C.B, Randeniya, P.V., Ratnasooriya, W. D. (2003)Roost Selection of the Common Flying Fox, *Pteropus giganteus* (Pteropodidae: Chiroptera) in Sri Lanka. *Zeleynica* (in press)

Yapa, W.B., Digana, P.M.C.B., Randeniya, P.V., Ratnasooriya, W. D. 2000,First Record of an albino bat in Sri Lanka. *Loris*. 30(1):31

Yapa, W.B., Digana, P.M.C.B., Ratnasooriya, W.D., Rübsamen, R, Costa, H.H., Randeniya, P.V.. 1998. Breeding associated migration of *Miniopterus schreibersii* between two natural caves in Sri Lanka. Proceedings of IOB 19h Sessions. P 21.

Yapa, W.B., Digana, P.M.C.B.,Randeniya, P.V.,Ratnasooriya, W. D. 1996. Some observations on the distribution and abundance of the microchiropteran bats in the wet zone of Sri Lanka. Proceedings of IOB 16th Sessions. P. 4

Yapa, W.B., Kumarasinghe, J, Digana, P.M.C.B, Randeniya, P.V., Ratnasooriya, W. D 1999. Food preferences (three fruit types) of Sri Lankan short-nosed fruit bat *Cynopterus sphinx* (Chiroptera) in a semi-natural condition. Vidyodaya J. Sci. 8:109-116

Yapa, W.B.,Rübsamen, R , Ratnasooriya, W.D.,Costa, H.H.. 1996. The pattern of reproduction of some cave dwelling bats in Wavul Galge, a natural cave in Uva province of Sri Lanka. Proceedings of SLAAS 45th Sessions. P 84 (1989)

Yapa. W. B. 1992. Ecological and ethological studies of cave dwelling bats in Sri Lanka. M. Phil Thesis, University of Colombo. Sri Lanka.