Interconnections between morphological design and function are central to biology. They underlie natural patterns in species distribution, phylogenetic diversification, and morphological specialization. At its core, ecology and morphology explores the causal relationships between organismal design and behavioral performance and investigates how these relationships influence an organism’s ability to exploit its environment (Swartz et al. 2003).

Bats are among the most diverse and widespread mammalian species on Earth. Approximately 1,240 chiropteran species are known and they are distributed on all the continents (except Antarctica) inhabiting a wide variety of ecological niches (Hill and Smith 1984, Nowak 1994, Hutson et al. 2001, Simon 2005a, Schipper et al. 2008). Bats are important component of the ecosystem. There are many indications to say that they have a significant ecological role in environments where they dwell (Fagan et al. 1999, Parmesan et al. 2000, Gotelli and Colwell 2001, Henle et al. 2004, Colwell 2006, Anne et al. 2011). Despite their importance, however bats are regularly neglected in biological studies in terms of both their ecology and distribution.
Quite a few number of bat species are listed under the International Union for the Conservation of Nature’s Red List of Threatened Species and are of global conservation concern (Mickleburg et al. 2002). Mammalian species diversity is greatest in the tropics between approximately 20° North and South of the equator (Johnsingh 1986, Kaufman and Willig 1988, Willig 2001, Menon et al. 2001). The process that drive bat species diversity includes long periods of relative stability, high energy availability and higher rates of speciation that occur as a result of high temperatures causing shorter generation times, higher mutation rates and accelerated selection pressures (Willig et al. 2003). Due to ecological and evolutionary radiation, bats occupy virtually every trophic level, from primary to tertiary consumer levels (Fenton et al. 1992, Bernard 2001). Bats constitute 25% of the total number of world’s mammals. According to IUCN Criteria Version 3.1, India has 120 species of bats representing 7 families of Microchiroptera and one family of Megachiroptera. About 45 species of bats occur in the Western Ghats and peninsular India and most of them inhabit Tamil Nadu (Kumar 1993, Vanitharani 2004, Korad et al. 2007).

**Bat bionetwork**

The two suborders of bats, Megachiroptera (megabats) and Microchiroptera (microbats) both occur at their peak richness in the tropics. They combine a range of features that make them excellent bioindicators of human-induced changes with respect to climate change and habitat quality, including a cosmopolitan distribution with high functional and taxonomic diversity (Koopman 1994, Neuweiler 2000, Magurran 2004, Jones et al. 2009). Moreover, many species fulfill key ecosystem services. Megabats include fruit and blossom bats generally use vision and smell to
locate food and play an important role in the dispersal of seeds and pollination of flowers. Microbats are termed “insectivorous bats” and are using echolocation for the navigation and to detect prey items. The ecological role microbats play in the environment is less clear than that of megabats (Simmons and Conway 2003). Foraging activity of microbats have a regulatory effect on insect populations which has direct economic implications on insect pest control (Douce et al. 2002, McCracken 2004, Cape nature 2004, Boyles et al. 2011). Microbats also serve as indicators of environmental health and quality in the tropics (Ehrenfeld 1983, Probst and Crow 1991, Richards and Hall 1998, Medellin et al. 2000, Ochoa 2000, Mudappa et al. 2001, Jones et al. 2009, Kunz et al. 2009, Hayes et al. 2009, Boyles et al. 2011). They have several attributes that make them as useful indicators of environmental change. They occupy every trophic level and have specialized diets and specific habitats for roosting and foraging (Medellin et al. 2000).

Plant-visiting bats are the pollinators of many economically important commercial/forest species; as seed dispersers, they greatly assist reforestation (Howe 1984, Appanah 1990, Ayyappan and Parthasarathy 1999, Vanitharani et al. 2009, Cole et al. 2010, Malleshappa 2012); insect-eating bats are known as nature’s pesticides, play a critical role in controlling agricultural pests and forest pests (Sophia 2006, Vanitharani 2008, Marais and Durand 2009). Chiropteran assemblage should be a welcomed guest in any ecosystem, but in India they are subjected to public apathy by causing unintentional mass killing in roosts.

Bats are highly sociable mammals and they show high level of inter-specific association (Brosset 1962a, Altringham 1996). Social organizations of bats in day
roost are very important for the maintenance of ecosystem (Brigam and Fenton 1986, Graham 1988, Arita and Vargas 1995, Foster and Kurta 1999, Srinivasulu and Srinivasulu 2001). The recent awareness of bats as an important biological resource has resulted in increased state and federal agency scrutiny for conservation.

**Bat taxonomy**

The classification of bats used today is based on the system developed by Miller in 1907. He classified 16 families of Microchiroptera on the basis of their bone structure. The family usually unites a number of related genera. Genera are sometimes divided into two or more subgenera, and families similarly into subfamilies (Hill and Smith 1984). Recent application of new and modern techniques and molecular phylogenetic studies has changed the traditional classification and proposed that the bats can be subdivided into two new suborders, Yinpterochiroptera (includes the families Pteropodidae, Rhinolophidae, Megadermatidae and Rhinopomatidae) and Yangochiroptera (includes all the remaining families) (Teeling *et al.* 2005). But still, the species is the lowest major category in classification (Hill and Smith 1984).

**Bat species distribution**

Compared to all other mammalian orders, bats have even greater concentration of species in the tropical zone. India, being a tropical country has an incredible diversity of bats excellent models for biodiversity science programs as they are diverse with over 120 species by representing 20% of India’s mammalian species and include rare, endemic taxa that provide key ecosystem services. The order Chiroptera makes a strong contribution to the overall mammalian pattern in the New
India inhabits 8 families of bats including the horseshoe bats. The tropical plains and forest area of Tamil Nadu encompasses 45 bat species representing 8 families (Vanitharani 2004). The distribution status has classified them into two categories. 30 bat species as forest bats and 23 bat species as bats of foothills and the adjoining tropical plains. Among them 12 bat species are distributed both in the forest and plains (Vanitharani 2007). Availability of suitable roost influences the distribution and abundance of bats.

**Bats as bioindicators**

Bats display a high number of roosting and feeding specialisations and play key functional roles in ecosystems (Williams *et al*. 2008, Marais and Durand 2009, Kunz *et al*. 2011). In light of their diversity and importance, bats have enormous potential as biodiversity, ecological and environmental indicators. The studies of Pineda *et al*. (2005), Kalcounis (2005) and Jones *et al*. (2009) has summarised a number of general parameters that make bats ideal indicators of human-induced climate change and habitat quality. Forest-dwelling bats are sensitive and respond to anthropogenic habitat fragmentation and disturbance. Insectivorous bats in particular have been used as indicators of wildlife toxicology as they have a number of characteristics that make them suitable for use as indicators of general environmental conditions (Macswiney *et al*. 2008, Racey 2009). Bio-indication through acoustics expression by bats is an attractive feature through which the goals of environment

**Bats and forest ecosystem**

Bats use forest habitats for two main reasons: roosting (Barclay and Kurta 2007) and foraging (Patriquin and Barclay 2003). Roosts are critically important for bats because they provide shelter, protection from potential predators as well as a location to mate, raise young, hibernate, and socially interact with other individuals (Kunz and Lumsden 2003, Barclay and Kurta 2007, Ormsbee et al. 2007). Bats spend over half of their life in roosts. Many bat species select tree cavities for roosting for at least part of their life cycle (Barclay and Kurta 2007). Roosts are selected according to a range of morphological characteristics and roosting pattern differ according to the season as well as in relation with individual features and physiological conditions (sex, age class, reproductive phase, etc.) (Grindal and Brigham 1999, Russo et al. 2004, Barclay and Kurta 2007, Russo et al. 2007). Roost switching has been proposed to be a response to avoid predators or disturbance, disrupt parasite life cycles, select specific microclimate requirements, get closer to feeding sites, maintain social relationships between small groups of individuals spread over large forest areas (Lewis 1995, Whitaker 1998, Kerth and Konig 1999, Willis and Brigham 2004, Russo et al. 2005, Popa et al. 2008). Forest loss or alterations affect their vital activities and lead to a decline in their populations. Bats are long lived and slow reproducing mammals (Altringham 2011). Therefore, they are vulnerable and put at risk by the loss of habitats. Since bats are important contributors to global mammal diversity and provide key ecosystem services, the
Bat morphology

Morphology provides the set of tools that organisms use to interact with their physical environment (Dumont 1997a). The relationship between an animal’s structure and its interactions with its environment are complicated and multifactorial. Morphology dictates an individual’s performance limits and restricts its behavioral repertoires; regardless of habitat, a bat cannot fly faster or eat larger prey than its anatomy will allow. However, while morphology constrains potential activities, the ecology of an animal is also strongly influenced by the local environment in which it functions day to day. Bats exploit a wider range of food types such as insects, amphibians, fish, fruits, nectars and pollen than any other mammalian order. This wide range of dietary niches is reflected in their morphological diversity such as wing and skull (Vaughan 1959, Kunz 1982, Kunz and Fenton 2003).


Feeding apparatus and the morphological aspects enable partitioning of food resources among bats (Norberg 1994, Norberg and Rayner 1987). Flying animals need different wing designs to do flight performance to match their ecological role. To suit their diet preference bats show considerable diversity in their wing morphology (Fenton 1972) and flight style (Neuweiler 1989) to match their foraging behaviour (Norberg 1987, 1989, Habersetzer and Storch 1989, Vanitharani 1996, Jeyapraba 2008).

**Bats acoustics and foraging in forest**

Insect eating bats forage by producing sound waves and detect the prey through echolocation (Pierce and Griffin 1938, Schnitzler *et al.* 2003). Through their sophisticated “biosonar” mechanisms, echolocation call structure tells a lot about their habitat utilization (Schnitzler *et al.* 2003). Both echolocation and wing design are clearly adapted to perform, the best in habitat exploitation (Norberg 1990).

Occurrence of different “microhabitats”, like small-scale habitat structures, within the forests makes coexistence of several species including bats in the same area possible with little or no competition for food. The cluttered structure of forest
interior and the noisy leaf litter covers makes acoustics prey detection a difficult task. To solve it, bats rely on broad-band echolocation calls, offering high discrimination performances (Siemers and Schnitzler 2004). In addition, microbats rely on passive listening, the detection of subtle “acoustic glints” [the noise from the moving prey against a structurally complex background] (Faure and Barclay 1992, Churchill 1994, Parsons and Jones 2000, Schmidt \textit{et al.} 2000, Schnitzler and Kalko 2001a b, Russo \textit{et al.} 2007a). Besides echolocation, vision and olfaction also help bats in prey detection. Forests offer bat foraging habitats such as small ponds and rivers which are typically insect-rich habitats. Overall forest ecosystem preserves a variety of habitat structures or heterogeneity which is crucial to host a diverse community of foraging bats (Anonymous 2005b).

Conclusion

The above reviewed literatures and earlier bat diversity survey reports of Vanitharani (2004) and Jeyaprabha (2008) has provoked to study more specifically on the horseshoe bats comprised under the family Rhinolophidae who are the common bats of the forest ecosystem. The present investigation has been designed to study on the ecomorphology, acoustics, activity pattern and their impact in the different forest habitats of Kalakad Mundanthurai Tiger Reserve (KMTR). This Reserve is situated in the south Western Ghats of India. The study area comprises forest habitats ranging from open forest at elevations of approximately 1000 m to 4000 m ASL. Various research reports by the earlier scientists worked in the study area confirms the richness of floral and faunal diversity including bats of KMTR (Govindarajulu and Swamy 1958, Henry and Subramanyam 1981, Henry et al. 1984, Parthasarathy and Mahadeva 1987, Ganesh et al. 1996, Gopalan 1997, Hajra and Mughal 1997, Henry and Gopalan 1995, Parthasarathy 2001, Johnsingh 2001, Vanitharani 2004, 2005, 2007).

The distribution state of *Rhinolophus* has revealed that there are four species of *Rhinolophids* exist in the study area: *Rhinolophus indorouixii* (Rufous Horseshoe Bat), *Rhinolophus pusillus* (Least horseshoe bat), *Rhinolophus lepidus* (Blyth’s horseshoe bat) and *Rhinolophid beddomei* (Lesser Woolly Horseshoe Bat). A common challenge in the study of these bats as pest control is the lack of basic ecological information regarding foraging behaviour and diet. These bats play a key role as bioresource management and thereby help to conserve biodiversity.
The conservation of these bats in KMTR is essential to maintain the ecosystem services which assist in the preservation of forest ecosystem. The present research project is to do an indepth study on the morphology and then correlate with the activity patterns in the habitat ecosystem. Therefore the protocol is formulated to encompass the following objectives.

- Ecology and morphology of rhinolophids of KMTR.
- Acoustics and activity patterns of horseshoe bats of KMTR.
- Impact of *Rhinolophus* species in the ecosystem of KMTR.