A Taxonomic Review of *Hipposideros halophyllus* Hill and Yenbutra, 1984, *Hipposideros ater* Templeton, 1848, and *Hipposideros cineraceus* Blyth, 1853 (Chiroptera: Hipposideridae) in Thailand and Myanmar

Bounsavane Douangboubpha

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Ecology (International Program)
Prince of Songkla University
2008

Thesis Title A Taxonomic Review of *Hipposideros halophyllus* Hill and Yenbutra, 1984, *Hipposideros ater* Templeton, 1848, and *Hipposideros cineraceus* Blyth, 1853 (Chiroptera: Hipposideridae) in Thailand and Myanmar
Author Mr. Bounsavane Douangboubpha
Major Program Ecology (International Program)

Major Advisor	**Examining Committee:**
……………………………………….	.....………………………...Committee
(Asst. Prof. Dr. Sara Bumrungsri)	(Assoc. Prof. Dr. Kitichate Sridith)
	.....………………………...Committee
Co-advisor	(Dr. Chavalit Vidthayanon)
……………………………………….	.....………………………...Committee
(Assoc. Prof. Dr. Chutamas Satasook)	(Asst. Prof. Dr. Sara Bumrungsri)
……………………………………….	.....………………………...Committee
(Dr. Paul J. J. Bates)	(Assoc. Prof. Dr. Chutamas Satasook)

The Graduate School, Prince of Songkla University, has approved this thesis as partial fulfillment of the requirements for the Master of Science Degree in Ecology (International Program).

………………………………………...
(Assoc. Prof. Dr. Krerkchai Thongnoo)
Dean of Graduate School

Thesis Title	A Taxonomic Review of *Hipposideros halophyllus* Hill and Yenbutra, 1984, *Hipposideros ater* Templeton, 1848, and *Hipposideros cineraceus* Blyth, 1853 and (Chiroptera: Hipposideridae) in Thailand and Myanmar
Author	Mr. Bounsavane Douangboubpha
Major Program	Ecology (International Program)
Academic Year	2007

ABSTRACT

A taxonomic review of *Hipposideros halophyllus* Hill and Yenbutra, 1984, *Hipposideros ater* Templeton, 1848, and *Hipposideros cineraceus* Blyth, 1853 (Chiroptera: Hipposideridae) in Thailand and Myanmar was undertaken between 2006-2007. The study assesses the taxonomic status, acoustic data, distribution, conservation status and ecology of these three small species of the *Hipposideros bicolor* group and clarifies their diagnostic characters through a detailed study of their external, cranio-dental and bacular morphology. Important findings include the first published data on the acoustic and bacular characters of *Hipposideros halophyllus*, Thailand's only endemic bat species. In addition, seven new localities of this endangered species (IUCN criteria) were discovered, one of which represents a range extension of 435 km into northern Thailand. The study also includes new distributional and ecological data for *H. ater* and *H. cineraceus*; new acoustic data for *H. cineraceus* and highlights taxonomic differences between specimens of *H. ater* from India and those currently referred to this taxon from Myanmar.

ACKNOWLEDGEMENTS

I would firstly like to thank Assistant Professor Dr. Sara Bumrungsri, who is my advisor; Associated Professor Dr. Chutamas Satasook, who is my co-advisor; and Dr. Paul J. J. Bates, who is my co-advisor; without all of them this study would not have been possible.

Thanks are due to Thesis Examining Committee, including Associated Professor Dr. Kitichate Sridith of Department of Biology, Faculty of Science, Prince of Songkla University, and Dr. Chavalit Vidthayanon of World Wildlife Fund – Thailand, for their correction and valuable suggestion.

Thanks are due to the students of the Bat Research Unit, Department of Biology, Prince of Songkla University, including Pipat Soisook, Phouthone Kingsada, Ariya Dejtaradol, Phansamai Phommexay, Sunat Karapun, Tanongsak Jongsiri, Tuanjit Srithongchuay, Anchana Thaisauriyan, Uraiporn Pimsai, Hathaikhwan Jansod, Kwan Nualcharoen, Medhi Yokubol, Piyathip Piyapan, and Booppa Pongsee for their help in field and also in laboratory. In addition, I would like to thank the staff of the Princess Maha Chakri Sirindhorn Natural History Museum, Prince of Songkla University for their help in the laboratory. I am also most grateful to the staff of the Chiang Dao Wildlife Research Station, Thailand for the loan of specimens and help in the field. Elsewhere, thanks are due to all lecturers of Department of Biology, Faculty of Science, Prince of Songkla University for their lecture and help when I was studying. Moreover, I would like to thank the drivers of Faculty of Science, and Mr. Vorraphong Phulphiphith, the driver from Bangkok for their help in the field.

In the UK, I thank the staff of the Mammal Section of the Natural History Meseum, London for their help in accessing the collection. At the Harrison Institute, I would like to thank David L. Harrison for his help and suggestion, and Malcolm Pearch for his help during my study visit to the UK. Elsewhere, I would like to thank Sébastien Puechmaille of University College Dublin for his advice and data on leaf-nosed bats in both Myanmar and Thailand.

In Lao PDR, I would like to thank Associated Professor Dr. Bounnam Phathumthong of Department of Biology, Faculty of Science, the National University of Laos, who was my advisor, co-ordinator and supported this project in Lao PDR. In

addition, I would like to thank Ms. Chanthima Phonthalith, a lecturer of Department of Biology, Faculty of Science, the National University of Lao for help me before came to study. Moreover, I would like to thanks the staff of the Centre for Environment and Development Studies, the National University of Laos for their supporting to study in this project. I am most grateful to Faculty of Science, the National University of Laos. Thanks are due to the Ministry of Education and Ministry of Affair for help and support. Thanks are due to Dr. Arlyne Johnson and all staff of Wildlife Conservation Society-Lao Program for their help and support, and gave experience when I was working there.

I would like to thank the Graduate School, Prince of Songkla University and the British Government for their financial support of the project through the Darwin Initiative. Without all of the above and the collaboration of many others, this study would not have been possible.

Finally, I would like to thank my family, especially my mother and older brother for their support and encouragement all time. I am also most grateful to all Lao's people for their encouragement.

Bounsavane Douangboubpha

Table of Contents

Table of Contents (Continue)

Appendixes

List of Tables

List of Figures

List of Figures (Continue)

List of Figures (Continue)

List of Figures (Continue)

List of Figures (Continue)

List of Figures (Continue)

CHAPTER 1

INTRODUCTION

As recently noted by Guillén-Servent and Francis (2006), the taxonomy of bats in the genus *Hipposideros* has been complicated by the morphological similarity of many species and the lack of adequate field collections in many regions of the Old World tropics. This is particularly the case with respect to the *Hipposideros bicolor* group, where despite a series of papers since Tate (1941) and Hill (1963) describing several new species (Khajuria, 1970; Hill and Yenbutra, 1984; Kock and Bhat, 1994; Francis *et al*., 1999; Guillén-Servent and Francis, 2006; Bates *et al*., 2007) and a number of additional publications, which have contributed to an understanding of the taxonomy and phylogeny, for example Jenkins and Hill (1981) and Bogdanowicz and Owen (1998), there remains considerable taxonomic confusion. This in turn had led to a lack of authorative information on species diagnosis, distributions, ecology and population status.

The *H. bicolor* group is the largest group in genus *Hipposderos*. There are 35 species worldwide (Simmons, 2005; Guillen-Servent and Francis, 2006), including 7 species found in Thailand (Bumrungsri *et al.* 2006) and 4 species found in Myanmar (Bates *et al.* 2000). In this group, there are two species that are very similar in the shape of the noseleaf, size of external and cranial morphology, and have an overlapping frequency of echolocation call. These two bats are: *H. ater* Templeon, 1848 and *H. cineraceus* Blyth, 1853.

H. cineraceus closely resembles *H. ater* in size and shape of the noseleaf. According to Hill (1963), and Payne *et al.* (1985), the internarial septum of *H. cineraceus* is distinctly expanded in the middle; but in *H. ater*, it is expanded at the base and narrowed in the middle. However, Suyanto and Struebig (2007) found that it is difficult to consistently discriminate these two species in this feature. In addition, these two bats are significantly different in baculum shape. The baculum of *H. cineraceus* has a bifid tip, but *H. ater* has simple tip (Topál, 1975; Bates and Harrison, 1997). Moreover, these bats differ in skull shape; there is a well-defined jugal projection on the zygomata in *H. ater*; it is absent in *H. cineraceus* (Bates and Harrison, 1997).

In these bats, the frequencies of echolocation calls of *H. cineraceus* are 135.0-159.6 kHz, and *H. ater* is 139.6-169.5 kHz. The echolocation calls varies from place to place. In Malaysia, *H. cineraceus* has a higher peak frequency of 151.0 kHz (Heller and v. Helversen, 1989; after Could, 1979), and 154.0 kHz (Francis and Habersetzer, 1998); whereas in specimens from Kuala Lompat, the frequency of echolocation call is 144.0 kHz (Kingston *et al.* 2000). In Thailand, the frequency was recorded at 135.0 kHz (Robinson, 1996) and in Vietnam at 159.6 kHz (unpublished data of Vuong Tan Tu). In Sabah, Borneo, the peak frequency of *H. ater* was 139.5 kHz (Francis and Habersetzer, 1998), in Australia 154 kHz (Heller and v. Helversen, 1989, after Fenton, 1982) and in India 163.1-169.5 kHz (Jones *et al.* 1994).

Corbet and Hill (1992) indicated that *H. ater* and *H. cineraceus* overlap in their distribution in many parts of Thailand. However, Yenbutra and Felten (1986) reported the presence of only locality of *H. ater*. Later, the bat specimen identified as *H. ater* from Khao Bin Cave by Yenbutra and Felten (1986) was named as a new species, *H. halophyllus* (Hill and Yenbutra, 1984). Thus, it is not clear whether *H. ater* is present in Thailand. Since these two bats are very similar, some specimens of *H. ater,* if present, may have been referred to *H. cineraceus* and *vice versa*.

H. halophyllus Hill and Yenbutra, 1984 is similar to *H. ater* and *H. cineraceus* in size of external and cranial characters, but clearly differs from both in the shape of internarial septum, which is kidney-shaped (Hill and Yenbutra, 1984). In the *H. bicolor* group, it was previously reported that a number of species show marked intraspecific variation in external and cranial morphology and size and the frequency of the echolocation calls was also found to differ between populations (Francis and Habersetzer, 1998). The intraspecific variation within *H. halophyllus* had not previously been investigated.

In this particular study, three species of small hipposiderid from the *bicolor* subgroup of the *bicolor* group (sensu Corbet and Hill, 1992) were studied in an area of western mainland Southeast Asia, where all three were reported to co-exist (Yenbutra and Felten, 1986; Corbet and Hill, 1992). The study was based on extensive recent field work in Thailand (2006-2007), and in Myanmar based on specimens in the collections of the Princess Maha Chakri Sirindhorn Natural History Museum, Prince of Songkla University, the Harrison Institute and the Natural History Museum, London, and a thorough review of the existing literature.

CHAPTER 2

LITERATURE REVIEW

2.1. ORDER CHIROPTERA

The origin and evolution of bats diversity remain poorly understood, but the roots of the chiropteran radiation clearly go back to at least the early Tertiary (Hill and Smith, 1984; Simmons and Conway, 2003). A scanty representation in the fossil record is often cited as the prime reason for the lack of evolutionary knowledge concerning bats. Approximately 30 fossil genera (representing eleven families) have been described. In addition, 37 living genera have been discovered in the fossil record, many of these occurring in bat faunas of the Ice Age. These 67 genera, consist of 40 fossil bat species and another 92 species that are still living; many of latter lived in the Ice Age (Hill and Smith, 1984). The fossil record of bats extents back to the early Eocene (approximately 60 million years ago). Twenty-four genera of Eocene bats are currently recognized, and at least nine of these were present in the early Eocene. Bats have been documented (earliest record in parentheses) on six continents: Europe (Eocene), Africa (Eocene and Oligocene), Asia (Miocene), North America (Eocene), South America (Miocene), and Australia (Eocene) (Hill and Smith, 1984; Simmons and Conway, 2003). However, the origin of bats is not known since (first), the majority of the fossils are highly fragmentary (isolated jaws and teeth in most cases) and (second) all fossil bats, even the oldest, are clearly fully developed bats and so they shed little light on the transition from their terrestrial ancestor (Hill and Smith, 1984).

The origin and evolution of bats evolves primarily around the origin of the wing and the development of its use in sustained flight. Wings have evolved independently at least three times among terrestrial vertebrates, including pterosaurs (Reptiles), birds (Aves), and bats (Mammals). These wings all vary in their structure and probably evolved under different circumstance. The pterosaur wings is perhaps most similar to that of a bat. Both are membranous and both rely upon modified fingers to support the flight membrane. There are a number of other parallels between pterosaurs and bats, such as marked body shortening; involvement of the hindlimb in the flight membrane; use of dorsal and ventral thoracic muscles to operate the wings; and various modifications of the tail. Pterosaurs apparently were a moderately successful group for many millions of years and were moderately diversified (Hill and Smith, 1984).

The earliest known insectivorous bat is *Icaronycteris index* (from the bat fossil record), which was recorded from Eocene (53 million years ago) of the Polecat Bench formation of Wyoming, USA (Hill and Smith, 1984; Altringham, 1996; Neuweiler, 2000; Simmons and Conway, 2003). It was thought to be intermediate between the two chiropteran suborders, Megachiroptera and Microchiroptera. This notion was based largely on the fact that the index or second finger of the wing has a strongly developed claw, a feature found in most living megachiropterans, but absent in all living microchiropterans (Hill and Smith, 1984; Neuweiler, 2000). Nevertheless, Neuweiler (2000) proposed that this bat does not provide any clues as to which tree-dwelling or ground-dwelling mammal might have been the first to take to the air.

The earliest megachiropteran is *Archaeopteropus transiens*, which is represented in the fossil record in the Oligocene of Venetia, Italy (35 million years ago) (Hill and Smith, 1984; Altringham, 1996). It has all of the post-cranial features of a pteropodid including a clawed index finger (Hill and Smith, 1984). But Neuweiler (2000) noted that it is also belonged to this extinct microchiropteran-like superfamily, Paleochiropterygoidea. The first true megachiropteran is thought to be the extinct African species, *Prototto leakeyi* from the early or middle Miocene period (20 million years ago) (Neuweiler, 2000), with the dentition adapted to a fruit eating diet (Bates and Harrison, 1997).

If the Megachiroptera and Microchiroptera shared a common ancestor, and they must in order to be considered closely related, then that ancestor must have had somewhat less insectivorous teeth and presumably a broader range of food preference (Hill and Smith, 1984). However, Altringham (1996) noted that the evolutionary pressures on ancestral megachiropterans which led to the evolution of flight, and the mechanisms by which it was achieved, were probably similar to those which gave us the microchiropterans. Nonetheless, Hill and Smith (1984) proposed that the Megachiroptera and Microchiroptera are not closely related and that wings and flight have developed twice, independently, in these two groups of flying mammals. While this idea may seem far-fetched at first, there is some evidence in its support. The Megachiroptera shared a number of special features with the Primates; these features are not also shared with the Microchiroptera. These shared features include various aspects of the brain and central nervous systems; musculatures; skeletal system (including portions of the wing); circulatory system; and reproductive system. In addition, the curious frugivorous dentition of megachiropterans is more readily derived from that of early Primates that were also arboreal. The Colugo appears to be more related, in an evolutionary sense, to the Primates and megachiroptera than it is to the Microchiroptera. Regardless of the relationships between the two suborders, adaptively each has pursued markedly different life styles, the microchiropterans having exploited the vast potential of night-flying insects (Hill and Smith, 1984).

2.1.1. CLASSIFICATION

All bats are currently included in the order Chiroptera (meaning hand-wing). This order includes two major suborders, the Megachiroptera, or fruit bats, comprising 185 species the Microchiroptera, insect-eating bats, currently comprising 934 species (Simmons, 2005). The classification of bats used today is based on the system developed by Miller (1907). The characteristics are front limbs adapted to the function of wings; elongated fingers; keeled sternum; legs rotated so that the knees are oriented toward the back (Neuweiler, 2000).

SUBORDER MEGACHIROPTERA

This suborder includes only a family, family Pteropodidae (Hill and Smith, 1984).

Family Pteropodidae – Old World Fruit Bats

The bats in this family consist of 42 genera and 185 species (Simmons, 2005), which are distributed throughout the Old World tropics and subtropics from Africa, Asia to Australia and the islands of the Pacific. Fossil pteropodids are known from the middle Oligocene and Miocene of Europe, the Miocene of Africa and from the Pleistocene of Madagascar and the East Indies. They are small to very large in size, with forearm length of 40-220 mm (Hill and Smith, 1984; Corbet and Hill, 1992). The eyes are comparatively large and the ears are simple-shaped, the sides of each pinna forming a complete ring at the base, and without tragus. The muzzle and jaws are strongly built (Altringham, 1996; Bates and Harrison, 1997). The second and third fingers are largely independent of each other, and the second has a claw (Altringham, 1996). The tail is very short or absent (Bates and Harrison, 1997). Tail membranes are typically small or non-existent (Altringham, 1996). In the skull, the rostrum is heavy and the postorbital processes are well developed. The angular process of each half mandible is broad and low (Bates and Harrison, 1997). The dentition is reduced, with a variable number of upper and lower incisors and molars; the third molar is always absent. The cheekteeth of the upper and lower jaws closely resemble each other in form; the molars have two blunt cusps on their anterior portions (Corbet and Hill, 1992; Bates and Harrison, 1997).

SUBORDER MICROCHIROPTERA

The suborder microchiroptera includes four superfamilies, and 17 families (Corbet and Hill, 1992; Altringham, 1996).

SUPERFAMILY EMBALLONUROIDEA

Family Rhinopomatidae – Mouse-tailed Bats

This family consist of only one genus, with four species (Simmons, 2005), which is distributed in the arid and semiarid regions of northern and northwestern Africa, southwestern Asia and India, perhaps to Myanmar and Thailand, and to Sumatra (Hill and Smith, 1984; Corbet and Hill, 1992). No fossils are known (Corbet and Hill, 1992). Rhinopomatids are small to moderate in size, with forearm length of 46-75 mm (Hill and Smith, 1984). There is a thickened narial pad present on the end of the muzzle, which comprises a rudimentary noseleaf consisting of a transverse dermal ridge above the valvular nostrils which can be closed, possibly to present sand and dust from entering. The ears are jointed across the forehead by a connecting membrane; the tragus is well developed. The second and third digits of each wing have two distinct bony phalanges. The tail is very long and slender, with the longest part projecting free from the membrane (Hill and Smith, 1984; Corbet and Hill, 1992; Bates and Harrison, 1997). The skull is relatively short and broad; it lacks postorbital processes. The nasal inflations are separated and present on each side of the rostrum. The premaxillae are separate from each other and from the adjacent part of the skull. The tympanic bullae are relatively large. The teeth are of the normal insectivorous type; the upper incisor is very small (Bates and Harrison, 1997).

Family Emballonuridae – Sheath-tailed Bats

The members of the family includes 13 genera and 51 species (Simmons, 2005), which occur throughout the tropical and subtropical regions of the world from the islands of the Pacific Ocean through Australia, Indonesia and the Philippines to Africa and the New World (Hill and Smith, 1984; Corbet and Hill, 1992). Fossil emballonurids are known from the Miocene of Africa and the late Eocene or early Oligocene of Europe. They are small to medium in size, with forearm length of 35-66 mm (Hill and Smith, 1984). The tail is loosely enclosed in the interfemoral membrane and the tip projects from the upper surface of the membrane at about the midpoint. The wings are long and narrow. The second digit of each is without phalanges. The muzzle is without a noseleaf. A tragus is present in each ear (Hill and Smith, 1984; Altringham, 1996; Bates and Harrison, 1997). The postorbital processes are well developed. The premaxillae are represented by nasal branches only and are not fused with each other or with the maxillae. Deep basisphenoid pits are present and the tympanic bullae are usually emarginated on their internal aspects (Bates and Harrison, 1997).

Family Craseonycteridae – Hog-nosed Bat; Bumblebee Bat

The family includes only one genus and species (Simmons, 2005), which is limited to small area of limestone caves in western Thailand (Corbet and Hill, 1992), and Mon State, Myanmar (Bates *et al.* 2001). No fossils are known (Corbet and Hill, 1992). It is very small in size, with forearm length of 22.5-26 mm (Hill and Smith, 1984). Its vertical, rather pig-like nose is surmounted by a low transverse dermal ridge. The ears are separately and relatively large, each with a swollen tragus; which has a curious oblate thickening about halfway along its anterior part. It has an extensive tail membrane but a complete absence of an external tail or calcars. The premaxillary bones carry the upper incisive teeth; the palatal branches are small and totally co-ossified, their narial branches exceptionally developed uniquely to fuse above the narial aperture, forming a subtubular flange around the narial opening (Hill and Smith, 1984; Corbet and Hill, 1992).

SUPERFAMILY RHINOLOPHOIDEA

Family Nycteridae – Slit-faced Bats; Hollow-faced Bats; Hispid Bats

The family includes one genus, with 16 species (Simmons, 2005); which are found in the tropical forests and semi-arid regions of Africa and adjacent Arabia and Palestine, southwest Asia, and Southeast Asia from southern Myanmar, Thailand, Malaysia, Sumatra, Java, Borneo, and the Kangean Island, to perhaps Sulawesi and Timor Island (Hill and Smith, 1984; Corbet and Hill, 1992). The members of the family range from small to moderate in size, with forearm length of 32-66 mm (Hill and Smith, 1984). There is a characteristic deep longitudinal furrow or slit along the top of the muzzle behind the nostrils. This furrow is bordered and partially concealed by large fleshy outgrowths. There is an extensive concave hollow at its upper end (Hill and Smith, 1984; Corbet and Hill, 1992). The ears are large and oval-shaped, joined anteriorly over the forehead by a low integument, with a small but well-developed tragus. The tail is enclosed in the uropatagium and has uniquely a T-shaped cartilaginous tip embedded in the membrane edge (Corbet and Hill, 1992). The cranium has and extensive large concave plate that rests on top of the rostrum and presumably supports this curious pouch (Hill and Smith, 1984).

Family Megadermatidae – False Vampires Bats

The bats in this family consist of four genera and five species (Corbet and Hill, 1992; Simmons, 2005), which are found in the Old World tropics, including central and eastern Africa, India, and Sri Lanka to the Philippines and Australia (Hill and Smith, 1984; Corbet and Hill, 1992). Fossil megadermatids are recorded from the late Eocene or early Oligocene of Europe and the Miocene of Asia (Hill and Smith, 1984). The members of the family range from medium to large, with forearm length of 50-115 mm (Hill and Smith, 1984). The ears are large and oval, and are joined above the forehead. The tragus of each ear is distinctly bifid, with a low anterior part and a tall, pointed posterior process. The noseleaf is simple, large and erect cutaneous (Hill and Smith, 1984; Bates and Harrison, 1997). The tail is absent. The second finger of each wing has only one phalanx; the third processes two phalanges (Bates and Harrison, 1997). In the skull, the postorbital processes are virtually absent; they are obscured by prominent supraorbital ridges (Bates and Harrison, 1997). The premaxillae are tiny, thread-like bones which are usually lost (Hill and Smith, 1984). They lack upper incisors. The bicuspidate upper canine projects noticeably (Hill and Smith, 1984; Bates and Harrison, 1997).

Family Rhinolophidae – Horseshoe Bats

The members of this family consist of only one genus and 77 species (Simmons, 2005), which are found throughout the tropics, subtropics and temperate zones of the Old World from Europe and Africa to Japan, Philippines, New Guinea, the Bismarck Archipelago and Australia. They are known from fossils from the late Eocene of Europe and the Miocene of Australia (Hill and Smith, 1984; Corbet and Hill, 1992). The members of this family range from small to medium, with forearm length of 30-75 mm (Hill and Smith, 1984). The noseleaf consists of an erect posterior lancet, a lower horizontal horseshoe that surrounds the nostrils and a perpendicular median sella. The horseshoe merges with a triangular, pointed, and pocketed structure called the lancet which stands erect behind the horseshoe and above the tiny eyes. The ears are pointed, each has a well developed antitragus lobe but no tragus. The tail is well developed and included in the interfemoral membrane (Hill and Smith, 1984; Corbet and Hill, 1992; Bates and Harrison, 1997; Csorba *et al.* 2003). The skull has the premaxillae represented by projecting narrow palatal branches only; these two bones are partly cartilaginous and are not fused with each other or with the maxillae. Postorbital processes are absent. The palate is deeply incised both anterior and posterior parts. The tympanic bullae are relatively small but the cochleae are well developed. The skull is always with rostral inflations. The upper incisor is very small. The first upper and second lower premolars are also small, often functionless and usually displaced externally from the toothrow; they are occasionally absent (Bates and Harrison, 1997; Csorba *et al.* 2003).

Family Hipposideridae – see Section 2.3.

SUPERFAMILY PHYLLOSTOMOIDEA

Family Mystacinidae – Short-tailed Bats

The members of the family include only one genus and two species (Simmons, 2005), which is restricted to New Zealand (Hill and Smith, 1984; Simmons, 2005). These bats are medium in size, with forearm length of 40-49 mm. The muzzle is rather long; the nose projects beyond the lower lip and the nostrils are set in a rudimentary narial pad, which has many short and stiff bristles. The tongue can be protruded to a certain extent and it has a rough, transversely ridged surface with a small patch of brush-papillae at its tip. The ears are separate, quite long and slender and tragus is long and point (Hill and Smith, 1984). The wing membranes are very tough close to the body, and the delicate distal regions can be folded away and tucked into skin pouches on the flanks. The legs are short and stout, and the toes and thumb have talons near the base (Altringham, 1996). The tail emerges through the tail membrane, with the tip lies on the upper surface of the membrane (Hill and Smith, 1984).

Family Noctilionidae – Bulldog Bats; Fisherman Bats

The bats in this family consist of only one genus, with two species (Hill and Smith, 1984; Simmons, 2005), which live in the tropical and subtropical parts of the New World. They are medium to large in size, with a forearm length of 55-90 mm (Hill and Smith, 1984). They have large swollen lips. The sexes are dimorphic in colour; males are reddish or slightly orange on the back, and females are generally brown or greyish. Males have an oily secretion that has a very pungent fishy odour. The tail membrane is supported by strong calcars, which are well developed in the fishing species. The long legs have enormously developed feet with strong gaff-like claws (Hill and Smith, 1984; Altringham, 1996).

Family Mormoopidae – Moustached Bats; Naked-backed Bats; Ghost-faced Bats

The members of the family consist of two genera, with 10 species (Simmons, 2005), which are distributed in the tropics of the New World. They are small to medium in size, with a forearm length of 35-65 mm. There is a rudimentary noseleaf, which is little more than a bump on the nose. The lips are rather large and the lower lip and chin bears on ornate array of plates and folds. These ornamentations give the mouth a distinct funnel-like shaped when it is opened (Hill and Smith, 1984). There is a moustache of many stiff hairs near the end of the muzzle. These structures further enhance the funnel-shape of the mouth (Hill and Smith, 1984; Altringham, 1996). The wing membranes arise close to the middle of the back (Altringham, 1996).

Family Phyllostomatidae – New World Leaf-nosed Bats

The family includes 55 genera and 160 species (Simmons, 2005), which are distributed in the tropical and subtropical parts of the New World. They are represented in the fossil record as early as the Miocene of South America. They are very small to large in size, with a forearm length of 25-110 mm (Hill and Smith, 1984). The noseleaf varies from a relatively simple or lanceolate to low and reduced and extremely rudimentary. In addition, there is an array of warts and tubercles that adorn the face and lips. The ears and tragi are generally simple, often pointed rather than rounded (Hill and Smith, 1984; Altringham, 1996). Several species have long ears. The tail and the extent of the tail membrane vary widely. Some species lack a tail altogether and the tail membrane is extremely narrow or non-existent. In others, it is long and enclosed in an extensive tail membrane. Additionally, the tail may be short and not extend to the full length of the tail membrane (Hill and Smith, 1984).

SUPERFAMILY VESPERTILIONOIDEA

Family Natalidae – Funnel-eared Bats; Long-legged Bats

The family consists of three genera and 8 species (Simmons, 2005), which are found in the tropical lowlands of the New World from northern Mexico to Brazil, and on the islands of Trinidad, Curacao, and the Antilles. The members of this family range from very small to small in size, with a forearm length of 27-41 mm (Hill and Smith, 1984). The body is small and slim; the head is high and domed. The ears are large and funnel-shaped (Hill and Smith, 1984; Altringham, 1996). The legs and wings are long and slender (Hill and Smith, 1984), althought Altringham (1996) notes that the wings are broad. Adult males have a curious, bulbous ‘natalis’ organ that lied just below the skin of the forehead (Hill and Smith, 1984).

Family Furipteridae – Smoky Bats

The bats in the family consist of two genera and two species (Simmons, 2005), which occur in tropical South America. They are small in size, with a forearm length of 30-40 mm (Hill and Smith, 1984). The ears are tall and funnel-shaped. The head is covered with dense fur. Although the thumb is present, it is so small and almost entirely enclosed in the antebrachial membrane (Hill and Smith, 1984, Altringham, 1996). The skull is high and domed (Altringham, 1996).

Family Thyropteridae – Disc-winged Bats; New World Sucker-footed Bats

The members of the family includes only one genus, with three species (Simmons, 2005), which is distributed from Mexico to the northern part of South America. Size ranges from very small to small, with a forearm length of 27-38 mm. The muzzle is long and slender, with small warts above the nostril (Hill and Smith, 1984). The crown of the head is high and domed, with funnel-shaped ears (Hill and Smith, 1984; Altringham, 1996). There is a circular adhesive disc or sucker-shaped cup at the base of the thumb and on the sole of the foot just in front of the heel. There is a short stalk, with the disc on the thumb. They are only two phalanges in each of the toes and the third and fourth toes are fused together to the tips of the claws (Hill and Smith, 1984).

Family Myzopodidae – Old World Sucker-footed Bats

This family includes only one genus and one species (Simmons, 2005), which are found in Madagascar, and is also represented in the early Pleistocene deposits at Olduvai in eastern Africa. It is medium in size, with forearm length of 46 mm (Hill and Smith, 1984). The ears are large. There is have a sucker-like disc at the base of the thumb, but it does not have a stalk or pedicle and there is a similar disc on the sole of the foot. The tragus is rather curious in structure, being mushroom-like with a kidney-shaped fleshy expansion surmounting a short stalk. The thumb is quite small and the claw is vestigial. The toes of the foot have only two phalanges and are united for much of their length (Hill and Smith, 1984; Altringham, 1996). The skull is high and domed (Altringham, 1996).

Family Vespertilionidae – Evening Bats

The bats in this family consist of 48 genera and at least 407 species (Simmons, 2005), which are distributed throughout the world except for the Polar and sub-Polar regions and some small oceanic islands. The fossils occur from the Eocene of Europe, the Oligocene and Miocene of North America, the Miocene and Pliocene of Asia, the Miocene and Pleistocene of Africa, and the Pleistocene in Australia and South America. Species range from small to moderate in size, with a forearm length of 24-80 mm (Hill and Smith, 1984; Corbet and Hill, 1992). The muzzle is simple, without any leaf-like appendages. The eyes are small. The ears vary from small to very large, and are separated from each other in most cases; their anterior borders often have a distinct basal lobe. The tragus varies from short and blunt to long and pointed. The tail is well developed and entirely enclosed within the membrane or only protrudes from it for a short distance (Hill and Smith, 1984; Corbet and Hill, 1992; Altringham, 1996; Bates and Harrison, 1997). The skull is small in size and in some species, the skull is extremely flat, not much thicker than several coins (Hill and Smith, 1984). It is without postorbital processes. The premaxillae are without palatal branches. The palate is widely emarginated anteriorly and abruptly narrowed behind the toothrows (Bates and Harrison, 1997). The teeth vary in number from 28 to 38. Incisors may be reduced to one above and two below on each side of the mouth. The molars are always three above and below, but the last molar in each series may be quite short (Hill and Smith, 1984).

Family Molossidae – Free-tailed Bats

The members of this family include 16 genera and 103 species (Simmons, 2005), which are found throughout the tropics, subtropics, and warmer parts of the world from southwestern Canada, and the central part of the United States through Mexico, Central America and most of South America including the West Indies, southern Europe to Japan, southern Asia to Africa, and southeast Asia to Australia, the Solomon Island, and the Fiji Islands. Fossil molossidae are recorded from the Eocene and the late Oligocene of Europe, the late Oligocene or early Miocene in South America, the Miocene of Africa, and from the Pleistocene of Asia, the East Indies and Australia. They are very small to large, with forearm length of 27-85 mm (Hill and Smith, 1984; Corbet and Hill, 1992). The muzzle is truncate with the snout often projecting beyond the lower lip and the nostril open in a fleshy, or raised in some, narial pad that may be covered with many short stout bristles. The ears vary in size and shape, and they often lie forward obscuring most of the face and eyes, sometimes joined across the forehead; the tragus of each ear is rudimentary and the antitragus is usually large. The wings are long and narrow, the fifth digit of each scarcely longer than the second metacarpal; the second digit has one rudimentary phalanx; the third digit has three phalanges, the first of these is retroflexed on to the dorsal surface of the metacarpal when the wing is at rest. The tail is stout which projects conspicuously beyond the narrow interfemoral membrane (Hill and Smith, 1984; Bates and Harrison, 1997). The skull is flattened and has no postorbital processes. The teeth are of the normal insectivorous type. The third lower incisor (i_3) is variable present or absent, even within species (Altringham, 1996; Bates and Harrison, 1997).

SUPERFAMILY PALAEOCHIROPTERYGOIDEA

There are three families, which are known only from fossils, all of them found in the Eocene of Europe or North America. They include the earliest known bats. These three families are currently placed together in the superfamily Palaeochiorterygoidae. Their relationships are not yet fully understood and some authorities consider that they should be united into a single family, the Palaeochiropterygidae, possibly as three subfamilies. In addition, three genera of fossil bats have been described from deposits of similar age in Europe, but their affinities have yet to be properly established and they have not been allocated to a particular family (Hill and Smith, 1984).

Family Palaeochiropterygidae – 3 genera (Eocene of Europe)
Family Archaeonycteridae – 2 genera (Eocene of Europe)
Family Icaronycteridae – 1 genus (Eocene of North America, ? Europe)

Family incertae sedis – 3 genera (Eocene of Europe)

2.1.2. FEEDING ECOLOGY

The feeding habits of bats are almost as varied as those of the mammals as a whole. This variety of diet is responsible for much of the morphological, physiological, and ecological diversity seen in bats (Altringham, 1996). The diets of bats include: eating insects and other small arthropods (insectivory); eating flesh of other vertebrates (carnivory); fish (piscivory); blood-eating (sanguivory); eating fruit and/or flowers (frugivory); eating pollen and/or nectar (nectarivory); and eating a variety of food items (omnivory) (Hill and Smith, 1984).

INSECTIVORY

Bats feed on insects and other small arthropods, such as spiders and scorpions (Hill and Smith, 1984). Approximately 70 per cent of the living species of bats and the majority of those known as fossils are or were insectivorous (Hill and Smith, 1984; Altringham, 1996). The vast majority of insectivorous microbats are small, and catch their food on the wing. Their small size gives them the manoeuvrability and agility necessary to catch flying insects detected by their short-range echolocation system (Altringham, 1996). There are three general categories of foraging styles used by bats to capture insect, including aerial insectivory, foliage cleaning and terrestrial acquisition.

Aerial insectivory involves several different hunting strategies. It may involve swift, straight-line flights along forest pathways, roadways, or other open areas that are unencumbered by obstacles. Foliage gleaning is a modification of the latter style of aerial insectivory. As the bat forages amongst the vegetation it scans for insects and/or other arthropods such as spiders sitting on the tops of leaves. When these are detected, the bat alights on the foliage and captures the prey item. Terrestrial acquisition is similar, but involves flying close to the ground in search of crawling arthropods such as beetles, crickets, and scorpions (Hill and Smith, 1984). The diet is often reflected in the number and size of teeth, the size of the jaw, and the size of the cranial crest where the chewing muscles are attached, and other morphological features. Bats which eat hard-cased insects like beetles have strong jawbones, large jaw muscles, and few, large teeth (Altringham, 1996).

CARNIVORY

These bats feed on small vertebrates (except fish). They include 10 species, four Megadermatidae, four Phyllostomatidae, one Nycteridae, and one of Vespertilionidae. They are widespread, from southern USA and Central America to South America throughout Africa to India, South-east Asia, and Australia (Hill and Smith, 1984; Altringham, 1996). The dentition of carnivorous bats is only slightly modified from that of insectivorous bats (Hill and Smith, 1984). None are small bats and all but one have low aspect ratio wings and low wing loadings, all useful attributes for catching and carrying large ground dwelling prey. Only one, *Phyllostomus hastatus*, has higher aspect ratio and wing loading (Altringham, 1996).

PISCIVORY

The bats in this group feed on fish. They include two species of bats in the tropical and subtropical regions of the New World, *Noctilio leporinus* and *Myotis vivesi* and *Myotis ricketti* in Asia. All these bats have long legs, and huge feet for effective fishing. The toes are tipped with long, sharp and strongly-hooked claws for gaffing fish (Hill and Smith, 1984; Altringham, 1996). These species have a long calcar, with folds forward along the lower portion of the hindlimb. The tail membrane is gathered up and held out of the way when the bat is fishing. The toes, calcar, and tibia are flattened laterally for streamlining, they can knife through water with minimal resistance (Hill and Smith, 1984). They have high aspect ratio wings for efficient flight over water, flight is free from clutter, making long wings practical, and lift is gained by flying close to the surface. These species have a low wing loading, an adaptation for slow flight, and for carrying large prey (Altringham, 1996).

SANGUIVORY

These bats feed on the blood of other warm-blooded vertebrates. There are three species of true vampires in the family Phyllostomatidae in the tropical and subtropical regions of the New World. These species are: *Desmodus rotundus,* *Diaemus youngi,* and *Diphylla ecaudata* (Fenton, 1983; Hill and Smith, 1984; Altringham, 1996). Vampires are quite agile on the ground or while clinging to and crawling on the victim. Their dentition is highly specialized (Hill and Smith, 1984). The grinding teeth are all but lost and the upper canines and incisors (one on each side of the jaw) are enlarged, with razor-shaped blades. The lower canines are large, but not as blade-like (Fenton, 1983; Hill and Smith, 1984; Altringham, 1996). They inflict a small, V-shaped wound by biting the victim in a region where there are rich surface blood capillaries. Typical wound sites are the tips of fingers and toes, lips and eyelids, tips of the nose and ears (Hill and Smith, 1984).

FRUGIVORY AND NECTARIVORY

The bats in this group feed on the fruits, flowers, nectar, and pollen, which is widespread in the tropical and subtropical regions of the world. There are three groups of bats that feed principally on nectar and pollen. One of these includes the members of the family Pteropodidae and the two belong to the family Phyllostomatidae. Their muzzles are long and reduced in diameter. The lower jaw is much reduced and frail, in marked contrast to the stout, heavy jaws of frugivorous species (Hill and Smith, 1984). The canines remain large and strong. The cheek teeth are small, rootless, rounded and are no longer suited for chewing (Neuweiler, 2000). The upper incisors are usually large and, in most species, are thrust forward (procumbent). The lower incisors are frequently reduced in number and size and set to either side of the jaw axis, thereby creating a medial open space, or they are absent altogether (Hill and Smith, 1984).

2.2. FAMILY HIPPOSIDERIDAE

The family consists of 84 known species. Fossils of the family Hipposideridae are found in the middle Late Eocene of Europe (Sigé and Legendre, 1983), early and middle Oligocene of south-western France (Legendre, 1982; Lekagul and McNeely, 1988; Sigé, 1990), early and middle Miocene of the north-western Mediterranean Region (Legendre, 1982), early Oligocene of Arabo-Africa (Sigé *et al.* 1994), middle Miocene of Morocco (Legendre, 1982), late Oligocene and middle

Miocene of Australia (Hand, 1997), and probably the Miocene and Pleistocene of Asia (Corbet and Hill, 1992; Bogdanowicz and Owen, 1998).

2.2.1. DESCRIPTION

The members of this family are small to large species, with a forearm length of 32-114 mm (Corbet and Hill, 1992). They have a complex noseleaf usually consisting of an horseshoe-shaped structure (Payne *et al.* 1985; Corbet and Hill, 1992), which lacks any posterior vertical lancet (Corbet and Hill, 1992). The noseleaf consist of a horizontal horseshoe, often with accessory folioles; an intermediate leaf (which is not always clearly differentiated in some genera, such as *Triaenops*) and a posterior leaf (Bates and Harrison, 1997). The anterior noseleaf is rounded and somewhat horseshoe-shaped (except in *Coelops*), usually with or without lateral supplementary leaflets. The nostrils open in the centre of the anterior leaf, separated by an internarial septum. The lateral narial lappets project from the outer walls of the nostrils (Payne *et al.* 1985; Lekagul and McNeely, 1988). The intermediate leaf is a low cushion-like structure expanded laterally without a sella (Payne *et al.* 1985), extending from the posterior boundary of the narial depressions transversely across the entire noseleaf. The intermediate leaf may be modified by the development of a raised median ridge (Lekagul and McNeely, 1988). The posterior leaf is erect structure (Lekagul and McNeely, 1988), low and rounded, usually divided by vertical septa into several pockets (Payne *et al.* 1985). It may be divided into sections with pointed tips. The anterior face of the leaf is more or less concave. Some species have an accessory structure behind the leaf (Lekagul and McNeely, 1988). It has a more or less semicircular edge, sometimes with folds, pockets, or swollen vertical projections; there is no strap-like sella above and behind the nostrils (Corbet and Hill, 1992). Bates and Harrison (1997) reported the posterior leaf of this family corresponds to the lancet of the Family Rhinolophidae. The internarial septum varies from very narrow to broadly expanded or inflated (Payne *et al.* 1985; Lekagul and McNeely, 1988). The ears vary from moderately small to large with a low antitragus (Payne *et al.* 1985; Corbet and Hill, 1992). There is no tragus, although some species have a well-defined antitragus. In other species the antitragus is lacking or reduced to a thickening of the antitragal lobe of the ear (Lekagul and McNeely, 1988). The tail is completely enclosed in the uropatagium; in some species, it is reduced or rudimentary (Corbet and Hill, 1992). The eyes are very small (Payne *et al.* 1985). Each toe has 2 bones. A frontal sac is often present behind the posterior leaf, it is usually better developed in males than in females (Lekagul and McNeely, 1988).

The skull varies considerably, from elongate and narrow to short and broad. All have a distinct sagittal crest and slightly inflated nasal region. In some species, supraorbital ridges are low and poorly defined, in others they are well defined and prominent. The dentition is reduced. Dental formula is usually i: 1/2, c: 1/1, pm: 2/2, m: 3/3 (Lekagul and McNeely, 1988).

2.2.2. DISTRIBUTION

The Hipposideridae are distributed throughout the tropics and subtropics of Old World from Africa and South Asia to the Philippines, North Australia and Vanuatu (Corbet and Hill, 1992).

2.2.3. CLASSIFICATION

Family Hipposideridae is a large family of insectivorous bats, which consists of 9 genera and 84 species of which at least 41 occur in South-east Asia (Simmons, 2005; Guillen-Sevent and Francis, 2006; Bates *et al.* 2007), including:

Family Hipposideridae
    Genus *Anthops*: 1 species
        A. ornatus Thomas
    Genus *Asellia*: 2 species
        A. patrizii DeBeaux
        A. tridens Geoffroy
    Genus *Aselliscus*: 2 species (1 species in South-east Asia)
        A. stoliczkannus Dobson
        A. tricuspidatus Temminck
    Genus *Cloeotis*: 1 species
        C. percivali Thomas
    Genus *Coelops*: 2 species (2 species in South-east Asia)

C. frithii Blyth

C. robinsoni Bonhote

Genus *Hipposideros*: 70 species (36 species in South-east Asia), see Section xx

Genus *Paracoelops*: 1 species (1 species in South-east Asia)

P. megalotis Dorst

Genus *Rhinonicteris*: 1 species (1 species in South-east Asia)

R. aurantia Gray

Genus *Triaenops*: 4 species

T. auritus Grandidier

T. furculus Trouessart

T. persicus Dobson

T. rufus Milne-Edwards

2.3. GENUS *HIPPOSIDEROS*

2.3.1. DESCIPTION

1). External character

The bats in this genus are small to large size, with forearm length 32.0-114.0 mm. The ears, which in a minority of species are united at the base by a low band of integument, vary in outline from comparatively short, broad and round or bluntly pointed to long, narrow and with an acute point. Their anterior (inner) edge is generally convex, their posterior (outer) edge is straight or with a shallow concavity or emargination just behind the tip. Some species exhibit a well-defined internal fold at the antritragal lobe, in others it is absent or represented by a thickening of the membrane of the ear at this point. The external surface of the ear is usually naked except at its base but in some species it can be covered with body fur for one half to two thirds the length of the ear (Hill, 1963).

The noseleaf is comprised of an anterior leaf, with or without lateral supplementary leaflets (Hill, 1963; Bates and Harrison, 1997), of which in some cases one may extend anteriorly beneath the anterior leaf on to the upper lip, sometimes forming a complete supplementary leaflet encircling the muzzle beneath the anterior leaf. The anterior noseleaf, extending over the upper lip, and is not usually much modified but occasionally displays a narrow median emargination. The nostrils open in paired depressions in the centre of this leaf, the narial openings separated by an internarial septum which is usually narrow or only slightly inflated but which may be bulbous, inflated or specialized to form a disc-like structure between the nostrils. Lateral narial lappets project from the outer walls of the narial depressions and together with the internarial septum may become modified to form deep pockets in which lie the narial apertures (Hill, 1963). The intermediate leaf is simple (Bates and Harrison, 1997). It lies immediately behind the narial depressions, forming their posterior boundary, and is a cushion-like structure extending transversely across the entire noseleaf. It may be variously modified by the development of raised median and lateral eminences or ridges, or a median club-like structure. Its posterior margin forms the base of the posterior leaf, an erect structure with a smooth or sometimes slightly lobulated upper ridge, usually convex in outline but on occasion slightly triangular or specialized by the development of a median projection (Hill, 1963). The anterior face of the posterior leaf is more or less concave, the concavity smooth or divided by one or more vertical septa, enclosing small cells or pockets, but without vertical processes (Hill, 1963; Bates and Harrison, 1997) or lacking any well-defined dorsal process (Borissenko and Kruskop, 2003). The posterior face is usually smooth but in some species is modified by the development of a transverse supplementary structure with a serrated upper ridge. The nasal foliations exhibit an exceptionally wide range of variation within the genus from small, comparatively simple structures showing little or no evidence of specialization to large, greatly modified structures completely covering the entire muzzle (Hill, 1963). Extra phalanges of the feet are completely fused and all toes have two phalanges (Borissenko and Kruskop, 2003). The tail is well-developed, relatively long and enclosed within the interfemoral membrane, except for extreme tip (Bates and Harrison, 1997; Borissenko and Kruskop, 2003). A frontal sac, which is usually less developed in females than in males, has its opening behind the posterior noseleaf, is to be found in a number of species, while a few species are noted for the development, especially in males, of transverse fleshy lobate prominences on each side of the opening of this sac (Hill, 1963).

2). Cranial character

The skulls of members of this genus are small to large in size, with a condylo-canine length of 11.6-34.7 mm. The skull demonstrates a similarly wide range of variation, especially in the rostral, palatal and sphenoidal regions. Its basic outline varies from elongate and narrow, the zygomatic width less than or equal to the mastoid width, to short and comparatively broad with the zygomatic width exceeding the mastoid width of the skull. The braincase is generally elongate and never globose, and in some species is somewhat inflated. Sagittal and lambdoid crests are usually present and in the larger species are often greatly developed (Hill, 1963), although Borissenko and Kruskop (2003) noted that sagittal crest not developed in the immediate postorbital region. The interorbital region is usually markedly constricted but exceptionally is broader with no shape constriction between the braincase and the rostrum. The supraorbital ridge is in some species are low and poorly defined and in others are well defined and prominent: they may partially enclose a frontal depression, itself sometimes absent. The rostrum, rounded in outline in some species, is in others more markedly pentagonal. It exhibits paired, inflated rostral eminences anterior to the anterorbital region, separated from each other by a shallow groove. The rostrum is expanded laterally to a greater or lesser degree, and in some species is markedly flattened and more greatly ossified (Hill, 1963), although sometimes these are low (Payne *et al.* 1985). Considerable variation is displayed in the form of the premaxillae, which basically form a projecting structure with a V-shaped or U-shaped junction with the maxillae. Considered together, they vary from a narrow oblong structure not greatly expanded posteriorly at its junction with the maxillae to a wide, sometimes fan-shaped union with the maxillae. Their lateral edges may be deeply notched so that with the maxillae they form the walls of the anterior palatal foramina. In some species, delicate anterior enclosing processes are developed to form the anterior walls of these foramina: these processes in other species completely enclose the foramina, which are thus contained within the premaxillae. The anterior palatal foramina in some species are small and rounded and in others are large and oval, elongate or slit-like. The palate is short and broad, the palation usually more or less U-shaped or square, with or without a median emargination or post-palatal spicule. The mesopterygoid fossa is wide and the pterygoids vary considerably in relative length between species. The sphenoidal bridge, flanked by rounded or elongate lateral apertures, usually partially conceal them but in some species are markedly constricted. A sphenoidal depression is usually present. The cochleae typically are approximately equal in width to their distance apart but exceptionally may be greatly enlarged so that their width is equal to six or eight times this distance (Hill, 1963).

3). Dentition

The upper toothrow lengths of members in this genus are 4.2-15.2 mm. The upper incisors are usually bilobed: the outer lobe, however, is present in varying degrees of obsolescence and in some species is virtually obsolete (Hill, 1963). The upper canines are heavy but simple, without prominent supplementary cusps (Payne *et al.* 1985; Borissenko and Kruskop, 2003), sometimes with a low anterior or posterior cusp. The first upper premolar (pm^2) is small or minute, variably reduced, often extruded outwards from the toothrow so that the canine and the second upper premolar (pm^4) are in contact or nearly so, rarely the anterior upper premolar is absent (Hill, 1963; Payne *et al.* 1985). The posterior cusp of the third upper molar is usually obsolescent or obsolete and its third commissure undeveloped, with the W-pattern of the tooth incomplete: exceptionally the third cusp may be more or less unreduced and the commissure present with the W-pattern of the tooth virtually complete. The crown area of the outer lower incisors in some species is less than or equal to the crown area of the inner teeth. The anterior lower premolar (pm_2), sometimes almost equal in size to the second lower premolar (pm_4), is more usually reduced, sometimes to one quarter or one third the size of the second tooth (Hill, 1963).

2.3.2. ECHOLOCATION

This genus use constant frequency of echolocation calls. The frequency ranges from 50 kHz to nearly 200 kHz (Francis, 2001).

2.3.3. DISTRIBUTION

This genus is distributed in the tropics and subtropics of the Old World, including much of Africa (except Sahara and extreme south), South-west

Arabia, Eastern Afghanistan to Philippines, Northern Australia and Vanuatu (Corbet and Hill, 1992).

2.4. SUPRASPECIFIC GROUPING WITHIN THE GENUS

Tate (1941) pointed that the morphological evidence indicating distinct evolutionary trends within the genus *Hipposideros* is perplexing and often contradictory. Such characters as, progressive simplification of the upper incisors or reduction of the first premolars, widening of the rostral region or increase in the number of supplementary leaflets to the horseshoe, seldom combine to indicate clearly recognisable evolutionary trends. Instead, those characters behave as independent tendencies latent perhaps in all species, active in some species, and quiescent in others. A review of the morphological features of these groups indicates that considerable similarity exists between several of them, and that some at least may be separated only with difficulty from each other (Hill, 1963).

Tate (1941) used the following criteria for the classification of the genus *Hipposideros*: In the *H. bicolor* and *H. calcaratus* groups, the tendency for the teeth to be displaced laterally outward from the toothrows can be discerned. In other groups, the first upper premolars (pm^2) usually become excluded and the second upper premolars (pm^4) and upper canines (c^1) attain virtual or total contact. The first lower premolars (pm_2) become modified. Pm^2 is moved out from the toothrow, pm_2 become progressively smaller, both by shortening of the cingulum and by reduction of the height of the cusp. Pm2 is two thirds or three quarters (in *H. bicolor* and *H. calcaratus*) to one half the height of pm_4. In *H. cyclops*, *H. semoni* and *H. sabanus,* pm^2 has become vestigial the height of the cusp of pm_2 is less than one third that of pm_4. The toothrow become shorter in proportion to the palatal width. Typically no occlusion occurs between the upper and lower incisors since the mandible is strongly undershot. The tip of the upper incisors (i^1) are convergent, except in the *H. commersonii* group; they are bilobate and with the outer lobe obsolescent to a degree varying with the species group. The lower incisors are trilobate and usually overlapping.. The crown area of the outer tooth (i_1) varies from sub-equal (in the *H. muscinus, H. cyclops, H. gigas, H. galeritus* and *H. bicolor* groups) to twice the thickness, one and a half times the width of the inner tooth (i_2) (in the *H. speoris, H.*

pratti, H. armiger, H. commersonii, and *H. diadema* groups). In latter groups, the upper incisors (i^1) retain most of the external lobe, are stouter, and become nearly contiguous (except *H. commersonii*). In the former the outer lobe is obsolescent and the teeth are weaker and spaced more widely. Posterior canine cusps are present in *H. abae, H. commersonii, H. calcaratus* and *H. galeritus* groups. The third upper molar (m^3) has a W-pattern. The third lower molar (m_3) has a reduced talonid, with the posterior cusp and commissure failing to develop and the antero-posterior length of the tooth reduced. In the *H. muscinus* group, m^3 and m_3 remain virtually unreduced. Elsewhere there is greater or lesser reduction. In *H. galeritus, H. caffer, H. bicolor, H. cyclops, H. larvatus, H. armiger* and *H. pratti,* there is partial reduction. In the *H. commersonii, H. diadema,* and *H. calcaratus* groups, there is marked reduction.

The rostral area exhibits fundamentally a double rounding or swelling from anterior to the anteorbital region, in combination with a varying degree of lateral expansion. In the *H. armiger* group, there is a marked flattening of the entire top of the rostrum, coupled with a greater degree of ossification. In the *H. commersonii* group, the rostum is very high; in *H. pratti*, it is elongated. In the *H. calcaratus* group, the rostrum has minimal lateral expansion. In *H. armigar, H. pratti, H. diadema, H. cyclops, H. semoni* and *H. speoris*, maximal expansion is reached. In *H. bicolor, H. cervinus, H. caffer*, and *H. sabanus,* it is an intermediate form.

The interorbital area shows a decided constriction between the rostral expansion and the braincase. In the *H. calcaratus* group and *H. coxi*, this condition is less marked because the rostrum its scarcely expanded;, the ratio of the interorbital width to rostrum width in *H. calcaratus* may exceed 65%. The zygomata width exceeds the mastoid width in all groups, except the *H. bicolor* group and part of the *H. calcaratus* group. In the *H. bicolor* group the zygomata are peculiarly narrow and the braincase is well inflated. In the *H. bicolor* group, the premaxillae are narrowly oblong, and taken together, form a wedge-shaped contact with the palate. Their lateral edges are deeply notched to form, with the maxillae, the incisive foramina. The centre of the anterior edge of each premaxilla is the alveolus of the incisor tooth. This pattern is strikingly modified in certain groups. In some groups, the posterior V-shaped is rounded to a U-shaped. In *H. cervinus*, the foraminal openings may become narrowly slit-like or oval in *H. calcaratus*. In *H. armiger* and *H. speoris,* the anterior enclosing processes may fail to reach the maxillae. They may become enlarged, encircle the foramina, and unite with the posterior processes (*H. pratti, H. cyclops* and *H. gigas*). In the *H. muscinus* group, the incisive foramina are large, and oval; the premaxillae reach the front of the palate by a narrow, spatulate process and the sides by two smaller lateral spatulate processes. The position of the incisive alveoli is at the middle of the anterior edge of the premaxilla in most species. In *H. muscinus* and *H. gigas*, they are placed at the outer corners of the anterior edge. The most groups, the cochleae are small. In the *H. bicolor, H. muscinus*, *H. cyclops* and *H. gigas* groups, the cochleae widths are wider than their distance apart. In the *H. galeritus, H. armiger* and *H. diadema* groups, they are sub-equal to their width apart, and in *H. pratti*, they are distinctly smaller.

The foremost character to claim attention is the development of two club-like processes one behind the other in the *H. cyclops* and *H. muscinus* groups. The posterior leaf is relatively simple and small in the *H. bicolor* and *H. calcaratus* groups. It may have one or three vertical supporting septa, which divide it into two or four shallow cells. In the *H. armiger* and *H. pratti* groups, it tends to be trilobate, and differ in size according to the sex. In the *H. caffer* subgroup, a secondary transverse ridge is present, rising behind from the base of the primary leaf. Its crest is serrate. The number of lateral supplementary leaflets varies in certain groups. In the *H. bicolor* group, there are usually no supplementary leaflets. In the *H. calcaratus* group none to one (incipient). In the *H. galeritus* and *H. pratti* groups, there are two. In the *H. speoris* group there are three. In *H. diadema* there are three or sometimes four. In *H. armiger* there are four. In *H. caffer* there are two and in *H. gigas* and *H. abae* three. In the *H. cyclops* and *H. muscinus* groups there are two, the outer one extending back to the rear of the posterior leaf. The frontal sac is present in males, it may be reduced or absent in females. It is entirely absent in the *H. diadema* group and in *H. lankadiva*, and approaches obsolescence in females of the *H. speoris* group. In *H. papua*, *H. pygmaeus* and *H. coxi*, females lack the frontal sac.

The ear in the *H. calcaratus* and *H. bicolor* groups is quite large and obtuse to round and with a pointed tip. The antitragus is absent, but there is an internal fold. This fold bears rarely a distinct tubercle in *H. speoris*. In the *H. bicolor* and *H. calcaratus* groups, the same fold becomes a distinct pocket. In *H. cyclops, H. gigas* and *H. muscinus*, the ears are elongate, acutely pointed. In the *H. speoris, H. galeritus, H. diadema, H. armiger* and *H. pratti* groups, the ears are large, broad, pointed, emarginated on the outer edge near the tip. The distal half of the pinna in most species, except *H. galeritus,* is naked. In *H. sabanus,* the ear is similar, but proportionally smaller. In the *H. galeritus* group, the ears are similar, the body fur extends outward over more than three quarters of the surface of the pinna. *H. (Syndesmotis) megalotis*, the ears are united at the base. In *H. muscinus*, a vestigial tragus is present.

Hill (1963) divided the genus *Hipposideros* into three primary divisions. The first division included the *H. megalotis, H. bicolor, H. calcaratus* and *H. galeritus* groups of Tate (1941) and the *H. curtus* group of Aellen (1954). Members of the groups are small size. The ears are broad and usually rounded, the internal fold present or thickening at the antitragal lobe. The noseleaves are comparatively simple, with or without lateral supplementary leaflets, some species have one incipient lateral leaflet, and some species have two lateral leaflets. The skull is more or less elongated and narrow, with inflated braincase. The zygomatic width is less than or not greatly exceeding the mastoid width. The upper incisors are usually weak and lack much of their outer lobe. The crown areas of the outer lower incisors only exceptionally greatly exceed those of the inner lower incisors. The *H. megalotis* group contains only one species, *H. megalotis.* The ears are uniquely conjoined. The noseleaf is simple, without lateral supplementary leaflets. The skull is elongate, with inflated braincase. The upper incisor is weak. The outer lower incisors are large, the crown area greatly exceeds the inner incisors. Members of the *H. bicolor* and *H. calcaratus* groups of Tate (1941) usually have simple noseleaves, without lateral supplementary leaflets or have one leaflet outline. Members of the *H. galeritus* group of Tate (1941) have two lateral leaflets. The skulls are short and broad.

The second primary division contains only the *H. cyclops* and *H. muscinus* groups of Tate (1941), which have been united into the *H. cyclops* group. This group shares some characteristics with the *H. bicolor* group, notably the small size of some of its members. Members of the *H cyclops* group have longer and narrower ears, sharply triangular, with little or no antitragal modification. The noseleaves have two lateral supplementary leaflets, the second lateral leaflet is uniquely distinguished to form an integral part of the posterior leaf and extends anteriorly beneath the anterior leaf, over the upper lip. The noseleaves are further specialised by the development of median tubercles or club-like processes from the intermediate and posterior leaves. The skull is less elongate and comparatively wider than in the *H. megalotis* and *H. bicolor* groups. The upper incisors are weak. Crown area of the outer lower incisors is very slightly larger than the inner lower incisors.

The third division of genus *Hipposideros* includes the *H. pratti, H. aemiger, H. speoris, H. diadema* and *H. commersoni* groups of Tate (1941). Members of the groups in this division are of larger size. The ears are comparatively smaller, triangular, and usually lack any antitragal modification. The noseleaves are simple, with two or more commonly three or four lateral leaflets. The skull is comparatively shorter, broader, with wider, more expanded zygomata. The upper incisors are stout and retain much of the outer lobe. The crown area of the outer lower incisors is greater than that of the inner lower incisors, sometimes greatly so. Monotypic species are rare among these groups, and there are no species with the exotic modifications such as are to be found in the first and second divisions. In the *H. pratti* group, the transverse supplementary lappets are greatly developed behind the posterior leaf. In the *H. armiger* group, the posterior leaf is slightly trilobate. The *H. commersoni* group of Tate (1941) is united to form a single group, the *H. diadema* group.

Hand and Kirsch (1998) suggested that among taxa in the first division of Hill (1963), there is no clear difference between the *H. bicolor* and *H. megalotis* groups or the *H. bicolor* and *H. galeritus* subgroups. Moreover, they suggested that Hill (1963) stressed the unity of the *H. galeritus* and *H. bicolor* subgroups within the *H. bicolor* group, but in reality there is no definitive line separating the subgroups, and that species in these subgroups are linked by exhibiting their respective characteristics in differing combinations. In fact, Hill (1963) divided the *H. bicolor* group into two subgroups according to their degree of specialisation rather than shared derived characters. The sister-taxa understood in the light of phylogenetic systematics, might be expected to belong to different subgroup, especially, *H. ater* and *H. fulvus*. Hill (1963) regarded these two species to be among the simplest members of the *H. bicolor* group, and were placed in the *H. bicolor* subgroup. For *H. galeritus* (including *H. cervinus*) and *H. caffer* (including *H. ruber*), Hill (1963) regarded to be among the most specialised, although not necessarily closely related to each other. They were placed in the *H. galeritus* subgroup.

Concerning the relationship of taxa in the second division, Hill (1963) proposed that the least specialised members of the *H. cyclops* group, especially *H. cyclops* and *H. camerunensis* show affinities with the *H. bicolor* group and their origins lie remotely with that species group. However, Hand and Kirsch's (1998) analyses suggested that their origins might lie with taxa in third division, *Asellia* and *Palaeophyllophora*. *H. semoni* and sister-species, *H. stenotis* are usually interpreted to be the most derived taxa in second division, and are distinguished among the hipposiderids by their extremely broad rostrum, deep frontal depression, and very wide sphenorbital fissure, as well as large m^3 and m_3, very reduced pm^2 and pm_2, and very tall c_1 and pm_4.

The relationships among taxa in third division were also poorly resolved. However, the species groups in this division might also be paraphyletic, being traditionally grouped according to degree of specialisation rather than relationship. Such as *H. lankadiva* and *H. larvatus* consistently appear sister-taxa, but Hill (1963) considered *H. lankadiva* to be the least modified members of the *H. diadema* group and *H. larvatus* is members of the *H. speoris* group.

Bogdanowicz and Owen (1998) studied the relationships within the Family Hipposideridae using two methods. The common-part-removed cladogram more or less agreed with Hill (1963). The cladogram grouped the majority of members in the *H. bicolor* group into one clade and members in the *H. diadema, H. pratti* and *H. armiger* groups into other clade. Meanwhile, the discrete-state consensus cladogram did not corroborate with the traditional systematic arrangements. Several taxa previously thought to be close systematically, especially the members in the *H. bicolor* group, were listed in different clades. This may have resulted from a lack of sufficient material. However, the consensus cladograme derived from the common-part-removed and discrete-state matrices have several features in common. First, the close relationship between members of the *H. diadema* and *H. armiger* groups is confirmed. Second, the three members of the *H. speoris* group are close to members of the *H. bicolor* group, although the taxonomic status of both groups needs to be redefined and revised. Third, *H.* (*Syndesmotis*) *megalotis* of the *H. megalotis* group is included in a clade together with some members of the *H. bicolor* group.

The arrangement below for the genus *Hipposideros* follows Hill (1963), with modifications based on Simmons (2005), Guillen-Servent and Francis (2006), Thabah *et al.* (2006), and Bates *et al.* (2007):

Genus *Hipposideros*
- *H. megalotis* group
  - *H. megalotis* Heuglin
- *H. bicolor* group
  - *H. ater* Templeton
  - *H. beatus* Aadersen
  - *H. bicolor* Temminck
  - *H. boeadii* Bates, Rossiter, Suyanto and Kingston
  - *H. breviceps* Tate
  - *H. caffer* Sundevall
  - *H. calcaratus* Dobson
  - *H. cervinus* Gould
  - *H. cineraceus* Blyth
  - *H. coronatus* Peters
  - *H. coxi* Shelford
  - *H. crumeniferus* Lesueur and Petit
  - *H. curtus* Allen
  - *H. doriae* Peters (*H. sabanus* Thomas)
  - *H. durgadasi* Khajuria
  - *H. dyacorum* Thomas
  - *H. fuliginosus* Temminck
  - *H. fulvus* Gray

  - *H. galeritus* Cantor
  - *H. halophyllus* Hill and Yenbutra
  - *H. hypophyllus* Kock and Bhat
  - *H. jonesi* Hayman
  - *H. khaokhouayensis* Guillen-Servent and Francis
  - *H. lamottei* Brosset
  - *H. macrobullatus* Tate
  - *H. maggietaylorae* Smith and Hill
  - *H. marisae* Aellen
  - *H. nequam* Andersen
  - *H. obscurus* Peters
  - *H. orbiculus* Francis, Kock and Habersetzer
  - *H. papua* Thomas and Doria
  - *H. pomona* Andersen
  - *H. pygmaeus* Waterhouse
  - *H. ridleyi* Robinson and Kloss
  - *H. rotalis* Francis, Kock and Habersetzer
  - *H. ruber* Noack
- *H. cyclops* group
  - *H. camerunensis* Eisentraut
  - *H. corynophyllus* Hill
  - *H. cyclops* Timminck
  - *H. edwardshilli* Flannery and Colgan
  - *H. muscinus* Thomas and Doria
  - *H. semoni* Matschie
  - *H. stenotis* Thomas
  - *H. thomensis* Bocage
  - *H. vittatus* Peters
  - *H. wollastoni* Thomas
- *H. pratti* group
  - *H. lylei* Thomas
  - *H. pratti* Thomas

H. scutinares Robinson, Jenkins, Francis and Fulford

H. armiger group

H. armiger Hodgson

H. turpis Bangs

H. speoris group

H. abae Allen

H. grandis Aellen

H. khasiana Thabah, Rossiter, Kingston, Zhang, Parsons, Zubaid and Jones

H. larvatus Horsfield

H. madurae Kitchener and Maryanto

H. sorenseni Kitchener and Maryanto

H. speoris Schneider

H. sumbae Oei

H. diadema group

H. commersoni Geoffroy

H. demissus Andersen

H. diadema Geoffroy

H. dinops Andersen

H. inexpectatus Laurie and Hill

H. inornatus McKean

H. gigas Wagner

H. lankadiva Kelaart

H. lekaguli Thonglongya and Hill

H. pelingensis Shamel

The *H. bicolor* group of Hill (1963) as here understood includes the *H. bicolor, H. calcaratus* and *H. galeritus* groups of Tate (1941), and the *H. curtus* group of Aellen (1954). The *H. cyclops* group includes the *H. muscinus* and *H. cyclops* groups of Tate (1941). The *H. commersoni* group of Tate (1941) is included in the *H. diadema* group of Hill (1963).

However, Simmons (2005) divided the genus into 9 groups, which separated the *H. commersoni* group of Tate (1941) from the *H. cyclops* group of Hill (1963), and divided the *H. speoris* group of Hill (1963) into two groups: the *H. speoris* and *H. larvatus* groups.

The description of each group in the Table below is based on Tate (1941), Hill (1963), Corbet and Hill (1992), and Robinson *et al.* (2003):

Table 1. Character matrix of the seven groups in the Genus *Hipposideros* (Tate, 1941; Hill, 1963; Corbet and Hill, 1992, Robinson *et al.* 2003).

Group	External Characters	Cranial Characters	Dentition
H. megalotis group	FA: 35.0-38.0 mm. Noseleaf small and simple, without supplementary leaflets. Posterior leaf moderate, supported by three septa. Ears large and round. Posterior margins without concavity behind the tip. Antitragal fold have a small internal fold.	Skull small and elongate, with CCL: 11.6-12.9 mm. The braincase inflated and narrowed rostrum, with low sagittal crest. The zygomata moderate, with a low jugal projection.	C-M^3: 4.2-4.8 mm. i^1 widely space, weakly bilobed. c^1 slender, well-developed posterior cusp. pm^2 absent. Posterior ridge of m^3 obsolescent. Crown area of i$_1$ much larger than i$_2$. pm$_2$ one half height, three quarters or more length of pm$_4$.
H. bicolor group	FA: 32.0-53.0 mm. Noseleaf small to moderate and simple to complex, with none to two supplementary leaflets. Posterior leaf thin, supported by three septa	Skull narrow and elongate, with CCL: 12.6-17.2 mm. Braincase moderately inflated and narrowed rostrum, with low sagittal crest. Zygomata narrow, with a low to high jugal projection.	C-M^3: 4.8-7.5 mm. i^1 weak, outer lobe obsolescent. c^1 without to high posterior cusp. pm^2 much reduced, included in toothrow. m^3 reduced. i$_1$ unenlarged to enlarged, overlapped with i$_2$. pm$_2$ one

Table 1 (Continue). Character matrix of the seven groups in the Genus *Hipposideros* (Tate, 1941; Hill, 1963; Corbet and Hill, 1992, Robinson *et al.* 2003).

	or without. Ears large, broad, and rounded, more or less triangular in outline. Antitragal fold with internal fold or thickening.		half to three fourth height of pm_4.
H. cyclops group	FA: 42.5-76.0 mm. Noseleaf much specialised, with two supplementary leaflets. Posterior leaf moderated, supported by three septa. Ears long, narrow, acutely pointed, without modification.	Skull short and broad, with CCL: 15.1-27.1 mm. Braincase wide, almost globose and greatly broadened rostrum, with low sagittal crest. Zygomata slender or moderated, with low projection.	C-M^3: 5.6-11.1 mm. i^1 weak, outer lobe obsolescent or absent. c^1 without cusp, but well-developed cingular. pm^2 much reduced, absent in *H. stenotis*. Posterior ridge of m^3 obsolescent or well-developed. i_1 without thickening i_2. pm_2 much reduced, one third height of pm_4.
H. pratti group	FA: 73.0-89.5 mm. Noseleaf with single median emargination, with two supplementary leaflets. Posterior leaf high in centre,	Skull moderate to large, with CCL: 24.2-30.0 mm. Rostrum narrow, with well-developed sagittal crest. Zygomata slender, with moderated jugal	C-M^3: 10.4-12.8 mm. Outer lobe of i^1 only slightly smaller than inner lobe. pm^2 reduced, extruded from toothrow. Posterior ridge of m^3 almost obsolete.

Table 1 (Continue). Character matrix of the seven groups in the Genus *Hipposideros* (Tate, 1941; Hill, 1963; Corbet and Hill, 1992, Robinson *et al.* 2003).

	supported by prominent median ridge flanked by two much weaker ridges. Ears large and broad, bluntly pointed. Posterior margins slightly concave behind, without antitragal modification.	projection.	Crown area of i_1 greater than i_2. pm_2 one half length and height of pm_4.
H. armiger group	FA: 63.0-100.0 mm. Noseleaf broad, four supplementary leaflets. Posterior leaf high and narrow, supported by prominent median septum and two less evidence lateral septa. Ears large and broad, without antitragal modification.	Skull moderate to large size, with CCL: 23.0-29.8 mm. Rostrum elevated posteriorly, with well-developed sagittal crest. Zygomata moderate to strong, with moderate to well-developed jugal projection.	$C\text{-}M^3$: 8.7-12.8 mm. i^1 bilobed, with outer lobe approximately equal to inner lobe. c^1 low anterior cusp. pm^2 small, extruded from toothrow. Posterior ridge of m^3 obsolescent. Crown area of i_1 greater than i_2. pm_2 one third to one half length and height of pm_4.

Table 1 (Continue). Character matrix of the seven groups in the Genus *Hipposideros* (Tate, 1941; Hill, 1963; Corbet and Hill, 1992, Robinson *et al.* 2003).

H. speoris group	FA: 53.0-67.0 mm. Noseleaf simple, with three supplementary leaflets. Posterior leaf high to moderate, without septum, upper edge semicircular and not lobate. Ears large and broad, triangular in outline. Antitragal fold with small process or thickening.	Skull medium and short, with CCL: 15.8-19.8 mm. Rostrum low, with moderated sagittal crest. Zygomata slender, with moderate jugal projection.	C-M^3: 6.7-9.5 mm. Outer lobe of i^1 obsolescent or absent. c^1 without definite cusp. pm^2 small, extruded from toothrow. Posterior ridge of m^3 obsolete or nearly obsolete. Crown area of i_1 greater than i_2. pm_2 one half to two third length and height of pm_4.
H. diadema group	FA: 73.0-101.0 mm. Noseleaf simple, with three or four supplementary leaflets. Posterior leaf high, supported by median septum and two weaker lateral septa. Ears traingular, acutely pointed, without antitragal modification.	Skull large, with CCL: 25.0-34.7 mm. Rostrum broad and high, with moderate or strongly developed sagittal crest. Zygomata massive, with prominent jugal projection.	C-M^3: 11.0-15.2 mm. i^1 bilobed. c^1 with or without posterior cusp. pm^2 small, partially or wholly extruded from toothrow. Posterior ridge of m^3 much reduced and obsolescent. Crown area of i_1 greater than i_2. pm_2 one third to one half or two thirds length and height of pm_4.

2.5. THE *HIPPOSIDEROS BICOLOR* GROUP

2.5.1. DESCRIPTION

1). External character

The bats in this group are small to medium size, with a forearm length of 32.0-53.0 mm (Corbet and Hill, 1992). The ears are large, broad, rounded, more or less triangular in outline, bluntly pointed or pointed, and often display a concavity on their posterior margin just behind the tip of the ears. The antitragal fold has an internal fold or a thickening of the membrane at the antitragal lobe, less prominent, and are haired for one half or less, or about two thirds of their length (Tate, 1941; Hill, 1963). The noseleaf is moderate, with a width of about 12-15% of forearm length (Tate, 1941). It varies from a relatively unspecialised and simple structure to a more complex, greatly developed structure, sometimes with bizarre foliations. The number of lateral supplementary leaflets varies from none or incipiently one in the more primitive species of the group to one or more usually two in those that are more specialised (Hill, 1963). The posterior leaf is supported by three weak septa, which divide it into four cells. Thumb is strongly developed. The metacarpal is equal in length or slightly exceeds the basal phalanx. Tibiae are 40-50% of forearm length. Each calcar is elongated, between 20-30% of forearm length. The tail is moderate, about 70-75% of forearm length. Part of the terminal joint of the tail often exceeds the patagium, not exceeding uropatagium in the *H. calcaratus* group. Frontal sac present in both sexes (Tate, 1941).

2). Cranial character

The skull is small to medium size, with a condylo-canine length of 12.6-17.1 mm (Corbet and Hill, 1992), elongate, narrow, and taper anteriorly (Tate, 1941; Hill, 1963). The braincase is moderately inflated (Hill, 1963) and enlarged. The interorbital region is unconstricted (attaining 70% of rostrum width). The zygomata are narrow, and have elongate, tapered outlines (Tate, 1941). The zygomata width rarely exceeds the mastoid width (Hill, 1963). Rostra are narrow, scarcely expanded (Tate, 1941; Hill, 1963), and the auditory region is unspecialised (Hill, 1963). In the *H. galeritus* group of Tate (1941), the rostral area is moderately full, rounded, with incipient post-orbital eminences, its width about 50% of zygomatic breadth, which last is greater than greatest mastoid width. Least inter-temporal width is about 50% of rostral width. The palate is broad and short; it is U-shaped in front, and does not extend posteriorly behind m^3. The vomer projects far back into the mesopterygoid fossa, with a thickened lower margin (Tate, 1941). The cochleae are never more than a little wider than their distance apart (Hill, 1963). The premaxillae are elongate and narrow; the incisive foramina are large and broadly oval, the eliptical opening of the incisive foramina closed extero-posteriorly by the maxillae, their extero-posterior margins formed by the maxillae in the *H. galeritus* group. The mandible has a strong coronoid process and a heavy knob-like angular process (Tate, 1941).

3). Dentition

The upper toothrow length is 4.5-7.5 mm (Corbet and Hill, 1992). The upper incisors (i^1) are weak, the outer lobe obsolete or becoming obsolete (Tate, 1941; Hill, 1963) or simplified, their crowns with only a trace of outer lobes, their tips projecting inwards but separated. The canine (c^1) is without a posterior cusp. The first upper premolar (pm^2) is usually included in the toothrow, partially excluded in the *H. galeritus* group. Second upper premolar (pm^4), though very much reduced, still retained in toothrow. Main cusp of pm^4 is higher than molar cusp line. Hypocone better developed in the first molar (m^2) than in the second (m^2). The W-pattern of third upper molar (m^3) is reduced. The lower outer incisor (i_2) is scarcely or not at all thicker than inner lower incisor (i_1) (Tate, 1941). The crown dimensions of i_2 are less than or only slightly greater than those of i_1 (Hill, 1963), but Corbet and Hill (1992) noted that the crown area of i_2 is equal to i_1. However, Tate (1941) reported i_2 unenlarged, slightly enlarged in the *H. calcaratus* group, but overlapped by i_1. The crown area of first lower premolar (pm_2) is about one half to three quarters height of crown area of second lower premolar (pm_4), typically two thirds in the *H. galeritus* group (Tate, 1941).

2.5.2. DISTRIBUTION

This group includes 36 species, 25 of which occur in the Indomalayan or Oriental Region and 22 species in South-east Asia (Simmons, 2005; Guillen-Servent and Francis, 2006; Bates *et al.* 2007). The distributional range extends from

Africa to India throughout peninsular Malaysia, Sunda Islands, Borneo, Philippines, and Celebes to New Guinea, Northern Australia and New Hebrides (Tate, 1941; Hill, 1963).

CHAPTER 3

SYSTEMATICS REVIEW

Diversity has interested humans ever since the beginning of our species. No matter how ignorant a native tribe may be in other matters biological, invariably it has a considerable knowledge of local plants and animals as well as names for them and often even a rudimentary classification (Mayr and Ashlock, 1991). As biologists began studying what are called ‘biodiversity patterns’, the primary data were observations of presence or absence of species across space and time, combined with geographical information regarding climate, soil, geology and other features of the regions in which they are found (Soberón and Peterson, 2004). This focus on primary occurrence information began with the earliest of the classic naturalists, and continued right up to the present (Krishtalka and Humphrey, 2000). This basis, of course, requires the collaboration of the entire systematic enterprise, for without sound taxonomic information and description an understanding of species diversity patterns and distributions would be impossible (Soberón and Peterson, 2004).

The important biological discipline concerned with the scientific study of diversity is often indiscriminately referred to as systematics or taxonomy. There is a broad overlap in the application of these terms, but there is also a subtle difference. The term “taxonomy” is derived from the Greek words “taxis” (arrangement) and “nomos” (law) and first proposed in its French form by de Candolle (1813) for the theory of plant classification. It agrees best with current thinking to define it as follows: “taxonomy is the theory and practice of classifying organisms” (Mayr and Ashlock, 1991).

The term “systematics” stems from the latinized Greek word “systema” as applied to the systems of classification developed by the term: “systematics is the scientific study of the kinds and diversity of organisms and of any and all relationships among them” (Simpson, 1961; Mayr and Ashlock, 1991). More simply, “systematics is the science of the diversity of organisms”. The word “relationship” is not used here in a narrow phylogenetic sense but it is broadly conceived to include all biological interactions among organisms. This explains why such a broad area of common interest has developed between systematics, evolutionary biology, ecology, and behavioural biology (Mayr and Ashlock, 1991). Additionally, Neuweiler (2000) suggests that the goal of systematics and/or taxonomy is to characterise the various taxa and organise them on the basis of their evolutionary relationships. Classical taxonomy depended heavily on museum material, especially bones. Taxonomy provides the bricks and systematics the plan, which the house of the biological sciences is built. Taxonomic and systematic knowledge underpin everything in evolution and ecology and are therefore the basis for applied responses to climate change and other environmental problems (May, 2004).

When we study taxonomy, we must understand the species concept. Many species concepts have been proposed in an attempt to facilitate the assembling of phena into biologically meaningful taxa at the species level. There are four groups of species concept, including typological species concept, nominalistic species concept, biological species concept, and evolutionary species concept. The first two have mainly historical significance but are still upheld by a few contemporary authors (Mayr and Ashlock, 1991).

The typological species concept states that species consist of similar individuals sharing the same essence, each species is separated from all others by a sharp discontinuity, each species is completely constant through time, there are strict limits to the possible variation within any one species (Mayr and Ashlock, 1991).

The nominalistic species concept was popular in France in the 18th century (Buffon and Lamarck in their early writings and Robinet) and has adherents to the present day (Mayr, 1982). Bessey (1908) expressed this point view particularly well: “nature produces individuals and nothing more … species have no actual existence in nature. They are mental concepts and nothing more … species have been invented in order that we may refer to great numbers of individuals collectively”.

The biology species definition which results from this theoretical species concept is as follows: a species is a group of interbreeding natural populations that is reproductively isolated from other such group (Mayr and Ashlock, 1991).

The evolutionary species concept: an evolutionary species is a lineage (an ancestral-descendent sequence of populations) evolving separately from others and with its own unitary evolutionary role and tendencies (Simpson, 1961). However, the problem of evolutionary species concept is the causation and maintenance of discontinuities between contemporary species. Rather, it concentrates on trying to delimit species taxa in the time dimension (Mayr and Ashlock, 1991).

Moreover, we must understand about taxon, and subspecies. Simpson (1961) defined taxon as: “a taxon is a group of real organisms recognized as a formal unit at any level of a hierarchic classification”. And Mayr and Ashlock (1991) defined subspecies as “the subspecies may be defined as follows: a subspecies is an aggregate of phenotypically similar populations of a species inhabiting a geographic subdivision of the range of that species and differing taxonomically from other populations of that species”.

Taxonomy is important for conservation planning. Mace (2004) noted that taxonomy and conservation go hand-in-hand. We cannot necessarily expect to conserve organisms that we cannot identify, and our attempts to understand the consequences of environmental change and degradation are compromised fatally if we cannot recognize and describe the interacting components of natural ecosystems (Mace, 2004). Several recent reviews have emphasized the fundamental role that taxonomy plays in conservation, and significant high-level science policy reports have additionally drawn attention to the funding and credibility gap faced by taxonomic and systematic science (NRC 1995; House of Lords, 2002; The Royal Society, 2003).

Taxonomy and species conservation are often assumed to be completely interdependent activities. However, a shortage of taxonomic information and skills, and confusion over where the limits to ‘species’ should be set, both cause problems for conservationists. There is no simple solution because species lists used for conservation planning, for example, threatened species, species richness estimates, and species covered by legislation are often also used to determine which units should be the focus of conservation actions. This despite the fact that the two processes have such different goals and information needs. Species conservation needs two kinds of taxonomic solution. First, a set of practical rules to standardize the species units included on lists. Second, an approach to the units chosen for conservation recovery planning which recognizes the dynamic nature of natural systems and the differences from the units in listing processes that result. These solutions are well within our grasp but require a new kind of collaboration among conservation biologists, taxonomists and legislators, as well as an increased resource of taxonomists with relevant and high-quality skills (Mace, 2004).

3.1. SYSTEMATICS OF BATS

Linnaeus (1758), the founder of modern taxonomy, knew of only seven species of bats. He grouped these bats together under the Genus *Vespertilio*, within the Order Primates. Blumenbach (1780) classified bats in a separate order, Order Chiroptera, the name that is used today. Nevertheless, as recently as the last century, there was still some uncertainty as to how to classify bats, so they were placed in various different mammalian orders. For along time the flying lemur *Cynocephalus* was classified under the Order Chiroptera. Since the Australian neurobiologist Pettigrew described the Megachiroptera as 'flying primates' based on their midbrain visual pathways, some have reclassified the megachiroptera within the primate group. The traditional system of taxonomy which seems so well established is in upheaval. The idea that the Order Chiroptera has a monophyletic origin rests on the fact that they are only mammals with wings. Nevertheless, it is possible that the wings of Megachiroptera and Microchiroptera developed through convergent evolution. The similarity of the wing structure in the two groups could simply be due to the constraints imposed by the mammalian body structure, which would allow few other options (Neuweiler, 2000).

In classifying the Order Chiroptera, the premaxillae and teeth were used as indicators of the diet; the bones of the limbs, especially the joint connecting the shoulder and upper arm, were used as indicators of the ability to fly. Joints that resemble those of flightless mammals are considered to be ancestoral. This type of joint is found in flying foxes of the genus *Pteropus*. Joints that show clear adaptations for flight are considered to be derived. This type of joint is found in molossid bats, among others. Patterns of dentition that resemble those of insectivores are considered to be primitive. It is on the basis of collections of characters such as this that family trees are deduced. However, these family trees are by no means definitive, especially since there is a tendency to underestimate the possibilities for convergent evolution as well as specific functional adaptations in taxa of equal rank (Neuweiler, 2000).

The system used today for classification of the Chiroptera is based on the organisation proposed by Miller (1907). He classified 16 different families of Microchiroptera on the basis of their bone structure. Although it is possible to divide bats into families based on these criteria, they do not provide any insight into how the different families are related to one another. Today, the issue of bat phylogeny is more controversial than ever, even though a number of new characters and new methods for studying this problem were introduced in the 1970s and 1980s (Neuweiler, 2000).

CHAPTER 4

MATERIAL AND METHODOLOGY

4.1. STUDY AREAS

The voucher specimens examined in this study were from 27 localities, including two localities in a state in India, three localities in three states in Myanmar, and 22 localities in 14 provinces of Thailand. In order to provide information for further research, brief descriptions of these sites are given below:

4.1.1. INDIA

Tamil Nadu: previous studies by members of the Harrison Institute were conducted at two sites, including:

(1) Thiruneer Malai is located some 26 km from centre Madras, approximately 13°03'N, 80°00'E. Four specimens of *H. ater* were collected on 5 March 1993, which are housed in the collection of Harrison Institute, England. A colony of about 30 individuals of both sexes was roosting in a store room (Bates and Harrison, 1997).

(2) Sankanthira Mandapam is located in northern Cheranmadevi, 16 km west of Tirunelveli, approximately 08°27'N, 77°25'E. A specimen of *H. ater* was collected on 23 February 2003, which is housed in the collection of Harrison Institute, England.

4.1.2. MYANMAR

Mon State: Study was conducted at one site, including:

(1) Saddan Sin Cave is located 16 km northeast of Mawlamyine, 16°19'N, 97°42'E [loc. 9, Fig. 46]. A specimen of *H. cineraceus* was collected on 2 November 2002, which is held in the collection of Harrison Institute, England. This cave is situated in a large isolated limestone outcrop set amongst extensive paddy fields and many toddy palms (Bates *et al.* 2005).

Tanintharyi Division: Study was conducted at one site, including:

(1) Tharabwin Village is located in Tanintharyi Division [loc. 9, Fig. 46]. A specimen of *H. ater* was collected on 12 November 2003, which is held in the collection of Harrison Institute, England. Tanintharyi Division is located between 10°14’N - 12°29’N, 98°25’E - 99°01’E. The original vegetation of the region was highland and lowland dipterocarp forest; the mature trees draped with numerous lianas, epiphytes and rattans. However, on the mainland most of the lowland areas have been deforested for agriculture, particularly for rice paddy and most of the remaining forest is restricted to the mountain tops (Bates *et al.* 2005).

Rakhine State: Study was conducted at one site, including:

(1) Kan Thar Yar Beach is located in Gwa Township, 17°43’N, 94°31’E, 1 m a.s.l. [loc. 6, Fig. 46]. A specimen of *H. ater* was collected on 15 November 2000, which is held in the collection of Harrison Institute, England. The habitat includes numerous palm trees, which were growing between the beach and the chalets, behind which was a little-used road with dense vegetation beyond (Pearch *et al.* 2003).

4.1.3. THAILAND

Chiang Mai Province: Studies were conducted at two sites, including:

(1) Khimee Cave is located in Chiang Dao Wildlife Sanctuary, Khong District, 19°21.266’N, 98°43.837’E, 718 m a.s.l [loc. 10, Fig. 46]. This is a very large limestone cavern surrounded by mixed deciduous forest including some dry evergreen forest. A specimen of *H. cineraceus* was collected in April 2006, which was held in the collection of Chiang Dao Wildlife Research Station.

(2) Pha Daeng Cave located in Srilanna National Park, Chiang Dao District, 19˚20.769’N, 99˚01.416’E, 480 m a.s.l., [loc. 11, Fig. 46; loc. 1, Fig. 50]. This site was surveyed on 22-23 October 2006. This is a limestone outcrop, with caverns inside, and with one large entrance. The cave is surrounded by hill evergreen forest, and ricefields. The harp traps were set at the entrance of the cave and on the trail behind the entrance. The harp traps were set before 6.00 pm until 8.30 pm and the following species were collected: *Hipposideros cineraceus, H. halophyylus, H.*

larvatus, Taphozous longimanus, Rhinolophus coelophyllus, R. malayanus, and *R. pusillus.*

Uthai Thani Province: Study was conducted at one site, including:

(1) Lup Lae Cave located in Ban Rai District, 15˚03.077'N, 99˚28.879'E, 200 m a.s.l., [loc. 13, Fig. 46; loc. 4, Fig. 50]. This site was surveyed on 23 March 2007. This is limestone outcrop, with a cavern inside and one small entrance. It is covered by mixed deciduous and bamboo forest, which is surrounded by tamarind and mango plantations, and corn fields (Fig. 1). The harp traps were set on the trail between the tamarind plantation and bamboo forest. The harp traps were set before 6.00 pm until earlier morning and the following species were collected: *H. cineraceus, H. halophyllus, H. lavatus, H. pomona, Megaderma spasma, R. malayanus, R. shameli* and *R. yunanensis.*

Fig. 1: Tamarind plantation in Lup Lae Cave, Ban Rai District, Uthai Thani Province.

Lop Buri Province: Studies were conducted at two sites, including:

(1) Khao Samor Khon located in Ta Wung District, 14˚54.548'N, 100˚30.342'E, 3 m a.s.l., [loc. 7, Fig. 50]. This site was surveyed on 24 January 2007. A harp trap was set across a small trail which leads from a local road to the foothills. The vegetation is *Syzygium cumini*. The following bat species were collected: *H. halophyllus, R. coelophyllus, R. malayanus* and *R. pusillus*.

- Ob Cave located in Khao Smorkhon, Tha Bung District, 14˚54.525'N, 100˚29.491'E, 38 m a.s.l., [also loc. 7, Fig. 50]. This cave was surveyed on 21 March 2007. The cave is in limestone outcrop, which is covered by mixed deciduous and dipterocrap forests and surrounded by a ricefield (Fig. 2). This cave is covered by a fig tree (*Ficus rumphii* Bl.). The cave has small entrance but is large inside. A hand net was used for capturing bats inside the cave. The bat species included: *H. halophyllus,* and *Myotis siligorensis.*

Fig. 2: Limestone outcrop in Khao Smorkhon, Ta Wung District, Lop Buri Province, which surrounded by agriculture areas.

(2) Khao Don Deung located Ban Mi District, 15˚08.888’N, 100˚36.819’E, 40 m a.s.l., [loc. 14, Fig. 46; loc. 6, Fig. 50]. This site was surveyed on 22 March 2007. Limestone outcrop covered by mixed deciduous and dipterocrap forests and surrounded by teak plantations, sun flower fields and corn fields. Harp traps set on trail at mountain's hill, not covered by canopy of trees and covered by canopy of bamboo trees (Fig. 3). The harp traps were set before 6.00 pm until 8.30 pm. The bats were found including *H. cineraceus, H. halophyllus, H. larvatus, H. pomona, R. malayanus, R. pusillus, R. shameli,* and *R. stheno.*

Fig. 3: Harp trap was set on the trail in mixed deciduous forest in Kao Don Dueng, Ban Mi District, Lop Buri Province.

Sara Buri Province: Study was conducted at one site, including:

(1) Ton Chan Cave located Phaphouthabat District, 14˚43.193’N, 100˚47.684’E, 33 m a.s.l, [loc. 8, Fig. 50]. This site was surveyed on 21 March 2007. A limestone cave is in a Chinese temple surrounded by mixed deciduous forest, which is small cave and has a small hole inside of cave (Fig. 4). This cave is in a limestone

outcrop which is surrounded by villages. The bat was captured using a hand net inside the cave. The bat was found including *H. halophyllus.*

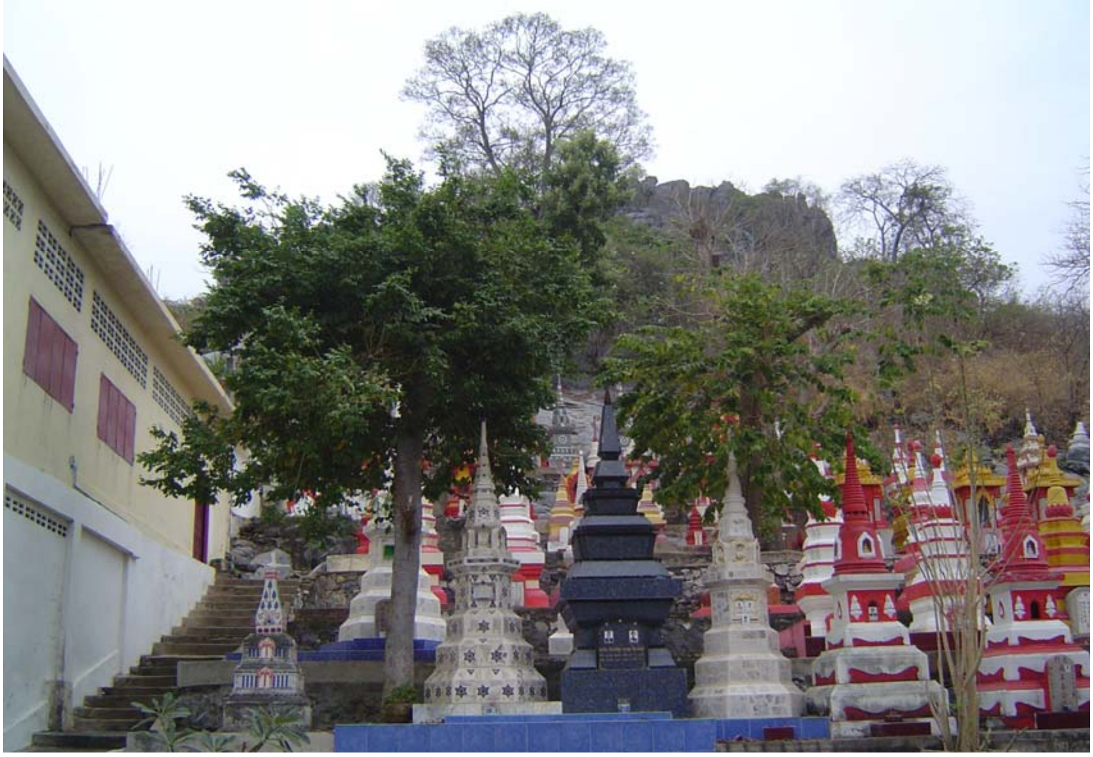


Fig. 4: Limestone outcrop in Ton Chan Cave, Phaphouthabat District, Sara Buri Province, which is covered by mixed deciduous forest and surrounded by villages. The cave is in Chinese Temple.

Sa Kaeo Province: Study was conducted at one site, including:

(1) Khao Singto located in Meuong District, 13˚59.417'N, 102˚00.465'E, 12 m a.s.l., [loc. 17, Fig. 46; loc. 9, Fig. 50]. This site was survey on 20 March 2007. The limestone outcrop is covered by mixed deciduous forest and surrounded by a eucalyptus plantation. Harp traps were set at the entrance to the cave under a canopy of trees, on a road with no canopy and on a trail under a canopy of trees. The harp traps were set before 6.00 until 8.30 pm. Bats species included: *H.*

cineraceus, H. halophyllus, H. galeritus, H. larvatus, H. pomona, M. spasma, and *R. shameli.*

Ratcha Buri Province: Study was conducted at one site, including:

(1) Khao Bin Cave located in Chom Bung District, 13˚35.527'N, 99˚40.012'E, 61 m a.s.l., [loc. 19, Fig. 46; loc. 13, Fig. 50]. This site was surveyed on 09 February 2007 and 24 March 2007. This is a limestone outcrop covered by mixed deciduous and bamboo forests which is visited by tourists. Harp traps were set at the entrance to the cave. The harp traps were set before 6.00 pm until 8.30 pm. The bats included: *Aselliscus stoliczkanus, H. cineraceus, H. pomona, R. malayanus,* and *R. thomasi.*

Phetcha Buri Province: Study was conducted at one site, including:

(1) Khao Yoi Cave located in Khao Yoi District, 13˚14.014'N, 99˚49.708'E, 53 m a.s.l., [loc. 20, Fig. 46; loc. 14, Fig. 50]. This site was surveyed on 11 February 2007. This cave is a limestone outcrop and is visited by tourists. The limestone outcrop is surrounded by a mixed deciduous forest, villages, ricefields and temple. The harp traps were set at the foothill under a tree canopy and one was set between trees and the hill at 13˚14.299'N latitude, 99˚49.509'E longitude, 33 m elevation behind the Ban Khao Yoi school. The harp traps were set before 6.00 pm until 9.00 pm. Bat species included: *H. cineraceus, H. halophyllus, H. larvatus, H. pomona, M. siligorensis, R. coelophyllus, R. malayanus,* and *R. pusillus.*

Chumphon Province: Studies were conducted at two sites, including:

(1) Khao Kram Cave located in Patiew District, 10˚55.131'N, 99˚22.440'E, 67 m a.s.l., [loc. 21, Fig. 46]. This site was surveyed on 10 October 2006. This is a limestone cave, with one large entrance and is home to a temple. It is surrounded by a rubber plantation. The harp trap was set at the small entrance to the cave and a hand net was used to capture the bats. The harp trap was set before 6.00 pm until 8.00 pm. The bats were found including *H. cineraceus, H. larvatus, H. pomona,* and *R. affinis.*

(2) Silawan Cave located in Patiew District, 10°41.461'N, 99°14.476'E, 68 m a.s.l., [loc. 22, Fig. 46]. This site was surveyed on 11 January 2007. This is a limestone outcrop, with a large entrance which is surrounded by disturbed forest on one side of the cave. The other side is surrounded by oil palm, rubber and orchard plantations (Fig. 5). The harp trap was set at the small entrance. The harp trap was set before 6.00 pm until 8.30 pm. The bats species included: *H. cineraceus, H. larvatus, H. galeritus, M. siligorensis, R. lepidus, R. malayanus,* and *Tylonycteris pachypus.*

Fig. 5: Rubber, oil palm and orchard plantation, and disturbed forest that surrounded Silawan Limestone outcrop, Pateiw District, Chumphon Province.

Ranong Province: Study conducted at one site, including:

(1) Pra Khayang Cave located in Kraburi District, 10°19.569'N, 98°45.923'E, 3 m a.s.l., [loc. 23, Fig. 46]. This site was surveyed on 13 January 2007. This is a limestone outcrop covered by deciduous forest which is surrounded by Nipa palm (*Nipa fruticans* Wurmb.) and mangrove forest (Fig. 6). The harp traps was set on a natural trail around the foothill under a canopy of trees and small hole leading

from the cave. The harp traps were set before 6.00 pm until 8.30 pm. Bat species included: *H. cineraceus, H. galeritus, H. lekaguli, Myotis horsfieldi, Miniopterus medius,* and *R. affinis.*

Fig. 6: Mangrove and Nipa palm forest, and natural trail around Pra Kayang Limestone outcrop, Kraburi District, Ranong Province.

Phang Nga Province: Study was conducted at one site, including:

(1) Ao Mai Ngam is located in Surin Island National Park, 9°25.873'N, 97°51.975'E, 20 m a.s.l., [loc. 24, Fig. 46]. A specimen of *H. cineraceus* was collected on the natural trail, which was surrounded by seasonal evergreen forest. This specimen was collected on 2 February 2006.

Trang Province: Study was conducted at one site, including:

(1) Khao Chong Waterfall located in Khao Banthat Wildlife Sanctuary, 7°32.894'N, 99°47.196'E, 81 m a.s.l., [loc. 25, Fig. 46]. This site was surveyed on 20

January 2007. The harp trap was set on a natural trail, which is surrounded by secondary forest, a stream and a waterfall were located nearby. The harp traps were set before 6.00 pm until earlier morning. The bats were found including *Cynopterus brachyotis, H. bicolor, H. cineraceus, H. larvatus, Kerivoula hardwickii, R. affinis,* and *R. lapillus.*

Songkhla Province: Studies were conducted at four sites, including:

(1) Khao Rak Kiat Cave located in Rattaphum District, 6°38.767'N, 99°37.383'E, 100 m a.s.l, [loc. 31, Fig. 46]. This site was surveyed on 16 December 2006. This cave is in a limestone outcrop which is surrounded by disturbed forest and a rubber plantation. The harp traps were set on natural trail under a canopy of the trees and a bat was captured using a hand net in the cave. The harp traps were set before 6.00 pm until 8.30 pm. The bats included: *H. cineraceus, H. larvatus, M. medius*, *R. affinis, R. lepidus* and *R. stheno*.

(2) Wildlife Education Centre located in Ton Nga Chang Wildlife Sanctuary, Rattaphum District, 6°56.739'N, 100°14.467'E, 107 m a.s.l., [loc. 29, Fig. 46]. This site was surveyed on 29 November 2006. The harp traps were set on natural trails under a canopy of trees, along a small stream, and near a pond, which was surrounded by lowland tropical rain forest. The harp traps were set before 6.00 pm until 8.30 pm. Bat species included: *Coelops frithii, H. bicolor, H. cineraceus, H. diadema, K. hardwickii, Megaerops ecaudatus, Murina cyclotis, R. acuminatus, R. affinis,* and *R. trifoliatus.*

(3) Khao Nouy Cave located in Rattaphum District, 6°59.537'N, 100°08.470'E, 130 m a.s.l., [loc. 30, Fig. 46]. This site was survey on 07 October 2006 and 07 February 2007. This is limestone outcrop, with many caverns and small holes inside. The outcrop was surrounded by disturbed areas, plantation, a road and a village. The harp trap was set at the entrance to the cave and some bats were captured using a hand net inside of the cave. The harp trap was set before 6.00 pm until 8.30 pm. The bats were found including *H. armiger, H. bicolor,* and *H. cineraceus.*

(4) Outaphao Watershed located in Rattaphum District, 6°47.777'N, 100°14.092'E, 197 m a.s.l., [loc. 28, Fig. 46]. This site was surveyed on 25 February 2007. A harp trap was set on the trail between rubber trees in a rubber plantation,

without canopy cover. Another was set on a natural trail near a stream. Both sites were surrounded by disturbed forest and rubber plantations. The harp traps were set before 6.00 pm until 8.30 pm. Bat species included: *H. bicolor, H. cineraceus, H. larvatus, K. hardwickii, R. affinis,* and *M. cyclotis*.

Satun Province: Studies were conducted at three sites, including:

(1) Talow Wao-Talow Oulang Road located in Tarutao Islands National Park. This site was surveyed on 07 March 2007. The harp traps were set at 2 sites: between km 1-2 (6˚36.501'N, 99˚40.435'E, 73 m a.s.l.) and km 6 (6°39.500'N, 99°40.833'E, 100 m a.s.l.) on the road from Talow Wao to Talow Oulang [loc. 34, Fig. 46]. At the first site, the harp traps were set on the side of the road, under a canopy of trees, which was surrounded by old-growth dry evergreen forest (lowland), densely covered at ground level (Fig. 7). At the second site, the harp traps were set on a trail, under a canopy of trees, which was surrounded by lowland evergreen forest and close to a limestone hill. The harp traps were set before 6.00 pm until 8.00 pm. The following bat species were collected: *H. bicolor, H. cineraceus, K. hardwickii, R. coelophyllus,* and *R. lepidus*.

Fig. 7: Lowland evergreen forest in Tarutao Islands National Park, Satun Province.

(2) Crocodile (Jorrake) Cave located in Tarutao Island National Park, 6˚41.946’N, 99˚39.096’E, 65 m a.s.l. [also loc. 34, Fig. 46]. This site was surveyed on 08 March 2007. A river runs within this limestone cave, which is covered by lowland dry evergreen forest and surrounded by mangrove forest and sea. *H. cineraceus* was captured using a hand net in the cave.

(3) Ao Son is located in Tarutao Islands National Park, 6°38.767’N, 99°37.383’E, 5 m a.s.l. [also loc. 34, Fig. 46]. A specimen of *H. cineraceus* was collected on the natural trail, which is near a stream and surrounded by moist evergreen forest; it was close to a beach. This specimen was collected on 3 March 2003.

Narathiwat Province: Study was conducted at one site, including:

(1) Sirinthorn Waterfall is located in Bala Forest, Hala-Bala Wildlife Sanctuary, 5°48.017’N, 101°50.000’E, 300 m a.s.l. [also loc. 34, Fig. 46]. A specimen of *H. cineraceus* was collected on the natural trails close to the stream, which is surrounded by lowland evergreen forest. This specimen was collected on 5 July 2003.

4.2. METHODS

4.2.1. Harp Trap

Bats were captured in four-bank harp traps (Francis, 1989). The size of the harp traps is approximately 1.5 m wide and 1.6 m high. The space between each wire is approximately 2.5 mm. The harp traps were set at the entrance to caves, on trails, over streams, and across paths in the forest, usually in relatively concealed positions (Fig. 8-9). Harp traps were set in the afternoon and checked every 15 minutes from early evening to 21.00 h. The harp traps work on the principle that the echolocation of bats cannot easily detect the wires. The tension of the wire banks is sufficient to stop the flight momentum of the bats. A large bag is attached to the harp traps to serve as a hopper to collect the falling bats.

Harp traps are best set on trails, along slowly flowing streams, between trees, rock faces, over water holes, and at the opening to roosts. Bats normally use these areas as natural flyways, and harp traps are easily set in these places. Moreover, if placed in the middle of a shallow pond or stream and abutted with mist nets that function much like a funnel, harp traps may be particularly successful. At sites where only a few bats may be present, it is possible to block areas around the harp trap with branches, nylon netting, or some other material to funnel as many bats as possible into the path of the harp trap. When a harp trap captures more bats than can be conveniently handled, the bag can be removed from the trap, or the trap can be turned sideways. The trap should not be laid down on the ground because the lines may become entangled in vegetation (Kunz and Kurta, 1988).

4.2.2. Mist-net

Mist-nets are very common devices used for capturing flying bats. Some of advantages for using mist-nets are: they are lightweight, compact, and easily erected in the field. However, they are expensive and easily torn. Mist-nets were used for capturing bats at various heights above ground level up to canopy height (Fig. 10). The size of the mist-nets range from 3-12 m in length and 2-3 m in width. Mist-nets were monitored continuously.

Fig. 8: Harp trap was set between mixed deciduous forest and tamarind plantation, under canopy in Lup Lae Cave, Ban Rai District, Uthai Thani Province.

Fig. 9: Harp trap was set at the cave's entrance in Khao Bin Cave, Chom Bung District, Ratcha Buri Province.

Fig. 10: Mist-net was set over stream at Making Waterfall, Ton Nga Chang Wildlife Sanctuary, Songkhla Province.

4.2.3. Hoop Net or Hand Net

Hand nets can be used for capturing bats in caves, mines, buildings, hollow trees, trees, buttresses and foliage (Fig. 11). Hand nets with adjustable handle lengths are particularly valuable for working in these places. Hand nets can be made from mosquito nets, a heavy-duty wire and with almost any type of pole. The diameter and depth of hand nets are approximately 60 cm and 100 cm, respectively. The bag of the hand nets should be deep enough to prevent bats escaping. Handles should be light weight and made from aluminium; each poles is approximately 100 cm in length and can be quickly connected together to increase the length for capturing bats in high roosts.

Fig. 11: A hand net was used for capturing bats within caves.

4.2.4. Sound Record

The echolocation calls were recorded from hand held bats and from those held inside a cloth bag (Fig. 13). The bat detector was a Pettersson ULTRASOUND DETECTOR D 240x (Fig. 12), which was set at 10x time expansion rate and 17 seconds max storage time. A recorder was connected to the bat detector. Sound was recorded when heterodyne sound was heard. A manual start was clicked for recording sound and manual stop was clicked for playback sound. Calls were digitized and recorded into a MP3 Recorder (MULTICODEC JUKEBOX) or iHP-120 Recorder (MULTI-CODEC JUKEBOX) (Fig. 12). The recorder was set at 20 volume of line.

Fig. 12: Pettersson ULTRASOUND DETECTOR D 240x (left), and iHP-120 Recorder (MULTI-CODEC JUKEBOX) (right).

Fig. 13: Sound was recorded using Pettersson ULTRASOUND DETECTOR D 240x, and was rigitized into iHP-120 Recorder (MULTI-CODEC JUKEBOX).

4.2.5. Data Record

The species, sex, age (adult or juvenile, juveniles were identified by the presence of unfused epiphyses of the phalanx of metacarpal joints – section 1.5.1) and the reproductive condition (Reproductive status) of bats were determined in the field. Adult females were examined to see if they had given birth (considered by the keratinized appearance of nipples without hairs or with short hairs). Bats taken for voucher specimens were euthanized in a jar using chloroform. Body mass was measured using a Pesola Spring Balance (50g – bats were held in the cloth bag or a plastic bag). External measurements were taken using a digital caliper (FAITHFULL – 150 mm or 6 inch). Locations were recorded using GPS, and habitats were described. All data were noted in a field notebook.

Wing culture and the liver of bats were collected. They were preserved in 100% ethanol. A wet specimen label was attached to the right hind foot. The bodies were fixed in 95% ethanol for 24-48 hours and transferred into 70% ethanol.

1). Epiphyses of Metacarpal Joints

Epiphyses of captured bats were studied to determine the relative age of the bats. The condition of cartilagenous epiphyseal plates in the finger bones, distinguishes young bats from adults. When the wings of bats are trans-illuminated, these plates are readily visible to the unaided eye; the cartilaginous zones appear lighter than ossified parts of the bones. The shapes of the finger joints of young bats remain less knobby and more evenly tapered than those of adult bats when these cartilaginous plates are no longer grossly visible, allowing some young bats to be provisionally identified by this characteristic until they are almost a year old.

2). Reproductive Condition

The reproductive status of captured female bats was assessed. Pregnancy was determined by the development of the nipples. The nipples of pregnant female bats become enlarged as the mammary system develops. During lactation, the nipples are enlarged and milk can be expressed. After lactation the nipples retain their enlarged keratinized appearance. Multiparity can quickly be established by the identification of large nipples.

6.2.6. Field Data

Taxonomic studies require that essential data are recorded for all voucher specimens sacrificed in the field. These data are recorded in a durable field notebook (covered with rigid plastic sheet) (Fig. 14). The information in the field was noted as below:

- Date of collection.
- Locality data, especially the village, the name of cave, etc, the district, province and geographical co-ordinates in degrees and minutes (latitude and longitude) and altitude.
- Habitat description.
- Specimen number.
- Unique identity code, which is recorded in the field notebook (especially number of bag).
- Provisional species identification.

- Sex of specimen.
- External measurements – including head and body, forearm, ear, tail and hindfoot length, and body mass.
- File number of recorded echolocation call.
- File number of bat photograph

4.2.7. Wet Specimen Label

The wet specimen labels are 7 cm long and 2.5 cm wide (Fig. 15). They are made from strong paper that is tear proof and resistant to water and alcohol. Information on the labels are as listed below:

- Museum number
- Sex
- Species name
- Frequency of echolocation call
- Date of collection
- Locality
- Geographical co-ordinates (latitude and longitude)
- Head and body length
- Forearm length
- Ear length
- Tail length
- Hindfoot length
- Body mass
- Habitat (brief description)
- Altitude
- Collector
- Field number
- The wet specimen label must be written by Indian or permanent ink pen or pencil.

Date		Locality					Habitat				
No.	Bag No.	Species	Sex	HB	FA	E	T	HF	W	Echo.	Photo.
10/10/2006	Khao Kram Cave, Patiew Dist., Chumporn Province. 10˚55.131'N, 99˚22.440'E										
	Limestone cave surrounded by rubber plantation. Alt. 67 m.										
6	62	*H. cineraceus*	♀	42.20	35.71	16.08	27.39	5.22	3.60	AUDIO001	5933-5938
15	92	*H. cineraceus*	♂	39.11	34.06	15.51	24.85	5.55	3.60	AUDIO045	5920-5932
19	L16	*H. cineraceus*	♀	42.38	34.93	14.63	24.22	4.58	3.90	AUDIO042	5939-5954
23/10/2006	Pha Dang Cave, Srilanna NP., Chiang Mai Prov. 19˚31.951'N, 98˚50.737'E										
	Limestone cave surrounded by mixed deciduous forest. Alt. 864 m.										
24	M02	*H. halophyllus*	♂	42.86	38.69	11.62	25.45	5.64	4.00	AUDIO049	6695-6705
28	F98	*H. halophyllus*	♀	42.82	38.99	12.64	25.26	6.30	4.00	AUDIO035	6745-6754
35	96	*H. halophyllus*	♂	43.28	38.33	11.14	28.00	4.92	4.00	AUDIO042	6810-6812

Fig. 14: Part of a page from a field notebook.

PSUZC-MM06.89 ♂
Hipposideros cineraceus 151.3 kHz
○ 10/10/2006 Khao Kram Cave, Patiew Dist.,
Chumporn Prov.
10°55.131’N, 99°22.440’E

○
HB: 42.20
FA: 35.71
E: 16.08
T: 27.39
HF: 5.22
W: 3.6

Limestone cave surrounded by
Rubber Plantation. Alt. 67 m.
Collector: Bounsavane
Douangboubpha
Field No. BD061010.6

Fig. 15: The wet specimen label and the skull label, above: front label, below: back of label.

1). Museum Number

The museum number is the registered number of a specimen, for example in the Prince of Songkla University, Princess Maha Chakri Sirindhorn Natural History Museum, e.g. PSUZC-MM06.89. PSU is the short name of the Prince of Songkla University, ZC is Zoological Collection, M is mammal, 06 is the year of collection specimen and 89 is the number of registered mammal specimens in the museum. For specimens collected before 2006, the collection number begins with PSUZC-MM05.

2). Field Number

The field number combines the initials of the collector, the date of collection and the number of specimens collected in the field on that date. For example BD061010.6, is specimen number 6 that was collected by Bounsavane Douangboubpha on 10 October, 2006.

4.2.8. External Measurements

In this study, 86 voucher specimens were measured, which were held in the collection of the Princess Maha Chakri Sirindhorn Natural History Museum, Prince of Songkla University, Songkla, Thailand (prefix PSUZC), the collection of

Chiang Dao Wildlife Research Station, Chiang Mai, Thailand (prefix CD), the collection of Harrison Institute, Kent, England (prefix HZM), and collection of British Museum (Natural History), London, England (prefix BM(NH)). The definitions of external measurement (also Bates and Harrison, 1997) in the present study are as follows:

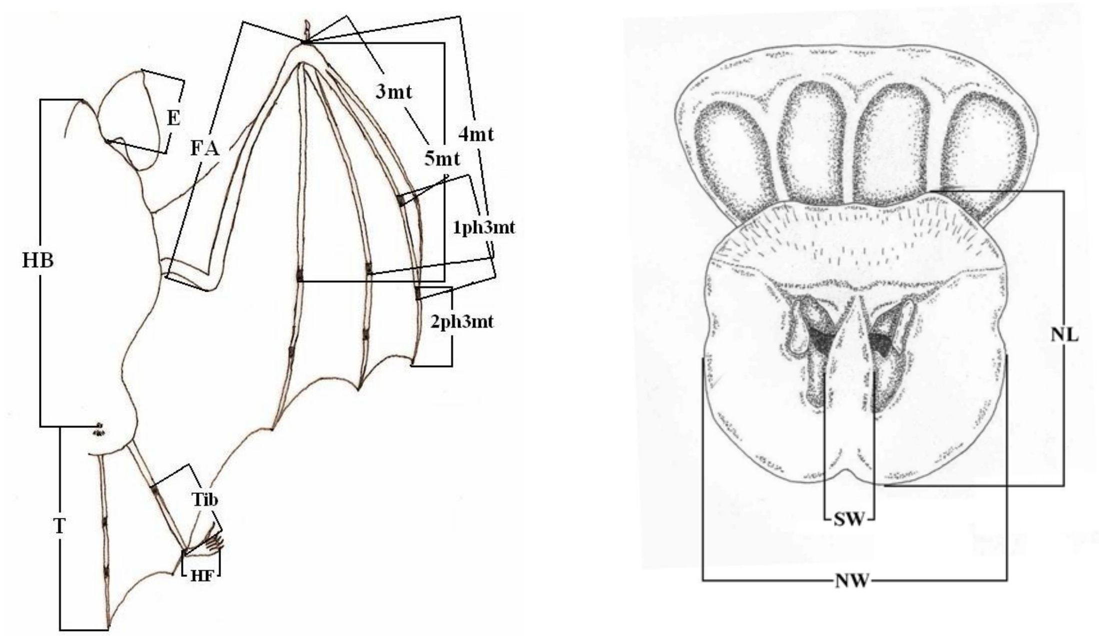


Fig. 16: Right wing of *Hipposideros bicolor* (left) and noseleaf of *Hipposideros cineraceus* (right).

HB: Head and body length – from the tip of the snout to the anus (Fig. 16).

FA: Forearm length – from the extremity of the elbow to the extremity of the carpus with the wings folded (Fig. 16).

EL: Ear length – from the lower border of the external auditory meatus to the tip of the pinna, not including any tuft of hair (Fig. 16).

EW: Ear width – greatest width across the pinna.

T: Tail length – from the tip of the tail to its base adjacent to the anus (Fig. 16).

HF: Hindfoot length – from the extremity of the heel behind the os calcis to the extremity of the longest digit, not including the hairs or claws (Fig. 16).

TIB: Tibia length – from the knee joint to the extremity of the heel behind the os calcis (Fig. 16).

3MT: Third metacarpal length – from the extremity of the carpus to the distal extremity of the metacarpal (Fig. 16).

4MT: Fourth metacarpal length – as third metacarpal, but for the fourth metacarpal (Fig. 16).

5MT: Fifth metacarpal length – as third metacarpal, but for the fifth metacarpal (Fig. 16).

1PH3MT: First phalanx of the third metacarpal length – from the proximal to the distal extremity of the phalanx (Fig. 16).

2PH3MT: Second phalanx of the third metacarpal length – from the distal extremity to the tip of the phalanx (Fig. 16).

1PH4MT: First phalanx of the fourth metacarpal length – as for the first phalanx of the third metacarpal, but for the fourth metacarpal.

2PH4MT: Second phalanx of the fourth metacarpal length – as for the second phalanx of the third metacarpal, but for the fourth metacarpal.

CL: Calcar length – from the extremity of the heel behind the os calcis to the tip of the calcar.

NL: noseleaf length – from anterior leaf to behind intermediate leaf (Fig. 16).

NW: Horseshoe width of the anterior leaf – greatest width across the horseshoe (Fig. 16).

SW: Internarial septum width – greatest width across the internarial septum (Fig. 16).

4.2.9. Skull Extraction

The skulls were extracted by hand. The methodology for skull extraction is as follows:

A small blunt scalpel was used to cut the facial skin on the front of mandible, close to the lower incisor. The facial skin was peeled from the front to the back of the mandible by using a combination of forceps, small blunt scalpel and small sharp scissors. The facial skin on the cranium, nearest to the upper incisors was cut and peeled from front to back. When cutting the skin free from the nasal bone region, it is important to avoid damaging the noseleaf. When removing the skin from the zygomatic arches, it is important to avoid damaging the zygomata. A small blunt scalpel is used to carefully remove the skin on each side of the skull by the ears. When removing the skull from the body, it is necessary to cut the upper cervical spine rather than risk cutting the occipital part of the skull. The tongue is removed by using a pair of forceps. A temporary skull label should be attacked to the skull and the mandible.

4.2.10. Temporary Skull Label

Temporary skull label is 3 cm long and 1 cm wide (Fig. 17). The label should be made from durable paper. Essential information recorded on the temporary skull label is collection number and field number. This label must be written in Indian or permanent ink pen or pencil.

○ PSU-M06.89

○ BD061010.6

Fig. 17: The temporary skull label, right: front of label, left: back of label.

4.2.11. Wet Specimen Storage

After the skull has been extracted, a cotton wool ball is fitted into the head skin. The mouth is sewn up with a needle and black cotton. Wet specimens are stored in air-tight jars. Each jar only contains one species, but may contain 1-3 specimens. Each specimen is identified and with its data included on a label. The label is attracted to the right foot. The jars contain 70% ethanol. The specimens must stay below the level of the ethanol. The jar is kept on open shelves in a dark place.

4.2.12. Skull Cleaning

The extracted skull with temporary skull label attached should be kept in alcohol or dry before final preparation. If kept in water for a long time it will became mouldy. Once boiling point is reached, the skull should remain in simmering water for about 15 – 20 minutes. The skull can be stored in cold water for sometime until it is cleaned. For cleaning, the muscle on the frontal is peeled off. The muscle between mandible and cranium is removed. The mandible is separated from the cranium. The muscle is removed from all parts of the skull by using a combination of small, fine pointed forceps and small scalpel. The brain is removed through the foramen magnum by using pointed forceps and cotton wool. The cartilage is removed from the palate and premaxilla. The mandible is cleaned after the cranium. The skull is cleaned under a stereo microscope. The temporary skull label is re-attached to the skull. The skull is brought to a colony of dermestid beetle for final cleaning.

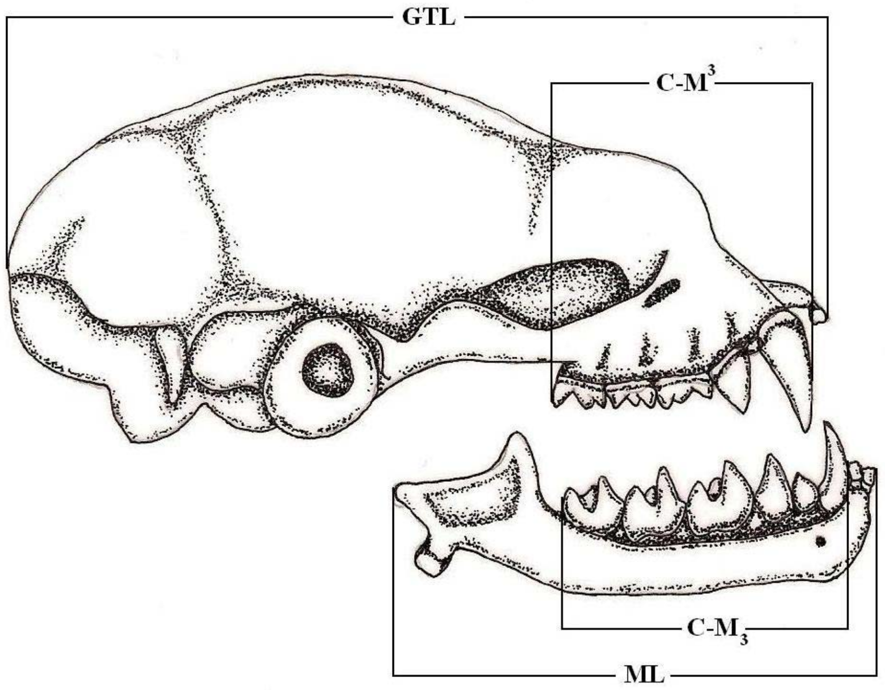
4.2.13. Skull Storage

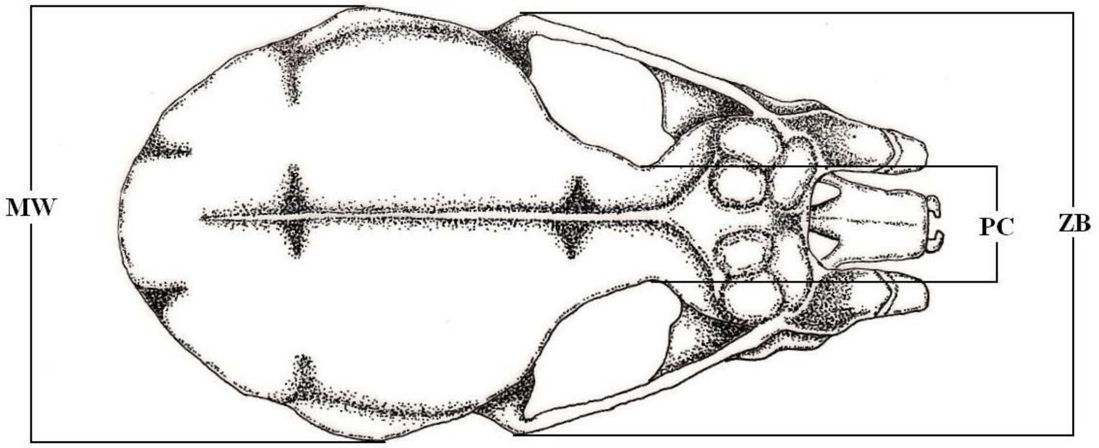
The temporary skull label is replaced with a collections skull label*. The skull threads are passed each side of the postorbital constriction, within the zygomatic arches. The skull should ride easily up and down the thread. The ends of thread are tied to the mandible. The skull is stored inside a small plastic pot with a secure lid. The label stays outside of the pot. The skull is supported on cotton wool to minimize any damage during storage. The skull pot is kept in a plastic bag, which is kept in a box.

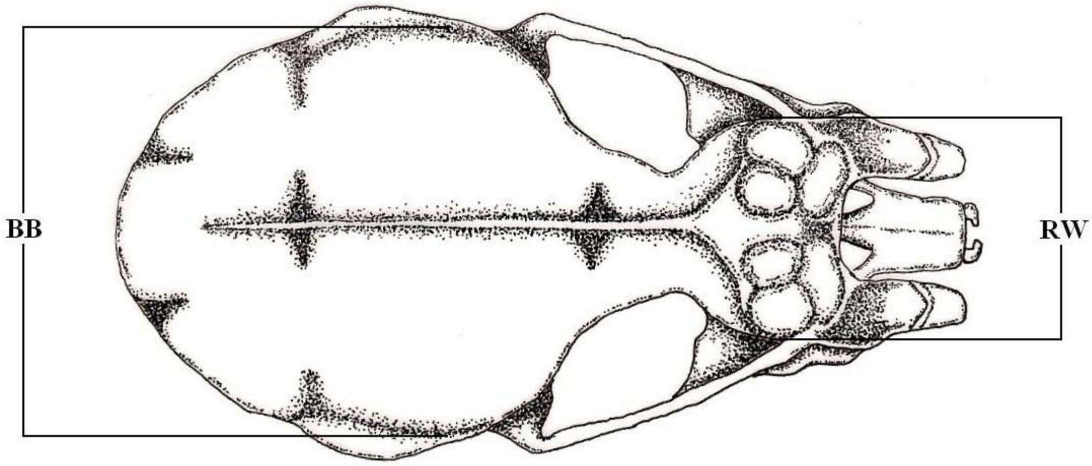
* The skull label is the same with the wet specimen label (Fig. 15).

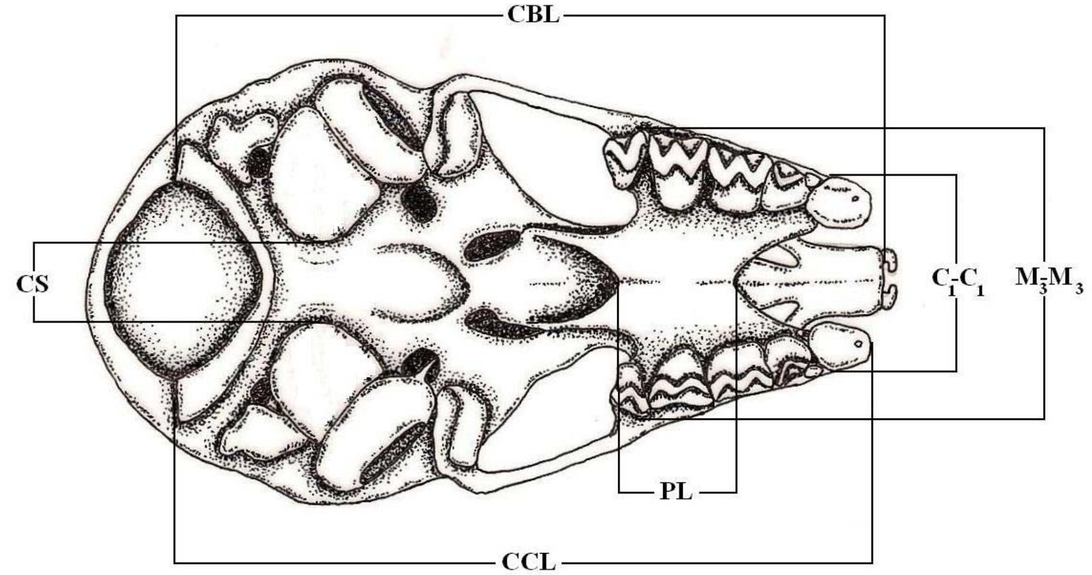
4.2.14. Skull Measurements

The definition of cranial measurement (also Bates and Harrison, 1997) in the present study was measured as following:






BB
RW


CBL
CS
C_1-C_1
M_3-M_3
PL
CCL

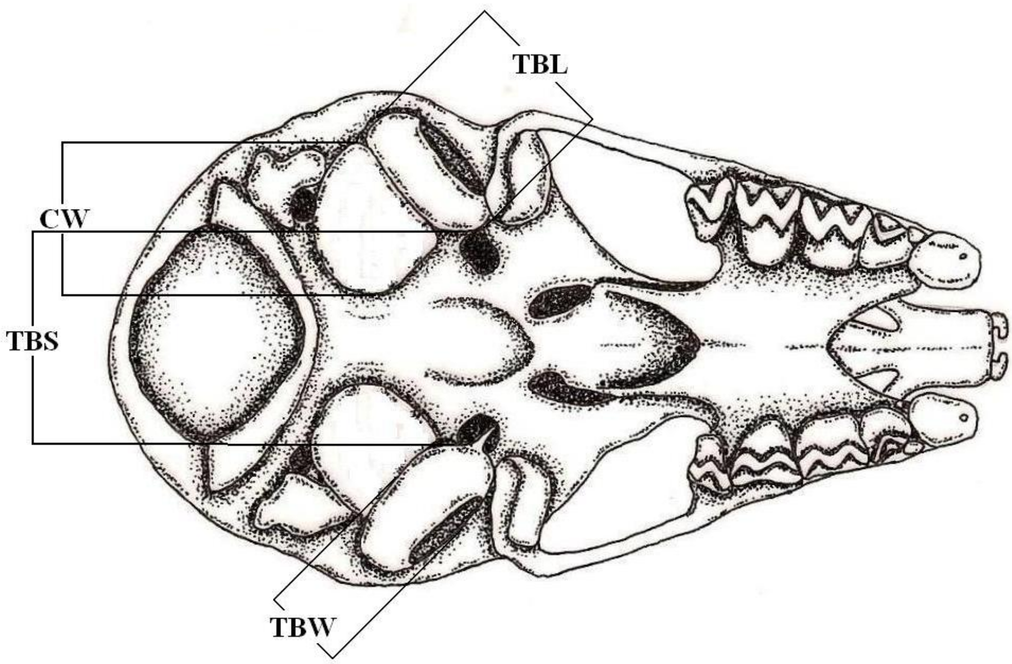


Fig. 18: Lateral, dorsal and ventral views of the skull of *Hipposideros ater*.

GTL: Greatest length of the skull – the greatest antero-posterior diameter of the skull, from the most projecting point at each extremity regardless of what structure forms these points (Fig. 18).

CCL: Condylo-canine length – from the exoccipital condyle to the anterior alveolus of the canine (Fig. 18).

CBL: Condylo-basal length – from the exoccipital condyle to the alveolus of the anterior incisor (Fig. 18).

MW: Mastoid width – the greatest distance across the mastoid region (Fig. 18).

ZB: Zygomatic breadth – the greatest width of the skull across the zygomatic arches, regardless of where this point is situated on the arches (Fig. 18).

BB: Breadth of the braincase – greatest width of the braincase at the posterior roots of the zygomatic arches (Fig. 18).

PC: Postorbital constriction – the narrowest width across the constriction posterior to the orbits (Fig. 18).

ML: Mandible length – from the most posterior part of the condyle to the most anterior part of the mandible, including the lower incisors (Fig. 18).

C^1-C^1: Anterior palatal width – taken across the outer borders of the upper canine (Fig. 18).

M^3-M^3: Posterior palatal width – taken across the outer borders of the last upper molar (Fig. 18).

C-M^3: Upper toothrow length or maxillary toothrow length – from the front of the upper canine to the back of the crown of the last upper molar (Fig. 18).

C-M_3: Lower toothrow length or mandibular toothrow length – from the front of the lower canine to the back of the crown of the last lower molar (Fig. 18).

PL: palate length – measured without the posterior spike (Fig. 18).

RW: Rostral chambers width – greatest width across the rostral chambers (Fig. 18).

CS: Cochleae space or intercochlear distance – between two cochleae, from the end of one cochlea to the end of another cochlea (Fig. 18).

CW: cochlear width – greatest width across cochlear (Fig. 18).

TBS: Tympanic bullae space or interbullae distance – between two tympanic bullae, from the end of one tympanic bulla to the end of another tympanic bulla (Fig. 18).

TBL: Tympanic bulla length – longest length across the tympanic bulla, from the end of one side to another side (Fig. 18).

TBW: Tympanic bulla width – greatest width across the tympanic bulla, at middle of the tympanic bulla (Fig. 18).

4.2.15. Preparing a Baculum

The penis is cut from the body ensuring that the dissection is as close to the surface of the body as possible to avoid damaging the baculum. The penis is placed in a small plastic tube with a secure lid. A temporary label is attached to the tube*. Subsequently, the penis is removed from the plastic tube using forceps and placed in a test tube half filled with cold water and brought to the boil. It simmers for two minutes. The test tube is inverted on to a very fine wire mesh suspended over a beaker, so that the penis is easily visible. Half fill the original plastic tube with 5% KOH (potassium hydroxide) and a pinch of alizarin red powder, this latter substance stains the baculum. The baculum is placed in the tube and left for 24 hours. The baculum is dissected from the tissue under a dissecting microscope with very fine forceps. The plastic tube is washed and half filled with glycerine. The baculum is carefully placed in the tube. A baculum label** is attached. The tube is stored in an upright position.

* The temporary baculum label is the same with the temporary skull label (Fig. 17).

** The baculum label is the same with the temporary label (Fig. 17).

4.2.16. Baculum Measurement

Baculum was measured under microscope using eyepiece graticule. The definition of baculum measurement (see also Zubaid and Davison, 1987) in the present study as area as follows:

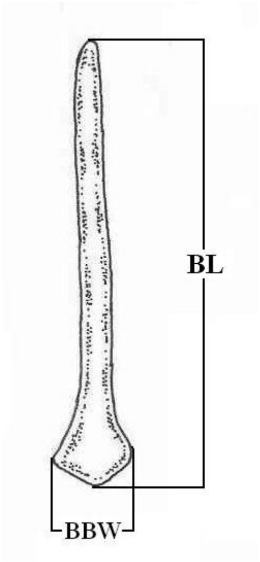


Fig. 19: Ventral view of baculum of *Hipposideros ater.*

BL: Baculum length – from the to the tip of baculum (Fig. 19).

BBW: Basal baculum length – greatest width of basal, from one side to another side (ventral view of the baculum) (Fig. 19).

4.2.17. Sound Analysis

Sound was recorded using MP3 Recorder (MULTICODEC JUKEBOX). It was converted from MP3 to Wave using the software GoldWave. Sound was analyzed using the software Batsound Pro v3.1 (Pettersson Elektronik AB). Software Batsound was set at 44100 samples per second and 10 time expansion. For each bat, sound is cumulative power spectra of whole pulses and was calculated for ten pulses chosen over the sound record in a prime number series (Fig. 20), to avoid possible periodical changes. Spectra were obtained using Power spectrum, FFT (Fast Fourier Transforms) size 1024 Hanning window (Fig. 21). The frequency of maximum energy corresponded to the frequency of the constant frequency (CF) segment of the second harmonic. Sound was measured in each spectrum, and the mode of the ten measurements were calculated and used as the value for the specimen.

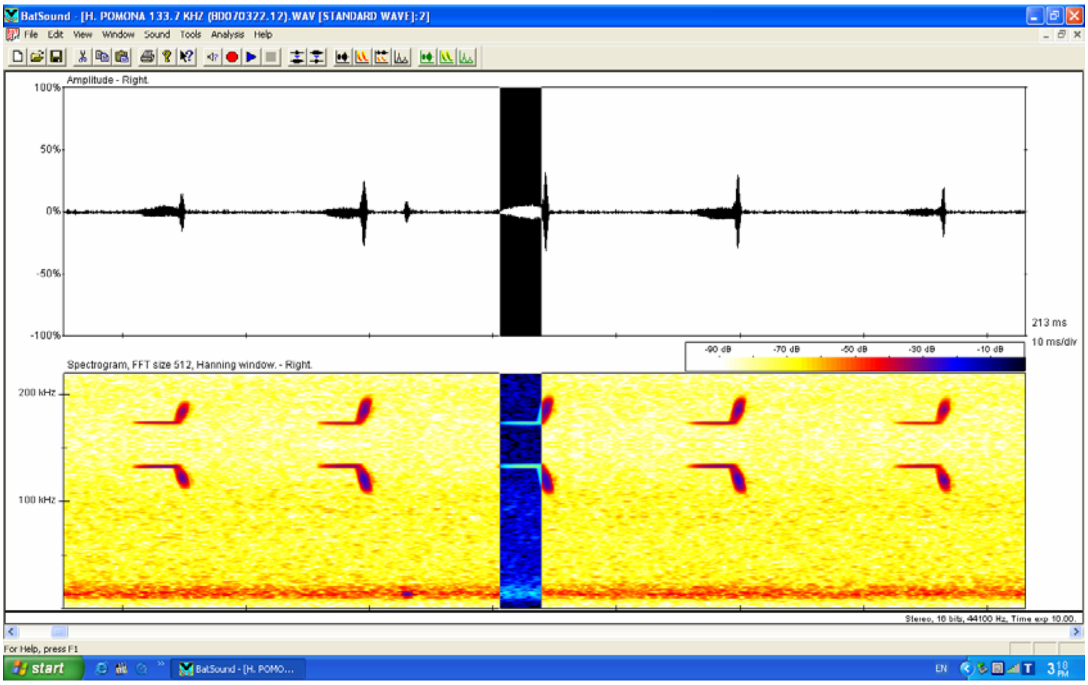


Fig. 20: Sound was analysed using the software Batsound Pro v3.1 (Pettersson Elektronik AB).

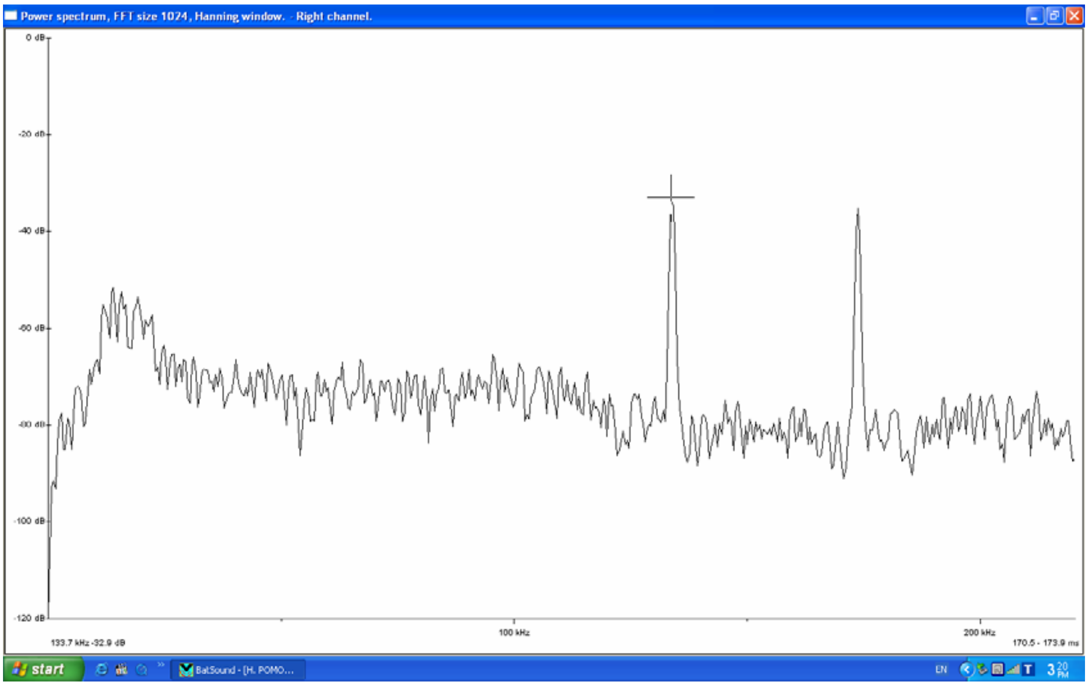


Fig. 21: Spectra were obtained using Power spectrum, FFT (Fast Fourier Transforms) size 1024 Hanning window.

4.2.18. Data Analysis

For each measurement, the minimum, maximum, mean and standard deviation of males and females were evaluated for the software SPSS 11.5 for Windows. The mean value of each character from each site was compared using multivariate statistics (the software PCOrd4) to test relationships between populations and within populations. Additionally, the morphology of each species was evaluated and described.

4.3. Morphology

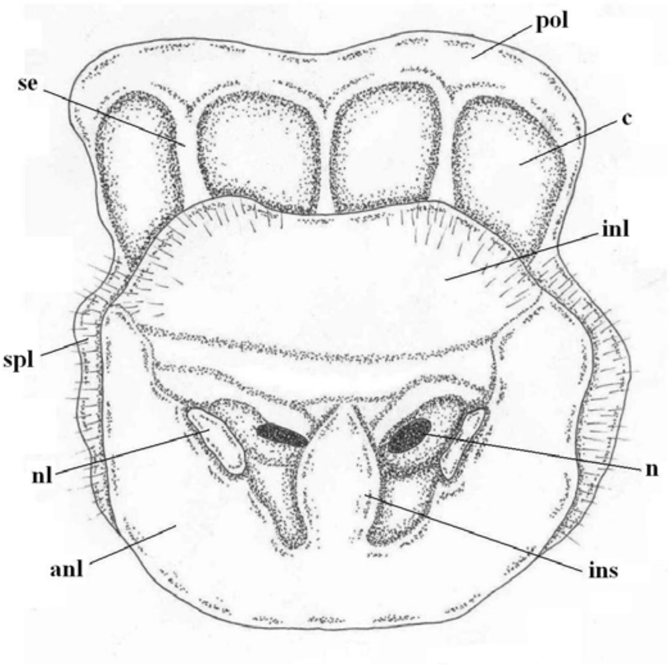


Fig. 22: Ventral view of noseleaf of *Hipposideros* af. *ater.*

anl: anterior leaf
c: cell
inl: intermediate leaf
ins: internarial septum
spl: lateral supplementary leaflet
n: nostril
nl: narial lappet
pol: posterior leaf

se: septum

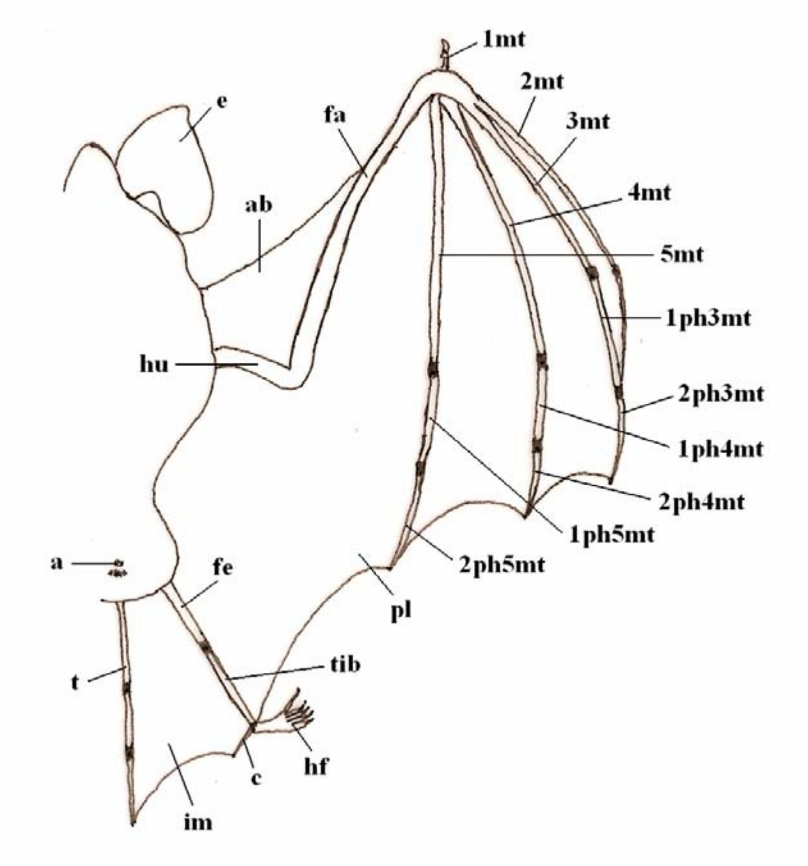


Fig. 23: Right wing of *Hipposideros bicolor*.

a: anus

ab: antebrachial

c: calcar

e: ear

fa: forearm

fe: femur

hf: hindfoot

hu: humerus

im: interfemoral membrance

pl: plagiopatagium

t: tail

tib: tibia

1mt: first metacarpal

2mt: second metacarpal

3mt: third metacarpal

1ph3mt: first phalanx of third metacarpal

2ph3mt: second phalanx of third metacarpal

4mt: fourth metacarpal

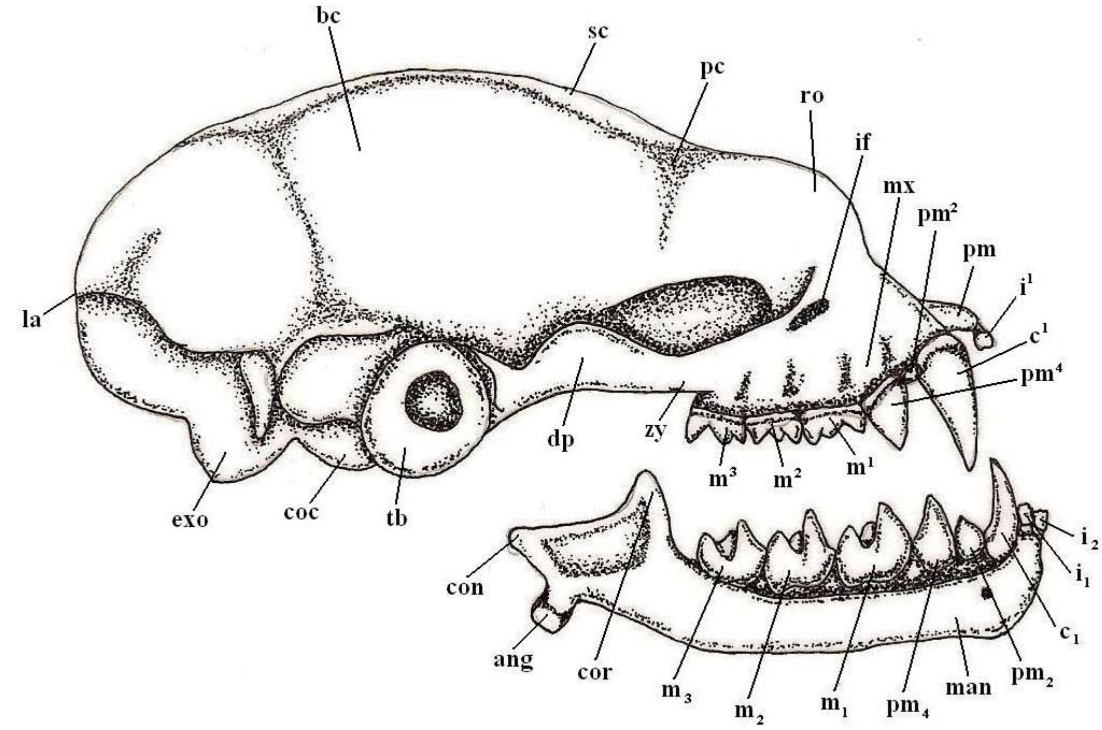
1ph4mt: first phalanx of fourth metacarpal

2ph4mt: second phalanx of fourth metacarpal

5mt: fifth metacarpal

1ph5mt: first phalanx of fourth metacarpal

2ph5mt: second phalanx of fourth metacarpal



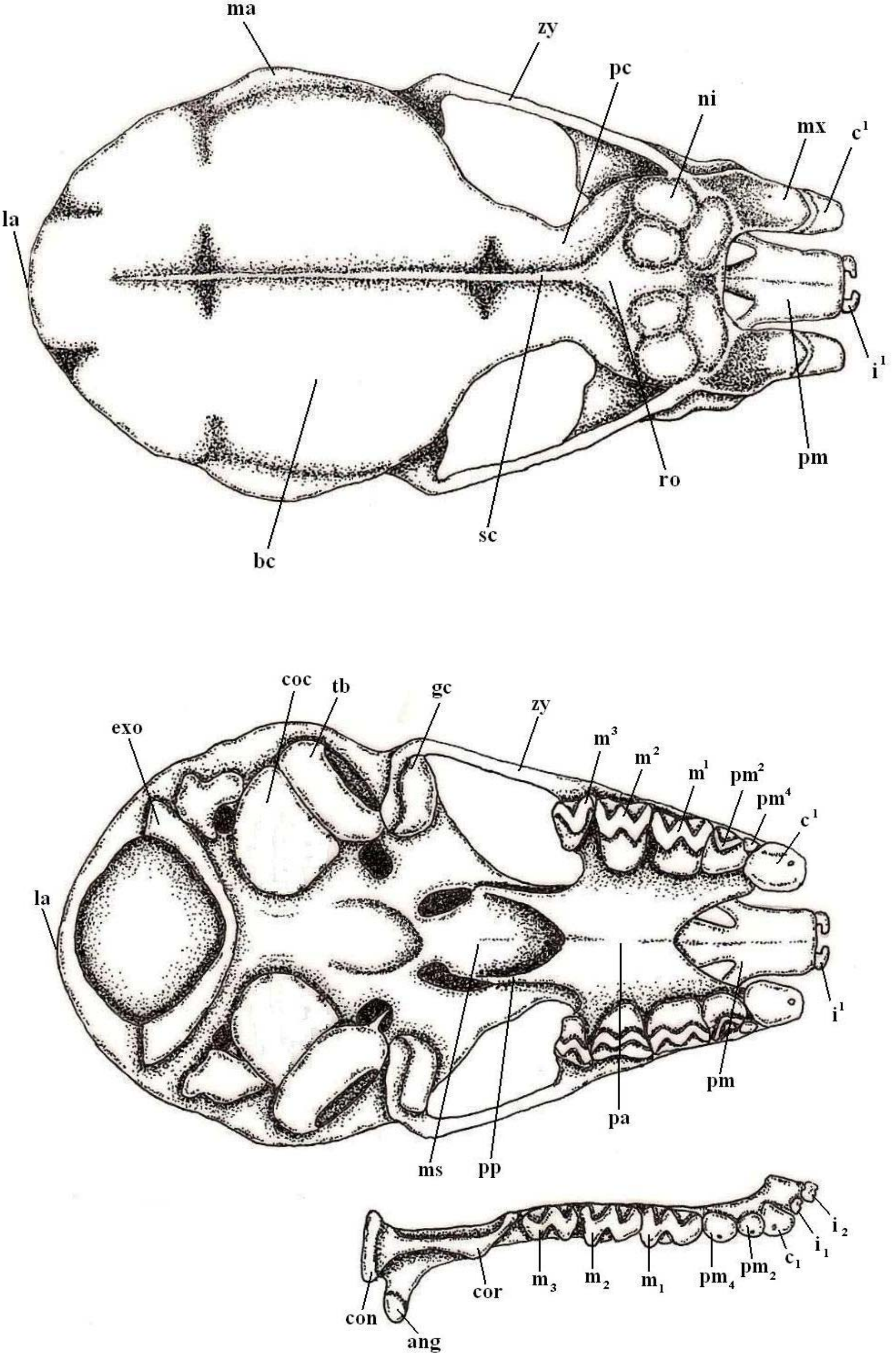


Fig. 24: Lateral, dorsal, and ventral views of skull of *Hipposideros ater*.

ang: angular process
bc: braincase
c^1: upper canine
c_1: lower canine
coc: cochlea
con: condyle
cor: coronoid process
dp: dorsal process of zygoma
exo: exoccipital condyle
i^1: upper incisor
i_1: outer lower incisor
i_2: inner lower incisor
if: infraorbital foramen
la: lambda
m^1: first upper molar
m^2: second upper molar
m^3: third upper molar
m_1: first lower molar
m_2: second lower molar
m_3: third lower molar
ma: mastoid
man: mandible
ms: mesopterogoid space
mx: maxilla
ni: nasal inflation
pa: palate
pc: postorbital constriction
pm: premaxilla
pm^2: first upper premolar
pm^4: second upper premolar
pm_2: first lower premolar
pm_4: second lower premolar

pp: pterogoid plate
ro: rostrum
sc: sagittal crest
tb: tympanic bulla
zy: zygoma

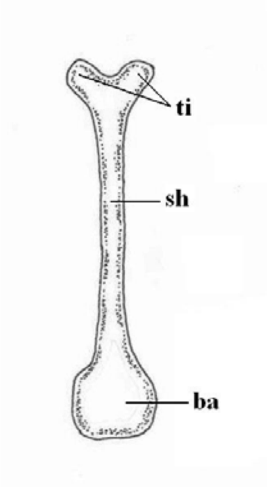


Fig. 25: Ventral view of baculum of *Hipposideros cineraceus*

ba: base
sh: shaft
ti: tip

CHAPTER 5

RESULTS

5.1. External and Bacular Characters

These are four small species in the *H. bicolor* group with forearm length ranging from 32.4 -40.3 mm and body mass of 2.7-7.0 g. Specimens of *H. ater* from India (FA 36.4-38.2 mm, *n*=5) are smaller than those from Myanmar (FA 39.5-40.3 mm, *n*=2). *H. cineraceus* (32.4-37.2 mm, *n*=51) is generally smaller than *H. ater,* which is more similar to that of *H. halophyllus* (36.4-39.2 mm, *n*=28) (Fig. 26, Table 2).

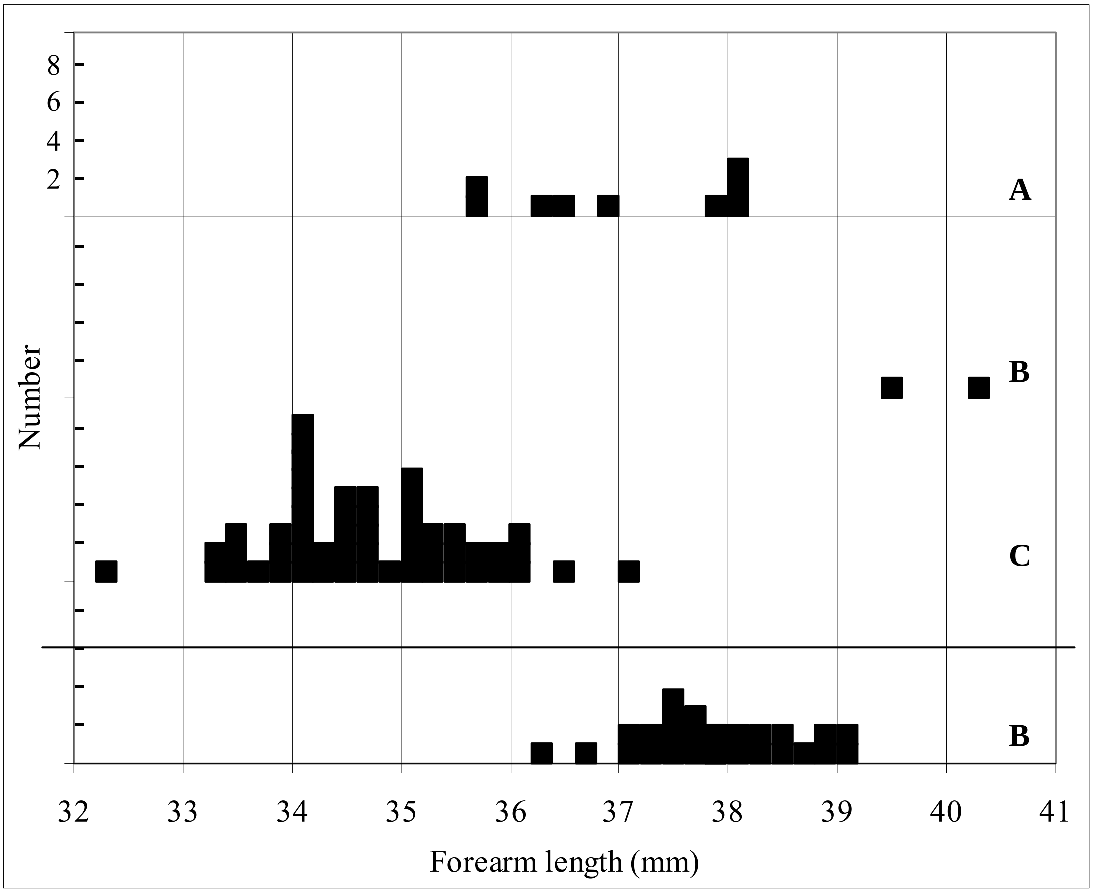


Fig. 26: Forearm length (in mm) of three species in the *Hipposideros bicolor* group. (A) *H. ater* from India, (B) *Hipposideros* af. *ater* from Myanmar, (C) *H. cineraceus*, and (D) *H. halophyllus*.

The ears of *H. ater* from India and *H. cineraceus* are not significantly different in shape and size. However, with pointed ear tips, they differ from the rounded ear tips of *H. ater* from Myanmar and *H. halophyllus*.

In comparison to *H. ater* from India, specimens of this taxon from Myanmar have a larger noseleaf with a pair of rudimentary lateral leaflets; these are not present in the Indian specimens or in *H. cineraceus* and *H. halophyllus* (Fig. 27-29).

The anterior leaf of *H. ater* from India and *H. halophyllus* is slightly curved; it is longer in *H. halophyllus*. It is more rounded in *H. ater* from Myanmar and in *H. cineraceus* (Fig. 27-29).

The internarial septum of *H. ater* from India is triangular-shaped, whilst in those from Myanmar it is more inflated; it is parallel and kidney-shaped in *H. cineraceus* and *H. halophyllus*, respectively (Fig. 27-29).

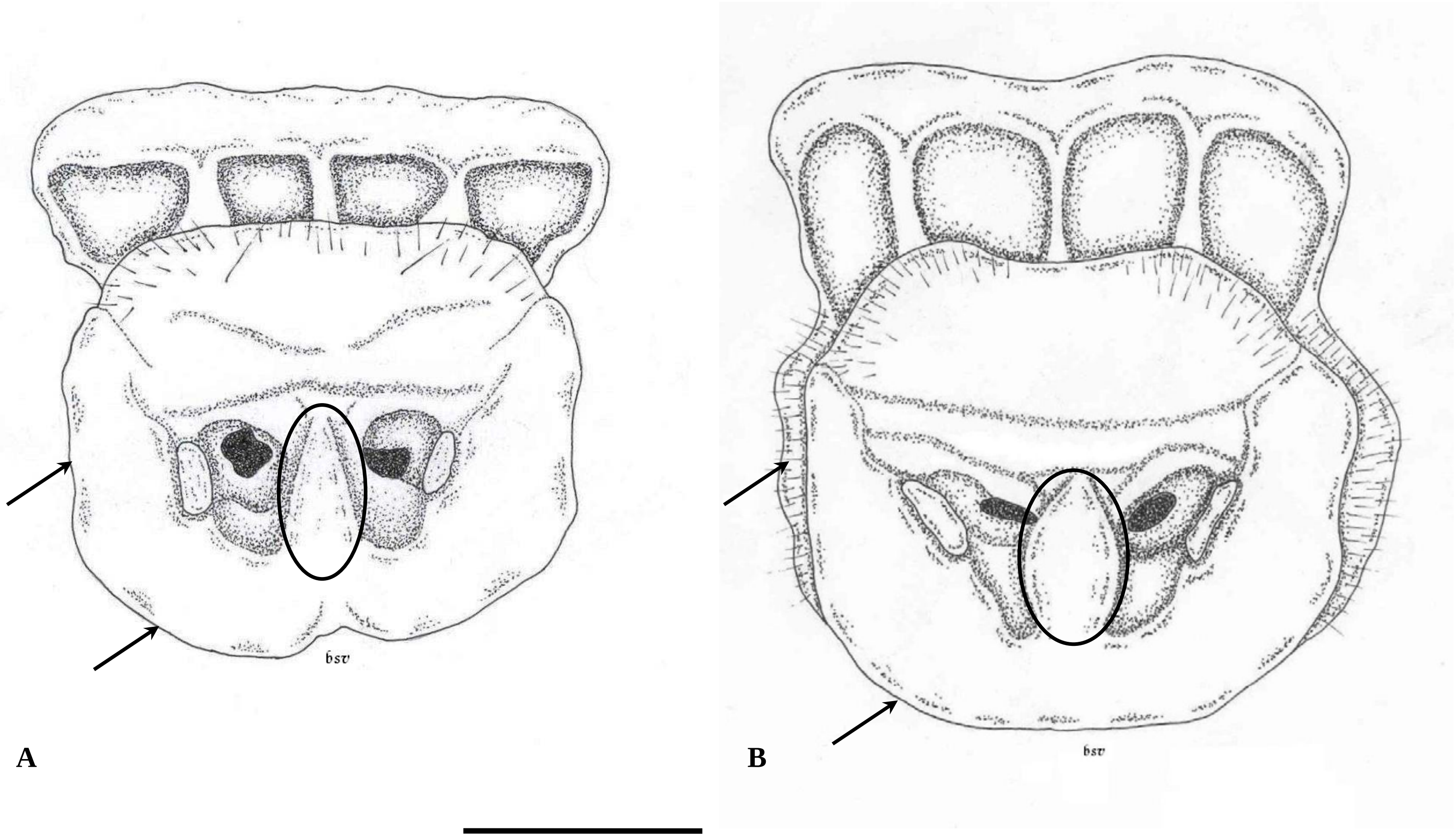


Fig. 27: Noseleaf and internarial septum of *Hipposideros ater*. (A) *H. ater*, HZM.2.28189, ♂, Thiruneer Malai, 26 km from Central Madras, Tamil Nadu, India; (B) *Hipposideros* af. *ater*, HZM.10.35983, ♀, Tharabwin Village, Tanintharyi Division, Myanmar. Scale: 2 mm.

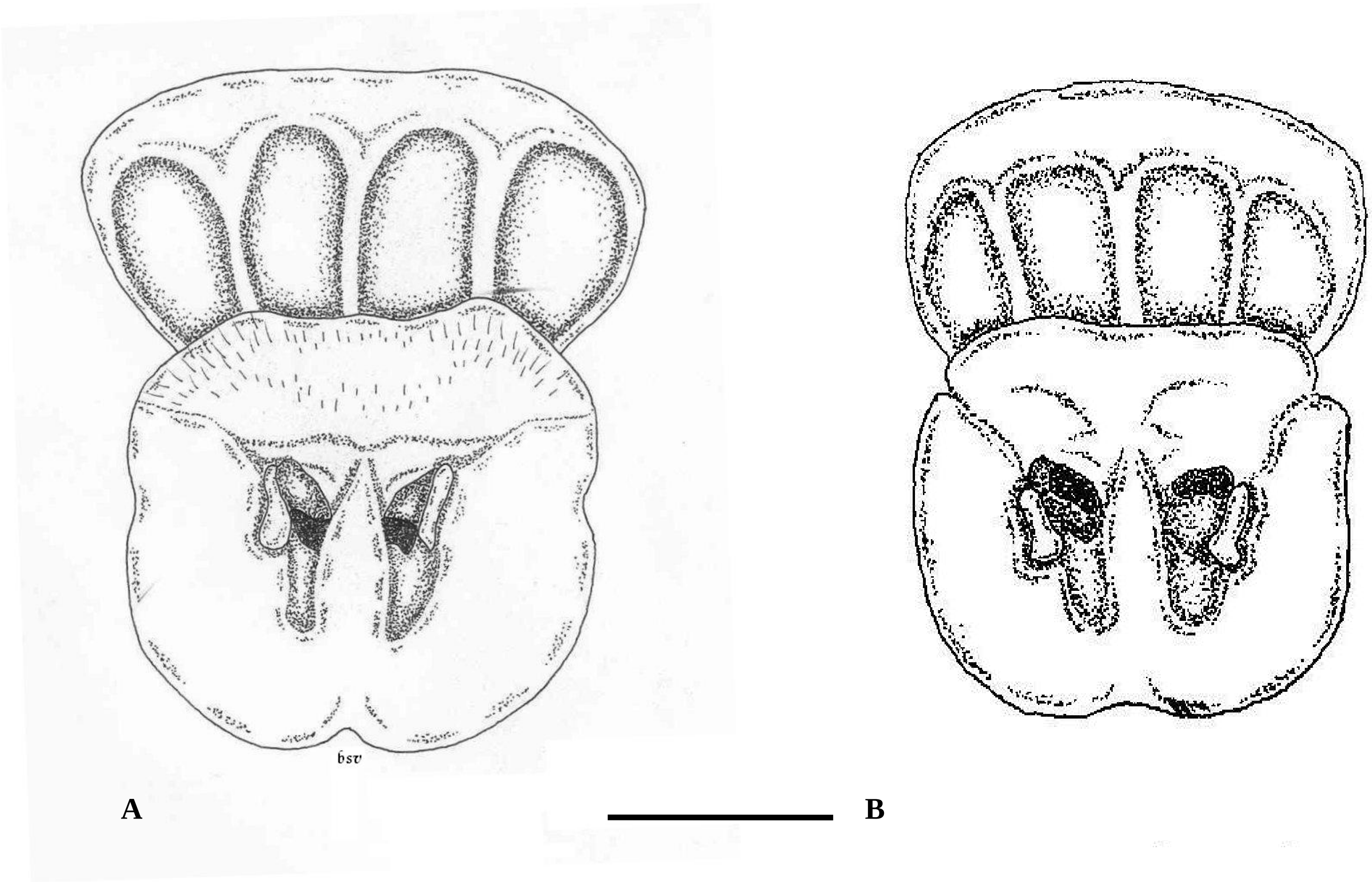


Fig. 28: Noseleaf and internarial septum of *Hipposideros cineraceus*, (A) PSUZC-MM06.126, ♂, Wildlife Education Centre, Ton Nga Chang Wildlife Sanctuary, Songkhla Province; (B) PSUZC-MM07.174, ♀, Khao Nouy Cave, Rattaphum District, Songkhla Province, Thailand. Scale: 2 mm.

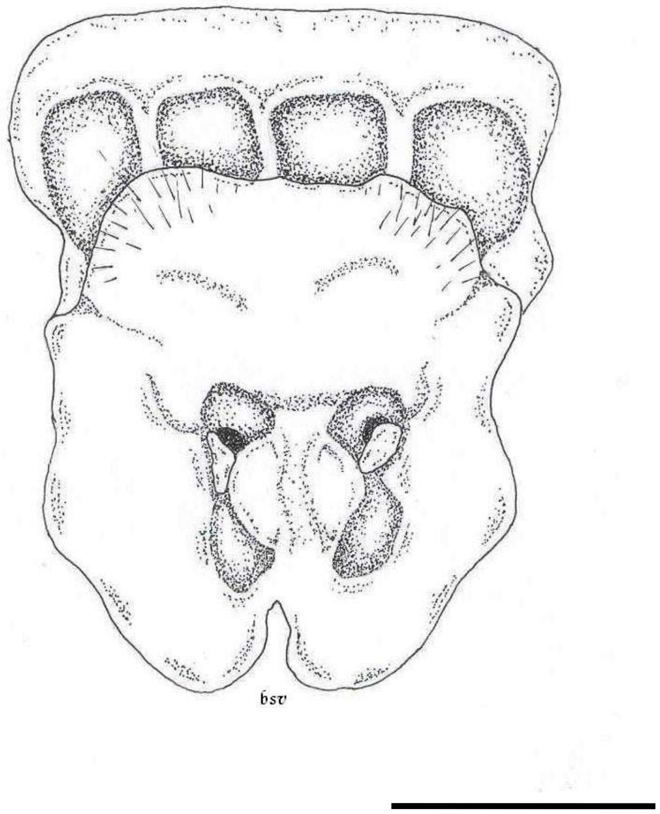


Fig. 29: Noseleaf and internarial septum of *Hipposideros halophyllus*, PSUZC-MM06.71, ♂, Pha Dang Cave, Chiang Dao District, Chiang Mai Province, Thailand. Scale: 2 mm.

In *H. ater* from India and *H. cineraceus*, the fifth metacarpal exceeds the third metacarpal in length, with third and fifth metacarpal length of *H. ater* from India of 27.2-30.1 mm and 27.3-31.1 mm, respectively, and third and fifth metacarpal length of *H. cineraceus* of 23.7-27.6 mm and 25.3-28.9 mm, respectively; but *H. ater* from Myanmar, one exceeds and one is shorter, with third and fifth metacarpal length of 31.0-33.4 mm and 31.2-33.2 mm, respectively; and *H. halophyllus* is shorter, with third and fifth metacarpal length of 28.7-32.2 mm and 26.0-28.5 mm, respectively (Fig. 30, Table 2).

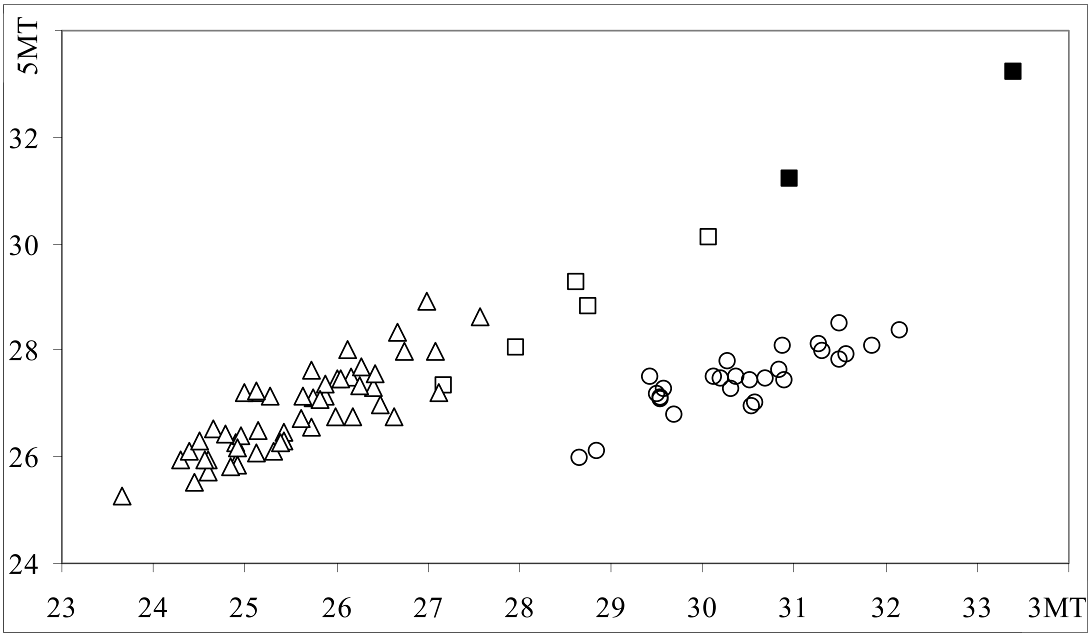


Fig. 30: The relationship between third and fifth metacarpal length of *H. ater* from India (open squares), *H. ater* from Myanmar (black squares), *H. cineraceus* (open triangulars), and *H. halophyllus* (open circles).

Table 2. External character (in mm), and body mass (in g) measurements of *Hipposideros ater, H. cineraceus* and *H. halophyllus* from India, Myanmar and Thailand.

n	**sex**	**HB**	**FA**	**EL**	**TL**	**HF**	**TIB**	**W**	**NW**
***Hipposideros ater* India**									
3	♂	43.8-44.5	36.4-38.1	15.2-17.8	23.0-23.6	6.8-7.0	15.6-16.9	-	4.5-4.6
		44.1, 0.4	37.0, 0.9	16.9, 1.5	23.3, 0.3	6.9, 0.1	16.4, 0.7		4.6, 0.1
2	♀	46.0, 48.0	38.2, 38.2	15.9, 16.8	21.0, 24.0	5.8, 6.2	16.3, 16.4	-	-
***Hipposideros ater* Myanmar**									
2	♀	43.3, 49.1	39.5, 40.3	16.6, 16.7	24.7, 28.7	6.5, 7.0	16.2, 17.8	4.5 (1)	4.9, 5.3
***Hipposideros cineraceus* Thailand and Myanmar**									
25	♂	35.4-45.4	32.4-36.5	13.4-18.3	19.0-27.8	4.4-5.9	14.5-16.2	3.0-5.5	3.6-4.5
		40.4, 1.9 (24)	34.6, 0.9	16.1, 1.5	24.2, 2.1	5.3, 0.5	15.1, 0.5	3.5, 0.6	4.0, 0.3
27	♀	37.4-45.8	33.3-37.2	13.4-20.2	20.4-28.6	4.3-5.8	14.4-19.9	2.7-5.0	3.6-4.6
		41.7, 2.4 (24)	35.0, 0.9	16.2, 1.4	24..9, 2.2	5.1, 0.4	15.6, 1.1	3.8, 0.5	4.2, 0.2
***Hipposideros halophyllus*Thailand**									
15	♂	40.5-44.7	36.4-38.7	11.1-15.4	22.4-28.7	4.9-6.4	16.4-18.5	4.0-4.8	3.4-3.9
		42.8, 1.1	37.6, 0.7	13.3, 1.0	25.5, 1.8 (14)	5.8, 0.4	17.6, 0.6	4.1, 0.2 (14)	3.7, 0.2
13	♀	40.6-47.0	37.2-39.2	11.4-15.1	23.8-28.6	4.5-6.3	16.4-18.6	4.0-7.0	3.4-4.2
		43.6, 1.9	38.2, 0.7	13.1, 1.1	26.7, 1.6	5.8, 0.5	17.7, 0.8	4.8, 0.8 (12)	3.7, 0.2 (12)

Table 2 (Continue). External character (in mm) measurements of *Hipposideros ater, H. cineraceus* and *H. halophyllus* from India, Myanmar and Thailand.

n	**sex**	**3MT**	**4MT**	**5MT**	**1PH3MT**	**2PH3MT**	**1PH4MT**	**2PH4MT**	**1PH3MTx 100/3MT**
				***Hipposideros ater* India**					
3	♂	27.2-28.6	29.1-31.2	27.3-29.3	15.3-15.7	15.2-16.1	9.3-10.0	7.8-9.0	55.0-56.2
		27.9, 0.7	29.9, 1.2	28.2, 1.0	15.5, 0.2	15.7, 0.5	9.6, 0.4	8.4, 0.6	55.6, 0.6
2	♀	28.8, 30.1	30.3, 30.3	28.8, 30.1	15.5, 16.6	15.8, 15.9	10.2, 10.4	8.4, 8.5	51.6, 57.6
				***Hipposideros ater* Myanmar**					
2	♀	31.0, 33.4	33.1, 34.8	31.2, 33.2	15.9, 16.8	15.3, 15.5	10.0, 10.3	7.9, 8.7	47.7, 54.1
				***Hipposideros cineraceus* Thailand and Myanmar**					
25	♂	23.7-27.6	26.4-29.7	25.3-28.9	14.1-16.6	12.2-15.2	8.2-11.1	6.3-8.9	53.8-62.5
		25.3, 0.9	27.8, 0.8	26.7, 0.9	15.0, 0.6	13.5, 0.8	9.2, 0.6	7.1, 0.5	59.3, 1.8
27	♀	24.5-27.1	26.4-29.7	25.8-28.4	14.5-16.7	12.1-19.1	8.5-10.0	5.6-7.9	57.0-64.1
		25.8, 0.8	28.4, 0.8	27.0, 0.7	15.4, 0.5	13.9, 1.3	9.3, 0.4	6.8, 0.5	59.7, 1.8
				***Hipposideros halophyllus*Thailand**					
15	♂	28.7-31.3	29.5-31.5	26.0-28.1	13.8-15.3	13.2-15.3	9.5-10.9	6.6-8.0	46.5-49.6
		30.0, 0.8	30.9, 0.6	27.2, 0.6	14.5, 0.5	14.4, 0.6	10.1, 0.4	7.3, 0.3	48.3, 0.9
13	♀	29.5-32.2	30.7-32.5	27.1-28.5	14.6-15.6	14.2-15.3	10.0-10.9	6.7-7.7	46.7-49.5
		31.0, 0.8 (12)	31.7, 0.5 (12)	27.8, 0.4 (12)	15.0, 0.3 (12)	14.8, 0.3 (12)	10.4, 0.3 (12)	7.3, 0.3 (12)	48.3, 0.8 (12)

The tail of *H. ater* from India and *H. halophyllus* are enclosed within the interfemoral membrane, except for the extreme tip; but in *H. ater* from Myanmar and *H. cineraceus* even the tip is enclosed within the interfemoral membrane.

The penis-shape of *H. ater* is short and flat, large at the base, narrow and rounded at the tip; but in *H. cineraeus*, the penis-shape is short and thin, and blunt at the tip; and in *H. halophyllus*, the penis-shape is thin, pointed at the tip (Fig. 31).

The baculum is a highly diagnostic character within these three species. The baculum of *H. ater* (India) and *H. halophyllus* is straight, with a simple base and tip; although it is significantly larger in *H. ater*, with a length of 1.7 mm and 0.4 mm, respectively. The baculum of *H. cineraceus* has a bifid tip (Fig. 32).

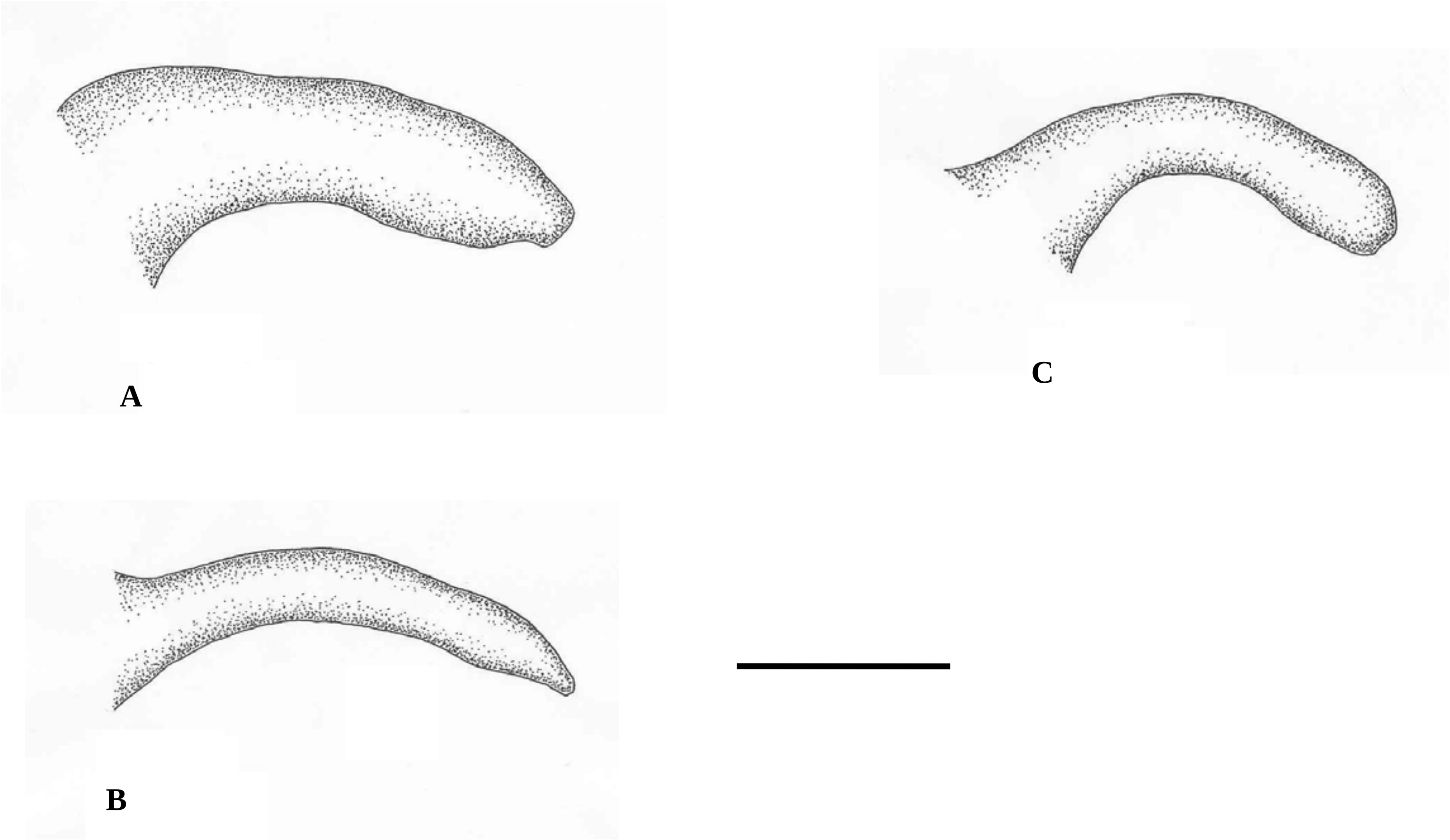


Fig. 31: Lateral view of the penis-shape of three species in the *Hipposideros bicolor* group. (A) *H. ater*, MM3, Thiruneer Malai, 26 km from Central Madras, Tamil Nadu, India; (B) *H. cineraceus*, PSUZC-MM06.126, Wildlife Education Centre, Ton Nga Chang Wildlife Sanctuary, Songkhla Province; and (C) *H. halophyllus*, PSUZC-MM06.71, Pha Dang Cave, Chiang Dao District, Chiang Mai Province. Scale: 2 mm.

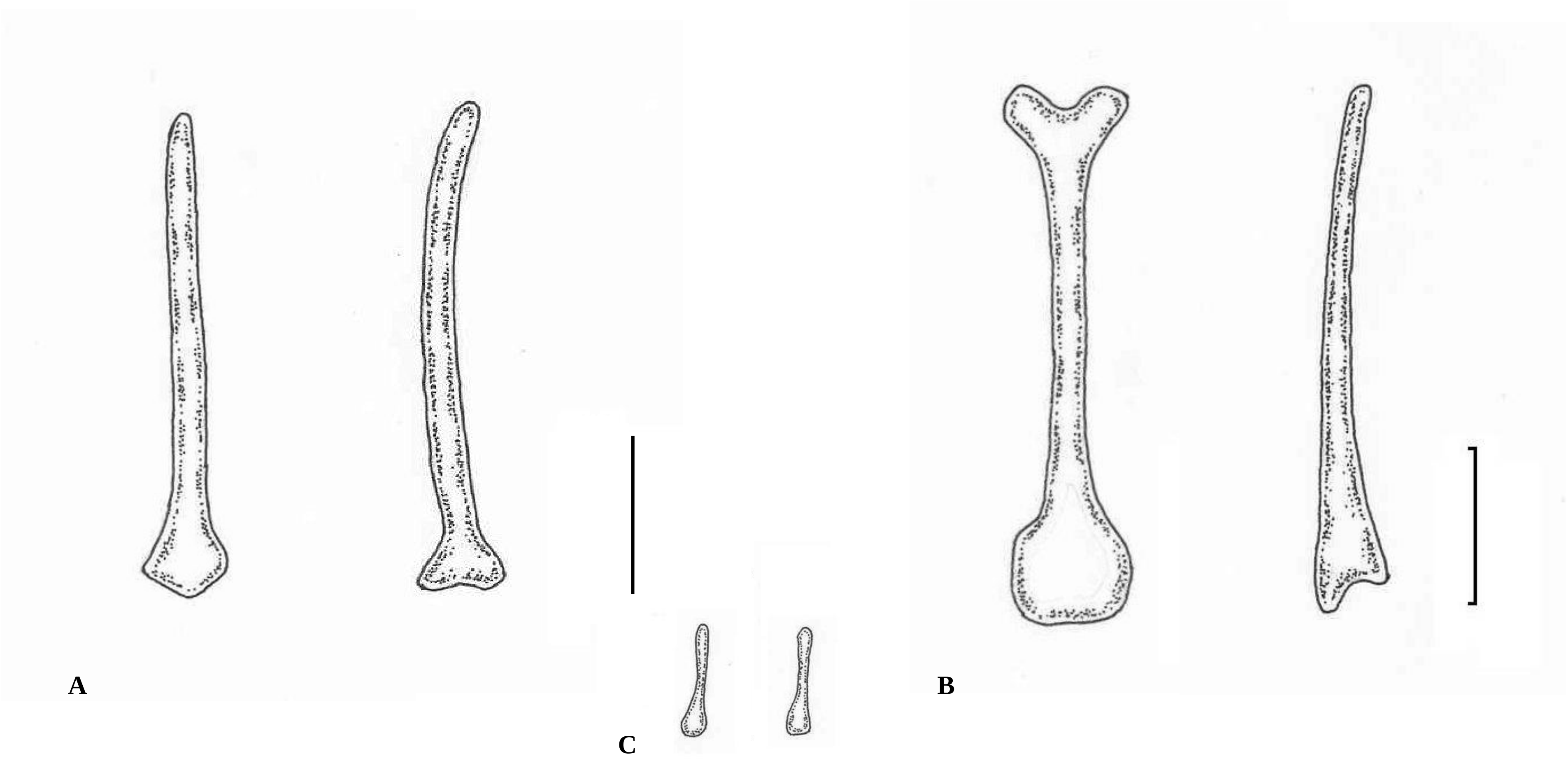


Fig. 32: Dorsal and lateral views of the baculum of three species in the *Hipposideros bicolor* group. (A) *H. ater*, HZM.4.35004, Sankanthira Mandapam, Northern Cheranmadevi, 16 km west of Tirunelveli, South India; (B) *H. cineraceus*, PSUZC-MM07.178, Tham Jorrake (Crocodile Cave), Tarutao Islands National Park, Satun Province, Thailand; and (C) *H. halophyllus*, PSUZC-MM07.203, Ob cave, Khao Smorkhon, Tawung District, Lop Buri Province, Thailand. Scales: 1 mm.

5.2. Cranial and Dentition Characters

The skulls of *H. ater* from India and Myanmar are small and wide, with a condylo-canine length of 13.5-14.2 mm and 13.5 mm, and mastoid width of 8.3-8.5 mm and 8.4 mm; but the skulls of *H. cineraceus*, are smaller and narrower, with condylo-canine length of 12.8-13.7 mm 12.6-13.0 mm, and mastoid width of 7.6-8.1 mm and 7.6-8.0 mm, respectively (Fig. 33, Table 4).

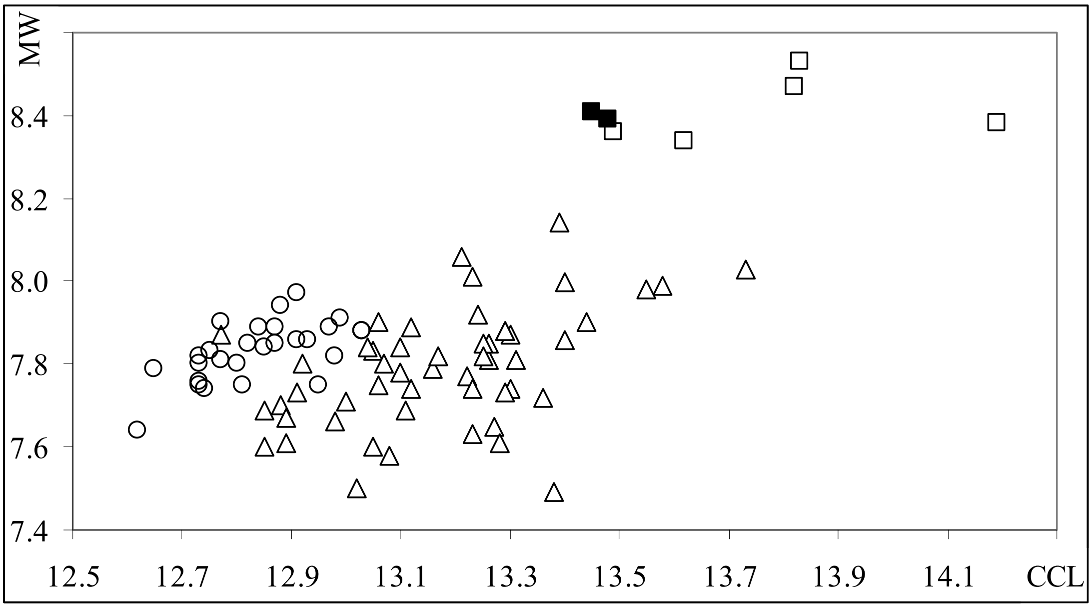


Fig. 33: Relationship between condylo-canine length and mastoid width of *H. ater* from India (open square), *H. ater* from Myanmar (black square), *H. cineraceus* (open triangular) and *H. halophyllus* (open circle).

The braincase is low and flattened in lateral view in *H. ater* (India and Myanmar) and *H. halophyllus*. It is more concave in *H. cineraceus* (Fig. 32). The breadth of braincase is always narrower than the zygomata width in *H. halophyllus* but in *H. cineraceus* and *H. ater* (Myanmar), it is more variable, sometimes exceeding and sometimes smaller than the zygomata width (Table 3).

Table 3. Percentage of the relationship between breadth of braincase and zygomata width.

Species	*n*	BB<ZB	BB=ZB	BB>ZB
H. ater India	5	80	0	20
H. ater Myanmar	2	50	0	50
H. cineraceus	51	58.8	9.8	31.4
H. halophyllus	27	100	0	0

The rostrum of *H. ater* from India is low, flat, and horizontal anteriorly, when seen in lateral view; but the rostrum of *H. ater* from Myanmar and *H. cineraceus* are inflated, and are concave anteriorly; the rostrum of *H. halophyllus* is inflated, and slopes downwards (Fig. 34).

H. ater from India has six nasal inflations on the rostrum; but *H. ater* from Myanmar has four nasal inflations (Fig. 39A, 39B). Additionally; *H. cineraceus* has four nasal inflations, with only one specimen having six nasal inflations; and *H. halophyllus* has both types (60.9% of 23 specimens with six inflations, and 39.1% with four).

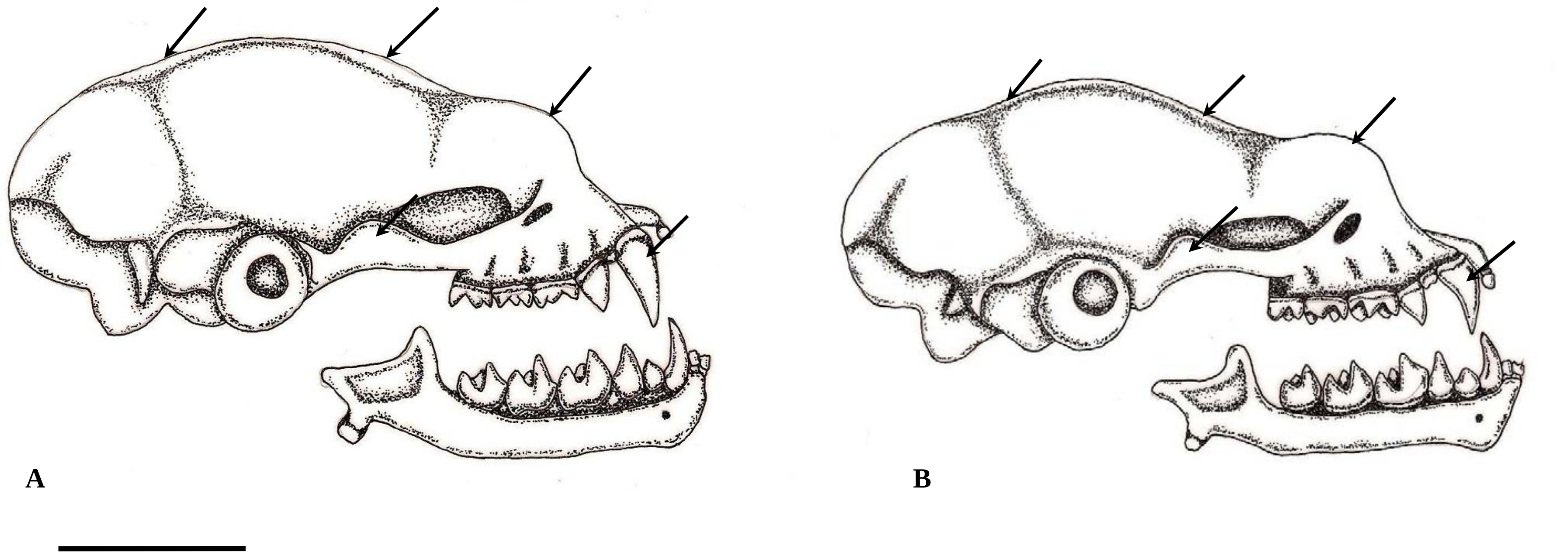


Fig. 34: Lateral view of the skulls and mandibles of *Hipposideros ater*. (A) *H. ater*, HZM.2.28189, ♂, Thiruneer Malai, 26 km from Central Madras, Tamil Nadu, India; (B) *Hipposideros* af. *ater*, HZM.10.35983, ♀, Tharabwin Village, Tanintharyi Division, Myanmar. Scales: 5 mm.

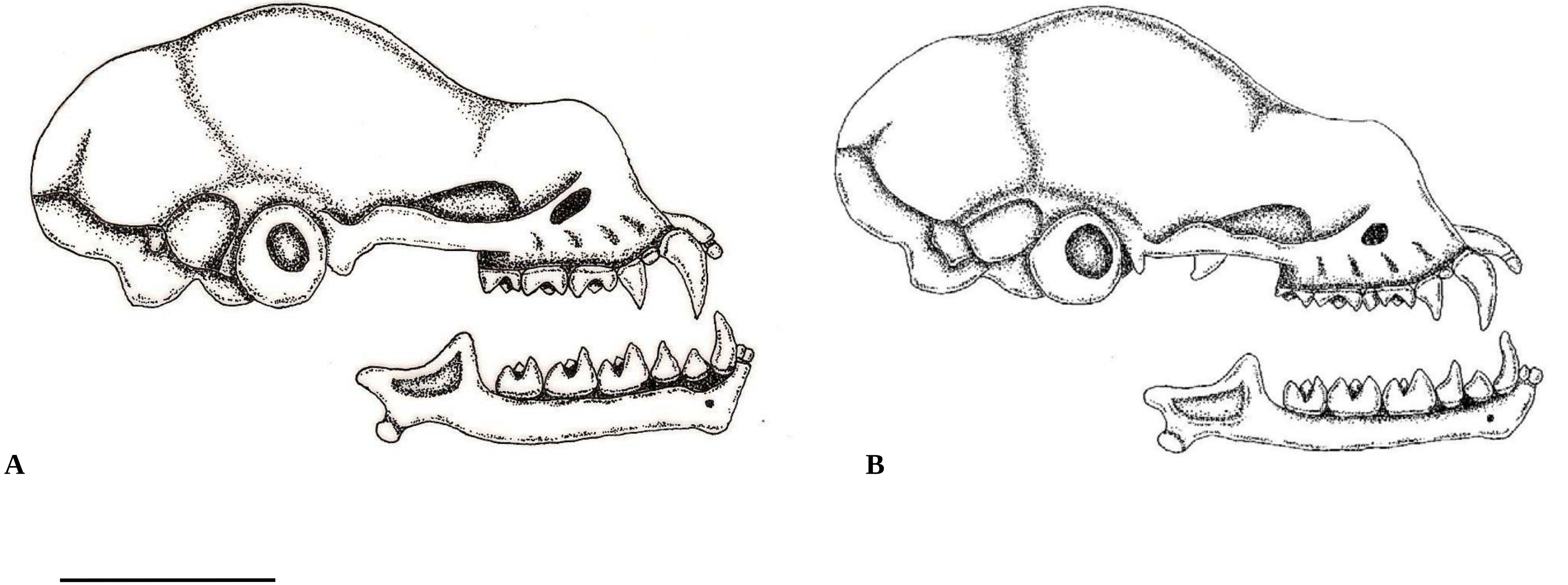


Fig. 35: Lateral view of the skulls and mandibles of *Hipposideros cineraceus*, (A) PSUZC-MM06.125, ♂, Wildlife Education Centre, Ton Nga Chang Wildlife Sanctuary, Songkhla Province, Thailand; (B) PSUZC-MM07.185, ♀, Khao Don Deung, Ban Mi District, Lop Buri Province, Thailand. Scales: 5 mm.

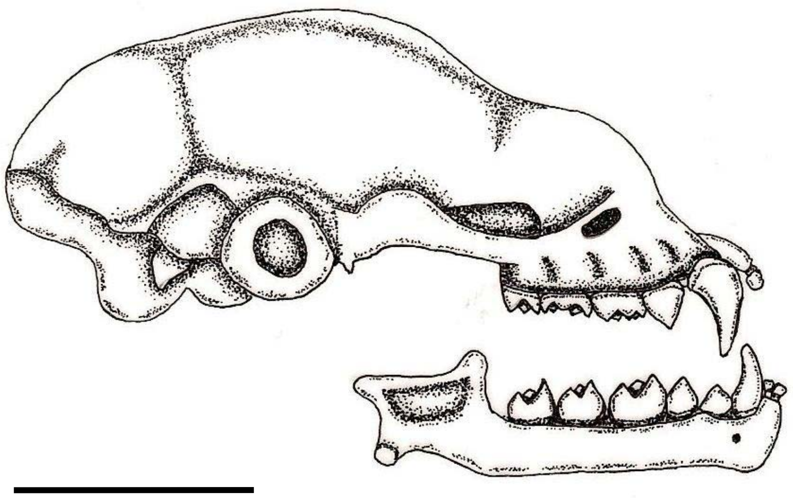


Fig. 36: Lateral view of the skulls and mandibles of *Hipposideros halophyllus*, PSUZC-MM07.38, ♂, Khao Yoi Cave, Khao Yoi District, Petcha Buri Province, Thailand. Scales: 5 mm.

The sagittal crest of *H. ater* from India and *H. halophyllus* are high on the anterior part and low on posterior part; but in *H. ater* from Myanmar and *H. cineraceus*, it is low in both parts (Fig. 34-36).

Zygomata width of *H. ater* from India is wider than *H. ater* from Myanmar, with 93.4 -99.5% and 88.9-92.2% of mastoid width, the latter case is comparable to that of *H. cineraceus* and *H. halophyllus* (Fig. 37).

The zygomata of *H. ater* from India and *H. halophyllus* have a well-developed jugal projection, but in specimens of *H. ater* from Myanmar they are lower. In *H. cineraceus,* 61.7% of 47 specimens have a process and 38.3% are without a dorsal process; when present it is very low (Fig. 34-36).

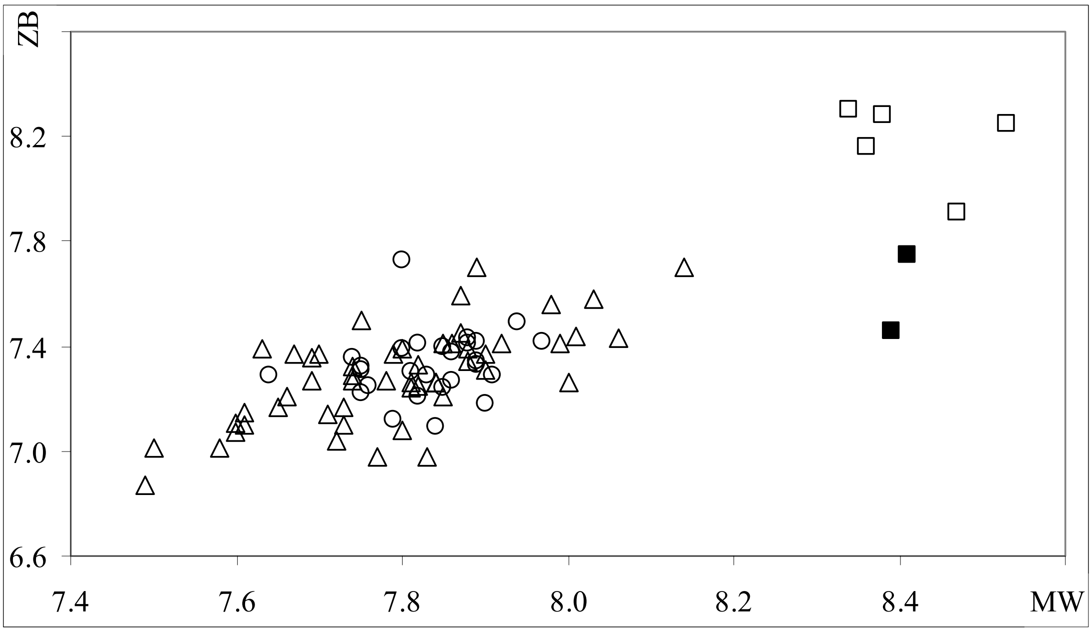


Fig. 37: Relationship between mastoid width and zygomatic breadth of *H. ater* from India (open square), *H. ater* from Myanmar (black square), *H. cineraceus* (open triangular) and *H. halophyllus* (open circle).

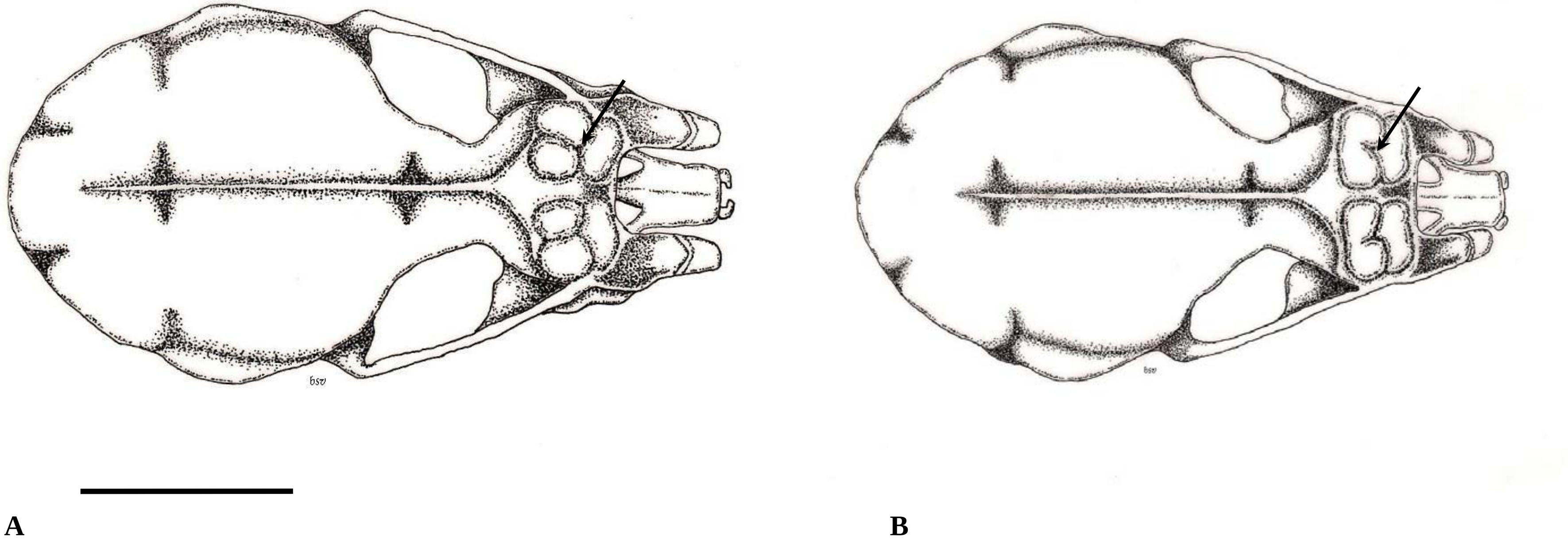


Fig. 38: Dorsal view of the skulls of *Hipposideros ater*. (A) *H. ater*, HZM.2.28189, ♂, Thiruneer Malai, 26 km from Central Madras, Tamil Nadu, India; (B) *Hipposideros* af. *ater*, HZM.10.35983, ♀, Tharabwin Village, Tanintharyi Division, Myanmar. Scale: 5 mm.

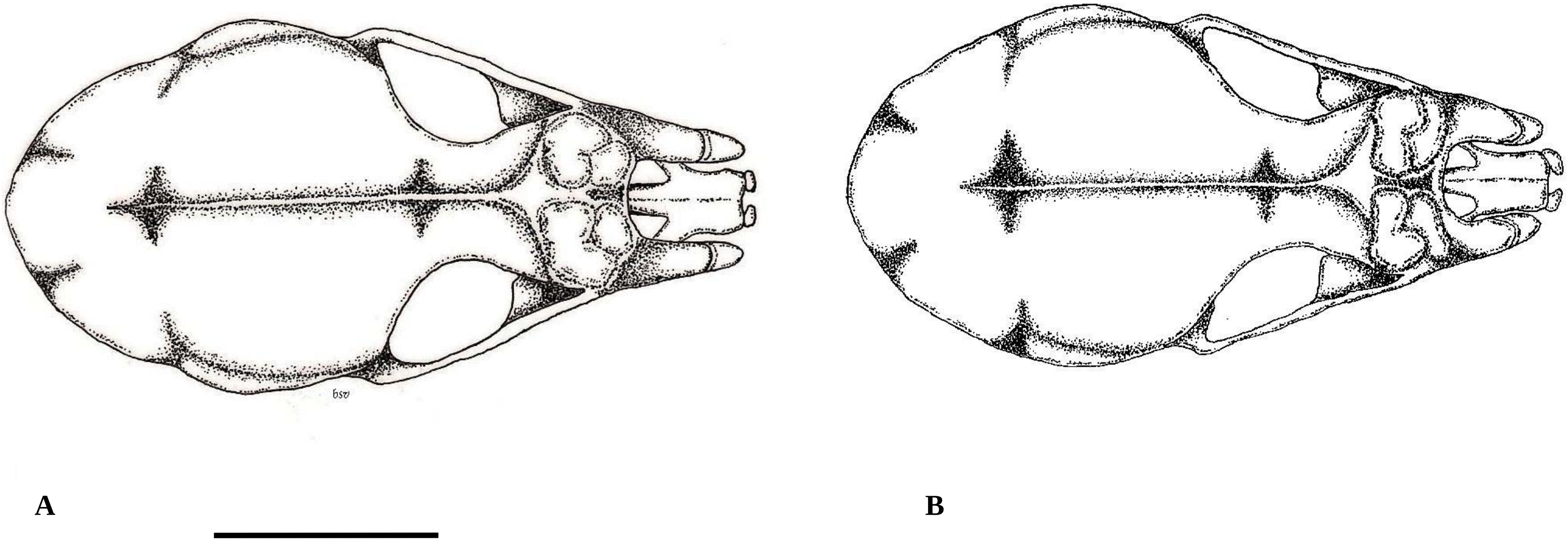


Fig. 39: Dorsal view of the skulls of *Hipposideros cineraceus*, (A) PSUZC-MM06.125, ♂, Wildlife Education Centre, Ton Nga Chang Wildlife Sanctuary, Songkhla Province, Thailand; (B) PSUZC-MM07.185, ♀, Khao Don Deung, Ban Mi District, Lop Buri Province, Thailand. Scale: 5 mm.

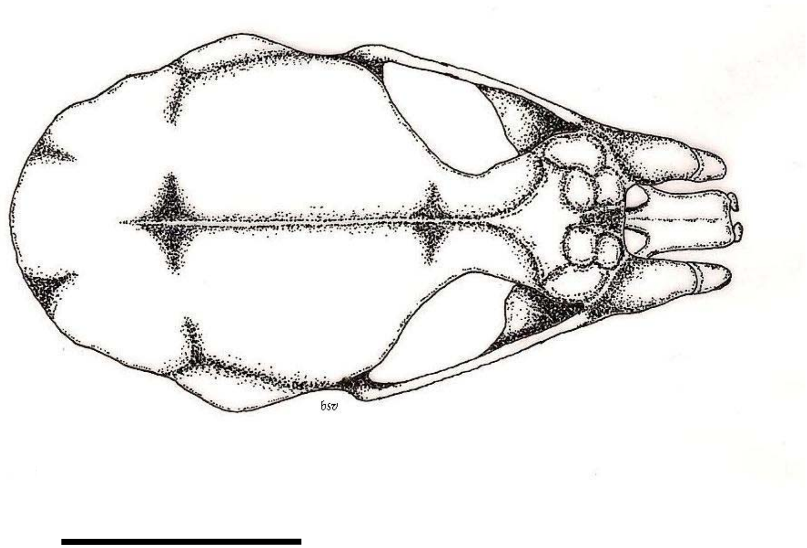


Fig. 40: Dorsal view of the skulls of *Hipposideros halophyllus*, PSUZC-MM07.38, ♂, Khao Yoi Cave, Khao Yoi District, Petcha Buri Province, Thailand. Scale: 5 mm.

Table 4. Cranial character measuremnets (in mm) of *Hipposideros ater, H. cineraceus* and *H. halophyllus* from India, Myanmar and Thailand.

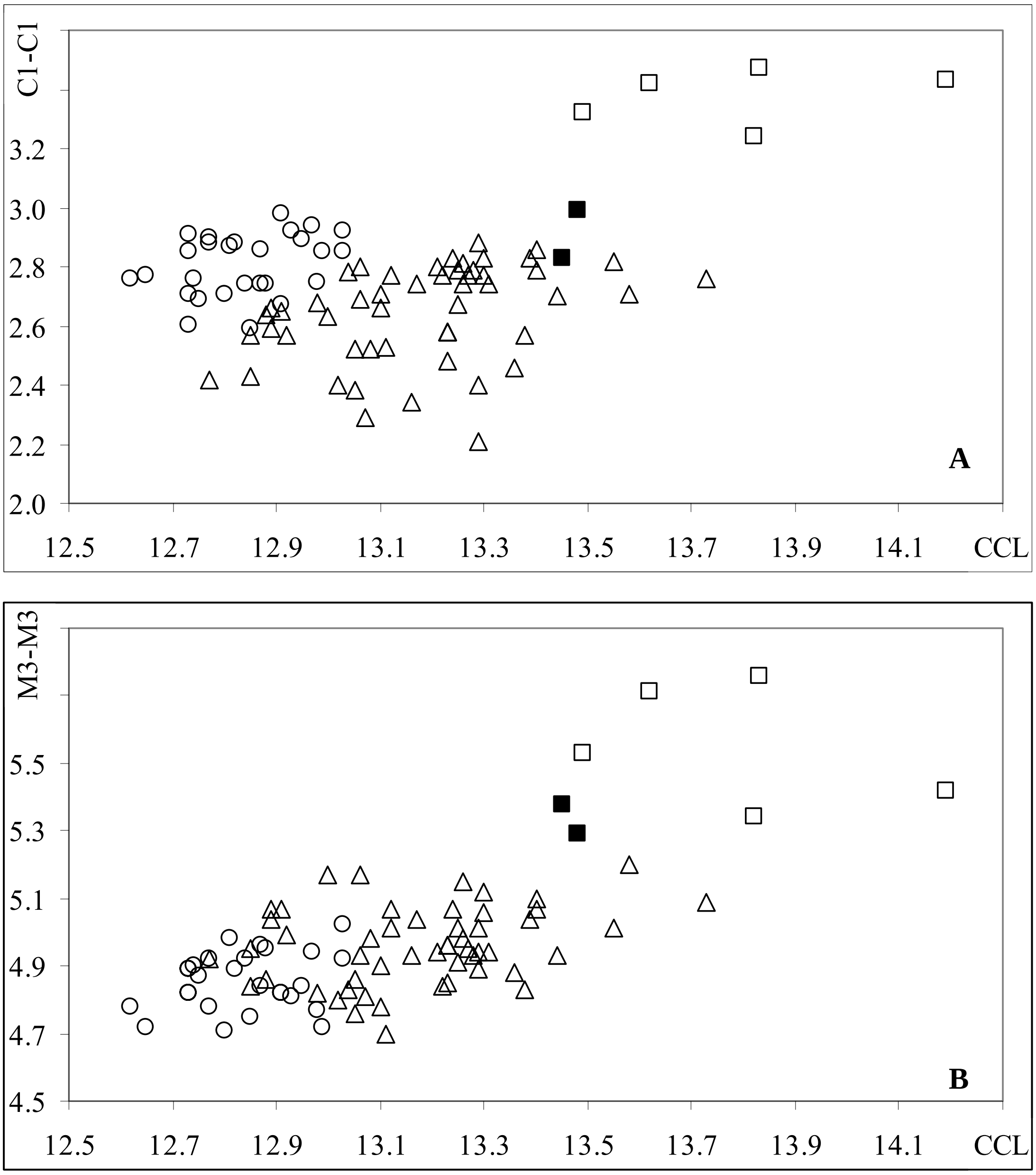
n	**sex**	**GTL**	**CCL**	**CBL**	**MW**	**MWx100/CC**	**ZB**	**ZBx100/MW**	**BB**
Hipposideros ater **India**									
3	♂	16.0-16.6	13.5-14.2	13.8-14.6	8.3-8.4	59.1-62.0	8.2-8.3	97.6-99.5	7.4-7.9
		16.2, 0.3	13.8, 0.4	14.1, 0.4	8.4, 0.1	60.8, 1.5	8.3, 0.1	98.6, 1.0	7.7, 0.3
2	♀	16.2, 16.4	13.8, 13.8	14.1, 14.3	8.5, 8.5	61.3, 61.7	7.9, 8.3	93.4, 96.7	7.9, 8.2
Hipposideros ater **Myanmar**									
2	♀	15.6, 15.7	13.5, 13.5	13.8, 13.8	8.4, 8.4	62.2, 62.5	7.5, 7.8	88.9, 92.2	7.5, 7.9
Hipposideros cineraceus **Thailand and Myanmar**									
25	♂	14.8-16.1	12.9-13.6	12.9-13.8	7.6-8.1	57.3-60.8	7.0-7.7	89.1-97.6	6.7-7.6
		15.5, 0.3 (24)	13.1, 0.2	13.4, 0.2 (24)	7.8, 0.1	59.2, 0.8	7.3, 0.2	94.1, 1.8	7.2, 0.2
27	♀	15.2-16.1	12.8-13.7	12.9-14.1	7.5-8.1	56.0-61.6	6.9-7.6	89.8-96.9	6.9-7.6
		15.6, 0.2	13.2, 0.2	13.5, 0.2	7.8, 0.1	59.1, 1.2	7.3, 0.2	93.0, 1.4	7.2, 0.2
Hipposideros halophyllus**Thailand**									
15	♂	14.8-15.2	12.6-13.0	12.8-13.3	7.6-8.0	59.8-61.9	7.2-7.5	90.9-95.4	6.7-7.3
		15.1, 0.1	12.9, 0.1	13.1, 0.1	7.8, 0.1	60.9, 0.6	7.4, 0.1	93.8, 1.2	7.0, 0.2
13	♀	14.8-15.3	12.7-13.0	12.7-13.4	7.8-7.9	60.5-61.6	7.1-7.7	90.4-99.1	6.6-7.4
		15.1, 0.2 (11)	12.8, 0.1	13.1, 0.2	7.8, 0.0	61.1, 0.3	7.3, 0.2	93.3, 2.2	6.9, 0.2

Table 4 (Continue). Cranial character measuremnets (in mm) of *Hipposideros ater, H. cineraceus* and *H. halophyllus* from India, Myanmar and Thailand.

n	**sex**	**PC**	**ML**	**C^1-C^1**	**M^3-M^3**	**C-M^3**	**C-M^{3}x100/CCL**	**C-M$_3$**	**RW**
***Hipposideros ater* India**									
3	♂	2.4-2.6	9.7-10.2	3.3-3.4	5.4-5.7	5.1-5.4	38.0-39.4	5.6-5.9	4.1-4.1
		2.5, 0.1	9.9, 0.3	3.4, 0.1	5.5, 0.2	5.3, 0.2	38.5, 0.8	5.8, 0.2	4.1, 0.0
2	♀	2.3, 2.4	10.0, 10.2	3.2, 3.5	5.3, 5.8	4.7, 5.2	34.1, 37.8	5.7, 5.8	4.2, 4.2
***Hipposideros ater* Myanmar**									
2	♀	2.5, 2.6	9.2, 9.4	2.8, 3.0	5.3, 5.4	5.1, 5.2	38.1, 38.4	5.2, 5.4	4.1, 4.3
***Hipposideros cineraceus* Thailand and Myanmar**									
25	♂	2.2-2.9	8.8-9.4	2.3-2.8	4.7-5.2	4.8-5.3	36.7-39.2	4.7-5.5	3.7-4.2
		2.5, 0.2	9.0, 0.2 (24)	2.6, 0.2	5.0, 0.1	5.0, 0.1	38.1, 0.6	5.2, 0.2 (24)	3.9, 0.1
27	♀	2.3-2.9	8.9-9.6	2.2-2.9	4.8-5.2	4.7-5.2	36.7-39.4	5.0-5.6	3.7-4.1
		2.5, 0.1	9.1, 0.2	2.6, 0.2 (26)	5.0, 0.1	5.0, 0.1	38.1, 0.6	5.3, 0.1	3.9, 0.1
***Hipposideros halophyllus*Thailand**									
15	♂	1.8-2.1	8.6-9.1	2.7-3.0	4.8-5.0	4.8-5.0	37.2-38.2	4.5-5.5	3.5-3.7
		1.9, 0.1	8.9, 0.1	2.8, 0.1	4.8, 0.1	4.9, 0.1	37.7, 0.3	5.0, 0.2	3.6, 0.1
12	♀	1.8-2.1	8.7-9.2	2.6-2.9	4.7-5.0	4.6-5.0	36.2-38.9	4.6-5.2	3.5-3.7
		1.9, 0.1	8.9, 0.1	2.8, 0.1	4.9, 0.1	4.8, 0.1	37.5, 0.8	5.0, 0.2	3.6, 0.1

Posterior constriction width of *H. halophyllus* is narrower than in the other species, with a width of 1.8-2.1 mm; but in *H. ater* from India and Myanmar, and *H. cineraceus* it is wider, with a width of 2.3-2.6 mm, 2.5-2.6 mm, and 2.2-2.9 mm respectively (Table 4).

The palate of *H. ater* is wide, with anterior palatal width of 3.2-3.5 mm and 2.8-3.0 mm, and posterior palatal width of 5.3-5.8 mm and 5.3-5.4 mm for specimens from India and Myanmar respectively; but in *H. cineraceus* and *H. halophyllus* it is narrower, with anterior palatal width of 2.2-2.9 mm and 2.6-3.0 mm, and posterior palatal width of 4.7-5.2 mm and 4.7-5.0 mm (Table 4, Fig. 41).



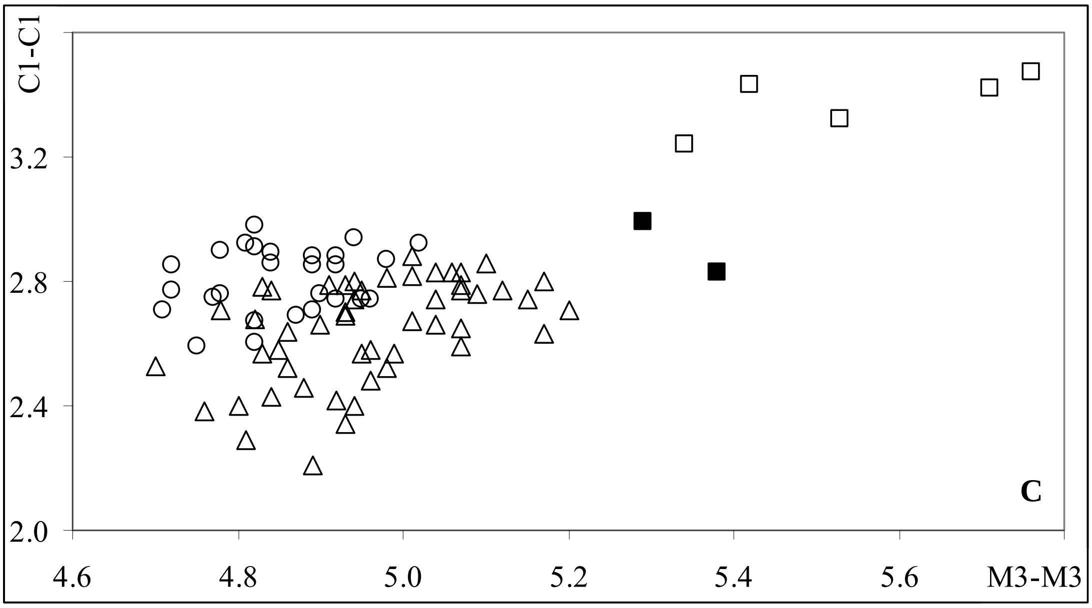


Fig. 41: Relationship between (A) condylo-canine length and anterior palatal width, (B) condylo-canine length and posterior palatal width, and (C) posterior and anterior palatal length of *H. ater* from India (open square), *H. ater* from Myanmar (black square), *H. cineraceus* (open triangular) and *H. halophyllus* (open circle).

The cochleae are broad and rounded in *H. ater* from India and *H. halophyllus*; but in *H. ater* from Myanmar and *H. cineraceus*, they are narrower and more elongate (Fig. 42-44, Table 4).

The tympanic bullae are narrow and long in *H. ater* from India and *H. halophyllus*; but they are shorter and broader in *H. ater* from Myanmar and *H. cineraceus* (Fig. 42-44, Table 4)

The mandible of *H. ater* from India is large and long, with a length of 9.7-10.2 mm; but in *H. ater* from Myanmar, *H. cineraceus*, and *H. halophyllus* are smaller and shorter, with a length of 9.2-9.4 mm, 8.8-9.6 mm and 8.6-9.2 mm, respectively (Table 4, Fig. 34-36 and 42-44).

Lower toothrow length of *H. ater* from India is 5.6-5.9 mm; but *H. ater* from Myanmar, *H. cineraceus* and *H. halophyllus* are shorter, with a length of 5.2-5.4 mm, 4.7-5.6 mm, and 4.5-5.5 mm, respectively (Table 4).

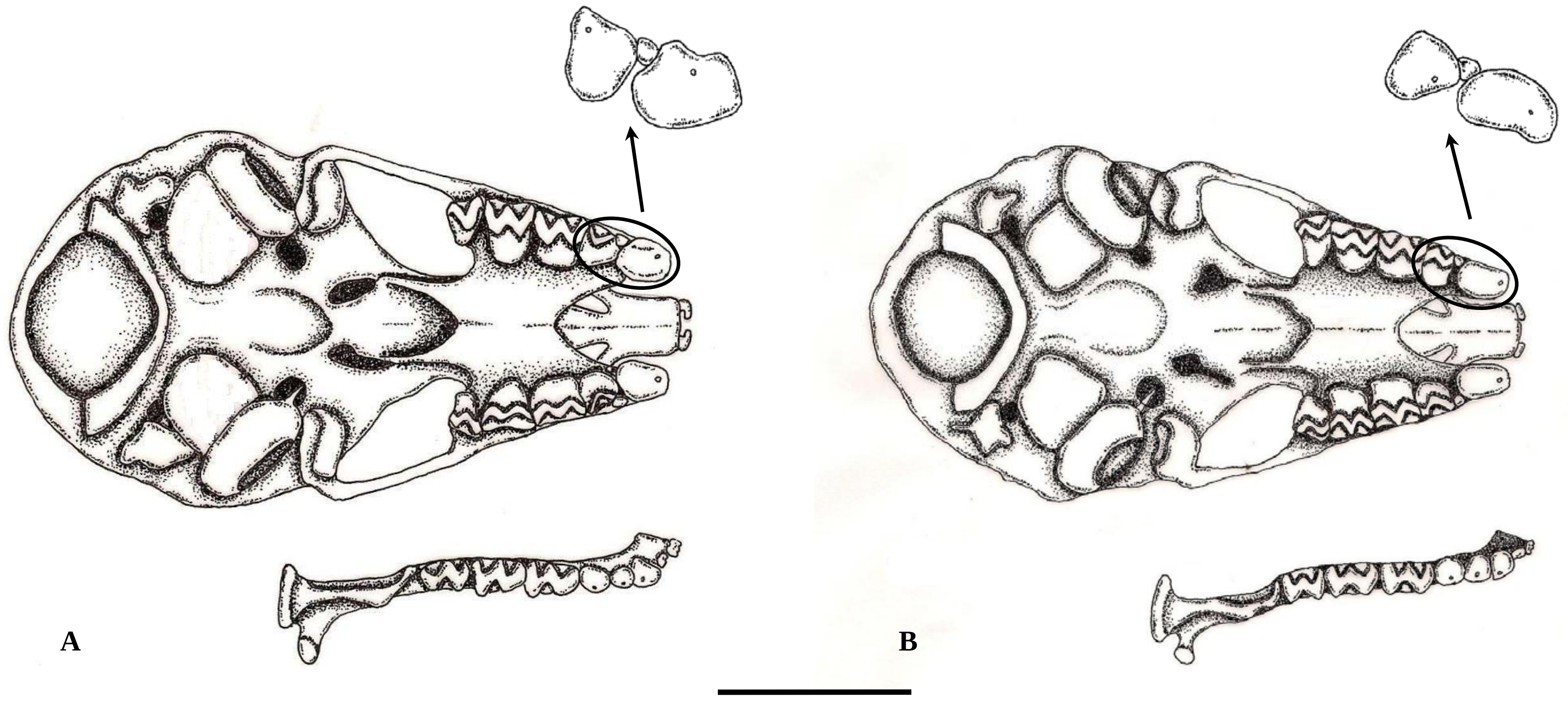


Fig. 42: Ventral view of the skulls and mandibles of *Hipposideros ater,* (A) *H. ater*, HZM.2.28189, ♂, Thiruneer Malai, 26 km from Central Madras, Tamil Nadu, India; (B) *Hipposideros* af. *ater*, HZM.10.35983, ♀, Tharabwin Village, Tanintharyi Division, Myanmar. Scale: 5 mm.

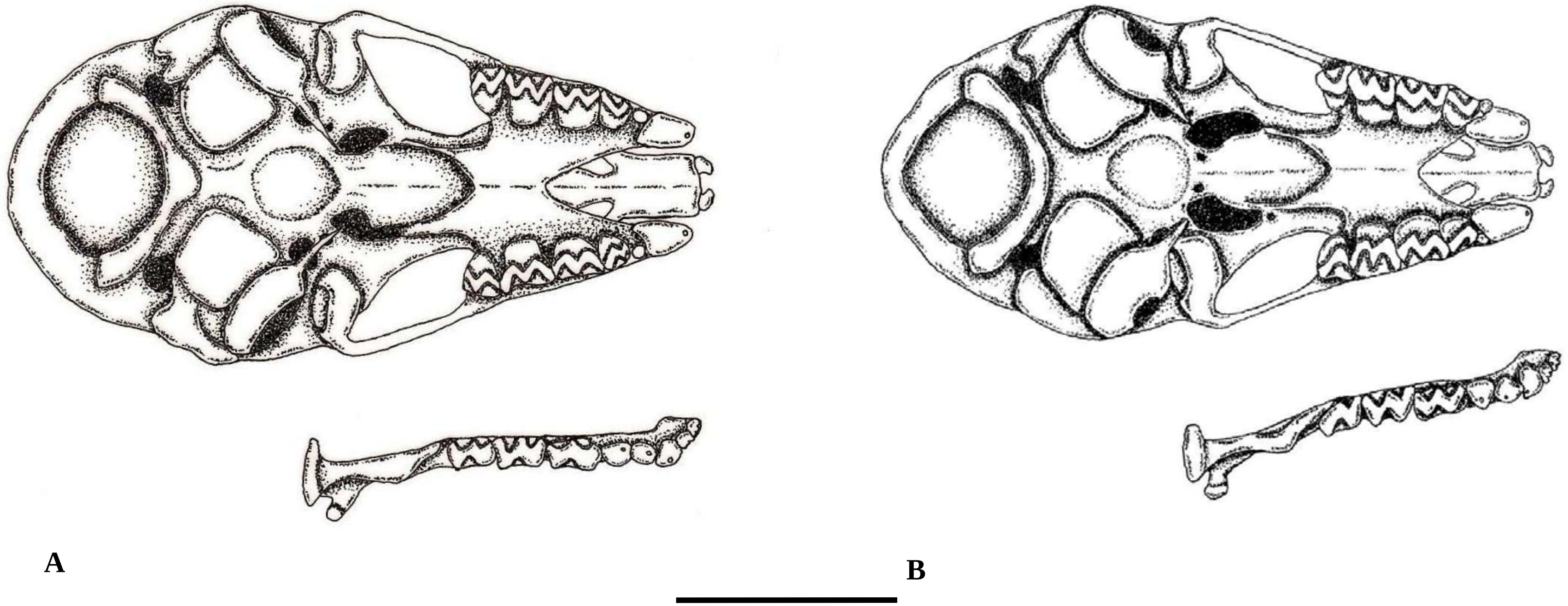


Fig. 43: Ventral view of the skulls and mandibles of *Hipposideros cineraceus*, (A) PSUZC-MM06.125, ♂, Wildlife Education Centre, Ton Nga Chang Wildlife Sanctuary, Songkhla Province, Thailand; (B) PSUZC-MM07.185, ♀, Khao Don Deung, Ban Mi District, Lop Buri Province, Thailand. Scale: 5 mm.

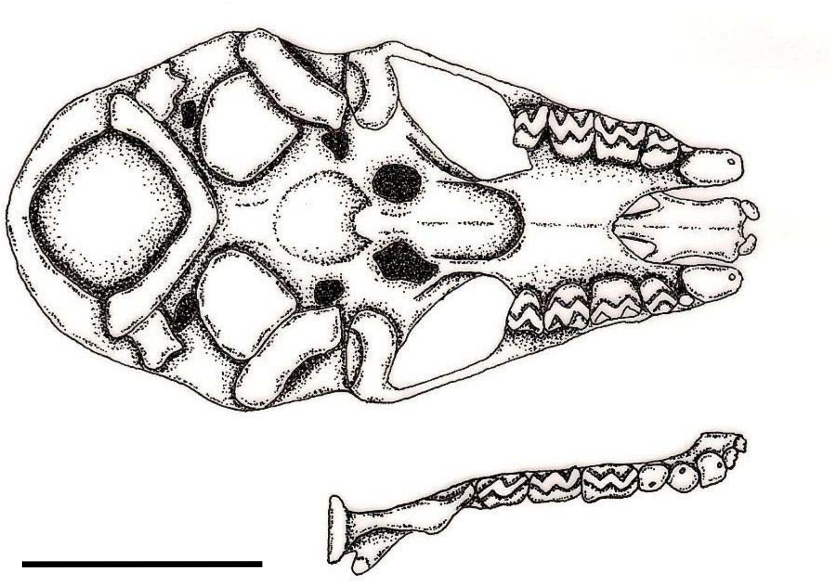


Fig. 44: Ventral view of the skulls and mandibles of *Hipposideros halophyllus*, PSU-M07.38, ♂, Khao Yoi Cave, Khao Yoi District, Petcha Buri Province, Thailand. Scale: 5 mm.

The upper canine of *H. ater* from India is large; those of *H. ater* from Myanmar, *H. cineraceus*, and *H. halophyllus* are smaller (Fig. 34-36).

The first upper premolar of *H. ater* (both India and Myanmar) is extruded from the toothrow; but in *H. cineraceus* and *H. halophyllus* 80.9% (of 47 specimens) and 39.1% (of 23 specimens) respectively are extruded; conversely 19.2% and 60.9% are included in the toothrow (Fig. 42-44).

The second upper premolar of *H. ater* from India is in contact with the canine. In *H. ater* from Myanmar and *H. halophyllus,* there is no contact. In *H. cineraceus*, most are not in contact (90.9%, of 47 specimens), with the remainder in contact (Fig. 42-44).

Table 5. Characters's summary of three species, *Hipposideros ater* from India, *H. ater* from Myanmar, *H. cineraceus* and *H. halophyllus*

Characters	***H. ater*** **India**	***H. ater*** **Myanmar**	*H. cineraceus*	*H. halophyllus*
FA	36.4-38.2	39.5-40.3	32.4-37.2	36.4-39.2
Noseleaf	**slightly curved**	**rounded**	rounded	long, curved
Supplementary leaflets	**no**	**one pair**	no	no
Septum	**triangular**	**inflated**	parallel-side	kidney-shaped
3MT and 5MT	<	< or >	<	>
Tail (enclosed)	**except tip**	**enclosed**	enclosed	except tip
Penis-shaped	short and flat	-	short and thin, blunt tip	short and thin, pointed tip
Baculum	straight single tip	-	bifid tip	straight, minute single tip
CCL	13.5-14.2	13.5	12.8-13.7	12.6-13.0
MW	8.3-8.5	8.4	7.6-8.1	7.6-8.0
Rostrum	**horizontal**	**concave**	concave	sloped
Nasal inflations	**six**	**four**	four or six	four or six
Sagittal crest	**high**	**low**	low	high
ZB	**7.9-8.3**	**7.5-7.8**	6.9-7.7	7.1-7.7
Jugal projection	**well-developed**	**moderate**	low or without	well-developed
C1-C1	**3.2-3.5**	**2.8-3.0**	2.2-2.9	2.6-3.0
M3-M3	5.3-5.8	5.3-5.4	4.7-5.2	4.7-5.0

Table 5 (Continue). Characters's summary of three species, *Hipposideros ater* from India, *H. ater* from Myanmar, *H. cineraceus* and *H. halophyllus*

Characters	***H. ater* India**	***H. ater* Myanmar**	*H. cineraceus*	*H. halophyllus*
ML	**9.7-10.2**	**9.2-9.4**	8.8-9.6	8.6-9.2
c-m3	5.6-5.9	5.2-5.4	4.7-5.6	4.5-5.5
C1	large	small	small	small
PM1	extruded	extruded	extruded or in toothrow	extruded or in toothrow
PM2 and C1	**in contact**	**not in contact**	contact or not in contact	not in contact

Twenty five morphological characters of *H. ater* from India and Myanmar, and *H. cineraceus* were analysed by the PCA. The two groups of *H. ater* was clearly separated: Myanmar and India. Additionally, *H. cineraceus* was clearly separated from *H. ater* from India and Myanmar (Fig. 36).

A PCA analysis of the three species showed that they subdivided into four groupings (Fig. 36). These were *H. cineraceus*, *H. halophyllus,* and to a lesser extent *H. ater* (India) and *H. ater* (Myanmar).

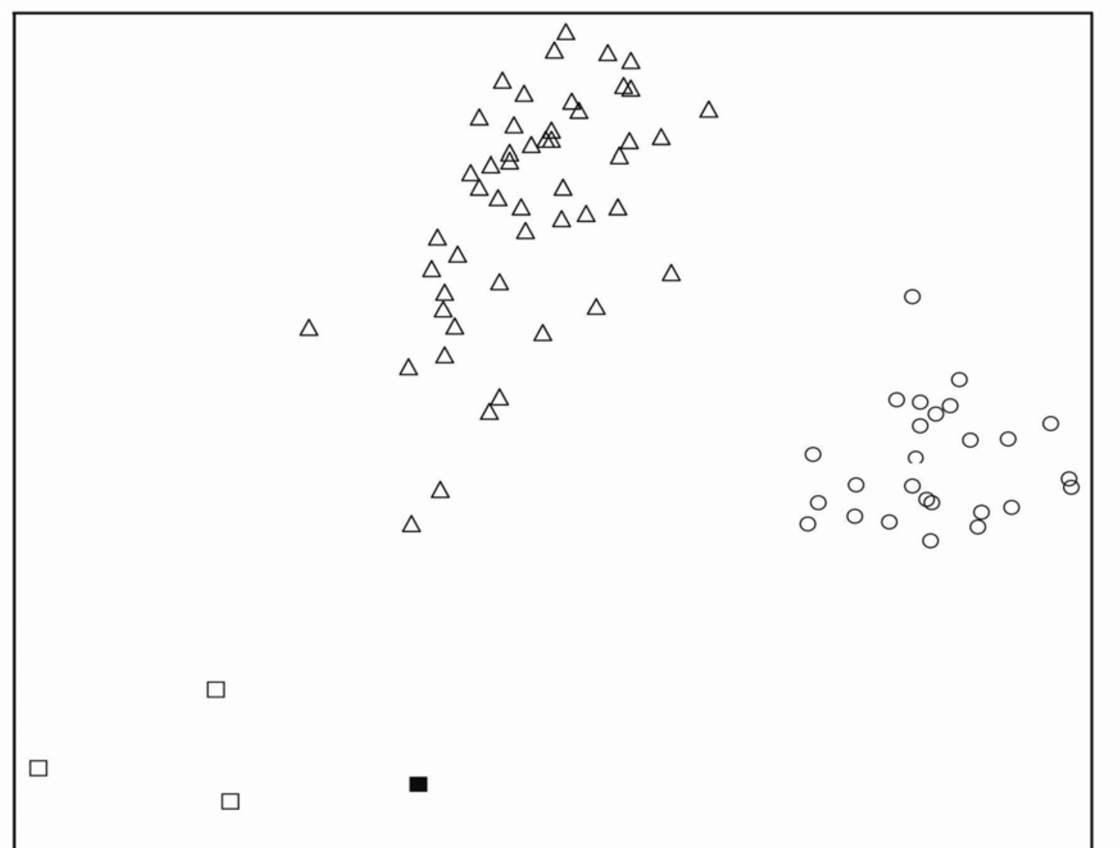


Fig. 45: PCA analysis of *H. ater* from India (open square), *H. ater* from Myanmar (black square), *H. cineraceus* (open triangular), and *H. halophyllus* (open circle).

5.3. Echolocation

Echolocation calls of *H. cineraceus* have a frequency range of 134.8-154.1 kHz, with male frequencies of 134.5-154.2 kHz (n=21) and female frequencies of 141.4-154.1 kHz; but *H. halophyllus* used higher frequency, with a frequency of

156.4-187.9 kHz; 156.4-187.9 kHz in males and 160.6-186.2 kHz in females (Fig. 46 and 47, Table 2). The echolocation call of *H. ater* was not available for comparison. There did not appear to be any significant geographical variation or variation between the sexes (Table 6).

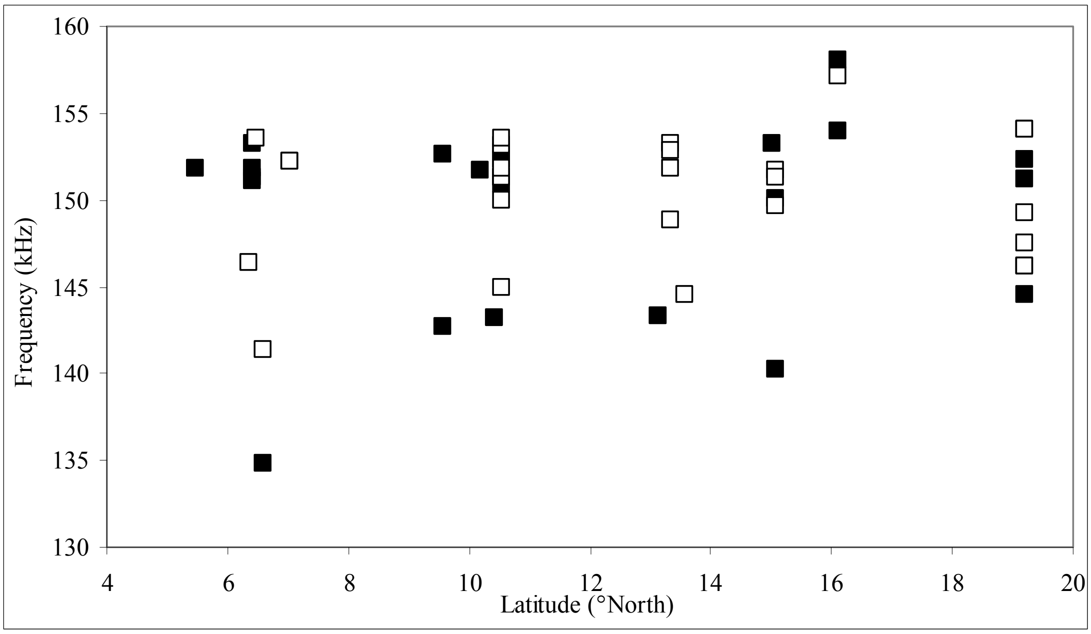


Fig. 46: Echolocation calls of *Hipposideros cineraceus* from 17 localities in Thailand and Myanmar. Frequency of call (kHz) plotted against latitude (degrees North) of locality. Black squares represent males and open squares are females.

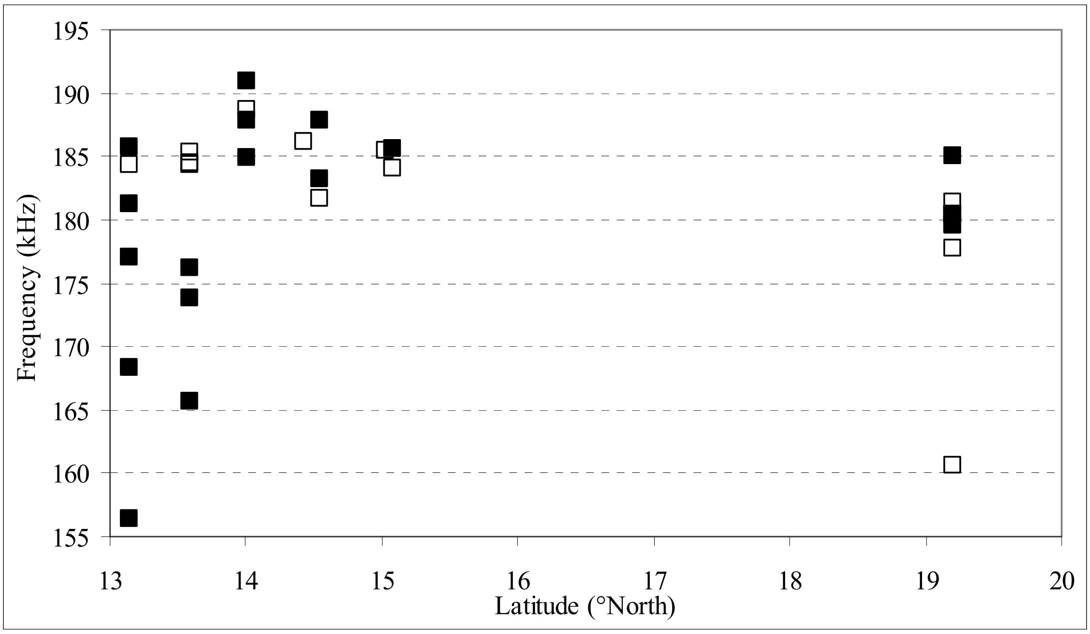


Fig. 47: Echolocation calls of *Hipposideros halophyllus* from 8 localities in Thailand. Frequency of call (kHz) plotted against latitude (degrees North) of locality. Black squares represent males and open squares are females.

5.4. Variation Test in *Hipposideros halophyllus*

In *H. halophyllus*, the frequency of echolocation calls did not vary significantly between each locality (P > 0.05). However, the forearm length does vary slightly with latitude. It is longest (FA: 37.6-39.4 mm, *n*=9) in high latitudes and shorter in lower latitudes (FA: 36.4-37.5 mm, *n*=6), except two localities (LLC and TCC) which have only one specimens (Table 7, Fig. 48). On the other hand, the cranial characters do not vary with latitude. In addition, the morphology of this species does not vary between populations.

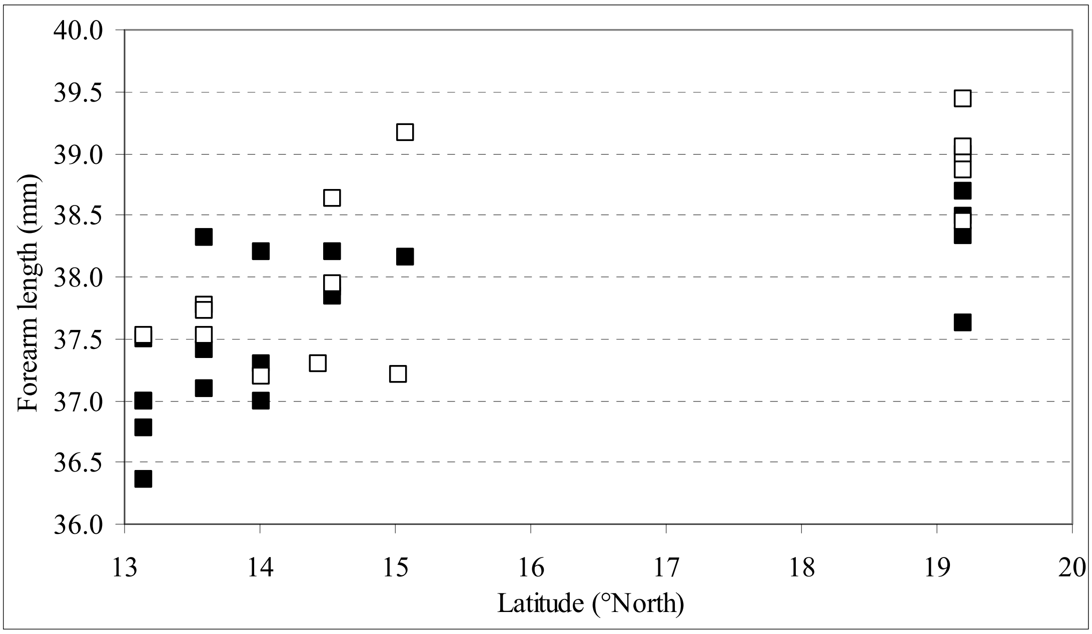


Fig. 48: Forearm lengths of *Hipposideros halophyllus* from 8 localities in Thailand. Forearm length (mm) plotted against latitude (degrees North) of locality. Black squares represent males and open squares are females.

Table 6. Forearm length (FA), condylo-canine length (CCL), and mastoid width (MW) of *H. halophyllus* in each locality (in mm).

LOCATION	FA		CCL		MW	
	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE
PHA DAENG CAVE	37.6-38.7	38.5-39.4	12.8-12.9	12.7-12.9	7.9-8.0	7.8-7.8
	38.2, 0.6 (4)	38.9, 0.3 (5)	12.9, 0.1 (3)	12.8, 0.1 (4)	7.9, 0.1 (3)	7.8, 0.0 (4)
KHAO DON DEUNG	38.2 (1)	39.2 (1)	12.6 (1)	12.7 (1)	7.6 (1)	7.8 (1)
LUP LAE CAVE	37.2 (1)	-	12.9 (1)	-	7.9 (1)	-
KHAO SMORKHON	37.8-38.2	38.6, 37.9	12.8-13.0	13.0, 12.8	7.9-7.9	7.9, 7.8
	38.0, 0.2 (3)	2	12.9, 0.1 (3)	2	7.9, 0.0 (3)	2
TON CHAN CAVE	37.3 (1)	-	-	-	-	-
KHAO SINGTO	37.1-38.3	37.5-37.8	12.7-13.0	12.8-13.0	7.8-7.9	7.8-7.9
	37.6, 0.6 (3)	37.7, 0.2 (3)	12.9, 0.2 (3)	12.9, 0.1 (3)	7.9, 0.1 (3)	7.8, 0.1 (3)
KHAO YOI	36.4-37.5	37.5	12.7-13.0	12.8	7.7-7.9	7.9
	36.9, 0.4 (5)	1	12.9, 0.2 (5)	1	7.8, 0.1 (5)	1

CHAPTER 6

SYSTEMATICS DESCRIPTIONS

6.1. *Hipposideros ater* Templeton, 1848

Dusky Leaf-nosed Bat
Hipposideros ater Templeton, 1848; Colombo, Sri Lanka

Synonyms (following Hill, 1963; Corbet and Hill, 1992; Simmons, 2005):
Hipposideros atratus Kelaart, 1850; Colombo, Sri Lanka
Hipposideros aruensis Gray, 1858; Aru Islands
Phyllorhina antricola Peters, 1861; Paracali, Luzon Island, Philippines
Hipposideros albanensis Gray, 1866; Port Albany, Northern Queensland
Phyllorhina amboinensis Peters, 1871; Ambon, Moluccas
Hipposideros nicobarulae Miller, 1902; Little Nicobar Island, Bay of Bengal
Hipposideros albanensis saevus Aadersen, 1918; Kei Island
Hipposideros gentilis toala Shamel, 1940; Toeare, Sulawesi
Hipposideros bicolor gilberti Johnson, 1959; Oenpelli, East Alligator River, Northern Territory, Australia (12°21'S, 133°04'E)

6.1.1. External and Baculum Characters

Hipposideros ater is a small species in the *H. bicolor* group, with an average forearm length of 37.5 mm (36.4-38.2 mm). The wings and 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 (Bates and Harrison, 1997). The ears are large and rounded, with a length of 16.7 mm (15.2-17.8 mm) and width of 14.0 mm (13.6-14.5 mm). The noseleaf is small, with a length of 4.2 mm (4.0-4.4 mm) and a width of 4.6 mm (4.5-4.6 mm); it lacks supplementary lateral leaflets. The internarial septum is small, with a width of 0.6 mm (0.5-0.7 mm); it is triangular-shaped, expanded at the base and narrowed at the tip. The anterior leaf is slightly curved on each side of anterior part. There is a well defined frontal sac in the middle behind the posterior leaf. The fifth metacarpal (28.7 mm, 27.3-30.1 mm) is about equal or slightly exceeds the third metacarpal (28.5 mm, 27.2-30.1 mm). . The fourth metacarpal is the longest, with a length of 30.0 mm (27.2-32.2 mm). The combined lengths of the phalanges of the third metacarpal 31.5 mm (30.5-32.3 mm) exceed the third metacarpal.. The tail length is 23.0 mm (21.0-24.0 mm); it is enclosed by the interfemoral membrane, except for the extreme tip. The tibia length is 16.4 mm (15.6-16.9 mm). The hindfoot is 6.5 mm (5.8-7.0 mm). The calcar is slender, broader at the base and narrowed at the tip; with a length of 9.0 mm (5.8-7.0 mm). The penis is short and flat, larger at the base, narrow and rounded at the tip. The baculum is small, with a length of 1.7 mm and a basal width of 0.3 mm. In dorsal view; it is straight with a simple, expanded base and a rounded tip. In the lateral view, it is a little curved.

Fig. 49: Face and noseleaf of *Hipposideros ater*; (left) *Hipposideros ater*, HZM.2.28189, ♂, Thiruneer Malai, 26 km from Central Madras, Tamil Nadu, India; (right) *Hipposideros* af. *ater*, HZM. 5.35011, ♀, Kan Thar Yar Beach, Gwa Township, Rakhine State, Myanmar.

6.1.2. Cranial Characters

The skull is small and wide, with an average condylo-canine length of 13.8 mm (13.5-14.2 mm) and a mastoid width of 8.4 mm (8.3-8.5 mm). The braincase is low or flat and wide; the breadth of braincase is about equal to (sometimes slightly narrower, sometimes wider than the zygomata width), with a braincase width of 7.8 mm (7.4-8.2 mm) and a zygomata width of 8.2 mm (7.9-8.3 mm). The rostrum is low and flat, with a width of 4.1 mm (4.1-4.2 mm); the anterior part is horizontal. There are six nasal inflations on the rostrum. The postorbital constriction is narrow, with a width of 2.4 mm (2.3-2.6 mm). The sagittal crest is high on the anterior part and low on the posterior part. The anterior part of the zygomata is slender, with a well-developed jugal projection on the posterior part of each zygoma. The mastoid width exceeds the zygomatic width. The palate is wide, with a length of 2.3 mm (1.8-2.6 mm), an anterior palatal width of 3.4 mm (3.2-3.5 mm), and a posterior palatal width of 5.5 mm (5.3-5.8 mm). The tympanic bullae are narrow and long, with the width (1.1 mm, 0.9-1.2 mm) about one third of the length (2.9 mm, 2.8-3.0 mm). The cochleae are broad and rounded, with the cochleae width (2.2 mm, 2.0-2.3 mm) about three quarters of the tympanic bullae length. The intercochlear distance is about two thirds to four fifth the cochlear width, and with the intercochlear distance of 1.7 mm (1.5-1.8 mm). The mandible is large, with a length of 10.0 mm (9.7-10.2 mm).

6.1.3. Dentition

Upper toothrow length is 5.2 mm (4.7-5.4 mm) and lower toothrow length is 5.8 mm (5.6-5.9 mm). The upper canine is large and robust. The first upper premolar is very small and extruded from the toothrow; the second upper premolar is in contact with the canine. The second lower incisor is one half the crown area of the first lower incisor. The first lower premolar is about two thirds to three quarters in length and one third to one half of its height of the second premolar.


MM1
Z.28189
MM1

Fig. 50: Lateral, dorsal and ventral views of skull and mandible of *Hipposideros ater*, HZM.2.28189, ♂, Thiruneer Malai, 26 km from Central Madras, Tamil Nadu, India. Scale: 5 mm.

6.1.4. Echolocation

In India, *H. ater* has a peak frequency of 163.1-169.5 kHz (Jones *et al.* 1994).

6.1.5. Taxonomic Notes

Following Corbet and Hill (1992) and Bates and Harrison (1997), specimens from India and Sri Lanka are referable to the nominate race *H. a. ater*.

6.1.6. Conservation Status

Hipposideros ater was included as 'Lower Risk, least concern' in Hutson *et al.* (2001), Simmons (2005) and Boitani *et al.* (2006).

6.1.7. Distribution

According to Simmons (2005), *Hipposideros ater* ranges from Sri Lanka, India to western Malaysia, Indonesia, Philippines, New Guinea to Australia. It was not included in Lekagul and McNeely (1977) for Thailand. Subsequently, Yenbutra and Felten (1986) included a single record from Ratchaburi Province. This specimen (BMNH.78.2344) from Khao Bin Cave, with a condylo-canine length of 12.7 mm and a mastoid width of 7.7 mm is actually referable to *H. halophyllus* (see Hill and Yenbutra, 1984). Corbet and Hill (1992) mapped the species' range as including much of western and peninsular Thailand but did not include any justification. In the recent study, no specimens of *H. ater* were collected in the many exhaustive surveys undertaken throughout the country and its presence in Thailand would appear to need confirmation.

Sri Lanka: North Central Province: Anoradhapura (= *fulvus* in Wroughton, 1915); **Central Province:** Peradeniya; Rattota; Kaduganava; Medamahanuwer (Bates and Harrison, 1997); Kandy (Kelaart, 11852); **Eastern Province:** Valaichenai; Trincomalee (= *fulvus* in Wroughton, 1915); **Western Province:** Colombo; Anasigaa; Matugama; Dehiwala (Bates and Harrison, 1997); Negombo; Kalutara (Kelaart, 1852); **Sabaraganuwa:** Pelmadulla (Bates and Harrison, 1997), **Unknown location** (BMNH collected).

India: Maharashtra: Nanded (appro. 19°11'N, 77°21'E) (Bates and Harrison, 1997); Marathwada (not located) (Gopalakrishna and Madhavan, 1977), **Karnataka:** Dharwar District (appro. 15°30'N, 75°04'E) (Bates and Harrison, 1997); Lingasugur (appro. 15°11'N, 76°54'E); Therhalli (appro. 13°05'N, 80°00'E); Hanumanhalli (appro. 13°09'N, 78°07'E) (= *cineraceus* in Bhat and Jacob, 1990); **Kerala:** Trivandrum (appro. 08°41'N, 76°57'E); Trichur District (appro. 10°32'N, 76°14'E) (Bates and Harrison, 1997; BM(NH).88.100-102, 3?); Ernakulam (appro. 10°00'N, 76°16'E) (Bates and Harrison, 1997); **Timil Nadu:** Cumbum (appro. 09°44'N, 77°19'E) (Wroughton, 1921); Kurumbapapatti (not located); Tirthamalai (appro. 12°06'N, 78°36'E) (= *cineraceus* in BMNH); near Madras (appro. 13°05'N, 80°18'E) (Bates and Harrison, 1997); near Madurai (appro. 09°55'N, 78°07'E) (Jones *et al.* 1994); Thiruneer Malai (appro. 13°05'N, 80°00'E) (HZM collection); Sankanthira Mandapam (appro. 08°45'N, 77°43'E) (HZM collection); **Orissa:** Konarak (appro. 19°52'N, 86°12'E); **Madhya Pradesh:** Guwarghat (appro. 23°09'N, 79°58'E) (Topál, 1975); **Meghalaya:** Cherrapunji (appro. 25°16'N, 91°42'E) (doubtful record in Kurup, 1968); **Mahasashta State:** (not located) (BMNH collection).

6.1.8. Ecological Notes

In Sri Lanka, this species roost in lofts of houses, old dwellings, abandoned mines, low dark road culverts, and hollow trees; most are in the wet lowland region. Males and females often roost separately in small single sex colonies. During the day, they spend much time grooming and cleaning their fur and membranes. When disturbed, it will escape from its retreat and take refuge in the denser foliage of some nearby tree, here it will remain for an hour or more before returning to its usual quarters. However, it will be soon desert its habitual roost if continually disturbed. In India, it roosts in deep wells and dark hollows in walls (Bates and Harrison, 1997). In Borneo, this species roosts in caves in colonies of up to a few hundred individuals (Payne *et al.* 1985). In Maharashtra, females become pregnant between mid-November and mid-December; the time of birth ranges from the last week of May to the end of June. It is carried by the mother for 25 days until it weighs 3.5 grams; lactation continues until mid-August. Females reach sexual maturity within one year of birth. In Sri Lanka, females are pregnant in March. In Kolar, it is pregnant in November and December and lactate in April and May. However, single pregnant females were found in May, June, and July. The gestation period is estimated to be 120-140 days. The young are weaned six to eight weeks after parturition and lactation ceases immediately (Bates and Harrison, 1997).

6.2. *Hipposideros* af. *ater* Templeton, 1848

6.2.1. External Characters

Based on two specimens from Myanmar, this is a small species in the *H. bicolor* group, with an average forearm length of 39.9 mm (39.5-40.3 mm). The noseleaf is dark. The wings and interfemoral membranes are dark. The upperparts are uniformly light black and underparts are uniformly lighter. Hair tips are dark and the bases are pale or dark brown (specimens preserved in alcohol). The ears are small and rounded, with a length of 16.7 mm (16.6-16.7 mm) and a width of 13.4 mm (12.3-12.4 mm). The noseleaf is small, with a length of 5.3 mm and a width of 5.1 mm (4.9-5.3 mm); it has one pair of rudimentary supplementary lateral leaflets, which have hairs. The internarial septum is small; it is inflated in the middle, and with a greatest width of 0.8 mm. The anterior leaf is rounded anteriorly. There is only a small gland on middle behind the posterior leaf. The third metacarpal (32.2 mm, 31.0-33.4 mm) exceeds or is shorter than the fifth metacarpal (32.2 mm, 31.2-33.2 mm). The fourth metacarpal is longest, with a length of 34.0 mm (33.1-34.8 mm). The combined lengths of the phalanges of the third metacarpal exceed or are shorter than the third metacarpal, with a combined length of 31.8 mm (31.4-32.6 mm). The tail length is 26.7 mm (24.7-28.7 mm); the tail is enclosed within the interfemoral membrane. The tibia length is 17.0 mm (16.2-17.8 mm). The hindfoot length is 6.8 mm (6.5-7.0 mm). The calcar is small with a length of 9.5 mm (8.6-10.3 mm).

Fig. 51: Noseleaf *Hipposideros ater*; (left) *Hipposideros ater*, HZM.2.28189, ♂, Thiruneer Malai, 26 km from Central Madras, Tamil Nadu, India; (right) *Hipposideros* af. *ater*, HZM.5.35011, ♀, Kan Thar Yar Beach, Gwa Township, Rakhine State, Myanmar.

6.2.2. Cranial Characters

The skull is small and wide, with a average condylo-canine length of 13.5 mm and a mastoid width of 8.4 mm. The braincase is inflated; the breadth of braincase (7.7 mm, 7.5-7.9 mm) is narrower or wider than the zygomatic width (7.7 mm, 7.5-7.8 mm). The rostrum is inflated, with a width of 4.2 mm (4.1-4.3 mm); the anterior part is concave. There are four nasal inflations. The postorbital constriction is narrow, with a width of 2.6 mm (2.5-2.6 mm). The sagittal crest is low. The anterior part of zygomata is slender, with a moderated sized jugal projection. The mastoid width exceeds the zygomatic width. The palate is wide, with the anterior palatal width of 2.9 mm (2.8-3.0 mm), and posterior palatal width of 5.4 mm (5.3-5.4 mm). The tympanic bullae are short and broad, with the tympanic bullae width (1.2 mm) about half the length (2.5 mm). The cochleae are broad and elongate, with the cochleae width (2.2 mm) about four fifths of tympanic bullae length, with cochlear width. The intercochlear distance (1.6 mm, 1.5-1.6 mm) is about two thirds of the cochlear width. The mandible is small, with a length of 9.3 mm (9.2-9.4 mm).

Fig. 52: Lateral, dorsal and ventral views of *Hipposideros* cf. *ater*, HZM.10.35983, ♀, Tarabwin Village, Tanintharyi Division, Myanmar. Scale: 5 mm.

6.2.3. Dentition

Upper toothrow length is 5.2 mm (5.1-5.2 mm) and lower toothrow length is 5.3 mm (5.2-5.4 mm). The upper canine is small. The first upper premolar is very small and extruded from the toothrow; the second upper premolar is not in contact with the upper canine. The second lower incisor is about two thirds the crown area of the first lower incisor. The first lower premolar equals or is slightly longer than second lower premolar and one half of its height.

6.2.4. Taxonomic Notes

Specimens of *Hipposideros* af. *ater* from Myanmar differ in a number of characters from those seen from southern India and Sri Lanka (the type locality). Specimens from the Indian Subcontinent (n= 3♂ and 2♀) have smaller wings (FA= 37.5 mm, 36.4-38.2), shorter metacarpals (3MET= 28.5 mm, 27.2-30.1 mm; 4MET= 30.1 mm, 29.1-31.2 mm; 5MET= 28.7 mm, 27.3-30.1 mm) and are without a supplementary lateral leaflet adjacent to the anterior noseleaf. Conversely the Indian skulls average larger (CCL= 13.8 mm, 13.5-14.2 mm; ZB= 8.2 mm, 7.9-8.3 mm; C-M^3= 5.2 mm, 4.7-5.4 mm). The sagittal crest appears to be more developed anteriorly. The taxonomic significance of these differences is not currently known but it is possible that the Myanmar population may belong to different discrete species.

Corbet and Hill (1992) referred specimens from Myanmar to *H. ater saevus* Andersen, 1918. However, with a condylo-canine length of 15.1 mm (Andersen, 1918) *saevus*, which was named from Kai Island, Indonesia, appears referable to *H. bicolor* rather than the smaller *H. ater*. Externally, the specimens from Myanmar are similar in size to the geographically isolated *H. a. nicobarulae* Miller, 1902 from the Nicobar Islands. However the skull of *nicobarulae* (CCL = 14.3-15.0, n= 6, from Bates and Harrison, 1997) is significantly larger than that of *H. a. ater* and there are also differences in the skull morphology. This all suggests that *nicobarulae* is incorrectly included in the synonymy of *H. ater*.

6.2.5. Distribution

These specimens were collected from Myanmar only.

Rakhine State: Kan Thar Yar Beach, Gwa Township (17°43'N, 94°31'E) [loc. 8, Fig. 46] (Pearch *et al.* 2003; HZM collection); **Tanintharyi Division:** Myeik (12°26'N, 98°36'E) [loc. 8, Fig. 46], (= Margui in Lindsay, 1926); Tharabwin Village (12°18'N, 99°04'E), [loc. 9, Fig. 46] (HZM collection); **Shortridge:** Tenasserim Village (not located) (= *atratus* in BMNH collection); **Unknown location:** Mekgui (not located) (= *atratus* in BMNH collection).

6.2.6. Ecology Notes

A single specimen was observed just before dusk flying around the bathroom of one of a row of wooden chalets next to the sandy beach at Kan Thar Yar. Numerous palm trees were growing between the beach and the chalets, behind which ran a little-used road with dense vegetation beyond (Pearch *et al.* 2003). A specimen was collected in Tanintharyi Division, with the original vegetation of the region was highland and lowland dipterocarp forest; the mature trees draped with numerous lianas, epiphytes and rattans. However, on the mainland most of the lowland areas have been deforested for agriculture, particularly for rice paddy and most of the remaining forest is restricted to the mountain tops (Bates *et al.* 2005).

6.3. *Hipposideros cineraceus* Blyth, 1853

Least Leaf-nosed Bat

Hipposideros cineraceus Blyth, 1853; Near Pind Dadan Khan, Salt range, Punjab

Synonyms (following Hill, 1963; Corbet and Hill, 1992; Simmons, 2005):

Phyllorhina micropus Peters, 1872; Dehra Dun, near Simla, Northwestern India

? *Hipposideros wrighti* Taylor, 1934; Baguio, Benguet, Luzon Island, Philippines

6.3.1. External and Baculum Characters

Hipposideros cineraceus is a smallest species in the *H. bicolor* group, with an average forearm length of 34.8 mm (32.4-37.2 mm). The pelage is individually variable in colour but tends to be a dull mid-brown to ginger or orange on the dorsal aspect with paler hair bases. On the ventral surface, it is uniformly pale, almost white in some specimens; in other the hair tips are tinged with brown or orange, especially on the flanks (Bates and Harrison, 1997). Wings are brown. The ears are brown or grey with pale bases. The noseleaf is pinkish or pink edged with grey or black (Kingston *et al.* 2006). The ears are large and rounded, with a length of 16.1 mm (13.4-20.2 mm) and a width of 12.3 mm (10.1-13.6 mm). The noseleaf is small, with a length of 4.2 mm (3.6-4.7 mm) and a width of 4.1 mm (3.6-4.2 mm); it lacks supplementary lateral leaflets. The internarial septum is small, with a width 0.6 mm (0.4-0.8 mm); it is slightly triangular to parallel-shaped, and is rounded and bulbous at the tip. The anterior leaf is slightly circular to round on the anterior part. In some specimens, there is a well developed frontal sac. The fifth metacarpal (26.8 mm, 25.3-28.9 mm) averages longer than the third metacarpal (25.6 mm, 23.7-27.6 mm). The fourth metacarpal is longest, with a length 28.1 mm (26.4-27.7 mm). The combined lengths of the phalanges (28.9 mm, 26.7-34.5 mm) of the third metacarpal exceed the third metacarpal in length. The tail length is 24.5 mm (19.0-28.6 mm); the tail is enclosed within interfemoral membrane. Tibia length is 15.4 mm (14.4-19.9 mm). The hindfoot length is 5.2 mm (4.3-5.9 mm). The calcar is slender, the base is narrow or large, with a length of 8.4 mm (7.2-9.4 mm). The penis is short and thin, with a blunt tip. The baculum is small, with a length of 2.0 mm (1.8-2.5 mm) and a basal width of 0.4 mm (0.4-0.5 mm). In dorsal view; it has a narrow shaft and a rounded base, the base is expanded and the tip is bifid. In the lateral view, it is slightly curved.

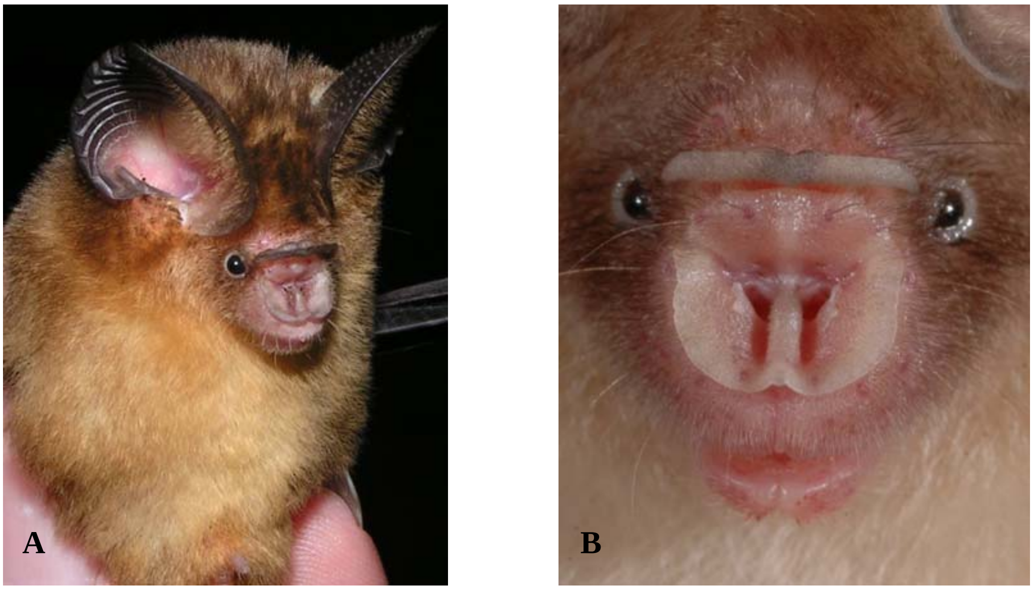


Fig. 53: (A) Face and noseleaf of *H. cineraceus*, PSUZC-MM06.125, ♂, Wildlife Education Centre, Ton Nga Chang Wildlife Sanctuary, Songkhla Province, Thailand; (B) Ventral view of noseleaf of *H. cineraceus*, PSUZC-MM06.69, ♂, Khao Kram Cave, Patiew District, Chumphon Province, Thailand.

6.3.2. Cranial Characters

The skull is small and elongate, with an average condylo-canine length of 13.2 mm (12.8-13.7 mm) and a mastoid width of 7.8 mm (7.6-8.1 mm). The braincase is inflated; the breadth of braincase (7.2 mm, 6.7-7.6 mm) is narrower to wider than the zygomata width (7.3 mm, 6.9-7.7 mm). The rostrum is inflated, with a width of 3.9 mm (3.7-4.2 mm); the anterior part is concave. There are four or six nasal inflations. The postorbital constriction is narrow, with a width of 2.5 mm (2.2-2.9 mm). The sagittal crest is low or has a little crest on the anterior part. The zygomata are narrow on anterior part, the jugal bone of each zygoma is with or without a dorsal process on posterior part; when present, it is very low. Mastoid width exceeds the zygomatic width. The palate is narrow, with an anterior palatal width of 2.7 mm (2.2-2.9 mm) and a posterior palatal width of 5.0 mm (4.7-5.2 mm). The tympanic bullae are short and broad, their width (1.1 mm, 0.9-1.2 mm) is about half their length (2.3 mm, 2.0-2.5 mm). The cochleae are broad and elongate, with a width of 2.2 mm (2.0-2.3 mm). The intercochlear distance is 1.3 mm (1.1-1.5 mm). The mandible is small and short, with a length of 9.1 mm (8.8-9.6 mm).

6.3.3. Dentition

Upper toothrow length is 5.0 mm (4.7-5.3 mm) and lower toothrow length is 5.2 mm (4.7-5.6 mm). The upper canine is small. The first upper premolar is very small, extruded or included in the toothrow; the canine is contact or not in contact with the second upper premolar. The first lower incisor is about one half to equal in crown area of the first lower incisor. The first lower premolar is about equal in length to the second lower premolar and about one thirds to three quarters its height.

Fig. 54: Lateral, dorsal and ventral views of *Hipposideros cineraceus*, PSUZC-MM06.125, ♂, Wildlife Education Centre, Ton Nga Chang Wildlife Sanctuary, Songkhla Province, Thailand. Scale: 5 mm.

6.3.4. Echolocation

H. cineraceus uses constant frequency echolocation calls. In Thailand, the frequency of highest energy averaged 149.0 kHz (134.8-154.1 kHz) in males and 150.1 kHz (141.4-154.1 kHz) in females. Other studies had reported 135.0 kHz (Robinson, 1996) and 154.2-156.3 kHz (for Kanchanaburi Province, unpublished data of Sébastien Puechmaille). In both sexes, the calls average lower than those of *H. halophyllus*. There is some individual variation in frequency but there appears to be no sexual or meaningful geographical variation in calls (Fig. 10). In Myanmar (from Nagamauk, Mon State, 16°19’N, 97°42’E, unpublished data of Sébastien Puechmaille), individuals (sex not specified) were recorded between 154.0-158.1 kHz.

6.3.5. Taxonomic Notes

Following Corbet and Hill (1992), specimens from throughout Myanmar and Thailand are referable to the nominate race *H. c. cineraceus.*

6.3.6. Conservation Status

Hipposideros cineraceus was included as ‘Lower Risk, least concern’ in Hutson *et al.* (2001), Simmons (2005) and the SAMD (2005) review.

6.3.7. Distribution

H. cineraceus is known from northeastern Pakistan, northern India, Myanmar, Thailand, Lao PDR, Vietnam, Cambodia, Malaysia, Sumatra, Krakatau Island, Borneo, and probably Philippines (Corbet and Hill, 1992; Matveev, 2005; Simmons, 2005). Its distribution in Myanmar and Thailand is mapped in Fig. 2.

Myanmar: **Kachin State**: Nam Tamai Valley (c.o. 27°50’N, 97°45’E) [loc. 1, Fig. 46]; **Mandalay Division**: Mogok (22°55’N, 96°30’E) [loc. 2, Fig. 46]; Mingun (22°03’N, 96°01’E) [loc. 3, Fig. 46]; **Sagaing Division**: nr Sagaing (21°52’N, 95.59’E) [loc. 5, Fig. 46]; **Shan State**: Gokteik (22°21’N, 96°55’E) [loc. 4, Fig. 46] (Bates and Harrison, 1997); **Mon State**: Saddan Sin Cave, 16 km NE of Mawlamyine, (16°19'N, 97°42'E) [loc. 7, Fig. 46] (HZM collection).

Thailand: **Chiang Mai Province**: Khimee Cave, Chiang Dao Wildlife Sanctuary, Khong District, (19°21.266'N, 98°43.837'E, 718 m) [loc. 10, Fig. 46] (Chiang Dao Wildlife Research Station collection); Pha Dang Cave, Srilanna National Park, Chiang Dao District (19°20.769'N, 99°01.416'E, 480 m) [loc. 11, Fig. 46] (PSUZC collection); **Tak Province:** Ban Jagae Guard Station and Lum Khao Ngu Guard Station, Thung Yai Naresuan Wildlife Sanctuary (approx. 15°41.310'N, 98°54.070'E, 718 m) [loc. 12, Fig. 46] (Robinson *et al.* 1995); **Uthai Thani Province**: Lup Lea Cave, Ban Rai District, (15°03.077'N, 99°28.879'E, 200 m) [loc. 13, Fig. 46] (PSU collection); **Lop Buri Province**: Khao Don Deung, Ban Mi District, (15°08.888'N, 100°36.819'E, 40 m) [loc. 14, Fig. 46] (PSUZC collection); **Nakhon Ratchasima Province**: Khao Yai National Park, Pak Chong District (approx. 14°32'N, 101°24'E) [loc. 15, Fig. 46] (Yenbutra and Felten, 1986); **Sara Buri Province**: Phu Nam Tok Tub Kwang (Tap Kwang), Kaeng Khoi District (approx. 14°35'N, 100°08'E) [loc. 16, Fig. 46] (Yenbutra and Felten, 1986); **Sa Kaeo Province**: Khao Singto Cave, Meung District, (13°59.417'N, 102°00.465'E, 12 m) [loc. 17, Fig. 46] (Waengsothorn *et al.* 2006b and PSUZC collection); **Chantha Buri Province**: Wat Khao Wong Kot, Tha Mai District (approx. 12°55'N, 101°58'E) [loc.

18, Fig. 46] (Yenbutra and Felten, 1986); **Ratcha Buri Province**: Khao Bin Cave, Chom Bung District, (13°35.527'N, 99°40.012'E, 61 m) [loc. 19, Fig. 46] (PSUZC collection); **Petcha Buri Province**: Khao Yoi Cave, Khao Yoi District, (13°14.014'N, 99°49.708'E, 53 m) [loc. 20, Fig. 46] (Yenbutra and Felten, 1986 and PSUZC collection); **Chumphon Province**: Khao Kram Cave, Patiew District, (10°55.131'N, 99°22.440'E, 67 m) [loc. 21, Fig. 46] (PSUZC collection); Silawan Cave, Patiew District, (10°41.461'N, 99°14.476'E, 68 m) [loc. 22, Fig. 46] (PSUZC collection); **Ranong Province:** Pra Kayang Cave, Kraburi District, (10°19.569'N, 98°45.923'E, 3 m) [loc. 23, Fig. 46] (PSUZC collection); **Phung Nga Province**: Ao Mai Ngam Natural Trail, Surin Islands National Park, (9°25.873'N, 97°51.975'E, 20 m) [loc. 24, Fig. 46] (PSUZC collection); **Trang Province:** Khao Chong Waterfall, Khao Banthat Wildlife Sanctuary, (7°32.894'N, 99°47.196'E, 81 m) [loc. 25, Fig. 46] (PSUZC collection); **Songkhla Province**: Outaphao Watershed, Rattaphum District, (6°47.777'N, 100°14.092'E, 197 m) [loc. 26, Fig. 46] (PSUZC collection); Khao Nouy Cave, Rattaphum District, (6°59.537'N, 100°08.470'E, 130 m) [loc. 27, Fig. 46] (Bumrungsri, 1997 and PSUZC collection); Wildlife Education Centre, Ton Nga Chang Wildlife Sanctuary, (9°56.739'N, 100°14.467'E, 107 m) [loc. 28, Fig. 46] (PSUZC collection); Khao Rak Kiat Cave, Rattaphum District, (7°4.254'N, 100°15.098'E, 100 m) [loc. 29, Fig. 46] (Bumrungsri, 1997 and PSUZC collection); Ka Cave (approx. 6°36.400'N, 100°51.300'E, 60 m) [loc. 30, Fig. 46] (Bumrungsri, 1997); Syson Cave (approx. 7°4.500'N, 100°10.010'E, 60 m) [loc. 31, Fig. 46] (Bumrungsri, 1997); Noy Cave (approx. 7°4.300'N, 100°15.100'E, 40 m) [loc. 32, Fig. 46] (Bumrungsri, 1997); **Satun Province**: Ao Son, Tarutao Islands National Park, (6°38.767'N, 99°37.383'E, 5 m) [loc. 33, Fig. 46] (PSUZC collection); Jorrake (Crocodile) Cave, Tarutao Islands National Park (6°41.946'N, 99°39.096'E, 65 m) (PSUZC collection); Km 1-2 road from Talow Wao to Talow Oulang, Tarutao Islands National Park (6°36.501'N, 99°40.435'E, 73 m) (PSUZC collection); Ban Wang Bla Chan, Muang Satun District (approx. 6°45'N, 100°10'E) [loc. 34, Fig. 46] (Yenbutra and Felten, 1986); **Narathiwat Province:** Sirinthorn Waterfall, Bala forest, Hala-Bala Wildlife Sanctuary, (5°48.017'N, 101°50.000'E, 300 m) [loc. 35, Fig. 46] (PSUZC collection).

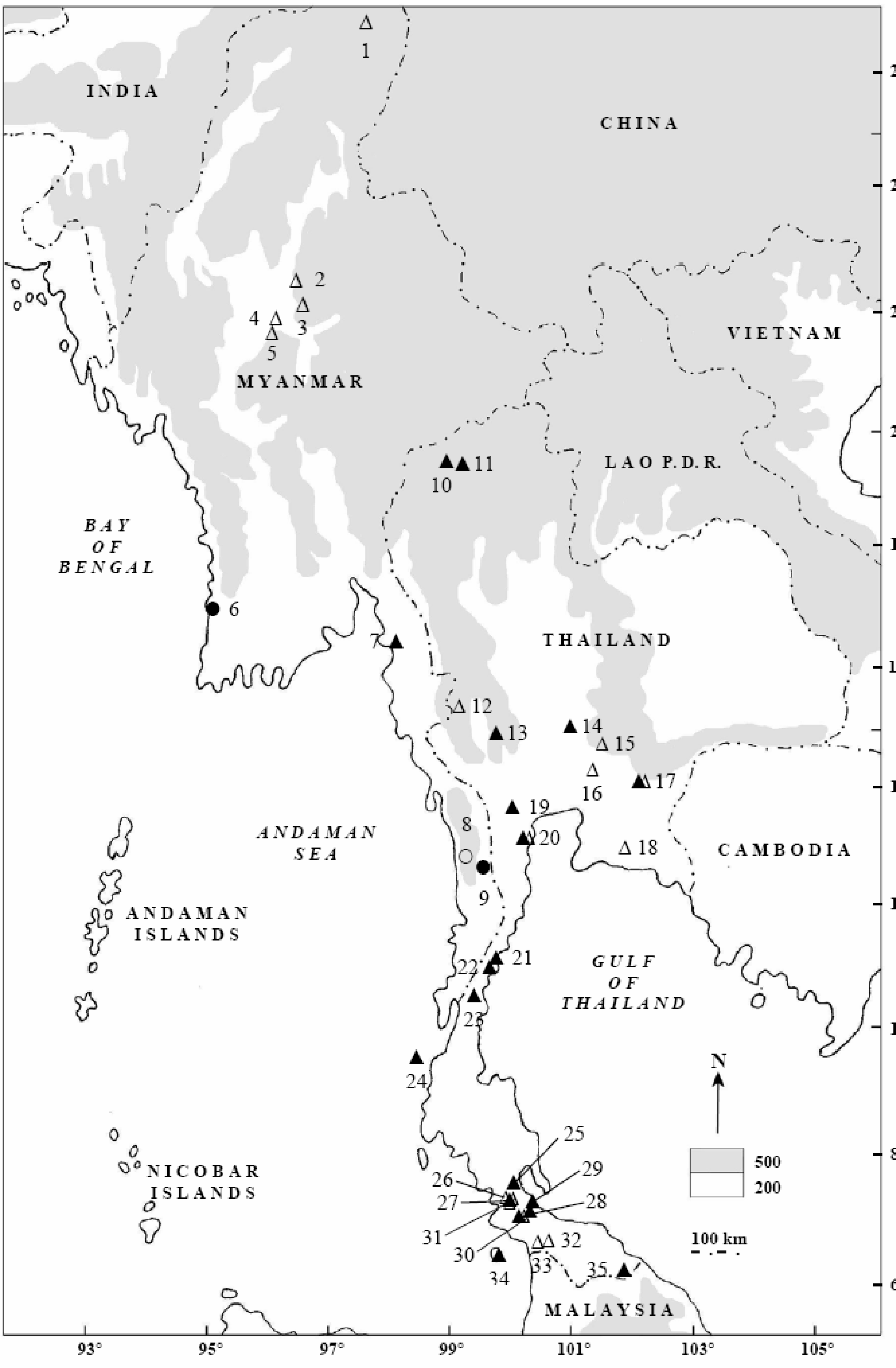


Fig. 55: Distribution map of *H. ater* (black circle: recent distribution, open circle: previous distribution) and *H. cineraceus* (black triangular: recent distribution, open triangular: previous distribution).

6.3.7. Ecological Notes

H. cineraceus roosts in small to large colonies in caves, sometimes in small holes within the caves. They share their roosts with many other bat species, especially *H. armiger, H. bicolor, H. larvatus, H. pomona,* and *R. affinis.* This bat was captured with other bats on natural trails or cave's entrances, especially *A. stoliczkanus, C. frithii, H. bicolor, H. diadema, H. galeritus, H. halophyllus, H. larvatus, H. lekaguli, H. pomona, K. hardwickii, Megae. ecaudatus, Megad. spasma, Mi. medius, Mu. cyclotis, My. horsfieldi, My. siligorensis, R. acuminatus, R. affinis, R. coelophyllus, R. lepidus, R. malayanus, R. pusillus, R. shameli, R. stheno, R. trifoliatus, R. yunanensis, Ta. longimanus, Ty. pachypus.*

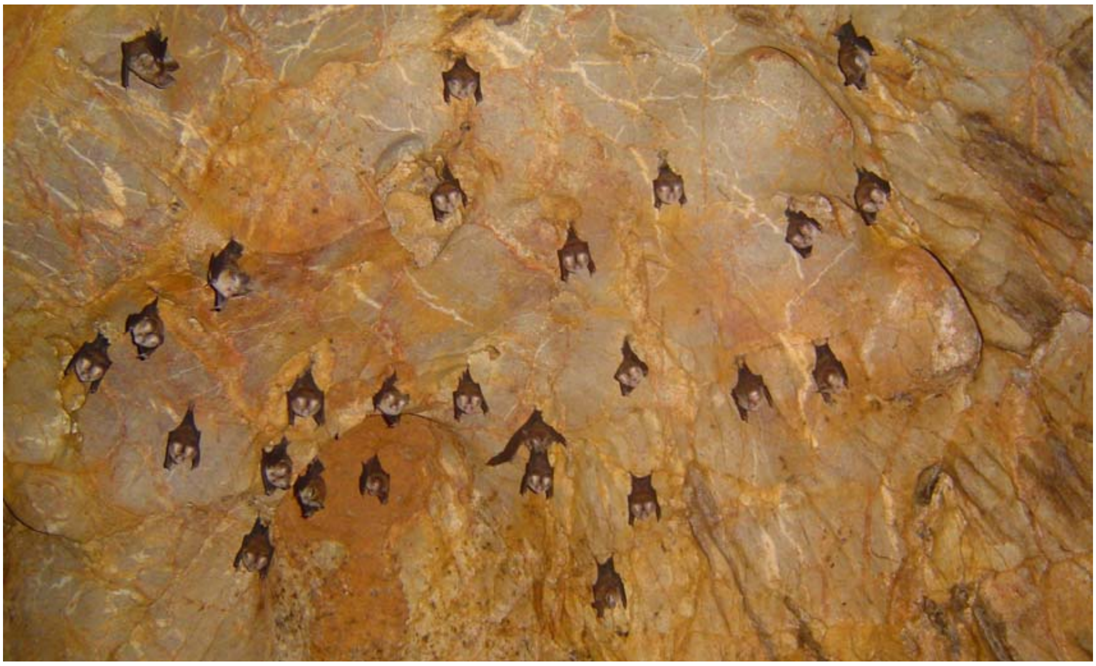


Fig. 56: Colony of *H. cineraceus* in Khao Kram Cave, Pateiw District, Chumphon Province.

It is most often found in areas with limestone outcrops which include caves of various sizes. Preferred habitat types include hill evergreen, dry evergreen, moist evergreen, lowland evergreen, mixed deciduous, seasonal, secondary, Nipa palm (*Nipa fruticans* Wurmb.) and mangrove forests; agricultural areas, teak, eucalyptus, rubber and oil palm plantations. Some localities are near small streams, ponds and waterfall; and some localities are surrounded by towns and villages. The altitude of the sites varies from 3-718 meters. The bats were caught in the harp traps from about 7.00 pm until the traps were collected about 8.30 pm or 9.00 pm. Females were found to be pregnant during February and March. In Malaysia, females were found to be pregnant with a single embryo in April, June and September (Kingston *et al*. 2006).

6.4. *Hipposideros halophyllus* Hill and Yenbutra, 1984

Thailand Leaf-nosed Bat

Hipposideros halophyllus Hill and Yenbutra, 1984; Khao Samorkhon (Sa Moa Khon), Ta Woong, Lop Buri, Thailand

6.4.1. External and Baculum Characters

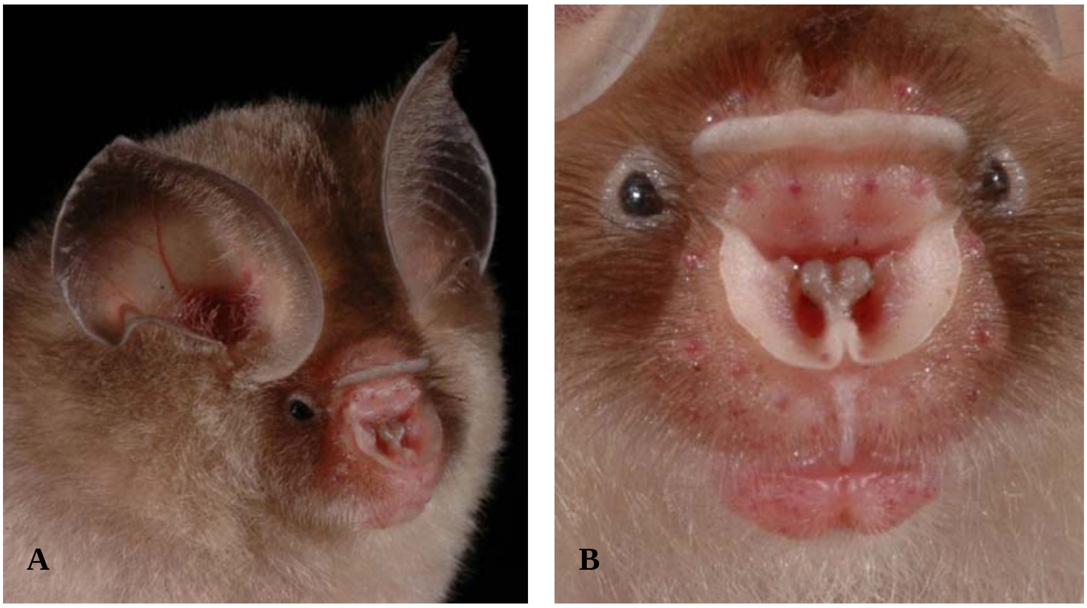


Fig. 57: (A) Face and noseleaf of *H. halophyllus*, SB061023.2, ♂, Pha Daeng Cave, Chiang Dao District, Chiang Mai Province, Thailand; (B) Ventral view of noseleaf of *H. halophyllus*, PSUZC-MM07.41, ♀, Khao Samor Khon, Tawung District, Lop Buri Province, Thailand.

Hipposideros halophyllus is a small species in the *H. bicolor* group, with an average forearm length of 37.9 mm (36.4-39.2 mm). The dorsal surface is mid-brown, the hairs pale cream at the base and generously tipped with the brown terminal colour. The ventral surface is paler, largely lacking any brown, and has a greyish or greyish buff tinge. The ears are small, with a rounded base and narrow tip; their length is 13.2 mm (11.1-15.4 mm) and width 10.9 mm (9.9-12.4 mm). The noseleaf is small, with a width of 3.7 mm (3.4-4.2 mm); it lacks supplementary lateral leaflets. The internarial septum is expanded into a small disc-like, kidney-shaped, structure with width of 1.0 mm (0.8-1.2 mm); the anterior part of the septum curves sharply inwards to join with the anterior leaf; and the posterior part is similar, and joins with the intermediate leaf. The anterior leaf is narrowed, slightly elongated; the anterior part is long and curved. There is a well-defined frontal sac, with a small gland in the mid-part behind the posterior leaf. The third metacarpal (30.5 mm, 28.7-32.2 mm) exceeds the fifth metacarpal (27.5 mm, 26.0-28.5 mm). The fourth metacarpal is the longest, with a length of 31.2 mm (29.5-32.2 mm). The combined lengths of the phalanges (29.3 mm, 27.5-30.6 mm) of the third metacarpal are shorter than the third metacarpal. The tail is 26.1 mm (22.4-28.7 mm) in length and is enclosed by interfemoral membrane, except for the extreme tip, which is thin. Tibia length is 17.7 mm (16.4-18.6 mm). The hindfoot length is 5.8 mm (4.5-6.4 mm). The calcar is slender, narrow or large at the base; with a length of 8.2 mm (7.7-9.1 mm). The penis is short and thin, with a pointed tip. The baculum is very small, with a length of 0.4 mm and a basal width of 0.1 mm. In dorsal and lateral views, it is straight, with a simple base and tip, the base is slightly expanded and slightly wider than the tip; and the tip is rounded.

6.4.2. Cranial Characters

The skull is small and elongate, with an average condylo-canine length of 12.8 mm (12.6-13.0 mm) and a mastoid width of 7.8 mm (7.6-8.0 mm). The braincase is inflated; the breadth of braincase (7.0 mm, 6.6-7.4 mm) is narrower than the zygomata width (7.3 mm, 7.1-7.7 mm). The rostrum is inflated, with a width of 3.6 mm (3.5-3.7 mm); the anterior part slopes downwards. There are four or six nasal inflations. The postorbital constriction is very narrow, with a width of 1.9 mm (1.8-

2.1 mm). The sagittal crest is high anteriorly and low posteriorly. The zygomata are narrow on the anterior part; the jugal projection of each zygoma has a well-defined dorsal process on posterior part. The mastoid width exceeds the zygomatic width. The palate is narrow, with an anterior palatal width of 2.9 mm (2.6-3.0 mm), and a posterior palatal width of 4.9 mm (4.7-5.0 mm). The tympanic bullae are narrow (0.8 mm, 0.7-1.0 mm) and long (2.5 mm, 2.4-2.7 mm). . The cochleae are broad and rounded, with a cochlear width of 2.2 mm (2.0-2.3 mm). The intercochlear distance is 1.5 mm (1.4-1.7 mm). The mandible is small, with a length of 8.9 mm (8.6-9.2 mm).

Fig. 49: Lateral, dorsal and ventral views of *Hipposideros halophyllus*, PSUZC-MM07.38, ♂, Khao Yoi Cave, Khao Yoi District, Petchaburi Province, Thailand. Scale: 5 mm.

6.4.3. Dentition

Upper toothrow length is 4.8 mm (4.6-5.0 mm) and lower toothrow length is5.0 mm (4.5-5.5 mm). The upper canine is small. The first upper premolar is very small, included or extruded from the toothrow; the upper is canine not in contact with the second upper premolar. The second lower incisor is about one half to equal in crown area with the first lower incisor. The anterior lower premolar is equal or exceeds in length the second lower premolar, and is about one half to three quarters its height.

6.4.4. Echolocation

H. halophyllus uses constant frequency echolocation calls. The frequency of highest energy averaged 177.6 kHz (156.4-187.9 kHz) for males and 181.6 kHz (160.6-186.2 kHz) for females (Table 1). Other studies had reported 188.8-191.2 kHz (for Kanchanaburi Province, unpublished data of Sébastien Puechmaille). Although there was some individual variation in frequency, there appears to be no sexual or meaningful geographical variation, with the population in Chiang Mai District in the north (latitude 19°21’N) similar to that of populations in the central zone (latitudes between 13°36’ and 15°27’N) (Fig. 8).

6.4.5. Taxonomic Notes

This species appears to be quite homogeneous with no significant geographical variation in echolocation (see above) or morphology. The forearm length of *H. halophyllus* does exhibit some variation with a decrease from the north, 39.4 mm (Chiang Mai Province, 19°20.769'N) to southern parts, 36.4 mm (Phetcha Buri Province, 13°14.014'N) (Fig. 9). However, currently all populations are referred to the nominate form *H. h. halophyllus.*

6.4.6. Conservation Status

Hipposideros halophyllus was included as ‘Lower Risk, near threatened’ in Hutson *et al.* (2001) and in Simmons (2005). However, more recently it was awarded ‘Endangered’ status in the SAMD (2005) review.

6.4.7. Distribution

H. halophyllus is endemic to Thailand, where it was previously known from central parts of the country (Fig. 50). The current study extends its known range by 435 km to northern Thailand as well as adding seven new localities to its known distribution. Despite intensive field work, it does not appear to be present in the Thai-Malay peninsula.

Thailand: **Chiang Mai Province**: Pha Dang Cave, Srilanna National Park, Chiang Dao District, (19°20.769'N, 99°01.416'E, 480 m) [loc. 1, Fig. 50] (PSU collection); **Phitsanulok Province:** Tham Pha, Tha Phol Non-hunting area, Neon Maprang District (16°30'N, 100°40'E) [loc. 2, Fig. 50] (unpublished data of Sara Bumrungsri); **Uthai Thani Province**: Khi Nok Cave, Huai Kha Khang Wildlife Sanctuary, Lan Sak (approx. 15°27'N, 99°17'E) [loc. 3, Fig. 50] (Yenbutra and Felten, 1986; Robinson *et al.* 1995); Lup Lae Cave, Ban Rai District, (15°03.077'N, 99°28.879'E, 200 m) [loc. 4, Fig. 50] (PSU collection); **Kanchana Buri Province**: Ma Duea Cave (14°01.673'N, 99°24.095'E, 64 m) [loc. 11, Fig. 50] (unpublished data of Sébastien Puechmaille); Ma Duea Fun Cave (14°01.822'N, 99°23.887'E, 60 m) [loc.10, Fig. 50] (unpublished data of Sébastien Puechmaille); **Lop Buri Province**: Khao Don Deung, Ban Mi District, (15°08.888'N, 100°36.819'E, 40 m) [loc. 6, Fig. 50] (PSU collection); Khao Samor Khon (Khao Sa Moa Khon; Khao Samokhon), Tawung (Tha Woong) District, (14°54.548'N, 100°30.342'E, 3 m) [loc. 7, Fig. 50] (Hill and Yenbutra, 1984; Yenbutra and Felten, 1986; PSU collection); Vi Moke Cave, Ban Mi District (approx. 15°08'N, 100°37'E) [loc. 5, Fig. 50] (Watthanakul, 1995); **Sara Buri Province**: Ton Chan Cave, Phaphoutthabat District, (14°43.193'N, 100°47.684'E, 33 m) [loc. 8, Fig. 50] (uncollected specimen); **Sa Kaeo Province**: Khao Singto, Meung District, (13°59.417'N, 102°00.465'E, 12 m) [loc. 9, Fig. 50] (Prachin Buri Province in Yenbutra and Felten, 1986; Waengsothorn *et al.* 2006a,b and PSU collection); **Ratchaburi Province**: Tham Khao Bin (13°35.527'N, 99°40.012'E, 61 m) [loc. 13, Fig. 50] (Hill and Yenbutra, 1984); Khao Chong Phran (approx. 13°40'N, 99°46'E) [loc. 12, Fig. 50] (Hillman, 1999); **Petchaburi Province**: Khao Yoi Cave, Khao Yoi District, (13°14.014'N, 99°49.708'E, 53 m) [loc. 14, Fig. 50] (Hill and Yenbutra, 1984; PSU collection).

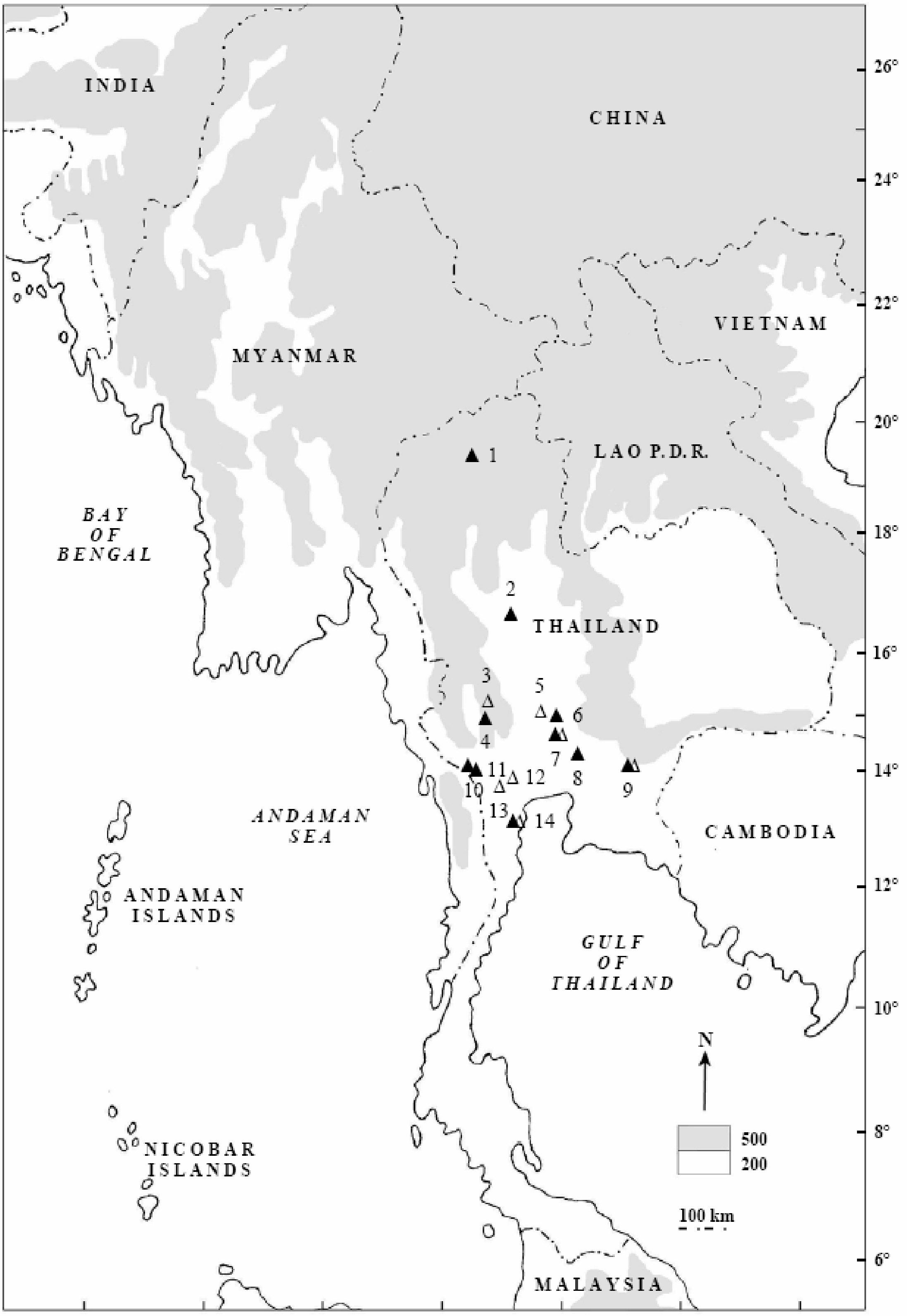


Fig. 59: Distribution map of *H. halophyllus* (black triangular: recent distribution, open triangular: previous distribution).

6.4.8. Ecology Notes

H. halophyllus roosts in small colonies in caves. It shares these roosts with a number of other bat species. When collected outside caves, it has been caught together with *H. cineraceus, H. galeritus, H. larvatus, H. pomona, Me. spasma, My. siligorensis, R. coelophyllus, R. malayanus, R. pusillus, R. shameli, R. stheno, R. yunanensis* and *T. longimanus.*

It has been found exclusively in areas with limestone outcrops and caves. The surrounding habitats included hill evergreen forest, mixed deciduous forest and agricultural areas, sometimes with villages and small towns. Altitudes varied from 12 to 480 meters. This species were captured from 7.30 pm until the traps were collected about 9.00 pm. It roosts in small colonies and when disturbed, it quickly moved from its roosting site.

Fig. 60: Colony of *Hipposideros halophyllus* in Khao Smorkhon, Tawung District, Lop Buri Province.

CHAPTER 7

DISCUSSION

From a conservation viewpoint, the study showed that *Hipposideros halophyllus* is more widespread than previously thought. In a recent review published in Boitani *et al.* (2006) the potential range was restricted to a small crescent-shaped area of approximately 12500 km^2 around Bangkok and the population was thought to number between 1000 and 1400 (Waengsothorn *et al*. 2006a,b). The species was given a Red List Category of Endangered with a criteria of B2ab(iii); C1. This was based on an inferred population decline of at least 10% in ten years; few known localities and absence from localities where it was previously known. It was suggested that more surveys were needed to resolve its distribution.

The current study identified seven new localities (Fig. 50) including one (Pha Dang Cave) in Chiang Mai Province in northern Thailand, which extends the known range by 435 km. In addition, the continuing presence of *H. halophyllus* at three previously recorded localities (Khao Samor Khon [type locality], Khao Singto, and Khao Yoi Cave) was confirmed. However, at one site, Khao Bin Cave, from which a specimen had been collected in September, 1969 (Hill and Yenbutra, 1984), only *H. cineraceus* was found during the present study. Three other sites (Khi Nok Cave, Vi Moke Cave, and Khao Chong Phran) from which *H. halophyllus* had been recorded previously were not visited and consequently the current status of the populations cannot be determined. Specific threats to the species were observed at three sites. In Khao Samor Khon, bats were collected by local hunters whilst in Ton Chan and KhaoYoi there was disturbance from tourists visiting Buddhist temples within the caves.

It is interesting to note that *H. halophyllus* was not found in peninsular Thailand. This is surprising since in northern and central Thailand it shares its roosts with *Hipposideros cineraceus,* such that of the seven sites from which *H. cineraceus* were recorded, five also had populations of *H. halophyllus* (for details see Methods). However, in peninsular Thailand, despite locating eleven sites of *H. cineraceus*, none were shared with *H. halophyllus*. This apparently anomalous distribution pattern of

H. halophyllus corresponds to recently observed patterns in some *Rhinolophus* (Pipat *et al*. submitted) and many other disparate taxa (Hughes *et al.,* 2003). Currently, *H. halophyllus* has not been located outside Thailand and field studies in the adjacent Myanmar states of Shan, Mon, Kayin and Tanintharyi have all proved negative for the species.

In contrast to *H. halophyllus*, the taxon currently referred to *Hipposideros* af. *ater* is entirely restricted to Myanmar and was not found in any part of Thailand. Its distribution suggests that it favours areas with a high annual rainfall, in excess of 2500 mm annually (for details of Myanmar climate, see Bender, 1983). It also suggests that it may prove to be more widespread in seaboard areas of western Myanmar. It may possibly occur in peninsular Thailand, although no individuals were observed during the recent extensive field research in the area. In Boitani *et al.* (2006), it was suggested that *H. ater* is likely to be a species complex and the current study would lend some support to this view. Despite small sample sizes, specimens from Myanmar appear to differ in a number of morphometric characters from material from Sri Lanka (type locality of *H. ater*) and also southern India. Further studies, including molecular analysis would be of considerable interest to help resolve the relationships of this taxon with those from the Indian Subcontinent, including the Nicobars, Malaysia and elsewhere in Southeast Asia. It should be noted that despite the apparent taxonomic differences between the populations in Sri Lanka and Myanmar, their ecology and behaviour have much in common. Both were found in wet lowland regions and both roost in the lofts of houses and old dwellings (Bates and Harrison, 1997 and this study). This is unlike *H. cineraceus* and *H. halophyllus* which appear to prefer more natural roosting sites such as caves.

H. cineraceus is the most widely distributed of the three taxa in the study area, where its range extends from the north of Myanmar to the south of the Thai peninsula. Francis (pers. comm.) in Boitani *et al.* (2006) suggested that there ‘appears to be more than one species in peninsular Malaysia’. However within the study area, there appeared to be no evidence of cryptic species. At present, *H. cineraceus* appears to widespread, relatively abundant and with no significant threats to its overall population status within Thailand and Myanmar.

REFERENCES

Aellen, G. V. 1954. Description d'un nouvel *Hipposideros* (Chiroptera) de la Côte d'Ivoire. Revue Suisse de Zoologie. 61(24): 473-483

Andersen, K. 1918. Diagnoses of new Bats of the Families Rhinolophidae and Megadermatidae. *Ann. & Mag. Nat. Hist.* 2: 374-384

Altringham, J. D. 1996. Bats Biology and Behaviour. Oxford University Press. ix + 262 pp.

Anthony, E. L. P.1988. Age determination in bats. pp: 47-58, *in* Ecological and behavioural methods for the study of bats (Kunz, T. H. Ed.). Smithsonian Institution Press, xxii + 533 pp.

Bates, P. J. J. and D. L. Harrison. 1997. Bats of Indian Subcontinent. Harrison Zoological Museum Publication, xvi + 258 pp.

Bates, P. J. J., T. Nwe, M. J. Pearch, K. M. Swe, S. S. Hla Bu and T. Tun. 2000. A review of bat research in Myanmar (Burma) and result of a recent survey. Acta Chiropterologica. 2(1): 53-82

Bates, P. J. J., T. Nwe, K. M. Swe and S. S. Hla Bu. 2001. Further new records of bats from Myanmar (Burma), including *Craseonycteris thonglongyai* HILL, 1974 (Chiroptera: Craseonycteridae). *Acta Chiropterologica*. 3(1): 33-41

Bates, P. J. J., T. Nwe, S. S. Hla Bu, K. Mie Mie, K. M. Swe, N. Nyo, A. A. Khaing, N. N. Aye, Y. Y. Toke, N. N. Aung, M. M. Thi and I. Mackie. 2005. A review of the genera *Myotis, Ia, Pipistrellus, Hypsugo,* and *Arielulus* (Chiroptera: Vespertilionidae) from Myanmar (Burma), including three species new to the country. *Acta Chiropterologica.* 7(2): 205-237

Bates, P. J. J., S. J. Rossiter, A. Suyanto and T. Kingston. 2007. A new species of *Hipposideros* (Chiroptera: Hipposideridae) from Sulawesi. *Acta Chiropterologica*. 9(1): 13-26

Bender, F. 1983. The geology of Burma. Gebrüder Borntraeger, Berlin, 293 pp.

Bergmans, W. and van Bree, P. J. H. 1986. On a collection of bats and rats from the Kangean Islands, Indonesia (Mammalia: Chiroptera and Rodentia). *Z. Säugetierkunde*. 51: 329-344

Bessey, C. E. 1908. The taxonomic aspect of the species. *Amer. Nat.* 42: 218-224

Bhat, H. R. and Jacob, P. G. 1990. Bio-ecology of *Hipposideros cineraceus* Blyth, 1853 (Chiroptera: Hrinolophidae) in Kolar district, Karnataka, India. *Mammalia*. 54(2): 182-188

Blyth, E. 1853. Report of the Curator, Zoological Department. *Journal Asiat. Soc. Bengal.* 22: 408-417

Boitani, L., G. Catullo, I. Marzetti, M. Masi, M. Rulli and S. Savini. 2006. The Southeast Asian mammal databank. A tool for conservation and monitoring of mammal diversity in Southeast Asia. www.ieaitaly.org/samd

Bogdanowicz, W. and Owen, R. D. 1998. In the Minotaur's Labyrinth Phylogeny of the Bat Family Hipposideridae. pp: 27-42, *in* Bat Biology and Conservation (Kunz, T. H. and P. a. Racey. Eds.). Smithsonian Institution Press, xiv + 365 pp.

Borissenko, A. V. and S. V. Kruskop. 2003. Biodiversity of Vietnam Series: Bats of Vietnam and Adjacent Territories, an identification manual. Science and Technological Tropical Centre, Zoological Museum of Moscow M. V. Lomonosov State University. 211 pp.

Bumrungsri, S. 1997. Roost selection of cave dwelling bats in Songkhla and Satun Provinces. M.Sc. Thesis, Kasetsart University, Bangkok, 79 pp. (Thai)

Bumrungsri, S., D. L. Harrison, C. Satasook, A. Prajukjitr, S. Thong-Aree, S. and P. J. J. Bates. 2006. A review of bat research in Thailand with eight new species records for the country. *Acta Chiropterologica*. 8(2): 325-359

de Candolle, A. P. 1813. Theorie elémentaire de la botanique. Paris: Chez Deterville.

Corbet, G. B. and J. E. Hill. 1992. The Mammals of the Indomalayan Region: A Systematic Review. Natural History Museum Publications, Oxford University Press, 488 pp.

Csorba, G., P. Ujhelyi, P. and N. Thomas. 2003. Horseshoe Bats of The World (Chiroptera: Rhinolophidae). Alana Books. xxxii + 160 pp.

Fenton, M. B. 1983. Just Bats. University of Toronto Press. x + 165

Francis, C. M. 1989. A comparison of mist nets and two designs of harp trap for capturing bats. *J. Mamm*. 70(4): 865-870

Francis, C. M. 2001. A photographic guide to mammals of South-east Asia including Thailand, Malaysia, Singapore, Myanmar, Laos, Cambodia, Vietnam, Java, Sumatra and Borneo. New Holland Publishers (UK) Ltd. 128 pp.

Francis, C. M. and J. Habersetzer. 1998. Interspecific and Intraspecific Variation in Echolocation Call Frequency and Morphology of Horseshoe Bats, *Rhinolophus* and *Hipposideros*. pp: 169-179, *in* Bat Biology and Conservation (Kunz, T. H. and P. A. Racey. Eds.). Smithsonian Institution Press, Washington D. C., xvi + 365 pp.

Francis, C. M., A. Guillén, and M. F. Robinson. 1999A. Order Chiroptera: Bats. Pp: 225-235, *in* Wildlife in Lao PDR: 1999 Status Report (Duckworth, J. W., R. E. Salter and K. Khounbolin. Eds.). the World Conservation Union, Wildlife Conservation Society, and Centre for Protected Areas and Watershed Managerment. xiv + 275 pp.

Francis, C. M., D. Kock and J. Habersetzer, J. 1999B. Sibling species of *Hipposideros ridleyi* (Mammalia, Chiroptera, Hipposideridae). *Senckenbergiana Biologica*. 79(2): 255-270

Gopalakrisna, A. and A. Madhavan. 1977. Breeding habits and associated phenomena in some Indian bats. Part 3 – *Hipposideros ater ater* (Templeton) – Hipposideridae. *Journal Bombay nat. Hist. Soc.* 74(3): 511-517

Gray, J. E. 1858. List of species of Mammalia sent from the Aru Islands by Mr. A. R. WALLACE to the British Museum. *Proc. zool. Soc. Lond.* 106-113

Gray, J. E. 1866. Notes on some Mammalia from Port Albany (Cape York Peninsula), North Australia, with the descriptions of some new species. *Proc. zool. Soc. Lond.* 219-221

Guillén-Servent, A. G. and C. M. Francis. 2006. A new species of bats of the *Hipposideros bicolor* group (Chiroptera: Hipposideridae) from central Laos, with evidence of convergent evolution with Sundaic taxa. *Acta Chiropterologica.* 8(1) 39-61

Hand, S. J. 1997. New Miocene leaf-nosed bats (Microchiroptera: Hipposideridae) from Riversleigh, Queensland. *Memoirs of the Queensland Museum*. 41: 335–349

Hand, S. J. and J. A. W. Kirsch. 1998. A Southern Origin for the Hipposideridae (Microchiroptera)? Evidence from the Australian Fossil Record. pp: 72-90, *in* Bat Biology and Conservation (Kunz, T. H. and P. A. Racey. Eds.). Smithsonian Institution Press, xiv + 365 pp.

Heller, K. G. and O. v. Helversen. 1989. Resource partitioning of sonar frequency bands in rhinolophoid bats. *Oecologia.* 80:178-186

Hendrichsen, D. K., P. J. J. Bates, B. D. Hayes, and J. L. Walston. 2001. Recent records of bats (Mammalia: Chiroptera) from Vietnam with six species new to the country. *Bonne. Zool.* 39: 35-122

Hill, J. E. 1963. A revision of the Genus *Hipposideros*. Bulletin of the British Museum (Natural History) Zoology. 2(1): 1-129

Hill, J. E. 1975. Taxonomic background, systematics section, summary of taxonomic work, bibliography, gazetteer). pp: 3-40, *in* The bats and bat's parasites of Thailand (CTNRC Staff, J. E. Hill, and J. A. McNeely. Eds.). U. S. Army Research and Development group Far East, Report No. FE-516-1.

Hill, J. E. and C. M. Francis. 1984. New bats (Mammalia: Chiroptera) and new records of bats from Borneo and Malaya. *Bull. Br. Mus. Nat. Hist.* (Zool). 47(5): 305-329.

Hill, J. E. and J. D. Smith. 1984. Bats: a natural history. British Museum (Natural History). 243 pp.

Hill, J. E. and S. Yenbutra. 1984. A new species of the *Hipposideros bicolor* group (Chiroptera: Hipposideridae) from Thailand. *Bull. Br. Mus. Nat. Hist.* (Zool.). 47(1): 77-82

Hill, J. E., A. Zubaid, and G. W. H. Davison, 1986. The taxonomy of leaf-nosed bats of the *Hipposideros bicolor* group (Chiroptera: Hipposideridae) from Southeastern Asia. *Mammalia.* 50(4): 535-540

Hillman, A. 1999. Study of Wrinkled-lipped bats *(Tadarida plicata)* at Khao Chong Phran, Ratchaburi. *Journal of Thai Forestry Research.* http://www.dnp.go.th/Research/Journal/Vol1_No1/Bats.htm

House of Lords. 2002. What on Earth? The threat to the scienceunderpinning biodiversity conservation. London: Select Committee on Science and Technology.

Hughes, J. B., P. D. Round and D. S. Woodruff. 2003. The Indochinese-Sundaic faunal transition at the Isthmus of Kra: an analysis of resident forest bird species distributions. *Journal of Biogeography*. 30: 569-580

Hutson, A. M., S. P. Mickleburgh and P. A. Racey. 2001. Global status survey and conservation action plan: Microchiropteran bats. IUCN/SSC Chiroptera Specialist Group. IUCN, Gland, Switzerland and Cambridge, U.K. 258 pp

Johnson, D. H. 1959. Four new mammals from the Northern Territory of Australia. *Proc. biol. Soc. Wash.* 72: 183-187

Jones, G., K. Sripathi and D. A. Waters. 1994. Individual variation in the echolocation calls of three sympatric Indian hipposiderid bats, and an experimental attempt to jam bat echolocation. *Folia Zoologica*. 43 (4): 347-362

Jenkins, P. D. and J. E. Hill. 1981. The status of *Hipposideros galeritus* Cantor, 1846 and *Hipposideros cervinus* (Gould, 1854) (Chiroptera: Hipposideridae). Bulletin of the British Museum of Natural History (Zoology), 41(5): 279-294

Kelaart, E. F. 1850. Description of new species and varieties of mammals found in Ceylon. *Journal Ceylon Brch. r. Asiat. Soc.* 2: 208-215 (321-328 in reprint of 1890)

Kelaart, E. F. 1852. *Prodromus faunae zeylanicae…* Colombo: published by author. 197, 66 pp.

Kingston, T., C. M. Francis, Z. Akbar and T. H. Kunz. 2003. Species richness in an insectivorous bat assemblage from Malaysia. *Journal of Tropical Ecology*. 19:67-79.

Kingston, T., G. Jones, A. Zubaid and T. H. Kunz. 2000. Resource partitioning in rhinoloph-oid bats revisited. *Oecologia*. 124: 332-342

Kingston, T., L. B. Liat and Z. Akbar. 2006. Bats of Krau Wildlife Reserve. Penerbit Universiti Kebangsaan Malaysia, Bangi. pp: 85-100

Krishtalka, L. and P. S. Humphrey. S. 2000. Can natural history museums capture the future? *Bioscience.* 50: 611–617

Kunz, T. H. and A. Kurta. 1988. Capture methods and holding devices. pp: 1-29, *in* Ecological and behavioural methods for the study of bats (Kunz, T. H. Ed.). Smithsonian Institution Press, xxii + 533 pp.

Kurup, G. U. 1968. Mammals of Assam and adjoining areas. *Proceedings zool. Soc. Calcutta.* 21: 79-99

Legendre, S. 1982. Hipposideridae (Mammalia: Chiroptera) from the Mediterranean Middle and Late Neogene and evolution of the genera *Hipposideros* and *Asellia*. *Journal of Vertebrate Paleontology*. 2: 386–399

Lekagul, B. and J. A. McNeely. 1988. Mammals of Thailand. Charoen Krung, Bangkok, Thailand. pp: 156-186

Lindsay, H. M. 1926. Report No. 39: Mergui Archipelago. Bombay Natural History Society's Mammal Survey of India, Burma and Ceylon. *Journal Bombay nat. Hist. Soc.* 30: 42-48

Mace, G. M. 2004. The role of taxonomy in species conservation. *Phil. Trans. R. Soc. Lond.* B. 359: 711–719

Matveev, V. A. 2005. Checklist of Cambodian bats (Chiroptera), with new records and remarks on taxonomy. *Russian J. Theriol*. 4(1): 43-62

May, R. M. 2004. Tomorrow's taxonomy: collecting new species in the field will remain the rate-limiting step. *Phil. Trans. R. Soc. Lond.* B. 359: 733–734

Mayr, E. 1982. The Growth of Biological Thought. Cambridge, MA: Harvard University Press.

Mayr, E. and P. D. Ashlock. 1991. Principles of Systematic Zoology. McGraw-Hill, Inc., the United States of America. xx + 475 pp.

Miller, G. S. 1902. The mammals of the Andaman and Nicobar Islands. *Proceedings U. S. Natural Museum.* 24(1269): 751-783

Miller, G. S. 1907. The families and genera of bats. Smithsonian Inst US Nat Mus Bull 57, Washington, DC.

Neuweiler, G. 2000. The Biology of bats. Oxford University Press. ix + 310 pp.

NRC. 1995. Understanding marine biodiversity. Washington, DC: National Academy Press.

Payne, J., C. M. Francis and K. Phillipps. 1985. A Field Guide of the Mammals of Borneo. The Sabah Society with World Wildlife Fund Malaysia, 332 pp.

Pearch, M. J., K. Mie Mie, P. J. J. Bates, T. Nwe, K. M. Swe, and S. S. Hla Bu. 2003. First record of bats (Chiroptera) from Rakhine State, Myanmar (Burma). *Nat. Hist. Bull. Siam. Soc.* 51(2): 241-259

Peters, W. 1861. Über die von Hrn. F. Jagor bisher auf Malacca, Borneo, Java und den Philippinen gesammelten Säugethiere … *Monatsberichte K. preuss. Akad. Wiss.* 706-712

Peters, W. 1871. Über die Gattungen und Arten der Hufeisennasen, Rhinolophi. *Monatsberichte K. preuss. Akad. Wiss.* 301-332

Peters, W. 1872. Mitteilung über neue Flederthiere … *Monatsberichte K. preuss. Akad. Wiss.* 256-264

Racey, P. A. 1988. Reproductive assessment in bats. pp: 31-45, *in* Ecological and behavioural methods for the study of bats (KUNZ, T. H. eds.). Smithsonian Institution Press, xxii + 533 pp.

Robinson, M. F. 1996. A relationship between echolocation calls and noseleaf widths in bats of the genera *Rhinolophus* and *Hipposideros*. *J. Zoll., Lond.* 239: 389-393

Robinson, M. F. 1998. Chiroptera Survey: Xe Pian National Biodiversity Conservation Area, Lao PDR. *Nat. Hist. Bull. Siam Soc.* 46: 155-170

Robinson, M. F. and M. Webber. 1998. Small mammal survey: Khammouan Limestone National Biodiversity Conservation Area, Lao PDR. World Wide Fund for Nature - Thailand, iii + 48 pp.

Robinson, M. F. and M. Webber. 2000. Survey of bats (Mammalia: Chiroptera) in the Khammouan Limestone National Biodiversity Conservation Area, Lao PDR. *Nat. Hist. Bull. Siam Soc.* 48: 21-45

Robinson, M. F., A. L. Smith and S. Bumrungsri. 1995. Small mammals of Thung Yai Naresuan and Huai Kha Khaeng Wildlife Sanctuaries in Western Thailand. *Nat. Hist. Bull. Siam Soc.* 43: 27-54

Robinson, M. F., P. D. Jenkins, C. M. Francis and A. J.C. Fulford. 2003. A new species of the *Hipposideros pratti* group (Chiroptera, Hipposideridae) from Lao PDR and Vietnam. *Acta Chiropterologica*. 5(1): 31-48

Shamel, H. H. 1940. The insectivorous bats collected by H. C. Raven in Celebes. *Journal Mammal.* 21: 352-354

Sigé, B. 1990. Nouveaux chiroptères de l'Oligocène moyen des phosphorites du Quercy, France. *Paléontologie.* 310 (2): 1131-1137

Sigé, B. and S. Legendre. 1983. L'histoire des peuplements des chiroptères du bassin méditerranéen. L'apport comparé des remplissages karstiques et des dépots fluviolacustres. *Mémoires de Biospéologie*. 10: 209–225

Sigé, B., H. Thomas, S. Sen, E. Gheerbrandt, J. Roger and Z. Al-Sulaimani. 1994. Les chiroptères de Taqah (Oligocène inférieur, Sultanat d'Oman): Premier inventaire systématique. *Münchner Geowissenschaftliche Abhandlungen A*. 26: 35-48

Simmons, N. B. 2005. Order Chiroptera. pp: 312-529, *in* Mammal Species of the World: A Taxonomic and Geographic Reference (Wilson, D. E. and D. M. Reeder. Eds.). The Johns Hopkins University Press, Baltimore. xxxv + 2142 pp.

Simpson, G. G. 1961. Principles of Animal Taxonomy. Columbia University Press, New York. xii + 247 pp.

Simmons, N. B. and T. M. Conway. 2003. Evolution of Ecological Diversity in Bats. pp: 493-535, *in* Bat Ecology (Kunz, T. H. and M. B. Fenton. Eds.). The University of Chicago Press. xix + 779 pp.

Soberón, J. and A. T. Peterson. 2004. Biodiversity informatics: managing and applying primary biodiversity data. *Phil. Trans. R. Soc. Lond.* B. 359: 689–698

Suyanto, A.and M. J. Struebig. 2007. Bats of the Sangkulirang limestone karst formations, East Kalimantan – a priority region for Bornean bat conservation. *Acta Chiropterologica.* 9(1): 67-95

Tate, G. H. H. 1941. A review of the Genus *Hipposideros* with special reference to Indo-Australian species. *Bull. Amer. Mus. Nat. Hist.* 35: 353-393

Taylor, E. H. 1934. Philippine land mammals. *Monographs. Philipp. Bureau. Sci.* 30: 548 pp, 25 pls

Templeton, W. E. 1848. In Blyth, E. Report of Curator, Zoological Department. *J. Asiat. Soc. Beng.* 17(1): 247-255

Thabah, A., S. J. Rossiter, T. Kingston, S. Zhang, S. Parsons, K. Mya Mya, A. Zubaid and G. Jones. 2006. Genetic divergence and echolocation call frequency in cryptic species of *Hipposideros larvatus s.l.* (Chiroptera: Hipposideridae) from the Indo-Malayan region. *Biological journal of the Linnean Society*. 88: 119-130

The Royal Sosiety. 2003. Measuring biodiversity for conservation. London: The Royal Society. p. 56

Topál, G. 1975. Bacula of some old world leaf-nosed bats (Rhinolophidae and Hipposideridae, Chiroptera, Mammalia). *Vertebr. Hung*. 16: 21-53

Waengsothorn, S., J. Nabhitabhata, T. Moonchan and K. Muangkham. 2006a. Intensive survey of the current status of Thai Endemic Mammals and their habitats outside Protected Areas in Central Thailand. *BRT 2006 Research Reports*. 285-297

Waengsothorn, S., J. Nabhitabhata, T. Moonchan and K. Muangkham. 2006b. The current distribution and population structures of Thailand roundleaf bat (*Hipposideros halophyllus*), a Thai endemic mammal. *Journal of Wildlife in Thailand*. 13 (1): 43-60

Wathanakul, W. 1995. Identification of bats of Thailand. Department of Biology, Faculty of Science and Technology, Petchaburi Rajabhat University, Petchaburi, Thailand, 855 pp. (Thai)

Wroughton, R. C. 1915. Report No. 18: Ceylon. Bombay National History Society's Mammal survey of India, Burma, and Ceylon. *Journal Bombay nat. Hist. Soc.* 24(1): 79-96

Wroughton, R. C. 1921. Report No. 33: High Wavy Mountains, Madura District. Bombay National History Society's Mammal survey of India, Burma, and Ceylon. *Journal Bombay nat. Hist. Soc.* 27: 545-549

Yenbutra, S. and H. Felten. 1986. Bats species and their distribution in Thailand according to the collections in TISTR and SMF. p: 9-45, *in* Contributions to the knowledge of the bats of Thailand (Felten, H. Ed.). Cour. Forsch.-inst. Senckenberg, 87 pp.

Zubaid, A. and G. W. H. Davison. 1987. A comparative study of the baculum in Peninsular Malaysian hipposiderines. *Mammalia.* 51(1): 139-144

APPENDIXES

Appendix 1. Specimen localities

Hipposideros ater

INDIA

Thiruneer Malai, 26 km from centre Madras, (appro. 13°03’N, 80°00’E): HZM.2.28189, HZM.3.28190, MM2-3

Sankanthira Mandapam, northern Cheranmadevi, 16 km western Tirunelveli, Tamil Nadu (appro. 08°27’N, 77°25’E): HZM.4.35004

Handed, Mahasashta State: BM(NH).65.657

Trichur District, Kerala: BM(NH).88.100-102

SRI LANKA

Unknown locality: BM(NH).21.1.17.44-45, 47, BM(NH).13.2.10.18, BM(NH).66.5524

MYANMAR

Tarabwin Village, Tanintharyi Division Tanintharyi Division: HZM.10.35983

Kan Thar Yar Beach, Gwa Township, Rakhine State (17°43’N, 94°31’E): HZM.5.35011

Mekgui: BM(NH).23.11.11.2

Tenasserim village, Shortridge: BM(NH).21.1.17.52-53

Hipposideros cineraceus

INDIA

Dehra Dun, near Simla (type locality of *H. cineracues micropus*): BM(NH).79.11.21.160

MYANMAR

Saddan Sin Cave, 16 km north of northeastern Mawlamyine, Mon State (16°19’N, 97°42’E): HZM.3.34873

Appendix 1. Specimen localities (Continue)

THAILAND

Pha Daeng Cave, Srilanna National Park, Chiang Dao District, Chiang Mai Province (19˚20.769’N, 99˚01.416’E): PSUZC-MM06.72-76, 80-81

Khimee Cave, Chiang Dao Wildlife Sanctuary, Khong District, Chiang Mai Province (19°21.266’N, 98°43.837’E): CD-B-0041

Lup Lae Cave, Ban Rai District, Uthai Thani Province (15˚03.077’N, 99˚28.879’E): PSUZC-MM07.192

Khao Don Deung, Ban Mi District, Lop Buri Province (15˚08.888’N, 100˚36.819’E): PSUZC-MM07.185-190

Khao Singto, Meuong District, Sa Kaeo Province (13˚59.417’N, 102˚00.465’E): PSUZC-MM07.184

Khao Bin Cave, Chom Bung District, Ratcha Buri Province (13˚35.527’N, 99˚40.012’E): PSUZC-MM07.22-23, 191, 194

Khao Yoi Cave, Khao Yoi District, Phetcha Buri Province (13˚14.014’N, 99˚49.708’E): PSUZC-MM07.21

Khao Kram Cave, Patiew District, Chumphon Province (10˚55.131’N, 99˚22.440’E): PSUZC-MM07.69, 84-86, 88-89

Silawan Cave, Patiew District, Chumphon Province (10°41.461’N, 99°14.476’E): PSUZC-MM07.9

Pra Khayang Cave, Kraburi District, Ranong Province (10°19.569’N, 98°45.923’E): PSUZC-MM07.10

Ao Mai Ngam, Surin Island National Park, Phang Nga Province (9°25.873’N, 97°51.975’E): PSUZC-MM06.18

Khao Chong Waterfall, Khao Banthat Wildlife Sanctuary, Trang Province (7°32.894’N, 99°47.196’E): PSUZC-MM07.8

Khao Rak Kiat Cave, Rattaphum District, Songkhla Province (6°38.767’N, 99°37.383’E): PSUZC-MM05.63, PSUZC-MM06.10, 144

Wildlife Education Centre, Ton Nga Chang Wildlife Sanctuary, Songkhla Province (6°56.739’N, 100°14.467’E): PSUZC-MM06.125-126

Appendix 1. Specimen localities (Continue)

Khao Nouy Cave, Rattaphum District, Songkhla Province (6°59.537’N, 100°08.470’E): PSUZC-MM07. 171-175

Outaphao Watershed, Rattaphum District, Songkhla Province (6°47.777’N, 100°14.092’E): PSUZC-MM07.194

Km 1-2 Talow Wao-Talow Oulang Road, Tarutao Islands National Park, Satus Province (6˚36.501’N, 99˚40.435’E): PSUZC-MM07.180, 182

Crocodile (Jorrake) Cave, Tarutao Island National Park, Satus Province (6˚41.946’N, 99˚39.096’E): PSUZC-MM07.177-179, 181

Ao Son, Tarutao Islands National Park, Satus Province (6°38.767’N, 99°37.383’E): PSUZC-MM05.62

Sirinthorn Waterfall, Bala Forest, Hala-Bala Wildlife Sanctuary, Narathiwat Province (5°48.017’N, 101°50.000’E): PSUZC-MM05.76

Hipposideros halophyllus

THAILAND

Pha Daeng Cave, Srilanna National Park, Chiang Dao District, Chiang Mai Province (19˚20.769’N, 99˚01.416’E): PSUZC-MM06.70-71, 77-798, 82-83

Lup Lae Cave, Ban Rai District, Uthai Thani Province (15˚03.077’N, 99˚28.879’E): PSUZC-MM07.204

Khao Don Deung, Ban Mi District, Lop Buri Province (15˚08.888’N, 100˚36.819’E): PSUZC-MM07.201-202

Khao Samor Khon, Ta Wung District, Lop Buri Province (14˚54.548’N, 100˚30.342’E) (Type locality): PSUZC-MM07.40-41, 203, 240-241

Khao Singto, Meuong District, Sa Kaeo Province (13˚59.417’N, 102˚00.465’E): PSUZC-MM07.195-200

Khao Bin Cave, Chom Bung District, Ratcha Buri Province (13˚35.527’N, 99˚40.012’E): BM(NH).78.2344

Khao Yoi Cave, Khao Yoi District, Phetcha Buri Province (13˚14.014’N, 99˚49.708’E): PSUZC-MM07.24, 35-39, BM(NH).78.2346

Appendix 2. List of localities in Fig. 46

Loc. 1: Nam Tamai Valley, Kachin State, Myanmar (c.o. 27°50’N, 97°45’E)

Loc. 2: Mogok, Mandalay Division, Myanmar (22°55’N, 96°30’E)

Loc. 3: Mingun, Mandalay Division, (22°03’N, 96°01’E)

Loc. 4: Gokteik, Shan State, Myanmar (22°21’N, 96°55’E)

Loc. 5: nr Sagaing, Sagaing Division, Myanmar (21°52’N, 95.59’E)

Loc. 6: Kan Thar Yar Beach, Gwa Township, Rakhine State, Myanmar (17°43'N, 94°31'E)

Loc. 7: Saddan Sin Cave, 16 km NE of Mawlamyine, Mon State, Myanmar (16°19'N, 97°42'E)

Loc. 8: Myeik, Myanmar

Loc. 9: Tarabwin Village, Tanintharyi Division, Myanmar

Loc. 10: Khimee Cave, Chiang Dao Wildlife Sanctuary, Khong District, Chiang Mai Province, Thailand (19°21.266'N, 98°43.837'E, 718 m)

Loc. 11: Pha Dang Cave, Srilanna National Park, Chiang Dao District, Chiang Mai Province, Thailand (19°20.769'N, 99°01.416'E, 480 m)

Loc. 12: Ban Jagae Guard Station and Lum Khao Ngu Guard Station, Thung Yai Naresuan Wildlife Sanctuary, Tak Province, Thailand (approx. 15°41.310'N, 98°54.070'E, 718 m)

Loc. 13: Lup Lea Cave, Ban Rai District, Uthai Thani Province, Thailand (15°03.077'N, 99°28.879'E, 200 m)

Loc. 14: Khao Don Deung, Ban Mi District, Lop Buri Province, Thailand (15°08.888'N, 100°36.819'E, 40 m)

Loc. 15: Khao Yai National Park, Pak Chong District, Nakhon Ratchasima Province, Thailand (approx. 14°32'N, 101°24'E)

Loc. 16: Phu Nam Tok Tub Kwang (Tap Kwang), Kaeng Khoi District, Sara Buri Province, Thailand (approx. 14°35'N, 100°08'E)

Loc. 17: Khao Singto Cave, Meung District, Sa Kaeo Province, Thailand (13°59.417'N, 102°00.465'E, 12 m)

Loc. 18: Wat Khao Wong Kot, Tha Mai District, Chantha Buri Province, Thailand (approx. 12°55'N, 101°58'E)

Appendix 2. List of localities in Fig. 46 (Continue)

Loc. 19: Khao Bin Cave, Chom Bung District, Ratcha Buri Province, Thailand (13°35.527'N, 99°40.012'E, 61 m)

Loc. 20: Khao Yoi Cave, Khao Yoi District, Petcha Buri Province, Thailand (13°14.014'N, 99°49.708'E, 53 m)

Loc. 21: Khao Kram Cave, Patiew District, Chumphon Province, Thailand (10°55.131'N, 99°22.440'E, 67 m)

Loc. 22: Silawan Cave, Patiew District, Chumphon Province, Thailand (10°41.461'N, 99°14.476'E, 68 m)

Loc. 23: Pra Kayang Cave, Kraburi District, Ranong Province, Thailand (10°19.569'N, 98°45.923'E, 3 m)

Loc. 24: Ao Mai Ngam Natural Trail, Surin Islands National Park, Phung Nga Province, Thailand (9°25.873'N, 97°51.975'E, 20 m)

Loc. 25: Khao Chong Waterfall, Khao Banthat Wildlife Sanctuary, Trang Province, Thailand (7°32.894'N, 99°47.196'E, 81 m)

Loc. 26: Outaphao Watershed, Rattaphum District, Songkhla Province, Thailand (6°47.777'N, 100°14.092'E, 197 m)

Loc. 27: Khao Nouy Cave, Rattaphum District, Songkhla Province, Thailand (6°59.537'N, 100°08.470'E, 130 m)

Loc. 28: Wildlife Education Centre, Ton Nga Chang Wildlife Sanctuary, Songkhla Province, Thailand (9°56.739'N, 100°14.467'E, 107 m)

Loc. 29: Khao Rak Kiat Cave, Rattaphum District, Songkhla Province, Thailand (7°4.254'N, 100°15.098'E, 100 m)

Loc. 30: Ka Cave, Songkhla Province, Thailand (approx. 6°36.400'N, 100°51.300'E, 60 m)

Loc. 31: Syson Cave, Songkhla Province, Thailand (approx. 7°4.500'N, 100°10.010'E, 60 m)

Loc. 32: Noy Cave, Songkhla Province, Thailand (approx. 7°4.300'N, 100°15.100'E, 40 m)

Loc. 33: Ao Son, Tarutao Islands National Park, Satun Province, Thailand

Appendix 2. List of localities in Fig. 46 (Continue)

Loc. 34: Ban Wang Bla Chan, Muang Satun District, Satun Province, Thailand (approx. 6°45'N, 100°10'E)

Loc. 35: Sirinthorn Waterfall, Bala forest, Hala-Bala Wildlife Sanctuary, Narathiwat Province, Thailand (5°48.017'N, 101°50.000'E, 300 m)

Appendix 3. List of localities in Fig. 50

Loc. 1: Pha Dang Cave, Srilanna National Park, Chiang Dao District, Chiang Mai Province (19°20.769'N, 99°01.416'E, 480 m)

Loc. 2: Tham Pha, Tha Phol Non-hunting Area, Neon Maprang District, Phitsanulok Province (16°30'N, 100°40'E)

Loc. 3: Khi Nok Cave, Huai Kha Khang Wildlife Sanctuary, Lan Sak, Uthai Thani Province (approx. 15°27’N, 99°17’E)

Loc. 4: Lup Lae Cave, Ban Rai District, Uthai Thani Province (15°03.077'N, 99°28.879'E, 200 m)

Loc. 5: Ma Duea Cave, Kanchana Buri Province (14°01.673'N, 99°24.095'E, 64 m)

Loc. 6: Ma Duea Fun Cave, Kanchana Buri Province (14°01.822'N, 99°23.887'E, 60 m)

Loc. 7: Vi Moke Cave, Ban Mi District, Lop Buri Province (approx. 15°08'N, 100°37'E)

Loc. 8: Khao Don Deung, Ban Mi District, Lop Buri Province (15°08.888'N, 100°36.819'E, 40 m)

Loc. 9: Khao Samor Khon, Tawung District, Lop Buri Province (14°54.548'N, 100°30.342'E, 3 m)

Loc. 10: Ton Chan Cave, Phaphoutthabat District, Sara Buri Province (14°43.193'N, 100°47.684'E, 33 m)

Loc. 11: Khao Singto, Meung District, Sa Kaeo Province (13°59.417'N, 102°00.465'E, 12 m)

Loc. 12: Khao Chong Phran, Phaphouthabath District, Ratchaburi Province (approx. 13°40'N, 99°46'E)

Loc. 13: Tham Khao Bin, Chom Bung District, Ratchaburi Province (13°35.527'N, 99°40.012'E, 61 m)

Loc. 14: Khao Yoi Cave, Khao Yoi District, Petchaburi Province (13°14.014'N, 99°49.708'E, 53 m)

VITAE

Name Mr. Bounsavane Douangboubpha

Student ID 4910220114

Educational Attainment

Degree	Name of Institute	Year of Graduation
Bachelor of Science	the National University of Laos, Vientiane, Lao PDR	2006

Work Position and Address

Work Position: Lecturer

Address: Centre for Environment and Development Studies, the National University of Laos, Vientiane, Lao PDR.

E-mail Address: bounsavanhd@yahoo.com

List of Publication and Proceeding

Douangboubpha, B., S. Bumrungsri, C. Satasook, S. S. Hla Bu, D. L. Harrison, and P. J. J. Bates. A taxonomic review of *Hipposideros halophyllus, H. ater*, and *H. cineraceus* (Chiroptera: Hipposideridae) in Thailand and Myanmar (Submitted).