A new species of *Mops* (Molossidae) from Pemba Island, Tanzania

WILLIAM T. STANLEY

*Field Museum of Natural History, 1400 South Lake Shore Drive, Chicago, Illinois 60605, USA*  
E-mail: bstanley@fieldmuseum.org

The bats of Pemba are poorly known, but recent surveys have provided material to critically examine the species that occur on this island, roughly 50 km off the coast of Tanzania. A new species of *Mops* (Molossidae) is described from Pemba and aspects of its distinguishing characteristics from other molossids and habitat are discussed. This new species differs from the type of *M. brachypterus* by lacking basisphenoid pits. The form *brachypterus* needs critical review.

*Key words*: Molossidae, *Mops*, new species, morphology, habitat, Pemba Island, Tanzania

INTRODUCTION

The family Molossidae is worldwide in distribution, and currently includes 16 genera (Simmons, 2005). The genus *Mops* Lesson 1842 contains 15 species, and all but two occur in Africa and islands off the eastern coast of the continent. Historically, the genus has been included as a subgenus of *Tadarida* Rafinesque 1814, by various authors, but others recognized the generic status of the group (Freeman, 1981; Legendre, 1984). Two subgenera: *Mops* and *Xiphonycteris* Dollman 1911 are currently recognized (Simmons, 2005). The latter initially included one species: *X. spurrelli* (Dollman 1911), but Koopman (1975) expanded the group to include *Mops brachypterus* (Peters 1852), *M. leonis* (Thomas 1908) — originally described in the genus *Nyctimomus*, and now considered a subspecies of *M. brachypterus* (El-Rayah 1981), *M. nanulus* J. A. Allen 1917, and *M. thersites* (Thomas 1903). Hayman and Hill (1971) cautioned that *brachypterus* may be an earlier name for *Mops thersites*. Koopman (1975) defined the subgenus *Xiphonycteris* using two main characters: a reduced last upper molar and a well-developed anterior palatal emargination, and described the group as occurring on the African mainland, but confined to the Afrotopics. The most recent member of the sub-genus described is *M. petersoni* El-Rayah 1981. Dunlop (1999) constructed a key to the genus *Mops*, and used the characters outlined by Koopman (1975) to define the subgenus *Xiphonycteris*, and then further differentiated certain members of the taxon using the degree of development of the basisphenoid pits — always present, but either shallow and oval (*brachypterus*), or deep and rounded (*thersites*).

The bats of Tanzania are poorly known, but recent work has improved our understanding of this fauna (Kock et al., 2000; Stanley and Kock, 2004; Stanley et al., 2005a, 2005b, 2005c; Thorn et al., 2007). Even more poorly understood are the bats of the islands off the coast of Tanzania, including Mafia, Pemba and Unguja (the island formerly known as Zanzibar, which now refers to the two islands of Pemba and Unguja, collectively). Many accounts have listed Unguja (Zanzibar) as part of the distribution of *M. brachypterus*, but with some ambiguity, in that most of these accounts list no referred specimens. The one exception is Neumann (1900), who deposited specimens in the Museum für Naturkunde, Berlin. No records of *Mops* are recorded from Pemba. To date, the most complete description of the mammalian fauna of these islands is that of Pakenham (1984), and the only molossids listed are *Mops brachypterus* and *Chaerephon pumilus* (Cretzschmar 1826), and the only records of *Mops* were from Unguja — which Pakenham (1984) called Zanzibar. Although Moreau and Pakenham (1941) listed *M. brachypterus* from Zanzibar, a record echoed by Swynnerton and Hayman (1951),
Variation of mitochondrial DNA in the *Hipposideros caffer* complex (Chiroptera: Hipposideridae) and its taxonomic implications

**Peter Vallo**1,2,7, Antonio Guillén-Servent3, Petr Benda4,5, Debra B. Pires6, and Petr Koubek1

1Institute of Vertebrate Biology, v. v. i., Academy of Sciences of the Czech Republic, Květná 8, 603 65 Brno, Czech Republic
2Institute of Botany and Zoology, Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic
3Instituto de Ecología, A.C., km 2.5 Ctra. Antigua a Coatepec #351, Congregación el Haya, 91070 Xalapa, Veracruz, México
4Department of Zoology, National Museum (Natural History), Václavské náměstí 68, 115 79 Praha 1, Czech Republic
5Department of Zoology, Faculty of Science, Charles University, Viničná 7, 128 44 Praha 2, Czech Republic
6Department of Life Sciences, University of California, 621 Charles E. Young Drive South, Los Angeles, California 90095–1606, USA
7Corresponding author: E-mail: vallo@ivb.cz

The Afrotropical leaf-nosed bat *Hipposideros caffer* has been traditionally regarded as a complex of populations, currently pertaining to two recognized cryptic species, *H. caffer* and *H. ruber*. Extent of distribution and morphological variation of these bats has raised concerns over whether the current perception of the complex reflects true phylogenetic relationships and taxonomic diversity. Our phylogenetic analysis of nucleotide sequences of the mitochondrial cytochrome *b* gene challenged the hypothesis of two cryptic species. Instead of the two reciprocally monophyletic lineages expected, corresponding to the two species, we recovered four distinct lineages with deep internal divergences. Two sister clades within a lineage of bats of *H. caffer* represent respectively the nominotypical form *H. c. caffer*, restricted to Southern Africa, and *H. c. tephrus*, inhabiting the Maghreb, West Africa and the Arabian Peninsula. Geographical isolation and deep genetic divergence suggest species status of both the forms. Another lineage comprises specimens of both morphotypes from West and East Africa. It probably represents a distinct species but its taxonomic assignation remains obscure. A Central African lineage of *H. ruber* comprises two sister clades, which become sympatric in Cameroon. Their status has to be clarified with additional evidence, since nuclear gene flow might be taking place. A further divergent lineage with *H. ruber* morphotype, most probably representing another distinct species, is restricted to West Africa. Although all three genetic forms of *H. ruber* may correspond to named taxa, their proper taxonomic assignation has to be assessed by comparison with type material.

**Key words**: Africa, *Hipposideros caffer*, *H. ruber*, leaf-nosed bats, cryptic species, cytochrome *b*, molecular systematics, phylogeny

**INTRODUCTION**

Flight and echolocation constrain bat morphology in a way that parallel and convergent evolution can be widespread among species that use similar ecological niches (Norberg, 1994; Ruedi and Mayer, 2001). This may make taxonomy difficult, since species evolutionarily related and ecologically similar may lack conspicuous morphological characters useful to discriminate among them. Genetic data may be fundamental in these cases, allowing the identification of deeply divergent lineages that may represent evolutionary independent units (Bradley and Baker, 2001). Molecular phylogenetic methods have been used extensively in recent years to reveal many new cryptic forms of bats within traditionally recognized species. The recent increase of about 20% in the number of species of the European fauna of bats, probably the best known Chiropteran fauna in the World, is an illuminating example of the utility of the genetic data to discover hidden taxonomic diversity within bats (Mayer and von Helversen, 2001; Ibáñez et al., 2006; Mayer et al., 2007).

The genus *Hipposideros* Gray, 1831, the largest in the Palaearctic family of the leaf-nosed bats, Hipposideridae, has traditionally had a difficult taxonomy due to the extreme morphological similarity of many of its members (Hill, 1963; Bogdanowicz and Owen, 1998). This morphological similarity suggests that cryptic species might be particularly common among these bats. Systematic biologists have so far paid most attention to the Southeast
Genetic diversity and phylogeography of the greater mouse-tailed bat
Rhinopoma microphyllum (Brünnich, 1782) in the Levant

ERAN LEVIN1, 3, YORAM YOM-TOV1, ANAT BARNEA2, and DOROTHÉE HUCHON1

1Department of Zoology, Tel Aviv University, 69978 Tel Aviv, Israel
2Department of Natural and Life Sciences, the Open University of Israel, 43107 Ra’anana, Israel
3Corresponding author: E-mail: levinere@post.tau.ac.il

The greater mouse-tailed bat (Rhinopoma microphyllum) possesses a large geographical range, covering most of the arid and warm areas of the Old World. We studied the genetic variability of this species using two mitochondrial markers (the cytochrome b gene and the control region), from several Israeli colonies and from over most of the species’ range. Our results show that the cytochrome b sequences, unlike those of the control region, are too conserved to separate among R. microphyllum populations. Based on the control region sequences, a high level of sequence similarity was found within the Israeli population. Three clades were observed over the species’ range: Oriental, Intermediate and Palaearctic. This division supports most of the traditional taxonomy of the species. The Israeli population, which belongs to the Palaearctic clade, was found to be isolated from the Oriental and Intermediate clades. We suggest that the colonization of the greater mouse-tailed bat in the Levant occurred from African populations during the late Pleistocene, when many Saharan plants and animals penetrated the northern part of the Great Rift Valley.

Key words: genetic diversity, mtDNA, Rhinopoma microphyllum, Levant

INTRODUCTION

The greater mouse-tailed bat (Rhinopoma microphyllum, also known as the rat-tailed bat) is a medium-sized bat (average body mass 25 g) inhabiting arid and subtropical regions of the Old World, covering about 12,000 km, from Sumatra and India in the east, through Arabia, to north-western Africa (Schlitter and Qumsiyeh, 1996; Simmons, 2005). During the summer, the species can be found in the north of Israel, which is the northern edge of its range. The greater mouse-tailed bat belongs to the monotypic family Rhinopomatidae that includes three other species — Rhinopoma harwickii, R. muscattellum, and R. macinnesi (Van Cakenberghe and De Vree, 1994; Simmons, 2005). Rhinopoma microphyllum is easily distinguished from these three species by its larger body size (Van Cakenberghe and De Vree, 1994; Hulva et al., 2007). Traditionally, R. microphyllum is morphologically divided into 4–6 different subspecies along its distribution range (Hill, 1977; Van Cakenberghe and De Vree, 1994; Schlitter and Qumsiyeh, 1996). All classifications agree with the presence of the subspecies R. m. sumatrae in Sumatra, R. m. asirensis in the southern part of the Arabian Peninsula, R. m. kinneari in the Indian subcontinent, and R. m. microphyllum in North Africa and the Levant. Schlitter and DeBlase (1974) described an additional subspecies: R. m. harrisoni from southern Iran, while Kock (1969) distinguished R. m. tropicalis from southern Sudan, Senegal, Mauritania, and central Nigeria. Classifications dividing R. microphyllum into six subspecies were presented by Schlitter and Qumsiyeh (1996). Conversely, Van Cakenberghe and De Vree (1994) synonymised R. m. harrisoni and R. m. tropicalis subspecies with R. m. microphyllum.

Almost nothing is known about the genetic variability of this species. The only existing data are based on partial cytochrome b sequences of two individuals: one from Jordan and one from India, and they show a low level of sequence variability (Hulva et al., 2007). Hulva et al. (2007) suggested that in spite of the 3,400 km separating between the Levant and Indian populations, a gene flow nonetheless exists, thus contradicting all classical morphological divisions of this species.

Here we present the first molecular study of a bat in Israel, showing a high sequence similarity
A new species of tube-nosed bat *Murina* (Vespertilionidae, Chiroptera) from Vietnam

SERGEI V. KRUSKOP1,3 and JUDITH L. EGER2

1Zoological Museum, Moscow M. V. Lomonosov State University, Ul. Bolshaya Nikitskaya, 6, 125009 Moscow, Russia
2Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario, M5S 2C6 Canada
3Corresponding author: E-mail: kruskop@zmmu.msu.ru

A new species of *Murina* is described from Lam Dong province, Vietnam. The new form is a very small tube-nosed bat with a forearm length less than 30 mm. Externally it looks similar to *Harpiola isodon* from which it is well differentiated by teeth shape. From other small *Murina* species the new species can be defined by pelage coloration and texture, longer nasal tubes, dark skin on muzzle and smaller anterior upper premolar. Provisional analysis of mitochondrial DNA sequence also supports its species status. This species is known only from mountainous forests of the Dalat plateau.

**Key words:** *Murina*, new species, Vietnam, taxonomy, skull morphology

INTRODUCTION

Within the subfamily Murininae inter- and intraspecific taxonomy is still insufficiently known. Potential revisions are difficult because of the relative rarity of most named forms in scientific collections and low abundance of these bats in the wild. This, together with the highly mosaic nature of habitats in tropical Asia can explain the regular finding of new or revalidation of missed taxa of different ranks (Maeda and Matsumura, 1998; Csorba and Bates, 2005; Kuo et al., 2006; Csorba et al., 2007), even on the northern edge of the group’s distribution (Kruskop, 2005). Recent collections of bats in south east Asia and south west China, indicate that bats of this subfamily are more common in pristine habitats (Tordoff et al., 2000; Hendrichsen et al., 2001; Kruskop et al., 2006; Csorba et al., 2007). The increased frequency of recent descriptions of new species in Southeast Asia suggests that this number could increase in the future.

An adult female of a very small tube-nosed bat (No. S-173401 in the mammalian collection of Moscow Zoological Museum) was captured in the north-east part of the Dalat plateau in Lam Dong province, Vietnam, in 2002 during the field work session organized by the Vietnamese-Russian Tropical Center. Initially, based on identification features provided by Corbet and Hill (1992), this individual was identified as *Murina aurata* (Kruskop, 2005; Borisenko et al., 2006). The second specimen of the same species (young male No. S-182119) was captured in 2008 close to the previous locality. Further comparison with collections stored in Royal Ontario Museum revealed certain morphological differences from *M. aurata* as well as from other small tube-nosed bats, particularly in cranial proportions and fur coloration and texture. Therefore, we describe
A taxonomic review of *Rhinolophus stheno* and *R. malayanus* (Chiroptera: Rhinolophidae) from continental Southeast Asia: an evaluation of echolocation call frequency in discriminating between cryptic species

**PIPAT SOISOOK**, **SARA BUMRUNGSRI**, **CHUTAMAS SATASOOK**, **VU DINH THONG**, **SI SI HLA BU**, **DAVID L. HARRISON** and **PAUL J. J. BATES**

1Department of Biology, Faculty of Science, Prince of Songkla University, Hat Yai, Songkla, Thailand 90112
2Institute for Ecology and Biological Resources (IEBR), Vietnamese Academy of Science and Technology, 18 Hoang Quac Viet Road, Cau Giay, Hanoi, Vietnam
3Department of Zoology, Mandalay University, Mandalay, Myanmar
4Harrison Institute, Centre for Systematics and Biodiversity Research, Bowerwood House, St. Botolph’s Road, Sevenoaks, Kent, TN13 3AQ, United Kingdom
5Corresponding author: E-mail: harrisoninstitute@btopenworld.com

The taxon *Rhinolophus microglobosus* is elevated to specific rank on the basis of clearly defined morphometric and acoustic characters which differentiate it from *Rhinolophus stheno*. It is recorded from Cambodia for the first time. *Rhinolophus malayanus* exhibits considerable geographical variation in echolocation calls, with apparently two phonic types: a northern population with lower frequency calls and a predominantly southern population with higher frequencies. However, this acoustic divergence is not reflected in any morphometric divergence, and the taxonomic status of the two phonic populations remains unclear. Discriminating characters of all three species are given, together with distribution data and short ecological summaries. The value of echolocation as an indicator of cryptic species and the zoogeographical implications of the study are briefly discussed.

**Key words**: *Rhinolophus microglobosus*, *R. malayanus*, *R. stheno*, taxonomy, echolocation, zoogeography, Southeast Asia

**INTRODUCTION**

*Rhinolophus malayanus* Bonhote (1903) and *R. stheno* Andersen (1905) are generally considered to be two closely related species and are usually included in the same species group of the Rhinolophidae (Andersen, 1905; Tate and Archbold, 1939; Corbet and Hill, 1992; Csorba et al., 2003); although for contrary views see Bogdanowicz (1992) and Guillén Servent et al. (1992) and Guillén Servent et al. (2003). In terms of morphometrics, some authors have found it difficult to distinguish between the two taxa (McFarlane and Blood, 1986), whilst others have published a range of discriminating characters (Lekagul and McNeely, 1977; Corbet and Hill, 1992; Robinson, 1995; Bates et al., 2000, 2004). However, as Csorba et al. (2003) pointed out that there has been little agreement between the authors as to the reliability of each so-called diagnostic feature. Meanwhile, the subspecific characters of *R. stheno* were discussed in some detail by Csorba and Jenkins (1998), who described a new subspecies, *R. stheno microglobosus*, whilst those of *R. malayanus*, with the exception of a few comments by Bates et al. (2004), have been largely ignored. The acoustic characters of the two taxa are also virtually unknown, although some data are available in Robinson (1996), Francis and Habersetzer (1998) and Kingston et al. (2000).

The idea for the current study came from observed differences of up to 10 kHz in the hand held frequencies of acoustic calls of both *R. stheno* (sensu Csorba et al., 2003) and *R. malayanus* from northern and southern Thailand. Previous studies in Asia had suggested that acoustic data are a useful tool to identify cryptic species (Francis and Habersetzer, 1998; Francis et al., 1999b; Kingston et al., 2001; Thabah et al., 2006). This study sought to determine if differences in echolocation were consistent, had distinctive geographical patterns, and were congruent with observable, discriminating, morphometric characters.
INTRODUCTION

Fruit-eating bats, *Artibeus*, comprise the most speciose genus in the family Phyllostomidae (Simmons, 2005) and one of the commonest groups of bats in Neotropical lowland forest but their systematics have been notoriously contentious. Although this is a speciose genus with some of the most common bats in Neotropical forests, resolution of taxonomy and their identification has been difficult. Our molecular phylogeny based on Bayesian and parsimony analyses of cytochrome *b* variation includes a well supported topology of *A. glaucus glaucus* sister to a clade of *A. gnomus* and *A. glaucus bogotensis* indicating that *A. glaucus* is a paraphyletic amalgam. A re-assessment of morphology corroborates differences between *A. g. bogotensis* from the Andean valleys of Colombia east into the Guianas and *A. g. glaucus* from western Amazonia. Thus, we recognize *A. bogotensis* and *A. glaucus* as distinct and allopatrically occurring species. Based on a Kimura-2 parameter model of substitution for cytochrome *b*, there was 1.2% sequence divergence within *A. bogotensis*, and 9.5% sequence divergence between *A. bogotensis* and *A. glaucus*. Compared to *A. glaucus*, *A. bogotensis* has prominent white facial stripes, a less hirsute interfemoral membrane, less robust orbitorostral region, and also lacks a small third lower molar. Within the Guiana region, there are three species with overlapping distributions (*A. bogotensis*, *A. cinereus*, and *A. gnomus*), however, they are sympatric only within the interior lowland forest near savannas. All other habitats including coastal forest, lowland forest, savanna, and highland forest have only two sympatric species, one of which is relatively more abundant (> 70%).

Key words: cytochrome *b*, Guyana, morphometrics, Phyllostomidae, Suriname

Systematic review of small fruit-eating bats (*Artibeus*) from the Guianas, and a re-evaluation of *A. glaucus bogotensis*

BURTON K. LIM1,3, MARK D. ENGSTROM1, JOHN C. PATTON2, and JOHN W. BICKHAM2

1Department of Natural History, Royal Ontario Museum, 100 Queen’s Park, Toronto, Ontario M5S 2C6, Canada
2Center for the Environment and Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana 47907-2966, USA
3Corresponding author: E-mail: burtonl@rom.on.ca

We studied molecular and morphological variation in small fruit-eating bats (*Artibeus*) in northern South America to establish species boundaries, evolutionary relationships, and distributional limits. Although this is a speciose genus with some of the most common bats in Neotropical forests, resolution of taxonomy and their identification has been difficult. Our molecular phylogeny based on Bayesian and parsimony analyses of cytochrome *b* variation includes a well supported topology of *A. glaucus glaucus* sister to a clade of *A. gnomus* and *A. glaucus bogotensis* indicating that *A. glaucus* is a paraphyletic amalgam. A re-assessment of morphology corroborates differences between *A. g. bogotensis* from the Andean valleys of Colombia east into the Guianas and *A. g. glaucus* from western Amazonia. Thus, we recognize *A. bogotensis* and *A. glaucus* as distinct and allopatrically occurring species. Based on a Kimura-2 parameter model of substitution for cytochrome *b*, there was 1.2% sequence divergence within *A. bogotensis*, and 9.5% sequence divergence between *A. bogotensis* and *A. glaucus*. Compared to *A. glaucus*, *A. bogotensis* has prominent white facial stripes, a less hirsute interfemoral membrane, less robust orbitorostral region, and also lacks a small third lower molar. Within the Guiana region, there are three species with overlapping distributions (*A. bogotensis*, *A. cinereus*, and *A. gnomus*), however, they are sympatric only within the interior lowland forest near savannas. All other habitats including coastal forest, lowland forest, savanna, and highland forest have only two sympatric species, one of which is relatively more abundant (> 70%).

Key words: cytochrome *b*, Guyana, morphometrics, Phyllostomidae, Suriname

INTRODUCTION

Fruit-eating bats, *Artibeus*, comprise the most speciose genus in the family Phyllostomidae (Simmons, 2005) and one of the commonest groups of bats in Neotropical lowland forest but their systematics have been notoriously contentious. Although the taxonomy of *Artibeus*, particularly in northern South America, was greatly clarified by Handley (1987), his nomenclature was not completely accepted by other researchers. For example, Koopman (1993) considered *A. planirostris* to be specifically distinct and allopatrically distributed from *A. jamaicensis*, and he synonymized *A. gnomus* with *A. glaucus*. Subtle morphological differences are confounded by geographic and individual variation, which have resulted in taxonomic confusion and difficulties in species identification. Other than a molecular study using primarily single-specimen exemplars for most recognized species of *Artibeus* (Van Den Bussche et al., 1998), there has not been a rigorous test of the opposing hypotheses of species boundaries. An exception has been the recent studies on large-sized *Artibeus*, wherein *A. planirostris* was recognized as distinct from *A. jamaicensis* based on genetic analyses (Lim et al., 2004; Larsen et al., 2007).

In many regions of South America, three species of small *Artibeus* are found broadly distributed (Handley, 1987). The taxonomy and distributional range of these species, however, are unclear due primarily to difficulties in recognizing slight differences in morphology and the use of different classifications in the literature. Recent biodiversity studies in Guyana (e.g., Lim and Engstrom, 2001b, 2005; Engstrom and Lim, 2002) have resulted in extensive reference material that is useful for re-evaluating the taxonomic limits and geographic occurrence of small species of *Artibeus*. The main objectives of this study were to establish species boundaries for small-sized *Artibeus* in the Guianas using...
INTRODUCTION

Extant species in the genus Anoura are relatively common and widespread throughout the Neotropics, especially at intermediate altitudes in the Andes. Members of this genus are among the most abundant and perhaps the most important mammalian pollinators in Neotropical cloud forests. However, Anoura also includes rare species, at least based on species assemblages that have been assessed using mistnets. Notwithstanding, most species in this genus are frequently represented by large series in museum collections implying large abundance, and often included in mammal-inventories suggesting broad distributions.

As with most groups of Neotropical bats, Anoura has suffered a long and tortuous history of taxonomic changes. Names come and go, but species as evolutionary entities persist. Notwithstanding, it is helpful to establish a historical perspective upon the evolution of taxonomic knowledge in order to fully assess species boundaries. According to Tamsitt and Nagorsen (1982), the genus ‘Anoura’ was first used by Gray (1838) in the description of the type species Anoura geoffroyi. However, the first described species belonged to another genus as Glossophaga caudifer and G. ecaudata (Geoffroy-Saint-Hilaire, 1818). Subsequently, the genus Anoura underwent a complex series of synonyms and re-descriptions (Tschudi, 1844; Agassiz, 1846; Peters, 1869; Tamsitt and Valdivieso, 1966; Nagorsen and Tamsitt, 1981). For example, during the period 1818–1941 at least nine synonyms were assigned to A. caudifer (Cabrera, 1957; Tamsitt and Valdivieso, 1966). The specific name caudifer has been changed to caudifera by a number of authors, originating with Dobson (1878) and later followed by several workers (e.g., Nowak, 1999). Despite this change, and opposed to the arguments by Handley (1984), the name used in the original description must be maintained, as recommended by Simmons (2005).
Analysis of twinning in flying-foxes (Megachiroptera) reveals superfoetation and multiple-paternity

SAMANTHA FOX1, 4, HUGH SPENCER2, and GEMMA M. O’BRIEN3

1School of Marine and Tropical Biology, James Cook University, Townsville, QLD 4811, Australia
2Cape Tribulation Tropical Research Station, RMB 5, Cape Tribulation, QLD 4873, Australia
3Department of Physiology, University of New England, Armidale, NSW 2351, Australia
4Present address and corresponding author: Wildlife Management Branch, Department of Primary Industries and Water, GPO Box 44, Hobart 7001, Tasmania, Australia; E-mail: Samantha.Fox@dpiw.tas.gov.au

Published records of twinning and superfoetation in monotocous wild mammals are rare. Flying-foxes (Pteropodidae, Megachiroptera) occasionally produce twin offspring, fraternal twins, as well as superfoetation twins. Superfoetation occurs when a foetus is conceived when there is a foetus already developing. The resultant twins may be months apart in developmental stages so that one twin is usually born prematurely. Here, we review the current literature available on twinning and superfoetation in flying-foxes, and describe nine occurrences of multiple conceptions in Australian Pteropus species. Differences in sex and age of offspring clearly showed that most resulted from simultaneous or serial ovulations, not zygote splitting, thus excluding monozygous twinning. Additionally, an example of superfoetation is genetically analysed using six highly polymorphic microsatellite loci, to show multiple-paternity of superfoetation twins. Multiple births by flying-foxes are rare, leading the authors to conclude that the polyovulation constraint theory, found in the Microchiroptera, is not applicable in flying-foxes. The rare occurrence of additional ovulations do not usually produce additional live offspring. Post-ovulatory constraints, including the extra energetic demand twins place on a female flying-fox, are implicated in preventing successful production of multiple offspring.

Key words: superfoetation, flying-foxes, Pteropus, twins, volant mammal

INTRODUCTION

Large mammals typically exhibit life history characteristics that place them at the ‘slow’ end of the life history continuum; late sexual maturation, a small number of large sized offspring that grow slowly, and long lifespans. A single young is usually produced in a single reproductive event annually. Although mono- or dizygotic twins are produced occasionally in some large mammal species, there are no published accounts of occurrence or frequency. Published records of any type of multiple conception occurring in a large mammal species that usually produce a single young are rare; the exception is that of superfoetation occurring in sheep (Ozmen and Koker, 2004). Superfoetation occurs where conception takes place when there is already a foetus present. In humans, superfoetation is possible when artificial reproductive technologies are used, but it has also been reported during natural cycles. While routine ultrasound examination has revealed occasional cases of superfoetation twins in humans (Soudre et al., 1992), there appears to be little known about the occurrence of this type of conception in non-human mammals, its frequency or the survival rate of offspring.

Within the order Chiroptera, a single young is common throughout most species, with the exception being those species within the families Vespertilionidae (one to four offspring) and Antrozoidae (two offspring — Barclay and Harder, 2003). Although there is considerable variation amongst bats in many ecological traits associated with life histories, there is remarkable consistency in the life histories themselves. One common ecological feature, flight, was believed to constrain a bat’s ability to produce more than one offspring (Barclay, 1994) but the presence of larger litter sizes in the Vespertilionidae and Antrozoidae falsifies this hypothesis. A comparison of bat species (Barclay and Harder, 2003) suggested that females of species that produce a single young only have one functional ovary, while species that commonly produce more than one offspring possess symmetrical reproductive tracts
Diet and prey selection in Mehelyi’s horseshoe bat *Rhinolophus mehelyi* (Chiroptera, Rhinolophidae) in the south-western Iberian Peninsula

**EGOITZ SALSAMENDI**1, 2, **INAZIO GARIN**1, **DAVID ALMENAR**1, **URTZI GOITI**1, **MARIA NAPAL**1, and **JOXERRA AIHARTZA**1, 3

1Department of Zoology and Animal Cell Biology, University of the Basque Country. Box 644, E-48080 Bilbo, Basque Country
2Department of Vertebrates, Aranzadi Society of Sciences. Zorroagagaina 11, 20014 Donostia, Basque Country
3Corresponding author: E-mail: joxerra.aihartza@ehu.es

We studied diet and prey selection in Mehelyi’s horseshoe bats *Rhinolophus mehelyi* in the south-western Iberian Peninsula, during the breeding seasons of 2003, 2006, and 2007. Faecal pellets were collected individually and arthropod fragments identified to family level, where possible. Arthropod availability was assessed using Malaise traps. Selection analyses were performed using Compositional Analysis and a Chi-square goodness-of-fit test. The bulk of the diet of *R. mehelyi* consisted of Lepidoptera, representing more than the 80% of the consumed volume on average (excluding juveniles), and more than 90% of the average percentage occurrence. This pattern was consistent across localities. Neuroptera and Tipulidae were locally abundant. Other important prey categories were Chrysomelidae, Brachycera, and Chironomidae. ANOVA tests showed that there were no significant differences between males and females in consumed prey categories, whereas juveniles consumed significantly less Lepidoptera than adults. Lepidoptera was the first prey category in the preference rank, followed by Myrmeleontidae, Chrysopidae and Tipulidae, and all of these were consumed more than expected by chance. This work shows that *R. mehelyi* is a moth specialist and suggests that juveniles may acquire this strategy while gaining hunting experience. Given the similarities in echolocation call characteristics and diet in the sibling *R. mehelyi* and *R. euryale*, they may compete for trophic resources in sympatry. Nevertheless, subtle differences in wing morphology between both species are probably large enough to permit spatial resource partitioning.

**Key words**: *Rhinolophus mehelyi*, diet, prey selection, Lepidoptera, south-western Europe

**INTRODUCTION**

Mehelyi’s horseshoe bat, *Rhinolophus mehelyi* Matschic 1901, is a medium-sized (10–18 g — Schober and Grimmberger, 1993) Mediterranean species that emits long and constant calls around 106 and 107 kHz (Ahlén, 1990; Russo et al., 2001, 2007; Salsamendi et al., 2005), which are followed, and often preceded, by brief frequency-modulated components. Doppler-shift compensation, together with a highly sensitive auditory system, allows them to detect and evaluate echoes from fluttering targets (Schnitzler, 1983). These characteristics of the echolocation system indicate that the species is specialized to hunt relatively large-winged insects, such as moths or beetles (Bogdanowicz et al., 1999). Like in most rhinolophid species *R. mehelyi*’s wings are broad and rounded, and flight is slow and very manoeuvrable, a clear adaptation to forage within or close to vegetation (Norberg and Rayner, 1987).

Hunting modes of *R. mehelyi* includes hawking and flycatching (Norberg and Rayner, 1987; Gaisler, 2001) and gleaning has been also suggested (Siebers and Ivanova, 2004).

*Rhinolophus mehelyi* is discontinuously distributed around the Mediterranean. In Europe, its distribution is fragmented, ranging from Portugal to Romania, predominantly in the Mediterranean peninsulas. It also occurs on some of the biggest islands in the Mediterranean Sea (Mitchell-Jones et al., 1999; Cserba et al., 2003). Populations are currently declining in various parts of its range and the species is thought to be extinct or seriously threatened in a number of European countries (Rodrigues and Palmeirim, 1999; Hutson et al., 2001). Although in Europe it is considered a vulnerable species, and is therefore strictly protected (Hutson et al., 2001), crucial information for effective conservation policies, such as knowledge of its spatial and trophic ecology, is scarce. In a preliminary study Russo et
Fishing behaviour in the long-fingered bat *Myotis capaccinii* (Bonaparte, 1837): an experimental approach

JOXERRA AIHARTZA1, 2, DAVID ALMENAR1, EGOITZ SALSAMENDI1, URTZI GOITI1, and INAZIO GARIN1

1Zoologia Saila, UPV/EHU, 644 p.k. E-48080 Bilbo, The Basque Country
2Corresponding author: E-mail: joxerra.aihartza@ehu.es

To study the fishing behaviour of *Myotis capaccinii*, we performed an experiment in a flight tent containing an artificial pond. We recorded the behaviour of two groups of bats — eight individuals from two different roosts — using IR video camcorders and ultrasound detectors, and evaluated diet by analyzing faeces. Nightly, increasing amounts of fish were released in the pond. Our data show that *M. capaccinii* is able to exhibit fishing behaviour when fish occur in high densities in shallow waters, gaffing live fish from the water using their hind feet. They were attracted neither by dead fish floating, nor by ripples made by fishes feeding on the water surface. Bats showed a specific fishing behaviour with two main foraging patterns: A) long series of circular flights, skimming along the water and dipping in softly twice or three times in each roundabout; B) long figure-eight loops with bats flying faster and higher, swooping down on the centre of the pond, where they snapped their hind feet hard into the water. Compared with the echolocation calls used to catch insects from the water's surface in the wild, terminal buzzes were incomplete during the dips made to fish. Buzz II were always lacking, and buzz I had much longer inter-pulse intervals. This suggests that they were not pursuing specific targets but dipping randomly. We propose a scenario in which fishing behaviour occurs in the wild, linked to the seasonal drought of small ponds, marshes, or channels where large numbers of small fish become readily available and thus a profitable resource.

Key words: fishing behaviour, foraging, evolution, bats, *Myotis capaccinii*

INTRODUCTION

Piscivory is the primary feeding strategy for *Noctilio leporinus* (Bloedel, 1955a, 1955b; Hood and Jones, 1984; Brooke, 1994; Bordignon, 2006). *Myotis* (*Pizonyx*) *vivesi* may eat either fish or shrimps, although crustaceans comprise the major food for them (Burt, 1932; Reeder and Norris, 1954; Altenbach, 1989; Blood and Clarck, 1998). Other species, although predominantly insectivorous, also prey on fish to varying degrees, e.g., *Myotis macropus* but *adversus* (Dwyer, 1970; Robson, 1984; Law and Urquhart, 2000), *M. alascens* (Whitaker and Findley, 1980), *M. macrotarsus* (Brosset, 1966), *M. ricketti* but *pilosus* (Brosset, 1966; Ma et al., 2003), *M. stalkeri* (Flannery, 1995), *Megaderma lyra* (Gudger, 1943), *Noctilio albiventris* (Hood and Pitocchelli, 1983), and *Nycteris grandis* (Fenton et al., 1990).

Piscivory is defined as a specialized form of carnivory. Most authors agree that the fishing behaviour likely evolved from ‘trawling’ (e.g., Dwyer, 1970; Novick and Dale, 1971; Suthers and Fattu, 1973; Norberg and Rayner, 1987; Kalko et al., 1998), a specialized form of insectivory in which bats fly low above the water’s surface and gaff insects with their hind feet (Jones and Rayner, 1988; Kalko and Schnitzler, 1989). Moreover, recent morphometric and molecular data suggest that both trawling and fishing behaviour have evolved independently several times (Ruedi and Mayer, 2001; Fenton and Bogdanowicz, 2002; Stadelmann et al., 2004). The evolution of this foraging behaviour seems to be limited by rigid physical and/or morphofunctional constraints, producing recurrent cases of convergent evolution (Findley, 1972; Siemers et al., 2001; Stadelmann et al., 2004). Comparing with trawling insectivores, fishing bats have larger hind feet armed with sharp claws specialized for gaffing fish from water (Norberg and Rayner, 1987). *Noctilio leporinus* also exhibits a specific fishing behaviour distinct from trawling for insects (Schnitzler et al., 1994). Kalko et al. (1998) proposed a hypothesis to explain how fishing behaviour evolved in
INTRODUCTION

When capturing flying insects, most species of microchiropteran bats use their interfemoral membrane (uropatagium), which stretches between the hindlimbs, to seize prey out of the air. The diameter of the interfemoral membrane is considerably larger than the opening of a bat’s mouth. Therefore, the bat can afford to hone in slightly less precisely on its prey when using this interfemoral membrane which functions as a ‘dip net’ instead of seizing the insect directly with its mouth. After successful capture, the bat bends its head into the interfemoral membrane in flight and retrieves the prey with its mouth (e.g., Webster and Griffin, 1962; Kalko and Schnitzler, 1989). In addition to its use as a dip net for scooping airborne prey, the uropatagium stabilizes the bats’ flight and may have originally evolved as a gliding adaptation. In most species, the uropatagium comprises the entire or at least a proximal portion of the tail. It is a thin skin membrane which has blood vessels, nerves, muscles, tendons, and it is covered by the epidermis; much like bat wing membranes (Schumacher, 1932; Nowak, 1994). The calcar serves as a cartilaginous frame for the lateral portions of the free distal edge of the interfemoral membrane.

Mouse-eared bats (*Myotis*, Vespertilionidae) represent the largest genus of Chiroptera with more than 100 species worldwide (Simmons, 2005). This genus comprises aerial foraging species, the so-called ‘trawling’ species (that take sitting and floating insects from water surfaces) and others that glean prey from ground and vegetation (Fenton and Bogdanowicz, 2002). Phylogenetic studies clearly show that the morphological and behavioural traits associated with the different foraging modes (ecmorphs) evolved several times convergently within biogeographically separated clades of *Myotis* (Ruedi and Mayer, 2001; Stadelmann *et al.*, 2007);
The aerodynamics of big ears in the brown long-eared bat *Plecotus auritus*

**JAMES D. GARDINER¹, GRIGORIOS DIMITRIADIS², WILLIAM I. SELLERS¹, and JONATHAN R. CODD¹, ³**

¹Faculty of Life Sciences, University of Manchester, Manchester, M13 9PT, United Kingdom
²Département d’Aérospatiale et Mécanique, Université de Liège, Chemin des Chevreuils, 1, 4000 Liège 1, Belgium
³Corresponding author: E-mail: jonathan.codd@manchester.ac.uk

Wings are the most obvious adaptation bats have for powered flight and differences in wing morphology are known to correlate with flight behaviour. However, the function(s) of ancillary structures such as the ears and tail, which may also play an important role during flight, are less well understood. Here we constructed a simplified model of a bat body with ears based upon morphological measurements of a brown long-eared bat (*Plecotus auritus*) to examine the aerodynamic implications of flying with large ears. The forces and moments produced by the model were measured using a sensitive 6-component force and torque balance during wind tunnel testing. The large ears of the model bat produced positive lift as well as positive drag of the same order of magnitude. At small ears angles (0° to 10°), increasing the angle of the ears resulted in an increase of the lift-to-drag ratio. At higher ear angles (> 10°) separation of the flow occurred which caused a large decrease in the lift-to-drag ratio produced. To maximise the benefit from the ears (i.e., lift-to-drag ratio) our model predicts that a horizontal free flying *P. auritus* should hold its ears at an approximate angle of 10°. The results of the pitching moment coefficient are inconclusive in determining if the large ears are important as flight control structures. The additional drag produced by the ears has consequences for the foraging behaviour of *P. auritus* with reductions in its flight speed and foraging range.

**Key words:** Chiroptera, flight, ear, aerodynamics, *Plecotus auritus*

**INTRODUCTION**

Variation in the shape and size of the wings has a clear relationship with feeding preferences in bats. A bat with a high wing loading (high ratio of body mass to wing area) and high aspect ratio wings (long and thin) is likely to use fast foraging flight in open areas whilst catching insects from the air, whereas a bat with a low wing loading and low aspect ratio wing is more likely to use slow flight amongst vegetation whilst gleaning insects from surfaces (Baagøe, 1987; Norberg, 1987; Norberg and Rayner, 1987). Bats are also distinguished by differences in the ears and tail which may also have an important influence on the aerodynamics of flight (Fenton, 1972; Bullen and McKenzie, 2001). Although these studies have suggested that ancillary structures play an important role in the aerodynamics of flight, no direct measurements of the forces and moments have been made.

The brown long-eared bat (*Plecotus auritus*) is a common European species that is remarkable for the very large size of its ears (length 29–41 mm) which are almost the same length as its forearms (34–42 mm — Altringham, 2003). For such structures to have evolved there must be a significant benefit. For example, it has been shown that bats with long ears are superior at avoiding thin wires stretched across their flight paths when compared to other bats with smaller ears (Griffin, 1958). Behavioural studies of *P. auritus* lead to similar conclusions about their hearing ability, since they often emit very quiet or no echolocation calls whilst gleaning prey, relying instead upon passive listening (Anderson and Racey, 1991). Furthermore studies of the acoustic properties of the outer ear have shown that the large ears possessed by many gleaning species are particularly sensitive at low frequencies, which aid prey detection by passive listening (Coles *et al*., 1989; Obrist *et al*., 1993). However, not all gleaning species adopt this technique, some species such as *Myotis nattereri* have been observed to carry on echolocating whilst gleaning and to make little use of prey-generated sounds (Swift and Racey, 2002). Therefore the large ears of *P. auritus* may have evolved to be highly effective at detecting prey-generated sounds, particularly the initial detection of faint sounds which
Roosts and activity areas of *Nyctinomops macrotis* in northern Arizona

RICHARD JASON M. CORBETT1, CAROL L. CHAMBERS1,3, and MICHAEL J. HERDER2

1School of Forestry, Northern Arizona University, Flagstaff, Arizona 86011, USA
2Bureau of Land Management, Arizona Strip Field Office, St. George, Utah 84790, USA
3Corresponding author; E-mail: Carol.Chambers@nau.edu

Female big free-tailed bats *Nyctinomops macrotis* have been captured over water in northern Arizona in high elevation (> 2,400 m) forests and low elevation (1,500 m) desert scrub vegetation. We hypothesized that roost sites were in vertical walls of cliffs that were up to 25 km away from capture sites given the flight capability of these bats. During summer 2005 we captured eight females over ponds and attached radio transmitters to locate day roosts. We also identified locations used during nightly movements from 1 to 6 nights of radio tracking. We found three day roosts for seven bats; average distance (± SE) from a capture site to a roost was 12.1 ± 3.0 km. Roosts were small maternity colonies used by ≥ four *N. macrotis* in cracks or crevices in upper portions of vertical cliffs and faced south or southeast. Average dimensions for ponds where we found *N. macrotis* were 24 × 46 m, larger than the average pond size (14 × 19 m) where we did not capture this species. We identified 73 night locations for five *N. macrotis* and for one individual with 32 night locations calculated a 95% activity area (minimum convex polygon method) of 29,590 ha. Straight line distance between successive locations averaged 5.1 ± 0.8 km. Maximum distance detected from roost averaged 25.3 ± 4.9 km. We conservatively estimated a maximum flight speed of 61 km per hour. Most locations were in desert scrub vegetation but three bats moved to higher elevations, using pinyon-juniper (*Pinus edulis-Juniperus* spp.) woodland and ponderosa pine (*Pinus ponderosa*) forest. The maternity roosts we located for *N. macrotis* were remote, difficult to access, and within protected areas (national parks) in northern Arizona; however, foraging areas and ponds used for drinking are managed by different public or private agencies. These features are not as well protected and could be critically important in this arid environment.

Key words: Arizona, big free-tailed bat, minimum convex polygon, movement, *Nyctinomops macrotis*, radio telemetry, roost

INTRODUCTION

*Nyctinomops macrotis* is found in the southwestern United States, northern and central Mexico, and portions of South America and the Caribbean (Borell, 1939; Jones, 1965; Milner et al., 1990; Forester et al., 1997; Jackson and Herder, 1997; Constantine, 1998; Navo and Gore, 2001; Geluso, 2002; Hinman and Snow, 2003). This species forages in lowland and desert riparian areas (Forester et al., 1997; Jackson and Herder, 1997; Hinman and Snow, 2003), and mid to high elevation forests (Jones, 1965; Mollhagen and Bogan, 1997; Rabe et al., 1998; Hinman and Snow, 2003). Roosts have been found in tall, vertical cliffs and occasionally in buildings and tree cavities (Findley et al., 1975; Milner et al., 1990; Navo and Gore, 2001). Day roosts described in published literature (e.g., Borell, 1939; Easterla, 1972; Bogan et al., 1998; Navo and Gore, 2001) were maternity colonies located in cracks near the tops of vertical sandstone cliffs. Four to several hundred *N. macrotis* were visually observed at these roosts (Borell, 1939; Easterla, 1972; Bogan et al., 1998; Navo and Gore, 2001).

There is little published information describing foraging and reproductive ecology for *N. macrotis*. Reproduction is energetically expensive, especially during lactation (Speakman and Racey, 1987; Heideman, 2000). Bats accommodate changing energy demands by altering foraging locations and prey to maximize benefits from changing conditions (Belwood and Fenton, 1976; Anthony et al., 1981; Racey and Swift, 1985; Rydell, 1989; Jones, 1990). Dietary studies indicate *N. macrotis* pursues and captures flying insects (e.g., lepidopterans, coleopterans, hemipterans — Ross, 1967; Easterla and Whitaker, 1972; Freeman, 1981; Ochoa et al., 1988; Sparks and Valdez, 2003; Debelica et al., 2006). This species is a rapid flier, capable of moving long distances (Norberg, 1987; Milner et
Bats select buildings in clearings in Białowieża Primeval Forest

KAROLINA MAZURSKA1 and IRENEUSZ RUCZYŃSKI2, 3

1Warchałowskiego 3/23, 02-776 Warszawa, Poland
2Mammal Research Institute, Polish Academy of Sciences, Waszkiewicza 1, 17-230 Białowieża, Poland
3Corresponding author: E-mail: iruczyns@zbs.bialowieza.pl

Species dominance structure and selection of buildings by bats were studied during the breeding season in areas surrounding the well-preserved stands of Białowieża Primeval Forest (BPF), potentially offering an abundance of tree cavities. Searches for bats were carried out during daylight hours and at evening emergence. Thirty eight of the 238 buildings surveyed from May to August, 2002 were used by 708 bats. Only three of the 12 resident species of bats occupied buildings, amongst these Vespertilio murinus and Eptesicus serotinus were the most common, found in 16 and 15 buildings, respectively. Pipistrellus pygmaeus was located in two buildings. This suggests that limited access to old-growth forests (potentially rich in tree cavities) may not be a crucial factor leading to the occupation of buildings by those species. Selection of buildings by bats was further investigated by comparing 14 characteristics of those buildings occupied by bats to those unused. Six of these characteristics were shown to have a significant influence. Using Akaike’s Information Criterion (AICc), the most important categories for selection were roof lining and building size. This would suggest that the criterion for the selection of buildings by these species is based not only on its location but on these key structural attributes.

Key words: Eptesicus serotinus, Vespertilio murinus, roost selection, conservation

INTRODUCTION

Summer roosts are critical resources for bats. Their availability and quality can influence their breeding success and distribution (Kunz and Lumsden, 2003). Therefore, knowledge concerning roost selection by bats is crucial for their conservation. Formerly, bats used only natural roosts such as tree holes and crevices (e.g., Nyctalus leisleri — Ruczyński and Bogdanowicz, 2005; Plecotus auritus — Heidecke, 1983; Pipistrellus nathusi — Heise, 1973), spaces under tree bark (e.g., Barbastella barbastellus — Russo et al., 2004), caves (e.g., Myotis myotis — Palmeirim, 1987) or rock crevices (e.g., Eptesicus fuscus — Lausen and Barclay, 2006). In the recent evolutionary history of bats man-made structures have appeared, providing bats with alternatives comparable to caves and tree cavities (Kunz, 1982). Examples include attics, cellars, crevices in buildings, spaces between concrete slabs in prefabricated-houses and spaces inside or under bridges (for reviews Kunz, 1982; Schober and Grimmberger, 1989; Reid, 1997). In habitats changed by man, buildings remain the most important roost resources for many species of bats e.g., Eptesicus serotinus, Vespertilio murinus, P. auritus (Entwistle et al., 1997; for review Baagøe, 2004a, 2004b; Horáček and Đulić, 2004).

Only a few studies in Europe have focused on comparisons between buildings used and unused by bats (Entwistle et al., 1997; Jenkins et al., 1998; Holzhaider and Zahn, 2001). Bats select roosts in buildings according to particular features, e.g. the presence of a full lining of wooden boarding (sarking) of the attic (Entwistle et al., 1997); distance from the roost to the nearest forest, watercourse, or pond (Speakman et al., 1991; Entwistle et al., 1997; Jenkins et al., 1998); and the risk of predation (Jenkins et al., 1998). Data about building selection by bats from eastern and middle Europe, where a stronger influence of continental climate is observed and where habitats are less modified than in Western Europe are still scarce.

In order to test this we have searched for bats in buildings situated in the vicinity of the well preserved forest stands of BPF, an area rich in natural tree cavities (Walankiewicz, 1991; I. Ruczyński, unpublished data). Given the abundance of alternative
The influence of riparian vegetation on the distribution and abundance of bats in an African savanna

ARA MONADJEM1, 2 and APRIL RESIDE1

1All Out Africa Research Unit, Department of Biological Sciences, University of Swaziland, Private Bag 4, Kwaluseni, Swaziland
2Corresponding author. E-mail: ara@uniswacc.uniswa.sz

Riparian habitats are known to be important for bats across the world, however this is largely unstudied in Africa. We investigated the community structure of bats in riparian areas and the surrounding savanna landscape in Swaziland’s lowveld using mist nets and a harp trap. We found riparian sites overall had higher bat activity, diversity, species richness and abundance. One species (Epomophorus wahlbergi) accounted for 52.6% of captures. Seasonality had no effect on overall captures, nor did distance from nearest riparian habitat for savanna sites. Echolocation guilds were correlated with vegetation characteristics, with CF (constant frequency), FM (steep frequency-modulated) and FM-QCF (broadband FM) bats more frequently captured at sites with denser undergrowth than QCF (quasi-constant frequency or narrowband FM) bats; conversely, QCF bats were more frequently caught at sites with lower canopy cover than other bats. Our findings suggest that although bats discriminate between microhabitats, they do not respond to larger-scale habitat features in the way that other taxa, such as birds, are found to. In conclusion it appears that riparian areas are important foraging sites for bats within African savannas.

Key words: community structure, riparian forest, savanna, Swaziland, Africa

INTRODUCTION

Savannas cover some 60% of sub-Saharan Africa and support a high diversity of vertebrates including birds and mammals (Scholes and Walker, 1993). African savannas are rarely homogenous, instead plant species composition tends to vary with the underlying soils, rainfall, fire and herbivory (Scholes, 1990). Furthermore, rivers and streams cut through creating linear strips of riparian vegetation. These riparian strips typically support lush forest, and associated fauna, which sharply contrasts with the adjoining dry savannas. For example, species composition and density of birds differ greatly between the riparian strip and adjacent savanna (Monadjem, 2005), greatly increasing the local avian diversity of sites with riparian forest. While this association has been shown for birds, little is known on how riparian habitats affect the distribution and abundance of bats in the same habitat.

Bat species richness patterns have been better studied on other continents: in the New World tropics, bat species richness decreases with increases in latitude (Willig and Selcer, 1989). Altitudinal gradients are also well documented in neotropical bats (Graham, 1983; Patterson et al., 1996). Similar studies are lacking for sub-Saharan Africa, although generic diversity appears to be highest in equatorial East Africa, decreasing to the south and west (Hutson et al., 2001). Within specific African biogeographic regions, diversity of species may be affected by the availability of suitable habitat (Fenton et al., 1977; Henry et al., 2004), roost sites (Cotterill and Ferguson, 1999), and other factors such as elephant impact on the vegetation (Fenton et al., 1998).

Quantification of habitat factors typically involves inter alia measuring vegetation cover at different strata (Herremans, 1993; Monadjem, 2005). Such habitat studies have been conducted on bats in subtropical savannas of South America (Aguirre, 2002) and Australia (Milne et al., 2005). But the habitat preferences of African bats have only been described qualitatively. For example, species have been described as being forest or savanna dwelling (Fahr and Ebigbo, 2003; Decher et al., 2005). Furthermore, little is known about the community structure of African bats. O’Shea and Vaughan (1980) recorded 26 species in a dense bushland savanna in East Africa, but did not examine habitat preferences. A few African studies have reported correlations...
Bat diversity in tropical forest and agro-pastoral habitats within a protected area in the Philippines

JODI L. SEDLOCK1, 2, 4, SARAH E. WEYANDT2, 3, LAURA CORORAN1, MARIN DAMEROW1, SHI-HSIA HWA1, and BENJAMIN PAULI1

1Biology Department, Lawrence University, P.O. Box 599, Appleton, WI 54911, USA
2Department of Zoology, The Field Museum, 1400 S. Lakeshore Drive, Chicago, IL 60605, USA
3Committee on Evolutionary Biology, University of Chicago, 1025 E 57th Street, Chicago, IL 60637, USA
4Corresponding author: E-mail: sedlockj@lawrence.edu

Parks and other protected areas in tropical forests often include secondary forest, cropland, and pasture. Documentation of the impact of such anthropogenic disturbance is essential for effective management. We re-sampled bats within Mount Isarog Natural Park (MINP), a protected area in southeastern Luzon, Philippines, seventeen years after a survey in old- and second-growth forest and in agro-pastoral areas was conducted in 1988. By employing harp traps and a tunnel trap, in addition to mist nets as used in the earlier study, we aimed to document species previously undetected by mist netting alone. We documented 26 bat species, seven of which were captured exclusively in harp traps, and two that were only captured in a tunnel trap. This survey resulted in nine new records of bat species for MINP, bringing the total number to 30. We did not recapture four species documented in 1988, all of which we noted in that study as uncommon. Nineteen species were captured in agro-pastoral areas on the south slope, including two Hipposideros spp. not captured at the forested sites.

Key words: agriculture, altitudinal gradient, fragmentation, Hipposideridae, re-sampling, Rhinolophidae, Vespertilionidae

INTRODUCTION

Former areas of tropical forest have been converted into crop fields, pastures and orchards in many of the world’s biodiversity hotspots (Myers et al., 2000; Achard et al., 2002). Disturbed habitat often is present within officially protected areas, either as remnant anthropogenic disturbance pre-dating its protected status, or is associated with resident human populations and weak enforcement of natural resource regulations (Bruner et al., 2001; Liu et al., 2001; Geist and Lambin, 2002; Curran et al., 2004; Verburg and Veldkamp, 2004; DeFries et al., 2005; Gaveau et al., 2007). Facing this reality, wildlife biologists are working to understand the effects of forest conversion on threatened species (e.g., Laurance, 1997; Kinnaird et al., 2003; Watling and Donnelly, 2006), and ultimately, how coexistence of wildlife and humans may be effectively managed (Lynch and Urich, 2002; Rindfuss et al., 2004; Robbins et al., 2006; McAlpine et al., 2007).

In the mountainous and biodiversity-rich Philippine archipelago, the great majority of accessible forest — in the lowlands and along gentle slopes — has been logged and cleared for agriculture or converted to secondary forest (Snelder, 2001; Verburg and Veldkamp, 2004). Despite the establishment of the National Integrated Protected Areas System (NIPAS) in 1992 (DENR-PAWB, 1992), land conversion for agriculture continues within many protected areas (Coxhead et al., 2002; Lynagh and Urich, 2002; Verburg et al., 2006). As a result, lowland forest remnants in some mountainous protected areas are shrinking, possibly at the expense of lowland-restricted forest-obligate species (Goodman and Gonzales, 1990; Brooks et al., 1999; Peterson et al., 2000). Philippine bats may be especially threatened, given that their diversity peaks at low elevations (Heaney et al., 1989; Rickart et al., 1991, 1993; Utzurrum, 1998), many endemic species exhibit a strong affinity to old-growth forest (Utzurrum, 1998), and cave roosts are often heavily disturbed by guano mining, treasure hunting, and ecotourism (Urich et al., 2001).

Between 1988 and 1990, Heaney et al. (1999) conducted an intensive mammal field inventory on
INTRODUCTION

Effective management of assemblages, species, and populations of animals requires information concerning the number of individuals present or, at least, knowledge of whether numbers are increasing or decreasing. Unfortunately, small size, nocturnal behavior, and cryptic roost sites make it impossible to obtain estimates of total population size for most North American bats (Kunz, 2003), except a few highly gregarious species, such as the Indiana bat, *Myotis sodalis* (Clawson, 2002). Even knowledge of simple trends in population size is limited and primarily comes from counts made at isolated roosts of a few colonial species (Ellison *et al*., 2003). However, it also is possible to obtain information on long-term changes in relative abundance of species and to infer whether a particular population is increasing or decreasing by replicating surveys of an entire assemblage in different years (e.g., Whitaker *et al*., 2002). It is essential, though, that the species in question have known detection probabilities or that studies completed at different times have comparable methodology for comparisons to be meaningful (Conroy and Nichols, 1996; Winhold and Kurta, 2008).

Although acoustic surveys of bat assemblages are becoming increasingly common, most summer surveys in North America during the latter half of the 20th century involved mist-netting (Kunz and Kurta, 1988). Mist-netting studies, however, typically have not been replicated over time by the original workers, possibly because of the labor-intensive nature of the technique. Furthermore, published accounts of netting surveys seldom provide sufficient methodological information to insure comparability of techniques during repeat surveys by new workers (Winhold and Kurta, 2008). Hence long-term information on entire bat assemblages from North America is rare.

In southern Lower Michigan, USA, the regional bat assemblage potentially consists of seven vesper-tilionid insectivores, with two additional species known from single sites that recently were discovered near the southern border (Kurta, 1995, 2008; Kurta *et al*., 2005, 2007). We have been studying bats in this region since 1978, which allows us to examine long-term changes in the assemblage using...
An experimental test of gating derelict mines to conserve bat roost habitat in southeastern Australia

CHRISTOPHER P. SLADE¹,² and BRADLEY S. LAW³

¹University of New England, Ecosystem Management, Armidale NSW 2351, Australia
²Present address: Forests NSW, Department of Primary Industries, Central Region Maher Street, Wauchope NSW 2446, Australia
³Science and Research, Department of Primary Industries, PO Box 100, Beecroft NSW 2119

Management of derelict mines to improve subterranean bat habitat and minimise safety risks to the unsuspecting public is occurring more frequently. Many caves and mines around the world have had gates placed at mine and cave entrances as a means of maintaining bat habitat and preventing human access, but there have been few replicated experiments to test their effectiveness. We experimentally tested a staged installation of a template gate at two mines while monitoring another two un-gated derelict mines in southeastern Australia. We recorded changes in numbers, behaviour and the relative species abundance of two bat species (Rhinolophus megaphyllus and Miniopterus schreibersii) before and after the gates were installed. The template gate (20 mm diameter plastic tubing) was installed in three stages, with the initial horizontal bar spacing at 450 mm, followed by a spacing of 300 mm and a final spacing of 125 mm. Bat numbers and behaviour were largely unaffected by bar spacings of 450 mm and 300 mm. The major findings were that immediately after the installation of bars at the final spacing (125 mm gap), numbers of bats declined significantly and a significant increase in the number of aborted exit and entry flights was observed. Detectors proved to be inadequate at quantifying changes in the relative abundance of species. Eleven days after the final installation there were no significant differences between the numbers of bats leaving gated and control mines, suggesting bats had learnt to negotiate the bars after a short period of time. However, flight behaviour was still affected after habituation, especially baulking at the structure when bats attempted to re-enter before dawn. The low replication of mines in the experiment warrants caution in extrapolating this result. Until further gating experiments are carried-out, we recommend site specific monitoring whenever mines are gated.

Key words: Rhinolophus megaphyllus, Miniopterus schreibersii, derelict mine, gates, experiment

INTRODUCTION

Disturbance to natural bat roosts has increased to the point where many subterranean roosting species have been listed on threatened species legislation (e.g., The Endangered Species Act, 1973 in the USA and the New South Wales Threatened Species Conservation Act 1995 in Australia). At least 40% of bats in the USA are listed as endangered or of federal concern (Flemming, 2000; Sherwin et al., 2000). Threats to bats are often the result of development and disturbance to natural roosts by increasingly high levels of human visitation (Currie, 2000b; Ducummon, 2000; Flemming, 2000). The disturbances to natural bat roosts can result in the abandonment of hibernation and maternity caves (White and Seginak, 1987; Tuttle and Taylor, 1998; Ludlow and Gore, 2000; Thomson, 2002). Noise, light and tactile disturbances to bats in torpor can reduce duration of torpor bouts with subsequent weight loss exhibited by individuals as the energy reserves are used (Thomas et al., 1990; Speakman et al., 1991). Disturbance at cave roosts has led to a greater reliance on derelict mines as important habitat for bats (Burghardt, 2000; Currie, 2000b; Ducummon, 2000), with some of the largest remaining bat populations in North America roosting in mines (Ducummon, 2000). Derelict mines can meet a range of habitat needs such as maternity sites, biogeographically significant sites, taxonomic reference points, day roosts, hibernacula and dispersal stopover roosts (Hall et al., 1997).

The successful management of derelict mines is vital given the biological importance of mines to roosting bats. Gating across the mine entrance is an obvious management option because gating a mine adit generally requires a barrier to be constructed across a conveniently small area. This option,
Flying-fox (Megachiroptera: Pteropodidae) flight altitudes determined via an unusual sampling method: aircraft strikes in Australia

JENNIFER G. PARSONS1, 3, DAVID BLAIR1, JON LULY2, and SIMON K. A. ROBSON1

1School of Marine and Tropical Biology, James Cook University, Townsville, QLD 4811, Australia
2School of Earth and Environmental Sciences, James Cook University, Townsville, QLD 4811, Australia
3Corresponding author: E-mail: jennifer.parsons@jcu.edu.au

Key words: altitude, flying fox, height, migration, wildlife strike

INTRODUCTION

The nocturnal behaviour of bats makes it difficult to determine their foraging habits at night, especially in regards to the height or altitude at which they fly. This is particularly true for the larger flying foxes that can travel up to 40 km in a single night (Spencer et al., 1991; Parsons et al., 2006). Despite the value of such information for many aspects of the foraging ecology and ecophysiology of bats, gathering information on the flight altitudes used by bats remains a challenge that has led to the use of inventive sampling techniques. Active radar systems monitoring aircraft movements have detected the Mexican free-tailed bat (Tadarida brasiliensis) flying at altitudes of over 3,000 m (10,000 feet) (Williams et al., 1973), while helium filled kite balloons in combination with bat echolocation detection devices have identified molossid and emballonurid bats foraging at heights of almost 600 m (1968.5 feet) (Fenton and Griffin, 1997). The diurnal Samoan flying fox, Pteropus samoensis, has been observed soaring on thermal updrafts (Richmond et al., 1998; Lindhe Norberg et al., 2000; Thomson et al., 2002), but unfortunately knowledge on the actual flying altitude of this or any other pteropodid species remains unknown.

Wildlife strike to aircraft is a major safety issue throughout the world, with most strikes on a global scale being a result of impact with birds (MacKinnon et al., 2001; Thorpe, 2003). In Australia and throughout the tropics however, large bats (e.g., Pteropus spp.) also collide with aircraft in significant numbers (Christidis et al., 2006; J. G. Parsons, D. Blair, J. Luly, and S. K. A. Robson, unpublished data). The large body mass of flying foxes and their habit of leaving roosts in large congregations makes them particularly damaging to aircraft. As part of a long-term program to minimise the risk of animal strike the Australian Transport Safety Bureau (ATSB) maintains a data base on the details of animal strikes involving plane within Australia. Here we use an unusual sampling design, the information provided in the ATSB database, to determine the altitudes at which flying foxes fly.

MATERIALS AND METHODS

Information was obtained by integrating the ATSB database for the period 1996–2006, the most recent period for which data is available. The database typically contains information on the location of strikes (with reference to local airports, altitude), the type of aircraft involved and any damage received, and the identity of the impacting organisms if known. Identification of species can be made visually if a strike is witnessed by pilots or by the identification of carcasses or other remains by ground crew. Strike locations can include sites outside of Australia, if they involve Australian aircraft. Reports can be submitted by a variety of airport staff but they are usually submitted by the aircrew involved in the incident or afterwards during inspections. Such reporting is mandatory in Australia under the Transport Safety Investigation Act of 2003.

We obtained all records from the database that included the terms ‘bat’, ‘fruit bat’ or ‘flying fox’ anywhere in the database, as well as information on the altitude of the collision. Although it is not possible to determine the species of bats involved in collisions based on the records in the ATSB database, we are confident that the majority are larger flying foxes as the larger body mass of Australian flying foxes (typically greater than 500 g — Churchill, 1998) means they are more likely to cause damage to aircraft. Smaller animals such as tiny birds and microchiropteran bats, in concern with modern aircraft design, tend to pass through or around engines and are much less likely to cause detectable damage to the plane (MacKinnon et al., 2001). All heights are listed as feet above ground level, the usual practice of the airline industry.
Mistakes in the formation of species-group names for Neotropical bats: *Micronycteris* and *Sturnira* (Phyllostomidae)

**SERGIO SOLARI**1, 2, 3

1Instituto de Biología, Universidad de Antioquia, A.A. 1226, Medellín, Colombia
2Nomenclature Committee, American Society of Mammalogists, Lawrence, KS 66044, USA
3E-mail: ssolari@matematicas.udea.edu.co

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Nomenclatural rules for creating species, genera, and family group names are found in the International Code of Zoological Nomenclature (ICZN, 1999), hereinafter referred to as the Code. The Nomenclature Committee of the American Society of Mammalogists (ASM) offers advice on its interpretation for fellow mammalogists. Over the last few years, I have become aware of certain inconsistencies and mistakes in the formation of species-group names (names of species and subspecies) based on personal names and applied to Neotropical bats of the family Phyllostomidae. Therefore, it is important to discuss these mistakes in the context of a proper use of those Nomenclature rules.

My intention here is to provide guidance for authors describing new species and for subsequent users of the names created thereby. The formation and subsequent changing of names are subject to rules which are sometimes ignored or misapplied. In particular, I will be discussing certain aspects of what does and does not constitute ‘incorrect original spellings’ that may properly be subject to emendation. Herein, I present examples involving names based on modern personal names and for species of Neotropical bats of the genera *Micronycteris* Gray 1866 (Phyllostominae) and *Sturnira* Gray 1842 (Stenodermatinae).

Pirlot (1967) described a subspecies of *Micronycteris* from western Venezuela, and named it *M. megalotis homezi*. After introducing the new name, the author made clear his gratitude to Professor J. Homez and to M[onsieur] A. Homez (owners of the property where Pirlot caught the type specimen; p. 265). The status of this taxon was essentially ignored for almost 30 years, until Simmons and Voss (1998) reported additional specimens from French Guiana and validated use of the name at the species level. However, Ochoa and Sanchez (2005) reviewed the bats which had been referred to in the literature as *M. megalotis* (Gray), *M. minuta* (Gervais), and *M. homezi*, and concluded that *homezi* was a junior synonym of *minuta*.

Peterson and Tamsitt (1968) described a new species of *Sturnira* from northwestern South America, which they named *S. aratathomasi*. In their introduction (p. 1), the authors made it clear that it was their intention to honor the contributions of Mr. Maurice Thomas and Dr. Andrew Arata, both of Tulane University, who had obtained the specimen. A similar instance occurred when McCarthy et al. (2006) described a new species from the Chocó of Ecuador and Colombia, and named it after Karl F. Koopman and John E. Hill (p. 102), as *S. koopmanhilli*.

The current edition of the Code (ICZN, 1999) has detailed criteria for formation of new species-group names. These are given in Art. 31, including names formed from personal names. Thus, Art. 31.1.2 states that a species-group name formed directly (without being Latinized) from a modern personal name is to be formed by adding any of the four specific endings as is appropriate. However, the Code (Art. 32.5) does not explicitly designate names with incorrect endings as constituting incorrect original spellings which are subject to emendation. However, there are cases in which such emendation has been done (e.g., Groves, 1993; *Aotus nancymai* Hershkovitz 1983 to *A. nancymaae*, after Nancy Ma, a woman). The issue is debatable (see Brandon-Jones et al., 2007; Dubois, 2007) but, in the interest of long-term stability, the original spelling should be preserved when there is no evidence of