Three new species of *Murina* from southern China (Chiroptera: Vespertilionidae)

JUDITH L. EGER1, 2 and BURTON K. LIM1

1Department of Natural History, Royal Ontario Museum, 100 Queen’s Park, Toronto, Ontario, Canada, M5S 2C6
2Corresponding author: E-mail: judithe@rom.on.ca

The biodiversity of tube-nosed bats (Murininae) from Asia has been underestimated by over 50%. Since 2005, eight taxa have been documented as distinct from the 19 previously known species. We describe three new species of *Murina* collected in southern China between 2004 and 2007. These species differ morphologically, morphometrically, and genetically from previously described species of *Murina*. Morphological differences include pelage color, size, skull shape and tooth morphology. Analysis of mitochondrial DNA barcodes of the cytochrome c oxidase subunit I (COI) gene supports species status based on divergent phylogenetic lineages.

**Key words**: COI, DNA barcodes, morphometrics, Murininae, Southeast Asia, tube-nosed bats

INTRODUCTION

Characterized by tubular nostrils, the subfamily Murininae Miller, 1907 consists of 19 species that range from Pakistan and Siberia eastward to Japan, Taiwan, Papua New Guinea and Australia (Simmons, 2005). Typically, these species are rare in collections, and this rarity has contributed to a poor understanding of their diversity and distribution. However, there has been an increase in biodiversity surveys in southeast Asia since the late 1990s, which has resulted in the description of eight new species in the subfamily based on morphological study: *Murina harrisoni* from Cambodia (Csorba and Bates, 2005), *Harpiola isodon* from Taiwan (Kuo et al., 2006), *Murina tiensa* from northern Vietnam (Csorba et al., 2007), *M. harpioloides* from southern Vietnam (Kruskop and Eger, 2008), *M. bicolor*, *M. gracilis* and *M. recondita* from Taiwan (Kuo et al., 2009), and *M. eleryi* from northern Vietnam (Furey et al., 2009).

Since 2003, DNA barcoding of the mitochondrial gene cytochrome c oxidase subunit I (COI) has been a useful taxonomic tool in combination with traditional morphology for species identification and discovery (Hebert et al., 2003). In a study summarizing DNA barcodes of almost 1,900 specimens of bats from Southeast Asia (Francis et al., 2010), there were 18 divergent lineages of *Murina* recognized, of which five or more lacked assignable species names. One of these unnamed lineages was referred to by Francis et al. (2010) as *Murina* JLE sp. H. Additional COI sequences indicate that there are two more lineages that are unlike any other species of *Murina*. Morphological study of external features, cranial anatomy, and multivariate analysis confirms the distinction of these taxa. The purpose of this paper is to describe these new species of *Murina* which were collected in southern China.

**MATERIALS AND METHODS**

For morphometric analysis, we examined 44 specimens of *Murina* deposited in collections of the Museum National d’Histoire Naturelle, Paris (MNHN); the Rijksmuseum van Natuurlijke Historie, Leiden (RMNH); the Royal Ontario Museum, Toronto (ROM); and the Zoological Museum of Moscow University, Moscow (ZMMU) (Appendix). External body measurements to the nearest 1 mm were recorded with a ruler in the field and body mass was recorded to the nearest 1 g using a Pesola 100 gram spring scale. In the lab, wing measurements of dry and alcohol-preserved specimens and cranial measurements were recorded to the nearest 0.1 mm using Mitutoyo digital calipers and a stereoscope.

External measurements include: TL: total length — from the tip of the face/chin to the tip of the tail; TV: tail vertebrae length — from the tip of the tail to the beginning of the tail vertebrae; HF: hind foot length — from the heel to the tip of the longest toe, including the claw; EAR: ear length — from the base of the ear where it attaches to the head to the tip of the pinna; TRAG: length of tragus — from the point where the proximal edge of the tragus joins the bottom of the ear to the tip of the tragus; TIB: length of tibia — from the knee to the ankle; FA: forearm...
Two species are currently recognised within the genus *Asellia*, a typical inhabitant of arid areas of northern Africa and south-western Asia. Most of the distribution range of the genus is covered by *Asellia tridens*, while the other species, *A. patrizii*, is restricted to Ethiopia, Eritrea and several Red Sea islands. We analysed the morphological variation in an extensive set of *Asellia* samples covering the range of the genus, including most of the available type material. In a representative subset of samples, we employed molecular genetic analysis to infer the phylogenetic relationships within the broadly distributed *A. tridens*. Morphological comparisons revealed four distinct morphotypes. Except for the endemic *A. patrizii*, almost all African *Asellia* were found to belong to the same morphotype as most of the Middle Eastern specimens. This morphotype was unambiguously identified as *A. tridens*. Two other morphotypes of tentative *A. tridens* were further recognised based on skull shape differences; one in the southern Arabian region of Dhofar, the other in Socotra and Somalia. Phylogenetic analysis of complete sequences of the mitochondrial cytochrome *b* gene yielded three main monophyletic groups, which corresponded to the morphotypes revealed for *A. tridens*. Significant genetic divergences reaching over 5% and 12%, respectively, were discovered between them. Based on the morphological and molecular data obtained, we propose a split of the current *A. tridens* into three separate species: *A. tridens* in northern Africa and most of the Middle East, *A. italosomalica* in Socotra and Somalia, and *Asellia* sp. nov. in southern Arabia. Molecular dating, along with the available paleontological information and geological history of the Arabian Peninsula, supports an Arabian origin of the contemporary *Asellia*. While profound divergence of the Socotran form may be linked to the split of Socotra from the southern Arabian coast in the Middle Miocene, the low sequence variation of *Asellia* in most of Africa and the Middle East suggests a relatively recent colonisation of this vast area during the Pleistocene. The newly described form from southern Arabia most likely represents a relic of aridisation during the Miocene–Pliocene transition.

**Key words**: *Asellia*, morphology, morphometry, mtDNA, taxonomy, phylogeny
A new mouse-eared bat (Mammalia: Chiroptera, Vespertilionidae) from South China

Mikhail P. Tiunov1,4, Sergei V. Kruskop2, and Jiang Feng3

1Institute of Biology and Soil Science Far East Branch of the Russian Academy of Sciences, Vladivostok 690022, Russia
2Zoological Museum, Moscow State University, Bolshaya Nikitskaya 6, Moscow 125009, Russia
3College of Urban and Environmental Sciences, Northeast Normal University, Changchun 130024, People’s Republic of China
4Corresponding author: E-mail: tiunov@ibss.dvo.ru

A small Myotis species belonging to the Myotis siligorensis group was found in four caves in Yunnan province, South China. Twenty specimens of this bat were compared with other East Asian Myotis species. Statistical and physical analysis of this sample demonstrates that, despite their similarity to M. siligorensis, the Yunnan specimens have characteristics of baculum morphology and cranial proportions suggesting that they represent a distinct species.

Key words: Myotis sp. nov., taxonomy, baculum, South China

INTRODUCTION

The genus Myotis is amongst the largest mammalian genera (Simmons, 2005). Its internal structure is very problematic since the traditionally accepted affiliations between Myotis species were called into question by recent molecular studies (Ruedi and Mayer, 2001; Zang et al., 2009; Lack et al., 2010). Thus the genus includes numerous species complexes with questionable and uncertain taxonomy. One of these is the Myotis ‘siligorensis’ species group. This group was initially proposed for only one species (Tate, 1941), characterized by small size, formal features of the subgenus Selysius, low rostrum, abruptly elevated frontal profile and small canines. Within this species four geographical races were usually recognized (Ellerman and Morrison-Scott, 1966; Simmons, 2005). This species group was accepted by e.g. Koopman (1994) but not defined in the latest published checklist (Simmons, 2005). It was considered to be a good taxonomic unit by Borisenko et al. (2008) and an additional species — Myotis phanluongi — was described. Here we suggest inclusion into this group of several other Asiatic species of similar size and skull proportions, namely Myotis laniger, M. longipes, M. annamiticus, M. taiwanensis and M. csorbai. This proposal is supported by molecular data (Borisenko et al., 2008; Zhang et al., 2009; Francis et al., 2010). Being distributed sporadically and not very well represented in scientific collections, bats of this species group are insufficiently investigated taxonomically.

In June 2006, during joint field work supported by the Russian Foundation for Basic Research (RFBR) and the National Natural Science Foundation of China (NNSFC), scientific voucher specimens of bats were collected from Yunnan province (southern China). The collection includes several specimens of small mouse-eared bats (genus Myotis) of uncertain taxonomic status. An analysis and comparison of the external and cranial morphological characteristics of these Myotis specimens indicate that they possess features that set them apart from other South Asian representatives of the genus Myotis. In our opinion, these mouse-eared bats, captured in Longxu, Xianren, Dashi, and Huyan caves (Yunnan province), represent a distinct species.

MATERIALS AND METHODS

Two males and 12 females of Myotis sp. nov. were captured in a mist net from Longxu Cave (24°30’N, 102°20’E); two females from Xianren Cave at Fagudian Village (24°30’N, 102°20’E); one male and two females from Dashi Cave (24°29’N, 102°22’E); and one male from Huyan Cave at Shuanghechang Village (24°29’N, 102°22’E). All are preserved in 75% ethanol with skulls extracted.

Forty-nine specimens of morphologically similar species were used for qualitative and quantitative morphological comparison (adult individuals of both sexes; dry or alcohol
Phylogeography and taxonomic status of the greater mouse-tailed bat
Rhinopoma microphyllum (Chiroptera: Rhinopomatidae) in Iran

Vahid Akmali1,2,5, Ali Farazmand3, Jamshid Darvish4, and Mozafar Sharifi2

1Department of Zoology, Faculty of Biology, College of Science, University of Tehran, 14155-6455, Tehran, Iran
2Department of Biology, Faculty of Science, Razi University, Baghabrisham 67149, Kermanshah, Iran
3Department of Cell and Molecular Biology, Faculty of Biology, College of Science, University of Tehran, 14155-6455, Tehran, Iran
4Rodentology Research Department, Faculty of Science, Ferdowsi University of Mashhad, 91735, Mashhad, Iran
5Correspondence author: v_akmali@khayam.ut.ac.ir

The taxonomic status of the greater mouse-tailed bat (Rhinopoma microphyllum) in Iran is not clear and researchers have reported conflicting results. The initial suggestion of the presence of two subspecies R. m. microphyllum and R. m. harrisoni has been questioned on the basis of small differences between the populations. These differing inferences are based on analysis of morphological characteristics. Here we present a study of the phylogeography of this species using 567 bp of the mitochondrial control region to infer the taxonomic status of this species. Based on the control region sequences, we found high genetic diversity in the Iranian population but variation between populations was not statistically significant. The phylogenetic trees and statistical parsimony network showed all Iranian samples were grouped in the same clade and Levant samples belonged to another clade. These results support the hypothesis that all Iranian specimens belong to one subspecies. We therefore recommend that R. m. microphyllum and R. m. harrisoni can be synonymized as the same subspecies with the name R. m. harrisoni, because molecular results indicate that Iranian samples differ from Levant and Moroccan samples (R. m. microphyllum).

Key words: Rhinopoma microphyllum, phylogeography, control region, Iran

INTRODUCTION

The greater mouse-tailed bat (Rhinopoma microphyllum) is a medium-sized bat with a free tail, inhabiting arid and semi-arid regions of the Old World. Records of R. microphyllum in Iran are restricted to the northern shores of the Oman Sea and the Persian Gulf and adjacent arid lands in the northern Mesopotamian plain where the climate is characteristically hot and prolonged in summer with no freezing period in winter (DeBlase, 1980). Although some reports indicate that R. microphyllum enters the Iranian plateau and stays in marginal areas of the Zagros range to the Mesopotamian plain for a short period in summer (Hemmati, 2001), this bat occurs mainly in dry lands of southern parts of Iran.

Rhinopoma microphyllum (Brünnich, 1782) is one of six species (R. microphyllum, R. muscatellum, R. hardwickei, R. macinnesi, R. cystops and R. hadramauticum) of the mouse-tailed bats (Rhinopomatidae) that are found in the arid and semi-arid regions of the Old World (Van Cakenberghe and De Vree, 1994; Hulva et al., 2007; Benda et al., 2009), covering about 12,000 km, from Sumatra and India in the east, the Middle East, and southern Asia, throughout Arabia, to north-western Africa (e.g., Hill, 1977; DeBlase, 1980; Van Cakenberghe and De Vree, 1994; Altringham, 1996; Schlitter and Qumsiyeh 1996; Simmons 2005; Hulva et al., 2007). Rhinopoma microphyllum is considered to be polytypic and four to six subspecies (R. m. microphyllum, R. m. sumatrae, R. m. kinneari, R. m. tropicallis, R. m. harrisoni and R. m. asiensis) have been reported (Hill, 1977; Koopman, 1994; Van Cakenbergh and De Vree, 1994; Simmons, 2005; Levin et al., 2008).

The taxonomic status of R. microphyllum subspecies in Iran is unclear, as different researchers have reported either one or two subspecies. Schlitter and DeBlase (1974) recognized R. m. harrisoni in southern Iran. According to these authors, R. m. harrisoni is smaller than R. m. microphyllum. In a more detailed survey of this genus, Hill (1977) confirmed the presence of two subspecies from Iran.
INTRODUCTION

Distinction in morphological characters is the most common feature used to identify species, and the presence of taximetric clusters is central to the phenetic definition of species (Michener, 1970; Sneath, 1973). Morphological differences are usually associated with genetic differentiation, the latter forming the base of the genetic species concept (Baker and Bradley, 2006). Although genetic analyses mostly confirm what morphological observations indicate, in case of cryptic species, situation is essentially reversed. In some cases, minor morphological differences between species, which comprise a cryptic complex, are noticed only after genetic data helped to delineate distinct lineages (Furman et al., 2010a). Sometimes, however, morphologically differentiated taxa share similar genetic lineages (Mayer and von Helversen, 2001), which poses many questions regarding their origin and evolution. The lesser and greater mouse-eared bats are a good example of the last category.

The lesser mouse-eared bat, Myotis blythii (Tomes, 1857), is present in Europe and Asia Minor, with its range extending further to Central Asia (Benda and Horáček, 1998). The greater mouse-eared bat, Myotis myotis (Borkhausen, 1797), occurs in Europe and western Asia Minor, reaching its easternmost border of distribution in Central/Eastern Anatolia (Arlettaz et al., 1997; Benda and Horáček, 1998). In Europe and Anatolia M. myotis and M. blythii are sympatric. Myotis blythii and M. myotis are distinguished by small differences in their size and cranial measurements (Spitzenberger, 1996; Evin et al., 2008; Aşan and Albayrak, 2011). Myotis myotis feeds largely on harder carabid beetles (Carabidae), while softer bush crickets (Orthoptera) constitute the main part of the M. blythii diet (Arlettaz, 1999; Pereira et al., 2002; Whitaker and Karataş, 2009). As differentiation in bats’ skull morphology is related to the size and hardness of insects they consume (Freeman, 1981; Redeker, 1983; Aldridge and Rautenbach, 1987), the cranium of M. myotis is more robust than the cranium of M. blythii (Spitzenberger, 1996). Because different food items are associated with distinct environmental domains, these species also differ in the selection of their foraging habitats; M. myotis tends to use...
Status and natural history of *Emballonura semicaudata rotensis* on Aguiguan, Mariana Islands

GARY J. WILES¹, ⁵, ⁸, THOMAS J. O’SHEA², DAVID J. WORTHINGTON³, ⁶, JACOB A. ESSELSTYN³, ⁷, and ERNEST W. VALDEZ⁴

¹Division of Aquatic and Wildlife Resources, 192 Dairy Road, Mangilao, Guam 96913, USA  
²United States Geological Survey, Fort Collins Science Center, 2150 Centre Avenue, Building C, Fort Collins, Colorado, 80526-8118, USA  
³Division of Fish and Wildlife, P.O. Box 1397, Rota, Commonwealth of the Northern Mariana Islands 96951, USA  
⁴United States Geological Survey, Fort Collins Science Center, Department of Biology, MSC03 2020, 1 University of New Mexico, Albuquerque, New Mexico 87131-0001, USA  
⁵Current address: Washington Department of Fish and Wildlife, 600 Capitol Way North, Olympia, Washington 98501-1091, USA  
⁶Current address: Capitol Reef National Park, Torrey, Utah 84775, USA  
⁷Current address: Biology Department, Life Sciences Building, Room 428, McMaster University, Hamilton, Ontario L8S4K1, Canada  
⁸Corresponding author: E-mail: wilesharkey@yahoo.com

Pacific sheath-tailed bats (*Emballonura semicaudata rotensis*) in the Mariana Islands declined greatly in abundance and distribution during the 20th century. The small island of Aguiguan now supports the only persisting population. We studied abundance and natural history of this population from 1995–2008. There was a likely population increase during the study, with 359–466 (minimum and maximum) bats counted at caves in 2008. Bats roosted only in caves, primarily those of relatively larger size. Bats were detected in only seven of 95 caves; three caves were always occupied when surveyed. One cave consistently had the largest colony (\( \bar{x} \pm SD = 333 \pm 33.6 \) in 2008). Others held 1–64 bats. Cave environments showed no complexities in temperature or humidity. Preliminary observations indicate a litter size of one and the possibility of birthing timed to coincide with the transitional period leading into the rainy season (June–July). We review potential threats to *E. s. rotensis* on Aguiguan and make suggestions for conservation.

INTRODUCTION

The Pacific sheath-tailed bat (*Emballonura semicaudata*) occurs across much of Oceania, including the Mariana and Caroline Islands, Samoa, Tonga, Fiji, and Vanuatu (Flannery, 1995; Koopman, 1997; Helgen and Flannery, 2002). These bats seem common at some locations, especially in the Caroline Islands (e.g., Bruner and Pratt, 1979; Wiles et al., 1997), but populations have inexplicably declined on many other islands (Lemke, 1986; Grant et al., 1994; Flannery, 1995; Hutson et al., 2001; Tarburton, 2002; Palmeirim et al., 2007). In the Mariana Islands, where the endemic *E. s. rotensis* occurs (there are four putative subspecies — Koopman, 1997), sheath-tailed bats disappeared from Guam, Rota, and Saipan between the late 1940s and 1970s (Lemke, 1986; Wiles et al., 1995). The species occurred in recent prehistoric times on Tinian (Steadman, 1999), but there are no historical records for this island. Lemke (1986) reported possible sightings on Anatahan and Maug in the northern Mariana Islands, but populations there remain unconfirmed. Lemke (1986) found no records of *E. s. rotensis* from Saipan, but we have since found one report (Schnee, 1910) and learned of a sighting of a few small insectivorous bats on Saipan in about 1945 (P. H. Krutzsch, in litt.). Fossil evidence suggests that *E. s. rotensis* was formerly common on Guam and Rota, but possibly less numerous on Tinian (Steadman, 1999; Pregill and Steadman, 2009).

The only known remaining population of this subspecies is on the island of Aguiguan, where it is the sole microchiropteran bat. Biologists first recorded *E. s. rotensis* on Aguiguan in 1984 and 1985, when three or four bats were found in each of two caves, the only bats found in searches of 13 of
**Molossus aztecus** and other small *Molossus* (Chiroptera: Molossidae) in Brazil

RENATO GREGORIN¹,  ², ARTHUR SETSUO TAHARA¹, and DEBORA FERRARI BUZZATO¹

¹Departamento de Biologia, Universidade Federal de Lavras, CP 3037, CEP 37200-000 Lavras, Minas Gerais, Brazil
²Corresponding author: rgregorin@dbi.ufla.br

We report the first record of *Molossus aztecus* from two localities in southeastern Brazil, Lavras and Viçosa, confirming the presence of this species in South America; both localities are located in the state of Minas Gerais. Samples from Lavras contained both *M. aztecus* and *M. molossus*, permitting direct comparison of the two taxa. At both sites, the original vegetation was Cerrado-Atlantic Forest ecotone and the bats were captured at elevations from 650 to 1,100 m. We compared our specimens of *M. aztecus* from southeastern Brazil with *M. aztecus* from Mexico, *M. molossus* from several parts of Brazil, *M. coibensis* from Panama, *M. barnesi* from French Guiana, and *M. currentium* from Paraguay. Capturing *M. aztecus* and *M. molossus* sympatrically reinforced their distinctiveness; they differ in morphometrical traits and qualitative characters of skull and pelage. We also found that specimens earlier identified as *M. coibensis* from Brazil, are referable to *M. barnesi* from French Guyana.

Key words: *Molossus aztecus*, *M. barnesi*, *M. coibensis*, *M. currentium*, *M. molossus*, morphology, Brazil

**INTRODUCTION**

*Molossus* É. Geoffroy is widespread in the Neotropical region and comprises seven or eight species, depending upon the taxonomic arrangement considered (Simmons, 2005; Eger, 2007). However, the taxonomy of *Molossus* is unsatisfactory because of poor diagnoses of taxa as well as our lack of knowledge regarding the geographic distributions of several species (Simmons and Voss, 1998; Eger, 2007). The taxonomic review of Dolan (1989) recognized seven species of *Molossus* in Central America and one additional species, *M. barnesi* Thomas, was later revalidated (Simmons and Voss, 1998). Cabrera (1958) synonymized *M. barnesi* with *M. cherriei* Allen, which is known exclusively by the holotype collected in the state of Mato Grosso, Brazil. Dolan (1989) considered *M. cherriei* and *M. coibensis* Allen as synonyms and subsequently Eger (2007) synonymized *M. barnesi* with *M. coibensis*. At present, most of valid species of *Molossus* occur in both Central and South America. However, more species in the genus are expected as a result of ongoing faunal inventories in many remote areas of South America, particularly Brazil, as well as with critical revision of material in collections. Indeed, the taxonomy of Central American *Molossus* is better known because there are good samples and due to Dolan’s (1989) review. Despite minor changes resulting from new data (e.g., González-Ruiz et al., 2010), the taxonomic decisions proposed by Dolan (1989) remain essentially unchanged for Central America.

In contrast to the situation in Central America, the taxonomy of *Molossus* of South America is considered provisional, and a taxonomic review of the genus is needed because there are an excessive number of nominal taxa, many defining regional sampling, and also due to the inadequate definition of the species on that continent, particularly in *M. molossus* (Dolan, 1989; Simmons and Voss, 1998; Eger, 2007). Even within South America, there are different perceptions about the taxonomy and diversity of *Molossus*: the bat fauna has been well-documented in some countries and regions such as Argentina (Barquez et al., 2006), Guiana shield (Brosset and Charles-Dominique, 1990; Simmons and Voss, 1998; Lim and Engstrom, 2001; Engstrom and Lim, 2002; Lim et al., 2005), Paraguay (Myers and Wetzel, 1983; Willig et al., 2000), and Bolivia (Anderson, 1997), but in highly diverse countries such as Colombia, Ecuador, and Brazil, only poor estimates of bat richness exist. Recently, Eger (2007) recognized seven species of *Molossus* and four subspecies of *M. molossus* (Pallas) in South America; she did not recognize *M. aztecus* Sauussure.
Environmental components and boundaries of morphological variation in the short-tailed fruit bat (Carollia spp.) in Ecuador

PABLO JARRÍN-V.1, 2, 5 and PABLO A. MENENDEZ-GUERRERO3, 4

1Estación Científica Yasuní, Escuela de Ciencias Biológicas, Pontificia Universidad Católica del Ecuador, Apartado 17-01-2184, Quito, Ecuador
2Center for Ecology and Conservation Biology, Department of Biology, Boston University, #5 Cummington Street, Boston MA 02215, USA
3Museo de Zoología, Centro de Biodiversidad y Ambiente, Escuela de Ciencias Biológicas, Pontificia Universidad Católica del Ecuador, Apartado 17-01-2184 Quito, Ecuador
4Department of Ecology and Evolution, Stony Brook University, Stony Brook, New York 11794, USA
5Corresponding author: E-mail: psjarrin@puce.edu.ec

Species in Carollia, although loosely recognizable by size and shape, show overlap in most morphological character states as well as in geographic distribution and use of resources. However, there is a lack of understanding regarding where and what this overlap is. Variation in the morphology of Carollia should correspond to the environment, yet such patterns remain unknown. Species may coexist as a function of environmental factors and sympathy may not be uniform along the distributional extent of these species. An informed perception of the morphological and ecological variation across their geographic range may clarify not only the limits and extents of their spatial and morphological boundaries, but also may provide insights into the relationships among size, shape and environment. In our quantitative analysis of the variation in morphology and environment we tried to answer what limits species distribution, as well as how morphology changes with the environment within and among species. A combination of multivariate contrasts and partial least square analyses were used to assess the correlations and interactions between size, shape, distribution and environment among C. castanea (small), C. brevicauda (medium) and C. perspicillata (large size) in Ecuador. We show how the three Carollia species vary and differentiate along an ecomorphological space of gradients, barriers, size and shape. From a macro-eccological perspective, and contrary to the theory of limiting similarity, the smallest species is the most distinct in its environmental space and also the one that experiences the strongest changes in shape across geographic regions. The other two more similar species, in both size and shape, show a larger overlap in their environmental space. This seems to suggest that size can act as a buffer in extreme or changing environments and that higher gene flow is more probable for larger high-altitude species.

Key words: Carollia, distribution, environment, shape, size, Ecuador

INTRODUCTION

At least three Carollia species co-occur in the Central Neotropics (sensu Eisenberg and Redford, 2000), but this number decreases with increasing latitude or altitude (York and Papes, 2007). Sympathy in Carollia typically includes one small (e.g., C. castanea), one medium (e.g., C. brevicauda) and one large (e.g., C. perspicillata) species in Ecuador (Albuja, 1999), Colombia (Muñoz-Saba et al., 1999), Peru (Ascorra et al., 1996) and Bolivia (Loayza-Freire, 2002). However, Solari et al. (2006) reported four sympatric species at a locality in the Amazonian basin of Peru. In Mexico, at the northern limits of the distributional range for Carollia (Ceballos et al., 2002), there are at least three species, but only two have been reported to coexist in sympathy (e.g., Medellín, 1994; Medellín et al., 2000). Towards the southern tip of the distributional range of Carollia there is a single known species in Argentina (Barquez, 1988).

There is little detailed information on patterns of co-occurrence throughout the distributional range of Carollia. Most of the available data are broad in detail, qualitative in their characterization and spread over numerous technical publications, as descriptions, inventories and species lists (e.g., Anderson, 1993; Emmons and Feer, 1997; Cherem et al., 2004). At a finer spatial and quantitative scale, uncertainties remain regarding whether these species are fully sympatric (sensu Albuja, 1999; Tirira, 1999), what their degree of overlap in geographic
Bats constitute a substantial proportion of mammalian diversity within the Asian tropics and subtropics and are particularly susceptible to population losses associated with human activities. This poses a conservation concern in Asian karst areas which support high bat species diversity, yet are experiencing habitat loss and degradation and increasing pressure from tourism and extractive industries. As disturbance during crucial reproductive periods (late pregnancy, lactation and weaning) threatens reproductive success, we investigated the reproductive phenology of a bat assemblage at two karst sites in North Vietnam. Our results indicate that the timing of major reproductive events coincides among two cave-dwelling pteropodids, and among 26 cave and foliage dwelling rhinolophids, hipposiderids and vespertilionids. March–July is the primary reproductive period for all insectivorous species sampled, and protection of maternity roosts during this time is critical. Reproduction in cave-dwelling pteropodids spanned a greater period (March–December), due to two birth periods each year. Lactation in the three insectivorous families studied was positively correlated with rainfall and temperature, with weaning occurring during the peak wet season. The strong congruence in reproductive phenologies in our results and climatic homogeneity of North Vietnam (18–23°N) suggests that our study may have wider applicability within the region. Vietnamese caves support high bat diversity which is likely threatened by harvesting for consumption and tourism development nationwide. Studies to investigate and address these threats should be given high priority.

Key words: bats, reproduction, caves, conservation, Vietnam

INTRODUCTION

Bats constitute a substantial proportion of mammalian diversity in SE Asia (ca. 30% — Corbet and Hill, 1992; Boitani et al., 2006). Unlike most small mammals, however, they possess distinctive life-history strategies which are characterised by longevity, low litter sizes and delayed onset of sexual maturity (Gaisler, 1989). Reproductive patterns within the group are diverse and in the old world, range from restricted seasonal monoestry (one litter within a two month period each year) in highly seasonal environments to aseasonal polyoestry (two or more litters in eight or more months of the year) in regions with limited or no seasonality (Happold and Happold, 1990). Polyoestry is common among pteropodids, whereas latitudinal reproductive trends are documented for insectivorous bats, with a change from monoestry to polyoestry occurring with increasing proximity to the equator (Bernard and Cumming, 1997). As a consequence, seasonal monoestry is the norm for most insectivorous bats above 13°N and 15°S (with the exception of molossids), whereas between these latitudes in Africa, the majority of insectivorous bats are bimodally polyoestry or aseasonal breeders (Bernard and Cumming, 1997; Racey and Entwistle, 2000). Most species bear a single young per litter, although polyoecy (more than one young per litter) sometimes occurs among vespertilionids (Racey, 1982).

Due to their low annual reproductive rate, bat populations take a relatively long time to recover from population losses associated with human activities (Racey and Entwistle, 2000). Slow population growth rates thus compound existing threats to bat populations. This is true of cave-dwelling species which are gregarious and colonial and any disturbance in these confined spaces tends to affect the entire aggregation (McCracken, 1989). These issues are highly relevant in SE Asia, one of the worlds’ premier regions for limestone karst (Day and Urich, 2000), which is characterised by extensive cave
Habitat use in the female Alpine long-eared bat (Plecotus macrobullaris): does breeding make the difference?

DAMIANO G. PREATONI1, 2, MARTINA SPADA1, LUCAS A. WAUTERS1, GUIDO TOSI1, and ADRIANO MARTINOLI1

1Dipartimento di Scienze Teoriche e Applicate, Università degli Studi dell’Insubria, Via J. H. Dunant 3, 21100 Varese, Italy
2Corresponding author: E-mail: prea@uninsubria.it

Recent discoveries of several new cryptic bat species in Europe, as well as the growing concerns on bat conservation, have resulted in increased efforts to study roost site selection, habitat use and spacing/foraging behaviour. For many of these cryptic species, management is problematic due to the lack of information. We present data on space and habitat use of 14 radio-tagged Plecotus macrobullaris females from a nursery in the central part of the species' distribution. They used home ranges larger than 10 km², and the behavioural pattern was typically a first foraging bout soon after emergence from the nursery, followed by fast non-foraging flight towards selected habitat types. Habitat selection, as evaluated by K-select analysis, is non-random with preference for ecotones at woodland borders and rural areas, whereas woods are avoided. Body condition differentially affects habitat use for breeding and non-breeding females: breeding females in good condition showed a strong preference for ecotones. Among non-breeding females, the preference for ecotones varied with body condition. Being the sibling species of P. auritus, which is considered a woodland bat, the selection pattern observed for P. macrobullaris raises some questions about the possible niche partition in cases of sympatry.

Key words: Plecotus macrobullaris, habitat selection, home range size, radio-tracking, Italy

INTRODUCTION

Recent discoveries of several new, cryptic bat species in Europe, and the growing importance of bat conservation have resulted in an increased research effort to study roost site selection, habitat use and spacing/foraging behaviour. For many of these cryptic species, management is problematic due to the lack of information. We present data on space and habitat use of 14 radio-tagged Plecotus macrobullaris females from a nursery in the central part of the species' distribution. They used home ranges larger than 10 km², and the behavioural pattern was typically a first foraging bout soon after emergence from the nursery, followed by fast non-foraging flight towards selected habitat types. Habitat selection, as evaluated by K-select analysis, is non-random with preference for ecotones at woodland borders and rural areas, whereas woods are avoided. Body condition differentially affects habitat use for breeding and non-breeding females: breeding females in good condition showed a strong preference for ecotones. Among non-breeding females, the preference for ecotones varied with body condition. Being the sibling species of P. auritus, which is considered a woodland bat, the selection pattern observed for P. macrobullaris raises some questions about the possible niche partition in cases of sympatry.

Key words: Plecotus macrobullaris, habitat selection, home range size, radio-tracking, Italy

Recent identification of new sibling species of long-eared bats (genus Plecotus) have increased the number of European species from two (brown long-eared bat, P. auritus and grey long-eared bat, P. austriacus) to six (P. macrobullaris — Kiefer and Veith, 2001; Spitzerenberger, 2003; P. kolombatovici — Mayer and von Helversen, 2001; Spitzenberger et al., 2002; P. sardus, endemic to Sardinia — Mucedda et al., 2002; P. teneriffae, endemic to the Canary Islands — Ibáñez and Fernández, 1985; Juste et al., 2004). The Alpine long-eared bat, P. macrobullaris, is a sibling species of P. auritus (Kiefer and Veith, 2001). It can be reliably identified by mitochondrial DNA sequencing (Kiefer and Veith, 2001; Kiefer et al., 2002; Trizio et al., 2003); recently, a discriminant function based on body measurements has been proposed which correctly classified 97.5% of specimens as belonging to the Plecotus sibling species present in the Alps (Ashrafi et al., 2010). The known distribution range of P. macrobullaris extends from the Pyrenees to Greece and Crete, including the Alps from France to Slovenia (Kiefer and von Helversen, 2004).
Ecological aspects of the tent building process by *Ectophylla alba* (Chiroptera: Phyllostomidae)

**BERNAL RODRÍGUEZ-HERRERA**1, 2, 4, **GERARDO CEBALLOS**3, and **RODRIGO A. MEDELLÍN**3

1Reserva Biológica Tirimbina, Sarapiquí, Costa Rica
2Escuela de Biología, Universidad de Costa Rica, San Pedro Montes de Oca, Costa Rica
3Instituto de Ecología, Universidad Nacional Autónoma de México, A.P 70-275, México D.F. 04510, México
4Corresponding author: E-mail: bernalr@racsa.co.cr

Twenty-two species of bats worldwide are known to use modified leaves as their roost, known as ‘tents’. It has been suggested that the mating system of these species is resource-defense polygyny, with the presumably male-constructed tent serving as an attractant of females, but in *Ectophylla alba* a female was observed building a tent. The objectives of this work were to determine: 1) if both sexes build the tent; 2) if there is a relationship between number of tents and mating seasons and 3) the time availability of the *Heliconia* leaves that this species uses to make its roost as well as the effect of the bats on the plant. The study site was the Tirimbina Biological Reserve, Sarapiquí, Costa Rica. During 53 weeks, we censused the tents of *E. alba* in nine hectares. Construction of tents was filmed with a video camera and infrared lights. To measure the average life of the tents and the leaves that had not been modified, we marked leaves that were visited weekly to monitor for deterioration. Our results show that both females and males construct tents. Roost construction is costly in terms of time and effort, so the bats maximize the time spent occupying the tent. The modifications that the bats make to the leaves considerably reduce the lifetime of the leaves. This has implications for both the plant used and for the bats that build the tents.

**Key words:** tent-roosting bats, *Ectophylla alba*, tents, *Heliconia*

**INTRODUCTION**

Investment of significant amounts of time and energy in roost construction and maintenance is a common trait in mammals such as rodents and carnivores. Given that a refuge provides protection against the elements and predation, and is often a suitable place for breeding and rearing of offspring, there is often a close relationship between the quality of the roost and the reproductive success of the individual (Morrison and Morrison, 1981; Alcock, 2001; Dechmann *et al.*, 2005). In some cases, females are exclusively in charge of constructing the refuge. In other cases, males participate in the refuge construction and invest in parental care to maintain access to females (Dawkins, 1976).

Bats are among the most ecologically and taxonomically diverse groups of mammals. Their diversity extends to roosts, with species known to use caves, hollow tree trunks, crevices, spaces under rocks, buildings, rolled up leaves, and others (Rodríguez-Herrera *et al.*, 2007). In contrast to other mammals, most bats use pre-existing sites for their roosts. A few species, however, have the ability to construct their own refuge (Kunz and Lumsden, 2003). Only 24 species of bats worldwide (2% of the total species) are believed to construct their own roost. Of these, 22 modify leaves of plants as roosts, which are known as ‘tents’. Seventeen of these species are Neotropical and belong to the family Phyllostomidae, while the rest are Palaeotropical (Kunz *et al.*, 1994; Rodríguez-Herrera *et al.*, 2007).

It has been suggested that the mating system in tent-making bat species is polygyny based on the defense of the tent resource (Brooke, 1990; Kunz *et al.*, 1994; Balasingh *et al.*, 1995; Kunz and McCracken, 1996; Storz *et al.*, 2000; Kunz and Lumsden, 2003; Chaverri and Kunz, 2006). The generally assumed hypothesis is that males make the tents and females select a male because of tent characteristics. Tent construction is also assumed to be a proxy for the male’s capability to defend themselves against other males (Balasingh *et al.*, 1995; Kunz and McCracken, 1996; Kunz and Lumsden, 2003). This idea has only been supported with observations on the flying fox *Cynopterus sphinx*. 
INTRODUCTION

Female and male bats have differing energy requirements throughout the reproductive cycle that are likely to affect choices made during roost selection (Hamilton and Barclay, 1994; Speakman and Thomas, 2003). Female bats have the high energy demands of pregnancy and lactation (Racey and Swift, 1981; Dietz and Kalko, 2006), whilst male bats have lower energy demands (Dietz and Kalko, 2006, 2007). Females and males choose roosts that cater best to their differing energy requirements, and therefore may roost in different locations (Boland et al., 2009). For example, roosts used by females are frequently closer to waterways than males’ roosts (Encarnação et al., 2005; Boland et al., 2009), presumably to take advantage of high invertebrate abundances there, to enable females to drink readily, and to maintain calcium levels required for fetal development and lactation (Adams et al., 2003). Female bats may also be found using roosts that are more exposed to the sun’s warmth than are males’ roosts (Perry and Thill, 2007b; Perry et al., 2007). These warmer roosts may be selected to help maintain the temperatures that promote pre- and postnatal development and milk production (Racey and Swift, 1981; Wilde et al., 1999; Hood et al., 2002; Speakman and Thomas, 2003; Willis et al., 2006; Allen et al., 2010).

Whilst reasons for sex-specific differences in roost selection are frequently acknowledged, the majority of studies have focused on either female-dominated maternity roosts or have pooled data between sexes, which likely masks selection by members of each sex (Miller et al., 2003; Barclay and Kurta, 2007). Consequently, information on roost selection by males is limited (Perry and Thill, 2008). Indeed, current knowledge of some species has been considered so limited by several bat biologists that they believe conservation and management of these species has been reduced to ‘an educated guess’ (Lacki et al., 2007). Studies that focus separately on the selection of roosts by each sex can greatly increase understanding of the locations of either the
INTRODUCTION

Bats use echolocation as well as visual and magnetic cues for orientation and navigation (Griffin, 1958; Holland et al., 2006; Holland, 2007). Echolocation is recognized as the most important sense for bats (Griffin, 1958), however it works only over distances up to a maximum of 90 m (Holderied and Helversen, 2003). For long-distance orientation bats must use other sensory cues, such as vision (Schnitzler and Kalko, 2001). Some species have relatively large eyes and use vision for homing as well as foraging (Williams et al., 1966; Williams and Williams, 1967; Eklöf et al., 2002; Eklöf and Jones, 2003). Visual information or distraction by visual cues may influence bats’ abilities to avoid colliding with stationary objects (Orbach and Fenton, 2010). Some bats are also likely to use visual information to calibrate a magnetic compass using the position of sunset (Holland et al., 2006, 2010). Much less is known about whether vision plays a role in finding roost sites. However, it is known that some bats strongly avoid illuminated areas, including cavities and other potential roosts (Downs et al., 2003; Boldogh et al., 2007; Stone et al., 2009). Roosts are critical resources for bats, and recent research has investigated how bats effectively find roosts and how they transfer information on roost suitability (Kunz and Lumsden, 2003; Kerth and Reckardt, 2003; Kerth et al., 2006). Detecting a tree cavity entrance in flight and from a distance is a difficult task, especially for fast flying, aerial hawking bats (Ruczyński et al., 2007, 2009). While echolocation and social calls increased the conspicuousness of a roost entrance (Ruczyński et al., 2007, 2009; Schöner et al., 2010), dim light had no effect in previous experiments (Ruczyński et al., 2007, 2009). This might be explained by the small entrance size and the fact that the low contrast between the entrance and the surrounding tree bark might have provided only a low visual salience to the bats. However, the authors hypothesized that bats may nonetheless use vision to identify candidate trees from a distance (Ruczyński et al., 2007). Those might include large old trees and trees with thick trunks or other conspicuous features like snags or dead branches without bark (e.g., Ruczyński and Bogdanowicz, 2008). So bats potentially may pre-select objects by vision. We hypothesize that some salient visual cues that can be associated with the presence of cavity entrances attract the attention of bats, and thus decrease time needed to find cavities. Especially larger (exceeding 3.5 cm), bright objects may be visible to bats (Rydell and Eklöf, 2003). To test our hypothesis we used...
Nocturnal activity patterns of northern myotis (Myotis septentrionalis) during the maternity season in West Virginia (USA)

JOSHUA B. JOHNSON¹, ³, JOHN W. EDWARDS¹, and W. MARK FORD²

¹West Virginia University, Division of Forestry and Natural Resources, Box 6125, Morgantown, WV 26506, USA
²U.S. Geological Survey, Virginia Cooperative Fish and Wildlife Research Unit, Virginia Polytechnic Institute and State University, 106 Cheatham Hall, Blacksburg, VA 24061, USA
³Corresponding author: E-mail: j-johnson3@juno.com

Nocturnal activity patterns of northern myotis (Myotis septentrionalis) at diurnal roost trees remain largely uninvestigated. For example, the influence of reproductive status, weather, and roost tree and surrounding habitat characteristics on timing of emergence, intra-night activity, and entrance at their roost trees is poorly known. We examined nocturnal activity patterns of northern myotis maternity colonies during pregnancy and lactation at diurnal roost trees situated in areas that were and were not subjected to recent prescribed fires at the Fernow Experimental Forest, West Virginia from 2007 to 2009. According to exit counts and acoustic data, northern myotis colony sizes were similar between reproductive periods and roost tree settings. However, intra-night activity patterns differed slightly between reproductive periods and roost trees in burned and non-burned areas. Weather variables poorly explained variation in activity patterns during pregnancy, but precipitation and temperature were negatively associated with activity patterns during lactation.

Key words: Anabat, bats, Myotis septentrionalis, night-roosting, northern myotis, West Virginia

INTRODUCTION

Temperate bat species are nocturnal and exhibit nightly and seasonal activity patterns that vary among species and individuals (Hirshfield et al., 1977; Anthony et al., 1981). During summer nights, bat roost-emergence activity commonly peaks immediately after sunset and can continue for several hours (Kunz, 1973; Barclay, 1982). Typically, a lesser activity peak occurs before sunrise as bats return to their diurnal roosts after foraging (Kunz, 1973). During the night, bats roost at intervals, either at their diurnal roosts or at night-roosts nearer their foraging areas (Adam and Hayes, 2000; Johnson et al., 2002; Daniel et al., 2008).

Females of many bat species form maternity colonies in anthropogenic (e.g., buildings) and/or natural (e.g., tree or snag) structures (Barbour and Davis, 1969; Lewis, 1995). During the maternity season, particularly during the lactation period, females return to their diurnal roosts several times during the night to nurse their young (Henry et al., 2002; Ormsbee et al., 2007). Activity at diurnal roosts at night typically is greater during lactation than during pregnancy (Henry et al., 2002).

Northern myotis (Myotis septentrionalis) is a small (5–8 g) insectivorous bat in the eastern United States and Canada (Caceres and Barclay, 2000). They typically roost in tree cavities or under exfoliating bark of snags or live trees, where they form maternity colonies of < 100 individuals during summer (May–July) (Caceres and Barclay, 2000). Moreover, many of these species exhibit fission-fusion societies during the maternity season whereby individuals switch roost trees about every other day (Caceres and Barclay, 2000; Garroway and Broders, 2007). Little research has examined activity patterns at non-anthropogenic roost sites or activity patterns of northern myotis maternity colonies during pregnancy and lactation at diurnal roost trees situated in areas that were and were not subjected to recent prescribed fires at the Fernow Experimental Forest, West Virginia from 2007 to 2009. According to exit counts and acoustic data, northern myotis colony sizes were similar between reproductive periods and roost tree settings. However, intra-night activity patterns differed slightly between reproductive periods and roost trees in burned and non-burned areas. Weather variables poorly explained variation in activity patterns during pregnancy, but precipitation and temperature were negatively associated with activity patterns during lactation.
Emergence time and foraging activity in Pallas’ mastiff bat, *Molossus molossus* (Chiroptera: Molossidae) in relation to sunset/sunrise and phase of the moon

RICHARD A. HOLLAND¹,²,⁸,⁹, CHRISTOPH F. J. MEYER³, ELISABETH K. V. KALKO⁴,⁵, ROLAND KAYS⁴,⁶, and MARTIN WIKELSKI⁷

¹Ecology and Evolutionary Biology Department, Princeton University, Princeton, New Jersey, 08544, USA
²IICB, University of Leeds, Leeds, LS2 9JT, United Kingdom
³Centro de Biologia Ambiental, Faculdade de Ciências, Universidade de Lisboa, 1749-016 Lisboa, Portugal
⁴Smithsonian Tropical Research Institute, Balboa, Republic of Panama
⁵Institute of Experimental Ecology, University of Ulm, Albert-Einstein Allee 11, D-89069 Ulm, Germany
⁶New York State Museum, CEC 3140, Albany, NY 12230, USA
⁷Max Planck Institute for Ornithology, Department for Migration and Immuno-ecology, Schlossallee 2, Radolfzell D-78315, Germany
⁸Current address: School of Biological Sciences, Queen’s University Belfast, Medical Biology Centre, 97 Lisburn Road, Belfast BT9 7BL, United Kingdom
⁹Corresponding author: E-mail: cholland@qub.ac.uk

The decision on when to emerge from the safety of a roost and forage for prey is thought to be a result of the tradeoff between peak insect abundance and predation pressure for bats. In this study we show that the velvety free-tailed bat *Molossus molossus* emerges just after sunset and just before sunrise for very short foraging bouts (average 82.2 min foraging per night). Contrary to previous studies, bats remain inactive in their roost between activity patterns. Activity was measured over two complete lunar cycles and there was no indication that phase of the moon had an influence on emergence time or the numbers of bats that emerged from the roost. This data suggests that *M. molossus* represents an example of an aerial hawking bat whose foraging behaviour is in fact adapted to the compromise between the need to exploit highest prey availability and the need to avoid predation.

Key words: *Molossus molossus*, emergence, foraging, nocturnal, predator pressure, activity

INTRODUCTION

The daily activity cycle of animals is shaped by many competing pressures such as predator avoidance, the need to forage successfully or the need to reproduce, and such pressures can profoundly impact the success of a species (Daily and Ehrlich, 1996; Refinetti, 2008). In particular emergence time and the duration of foraging activity are crucial aspects of the behavior of insectivorous bats which in turn can have a significant influence on their fitness (Duverge *et al.*, 2000; Lee and McCracken, 2001). Aerial hawking bats typically emerge earlier than gleaning insectivores or frugivorous species, presumably to exploit the dusk peak of aerial insect abundance (Jones and Rydell, 1994; Speakman *et al.*, 2000; Weinbeer and Kalko, 2004; Thies *et al.*, 2006). Bats emerging after dusk may therefore be less efficient feeders. However, predation pressure by raptorial birds is often greater before full darkness and so early emergence increases the risk of predation, particularly for species that hunt in open habitats (Jones and Rydell, 1994; Rydell *et al.*, 1996; Welbergen, 2006). Predation risk has been shown to be incredibly important to shaping the activity and behavior of terrestrial small mammals (Brown, 1988), but has not been well quantified for bats.

Intrinsic (e.g. age, sex, reproductive status) and extrinsic (e.g. ambient temperature, moonlight) factors correlate with the timing of emergence in bats (Duverge *et al.*, 2000; Lang *et al.*, 2006; Petrželková *et al.*, 2006; Esberard, 2007). In particular, if predator avoidance is a factor in why animals are nocturnal, then these animals should also be less active on brightly moonlit nights. Such lunar phobic behavior has indeed been found in a number of studies (Morrison, 1978; Hecker and Brigham, 1999), including the species studied in this paper (Erkert,
Activity of two species of free-tailed bats over a stream in southeastern Brazil

LUCIANA DE MORAES COSTA¹, ELIZABETE CAPTIVO LOURENÇO¹, JÚLIA LINS LUZ², ANA PAULA FÉLIX DE CARVALHO¹, and CARLOS EDUARDO LUSTOSA ESBERARD¹, ²

¹Laboratório de Diversidade de Morcegos, Instituto de Biologia, Universidade Federal Rural do Rio de Janeiro, CP 74503, 23851-970, Seropédica, Rio de Janeiro, Brazil
²Corresponding author: E-mail: cesberard@superig.com.br

The objective of the present study was to investigate activity time of the molossid bats Nyctinomops laticaudatus and Molossus molossus at the same locality, and to test whether activity of one species affects activity of the other. During January 2007–May 2009, we sampled for 15 nights over a stream in southeastern Brazil. Total sampling effort was 166 h and 693 m of nets. Time of capture was transformed into minutes in relation to sunset. First captures of M. molossus occurred just after sunset except for one individual that was captured before sunset. Total activity time of M. molossus ranged from 27 min before sunset to 743 min after sunset. Total activity time of N. laticaudatus ranged from 42 to 675 min after sunset and activity differed significantly between species. Activity of M. molossus was related to time of sunset, as expected based on behavior of other insectivorous species, whereas activity of N. laticaudatus seemed independent of sunset.

Key words: capture time, sunset, activity, Molossus molossus, Nyctinomops laticaudatus, insectivorous bats, Brazil

INTRODUCTION

Activity time in bats, as in other animals, is related to three main factors: availability of food, risk of predation (Jones and Rydell, 1994; Kunz and Anthony, 1996; Esbéard and Bergallo, 2008) and competition (Kunz and Anthony, 1996). Activity pattern may be adjusted to these factors at a daily, monthly or annual scale (Erket, 1982).

Insectivorous bats have short periods of activity each night (e.g., Fenton et al., 1998; Esbéard and Bergallo, 2010), when they try to obtain the greatest amount of prey in the shortest possible time. Beginning of activity is related to time of sunset (e.g., Cockrum and Cross, 1964; Bateman and Vaughan, 1974; Esbéard and Bergallo, 2010). Most insectivorous bats restrict activity to periods close to sunset or sunrise (Erket, 1978, 1982; Ransome, 1990); therefore a bimodal temporal pattern frequently is observed (e.g., Cockrum and Cross, 1964; Marques, 1986; Esbéard and Bergallo, 2010).

Most exclusively, insectivorous bats in the Neotropics use roosts with one or a few accesses (Lewis, 1995) and before sunset, activity near these accesses is high. These bats frequently can be observed leaving their roosts in groups to go to foraging sites (e.g., Brooke, 1994, 1997; Fenton et al., 1998). Therefore, captures next to roosts usually are highest near time of sunset and tend to decrease as night progresses.

Most studies on activity times of bats were conducted with bat detectors or involved captures next to roosts (e.g., Marques, 1986; Fenton et al., 1998), and they were limited mainly to temperate species (Subbaraj and Chandrashkearan, 1977). However, knowledge of activity of Neotropical insectivorous bats is scarce (e.g., Marques, 1986; Fenton et al., 1998). Thus, the objective of the present study was to investigate the activity time of the molossid bats Nyctinomops laticaudatus (E. Geoffroy, 1805) and Molossus molossus (Pallas, 1766) at the same locality, and to test whether activity of one species affects activity of the other.

MATERIALS AND METHODS


Bats were captured in mist nets (9 × 2.5 m and mesh 19 × 19 mm) set up over water in sites where the stream was shallow...
Finding your friends at densely populated roosting places: male Egyptian fruit bats (Rousettus aegyptiacus) distinguish between familiar and unfamiliar conspecifics

OFRI MANN, VIKA LIEBERMAN, ANGELA KÖHLER, CARMI KORINE, HELEN E. HEDWORTH, and SILKE L. VOIGT-HEUCKE

1Department of Life Sciences, Eilat Campus, Ben-Gurion University of the Negev, POB 653, Beer-Sheva 84105, Israel
2Mitrani Department of Desert Ecology, Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, 84990 Midreshet Ben-Gurion, Israel
3Department of Zoology and Entomology, University of Pretoria, Pretoria 0002, Republic of South Africa
4Lighthouse Field Station, University of Aberdeen, George Street, Cromarty, Ross and Cromarty, IV11 8YJ, United Kingdom
5Department of Animal Behaviour, Institute of Biology, Freie Universität, Takustraße 6, 14195 Berlin, Germany
6Corresponding author: E-mail: voigt.heucke@googlemail.com

Individual recognition via olfactory, auditory, or visual cues is crucial for animals to form and maintain stable social groups, particularly in large colonies such as those of Egyptian fruit bats (Rousettus aegyptiacus). We tested whether Egyptian fruit bats are able to distinguish between familiar and unfamiliar conspecifics, using two captive groups of male bats. We recorded the behavioural and auditory responses of focal animals in a binary choice experiment in which they could approach either members of their own social group or unfamiliar individuals. In general, bats preferred to stay close to other bats, familiar or unfamiliar, over resting alone and spent more time in close proximity to members of their own group than to unfamiliar conspecifics. The majority of bats interacted more with the unfamiliar individuals, although this result did not reach significance. We conclude that Egyptian fruit bats are able to distinguish between familiar and unfamiliar conspecifics. Since only one individual emitted social calls and bats never produced echolocation calls during the experiment, we infer that individual recognition was most likely mediated via olfactory and/or visual cues. The ability to identify familiar individuals may indicate that males of Egyptian fruit bats form stable groups within their large colonies.

Key words: Pteropodidae, recognition, choice test, social system, male stable groups, cues

INTRODUCTION

The ability to recognize individuals is essential for group-living animals and a prerequisite for sociality. Individual recognition allows animals to maintain stable social groups, recognize parents, offspring and mates, engage in reciprocal interactions and mediate territorial interactions. Given its central role in sociality, individual recognition has been studied extensively in a variety of taxa, e.g. birds (Thorpe, 1968); fish (Myrberg and Riggio, 1985); amphibians (Bee and Gerhardt, 2000); and mammals (Hurst et al., 2001). Most studies have focused on parent-offspring recognition (Sayigh et al., 1998; Jouventin et al., 1999), and neighbor-stranger recognition in territorial species (e.g., Myrberg and Riggio, 1985; Bee and Gerhardt, 2000). Discrimination between familiar group mates and unfamiliar individuals has also been investigated in various species, e.g. squirrel monkeys (Biben and Symmes, 1991) and chickens (Vallortigara and Andrew, 1994). In mammals, individual recognition mostly takes place via olfactory cues (reviewed in Brennan and Kendrick, 2006). For instance, mice and squirrels use olfactory cues to identify familiar conspecifics (Hurst et al., 2001; Mateo, 2005). Olfactory individual recognition has also been described in insects (Smith, 1983), crustaceans (Johnson and Attema, 2005) and birds (Bonadonna and Nevitt, 2004). Vocalizations may provide an additional cue for individual recognition, such as in individually distinct bird songs (Mundinger, 1970) and frog calls (Bee and Gerhardt, 2000). Lastly, animals can recognize each other via visual cues, as shown in chickens (Vallortigara and Andrew, 1994) and primates (Parr and de Waal, 1999). To date, however, these last two modes of individual recognition have been less intensively studied in mammals.
INTRODUCTION

This study was initiated following reports from several parts of the world, that some species of flying-fox had become extinct and others were in danger of extinction, especially from habitat loss and unregulated hunting (e.g., Cheke and Dahl, 1981; Wodzicki and Felten, 1981; Wiles and Payne, 1986). It was clear that informed management was urgently needed to conserve flying-foxes, and in particular, calculations of maximum sustainable yield of populations were impossible without good data on life expectancy or generation time to assess pressure from hunting — and other sources of mortality. Hence, the primary objective of the study was to establish the life expectancy of large flying-foxes, genus *Pteropus*, of which Australia has four species (Tidemann, 1999; Van Dyck and Strahan, 2008). It was hoped that this information would, in turn, enable assessment of population turnover rates and causes of death, with the possibility of reducing mortality and enhancing survival, and generate information on movements, about which little was known at that time (Nelson, 1965). The study was enabled by the development of a harp-trap for catching flying-foxes in large numbers at camps (Tidemann and Loughland, 1993), that opened up the possibility of banding sizeable groups of animals — and tracking selected individuals by other means, e.g., radio-tracking (Eby, 1991; Augee and Ford, 1999).

The primary species selected for the banding study was *P. poliocephalus*, camps of which are distributed along the east coast of Australia from central Queensland to Victoria, and beyond, into South Australia (Parsons et al., 2008; Tidemann et al., 2008; Roberts et al., 2011). In the more northerly parts of its range, *P. poliocephalus* shares camps with *P. alecto* and sometimes with *P. scapulatus*, so these two species also were added to the list of targets for banding, as they were often caught as...
Potential and limits in detecting altitudinal movements of bats using stable hydrogen isotope ratios of fur keratin

Anna Erzberger1, 2, Ana G. Popa-Lisseanu3, Gerlind U. C. Lehmann2, and Christian C. Voigt1, 3, 4

1Leibniz Institute for Zoo and Wildlife Research, Alfred-Kowalke-Strasse 17, 10315 Berlin, Germany
2Humboldt-Universität zu Berlin, Department of Biology, Behavioral Physiology, Invalidenstrasse 43, 10115 Berlin, Germany
3Freie Universität Berlin, Verhaltensbiologie, Takustrasse 6, Berlin, Germany
4Corresponding author: voigt@izw-berlin.de

Despite their small size, bats are exceptionally mobile. But where and when bats move seasonally often remains enigmatic, particularly for altitudinal movements. Recently, stable hydrogen isotope ratios (δD) of metabolically inert material like hair keratin have been utilized to track altitudinal movements of animals. Here, we measured δD in hair keratin of seven bat species captured in the Merendon Mountain Range in Honduras: three species were captured only at the low elevation site (≈ 1,100 m above sea level), one species only at the high elevation site (≈ 1,500 m a.s.l.) and three species at both sites. Based on information from the literature, we categorized two out of the seven species as sedentary (obligate fruit-eating Artibeus toltecus and insect-feeding Miconycteris microtis). All others were categorized as potentially migratory species (obligate fruit-eating Artibeus jamaicensis, Sturnira ludovici and Sturnira lilium and insect-feeding Myotis keayi and Molossus ater). Hair keratin of insectivorous species was enriched in deuterium by about 40‰ relative to that of co-existing fruit-eating species, irrespective of whether they were sedentary or potentially migratory, suggesting that δD of consumer tissue increases markedly with increasing trophic level. Hair keratin of sedentary A. toltecus and potentially migratory S. ludovici did not differ between populations of the two elevations indicating that the altitudinal gradient in δD may be too small and/or that variation in hair keratin δD too large to unravel altitudinal movements of less than 400 m in bats based on keratin δD alone.

Key words: altitudinal migration, Honduras, Neotropical bats, stable hydrogen isotopes, trophic level, tropical mountain ecosystems

INTRODUCTION

Recent studies have highlighted that bats are key players for ecosystem functioning by controlling populations of herbivorous insects (e.g., Kalka et al., 2008; William-Guillén et al., 2008), by dispersing seeds into deforested areas (e.g., Hernandez-Conrique et al., 1997; Kelm et al., 2008) and by pollinating plants (e.g., Quesada et al., 2008). Nonetheless, we lack fundamental information about the movement ecology of this important mammalian taxon, particularly about their large-scale, seasonal migrations. Yet, understanding movement patterns of animals is central for evaluating the sensitivity of a specific taxon to the loss of habitat connectivity (Nathan et al., 2008).

In mountainous areas, rapid shifts in climates and vegetation composition along elevations are important factors that determine the life history of highly mobile vertebrates such as birds (e.g., Hobson et al., 2003) and bats (e.g., Dinerstein, 1986; Hernandez-Conrique et al., 1997; LaVal, 2004). Insectivorous, frugivorous and nectarivorous bat species may exhibit seasonal altitudinal movements when food resources vary in abundance throughout the year. Yet, when and where such seasonal migrations occur is largely unknown, although such an understanding may contribute significantly to our knowledge of mountain ecosystems and their susceptibility to ecological perturbation or global climate change (LaVal, 2004).

During the past decades, stable isotopes have been increasingly used as tracers to infer the origin of migratory animals in general (Wassenaar and Hobson, 1998, 2005; Hobson, 1999, 2007) and bats in particular (e.g., Cryan et al., 2004; Britzke et al., 2009; Fraser et al., 2010). This approach is based on the premise that body tissues or products, such as hair, are made of dietary nutrients that animals assimilate at the places where they live. Thus, body material can serve as an isotopic memory of what animals have consumed and where they have lived.
INTRODUCTION

The West Indian archipelago forms a zoogeographically distinct region within the Neotropics with a high level of endemism. The structure of this archipelago’s bat faunas are not random assemblages from tropical mainland source pools (Fleming, 1982; Rodríguez-Durán and Kunz, 2001). For instance, whereas 46% of bats in northern South America are fruit-eating species, only 33% feed on fruits in the West Indies (Silva-Taboada, 1979). These insular phytophagous species (Rodríguez-Durán and Kunz, 2001) are particularly sensitive to the regular disturbances caused by hurricanes and other natural events (Jones et al., 2001; Rodríguez-Durán and Vázquez, 2001; Pedersen et al., 2009; Gannon and Willig, 2009), but neither their importance on the recovery and reforestation of disturbed areas, nor the impact of anthropogenic disturbances on their populations, have been thoroughly examined. Moreover, the effect, on non-target species, of changes to the landscape due to management is not well known (Conner et al., 2002). These conditions contribute to make the region a hotspot for biodiversity.

In 1940, forests represented 6% of the surface of Puerto Rico, and by 1985, that number had increased to 34% (Birdsey and Weaver, 1987). However, at almost four million human inhabitants, Puerto Rico is very densely populated, and while the population increased by 286% from 1935 to 1990, the amount of urbanized land increased by 1,285% (G. Moreno-Viqueira, in litt.). This accelerated urbanization is increasingly seen elsewhere in the region (Wright, 2005), but the amount of bat work performed on this island in the past (Gannon et al., 2005) puts Puerto Rico in an excellent position to better understand the consequences of habitat disruption in an island ecosystem.

Located along the highly developed north coast of Puerto Rico, Hacienda La Esperanza Nature Reserve (HLE) provides good examples of both: the kind of environmental disturbance that resulted in the almost complete deforestation of Puerto Rico during the XIXth century and the first half of the XXth century; and a natural reserve partly isolated from the surrounding karst region by urban sprawl. We hypothesized that, given the rather generalist nature of bat assemblages in the region (Rodríguez-Durán and Kunz, 2001), we would find a diverse community at this location in spite of the anthropogenic environmental disturbance.

We examined the assemblage of bats in a fragmented landscape along the northern coast of the island of Puerto Rico, West Indies, by mist netting and acoustic monitoring over a period of 25 months. Twelve of the 13 species present in the region were detected. It took nine nights of net and acoustic monitoring to detect 69% of the species, and 44 nights to reach 92%. Diversity was high, considering the insular nature of the assemblage and the fragmented nature of the ecosystem. We did not detect any important seasonal pattern in bat activity. The fruit eating bats at this study site are important importers of various seeds. *Artibeus jamaicensis* was most frequently captured and it appears to breed throughout the year at this location. Our results have important implications for management and conservation of biological diversity on tropical islands, and set a baseline against which the effect of further urban encroachment can be compared.
INTRODUCTION

Thailand has a rich bat fauna with at least 121 species officially recognised at present, and an additional 10 currently being classified or in the process of being confirmed as new to the country (Bumrungsri et al., 2006). Many of these species are likely to produce echolocation calls that include frequency-modulated (FM) components dominating their calls. For example, Bumrungsri et al. (2006) list 54 species of vespertilionids from Thailand, and all of these are likely to include substantial FM components in signals. In addition, five emballonurid, two megadermatid, one nycterid, one craseonycterid and four molossid species documented in Thailand (Bumrungsri et al., 2006) are also likely to use echolocation calls of this type. The purpose of this study is to investigate the value of using call structure to identify a selection of Thai bats from the families Vespertilionidae, Emballonuridae, Nycteridae and Megadermatidae as members of these families typically include FM components in their calls. Due to limited taxon sampling we concentrate on describing the temporal and spectral features of calls, although a sample of calls from 19 species were analysed by using discriminant function analysis (DFA) to determine the potential for species identification from call parameters alone in these species.

Similar analyses on acoustic identification have been performed previously, though the majority have taken place in Europe (e.g., Parsons and Jones, 2000; Teixeira and Jesus, 2009). However no previous studies of bat species identification based on acoustic parameters (for species producing calls dominated by frequency modulated components)
INTRODUCTION

All microchiropteran bats make use of echolocation to navigate the nocturnal air space (Griffin, 1958). The extensive adaptive radiation in echolocation call design that has taken place within both, Yangochiroptera and Yinochiroptera, is shaped largely by ecology, an evidence of how perceptual challenges imposed by the environment can often override phylogenetic constraints (Jones and Teeling, 2006). Factors affecting the spectral and temporal structure of bat calls include foraging mode and site (Schnitzler et al., 2003), atmospheric attenuation (Griffin, 1971; Lawrence and Simmons, 1982), prey size (Hartley, 1989), body size (Bogda-nowicz et al., 1999; Jones, 1999), and ear size (Obrist et al., 1993). Phylogeny is however, essential to understand the evolutionary scenario in which the acquisition of species-specific echolocation call inventories took place, and powerful to predict call design in little studied species, what is essential for acoustic monitoring studies.

In general, bat species within a family share the same type of call design: rhinolophids and hipposiderids emit constant frequency echolocation calls, molossids emit narrowband calls dominated by the fundamental harmonic, and phyllostomids emit short, broadband and multiharmonic calls (Jones and Teeling, 2006). In families such as Vesperophilidae, Noctilionidae and Mormoopidae, which show polymorphic call design across species, certain patterns in echolocation can still be used to understand and predict species call inventories.

Within the family Mormoopidae, for example, frequency modulated (FM) calls are emitted by the two species of the genus Mormoops, long constant frequency (CF) calls are emitted by Pteronotus parnellii and short CF-FM (sCF-FM) calls often ending in a sCF component, are emitted by the other five species of the genus Pteronotus: P. personatus, P. davyi, P. gymnornotus, P. macleayii and P. quadri dens (Fenton, 1994; Ibañez et al., 1999, 2000; Kössl et al., 1999; O’Farrell and Miller, 1999; Macías and Mora, 2003; Macías et al., 2006; Smotherman and Guillén-Servent, 2008). Recent phylogenetic evidence has indicated that after the separation from Mormoops, P. parnellii stemmed from the most basal node in the Pteronotus, followed by P. personatus (in the second most basal node) and afterward by the other four small Pteronotus species that represent the most recently evolved lineages of the Mormoopidae (Van Den Bussche and Weyandt, 2003). Phylogeny indicates therefore that the ancestral long CF call design distinctive of P. parnellii has

ABDULAZIZ N. ALAGAILI1,2, DOUGLAS A. JAMES2, and OSAMA B. MOHAMMED3

1KSU Mammals Research Chair, Department of Zoology, College of Science, King Saud University, P.O. Box 2455, Riyadh 11451, Saudi Arabia
2Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701-1201, USA
3Corresponding author: E-mail: aalagaili@ksu.edu.sa

Kuhl’s bat (*Pipistrellus kuhlii*) from Unizah Province, near the center of Saudi Arabia, was studied monthly from May 2005 to August 2006 to investigate the timing and patterns of molt. Adults and juveniles undergo a single molt extending annually over a five month period in summer from late April until September and following the breeding season. Few males of Kuhl’s bat initiate molt before females but the majority of both sexes molt in July and terminated the molt almost simultaneously. Molting begins on the dorsum and then spreads to the ventrum once the dorsal molt is completed. Our findings provide comparable observations to previous studies on molt in bats suggesting that bats appear to exhibit a species-specific timing and sequence of molt.

**Key words**: molt, pattern, timing, *Pipistrellus kuhlii*, Unizah, Saudi Arabia

INTRODUCTION

Molting in different bat species has been a neglected area of knowledge. Information regarding molt timing and pattern is sparse, except for short personal notes when capturing bats with no further information on patterns (Phillips, 1966; Jones and Genoways, 1967; Kunz, 1973, 1974; Turner, 1974). Beside morphological characteristics, pelage coloration is another key characteristic used by bat biologists to identify species while in the field, thus knowledge of the timing of molting, patterns, and old and new pelage coloration could help avoid the misidentification of bats. Bat biologists must correct this deficiency of knowledge on molting if bat taxa are to be correctly identified. Molt understanding is also of a concern when obtaining bat hair for stable isotopes analysis while bats are molting (Cryan et al., 2004), thus assuring precise results for that purpose.

Detailed observations on the timing and patterns of molt were reported by Constantine (1957, 1958b) for the Brazilian free-tailed bat (*Tadarida brasiliensis*), cave bat (*Myotis velifer*), and ghost-faced bat (*Mormoops megalophylla*) in the United States, Dwyer (1963) on Schreibers’s long-fingered bat, (*Miniopterus schreibersi blepotis*) in Australia, and Starrett (1976) on Niceforo’s big-eared bat (*Micronycteris nicefori*) in Costa Rica, and Tiunova and Makarikova (2007) on female water bats (*Myotis petax*) in Russia. However, previous studies have focused on bats from forested, grassland, and subtropical environments but not arid regions. Latitudinal gradients and weather conditions may affect molt pattern and timing as *M. s. blepotis* molt throughout the year (Dwyer, 1963).

Bats have different seasonal energetic demands and need to precisely allocate their energy budget for reproduction (pregnancy and lactation), molting, migration or hibernation etc. Molting is a very energetically stressful period in the annual cycle of bats; especially for females as it usually coincides with their breeding season. The energetic cost associated with molt could influence the timing and duration of molt in temperate zone bats as males molt before females with females delaying molt until after lactation ceases (Cryan et al., 2004). Molting may be particularly challenging to desert bats as it can interfere with their breeding season and may force females to delay molting until after their breeding period. Bats living in deserts may differ in their molting time, pattern, and new pelage coloration. Therefore, Kuhl’s bat, *Pipistrellus kuhlii*, a dominant species captured in deserts of central Saudi Arabia was studied to document the timing and pattern of molt and for comparison with previously reported patterns of molt in other bat species.