

Two new cryptic bat species within the *Myotis nattereri* species complex (Vespertilionidae, Chiroptera) from the Western Palearctic

JAVIER JUSTE^{1,4}, MANUEL RUEDI², SÉBASTIEN J. PUECHMAILLE³, IRENE SALICINI¹, and CARLOS IBÁÑEZ¹

¹*Estación Biológica de Doñana (CSIC), Avda. Américo Vespucio 26, 41092 Sevilla, Spain*

²*Natural History Museum of Geneva, P.O. Box, 6334, 1211 Genève 6, Switzerland*

³*ISEM, University of Montpellier, CNRS, EPHE, IRD, Montpellier Cedex 05, France*

⁴*Corresponding author: E-mail: juste@ebd.csic.es*

The *Myotis nattereri* species complex consists of an entangled group of Western Palearctic bats characterized by fringing hairs along the rear edge of their uropatagium. Some members are relatively common while others are rare but all forms are morphologically very similar and their taxonomy is unresolved. Recent studies based on different molecular markers have shown that several major and unexpected lineages exist within this group of forest-dwelling bats. All the mitochondrial and nuclear markers tested to date have shown that these major lineages evolved as fully independent and coherent units and therefore each qualifies as distinct species. In the absence of proper morphological diagnosis, these lineages are informally referred to in the literature under different names. We explore here the external and craniodental variation of these lineages. Although all morphological measurements were overlapping between these lineages, we show that lineages can be completely discriminated in a multivariate morphometric space. Consistent with previous molecular reconstructions, these four major lineages represent two pairs of related species, each represented by a named species (*Myotis nattereri* s. str. and *M. escaleraei*, respectively) and by unnamed forms (*Myotis* sp. A and *Myotis* sp. B, respectively). Herein we describe formally these two unnamed forms to clarify the taxonomy within this species complex. This new taxonomic view has important implication for the protection of these species, as three of the four taxa must now be considered as range-restricted species in need of conservation actions.

Key words: cryptic species, DNA, systematics, speciation, taxonomy

The identity of ‘*Falsistrellus*’ *affinis* from Myanmar and Cambodia and new records of *Hypsugo dolichodon* from these countries

TAMÁS GÖRFÖL^{1,4}, NEIL M. FUREY², PAUL J. J. BATES³, and GÁBOR CSORBA¹

¹*Department of Zoology, Hungarian Natural History Museum, Baross utca 13, Budapest, H-1088 Hungary*

²*c/o Fauna & Flora International, No. 19, Street 360, Sangkat Boeung Keng Kang 1, Khan Chamkarmon,
Phnom Penh, Cambodia*

³*Harrison Institute, Bowerwood House, 15 St. Botolph’s Road, Sevenoaks, Kent, TN13 3AQ, United Kingdom*

⁴*Corresponding author: E-mail: gorfol.tamas@nhmus.hu*

The long-toothed pipistrelle (*Hypsugo dolichodon*) was recently described as a new bat species based on four specimens from Laos and Vietnam. During investigations of taxa in the Vespertilionini tribe, we noted that specimens reported as *Falsistrellus affinis* (recently transferred to genus *Hypsugo*) from Myanmar and Cambodia have mtDNA sequences and craniodental characteristics similar to *H. dolichodon* and different from genuine *H. affinis*. Mitochondrial homogeneity within *H. dolichodon* was also apparent as there was no nucleotide difference between the widely distributed Cambodian, Lao and Vietnamese specimens in *CO1* or *Cytb* genes. Although ecological data are scarce, *H. dolichodon* appears to be a cave-dweller which would suggest that conservation measures are a priority because tropical caves are under high pressure from human use.

Key words: Indomalayan region, long-toothed pipistrelle, mtDNA, phylogeny

Parallel amino acid deletions of prestin protein in two dramatically divergent bat lineages suggest the complexity of the evolution of echolocation in bats

MIN REN¹, HAIJIAN SUN², SHUNQI BO³, SHUYI ZHANG^{4,5}, and PANYU HUA^{1,6}

¹*School of Ecological and Environmental Sciences, East China Normal University, Shanghai, 200062, China*

²*Shanghai Engineering Research Center of Molecular Therapeutics and New Drug Development, East China Normal University, Shanghai, 200062, China*

³*Department of Wildlife Protection Management Administration, Shanghai, 200023, China*

⁴*State Key Laboratory of Estuarine and Coastal Research, Institute of Estuarine and Coastal Research, East China Normal University, Shanghai, 200062, China*

⁵*College of Animal Science and Veterinary Medicine, Shenyang Agricultural University, Shenyang, 110866, China*

⁶*Corresponding author: E-mail: pyhua@bio.ecnu.edu.cn*

The membrane motor protein, prestin, encoded by gene *Prestin*, provides the electromotility to cochlear outer hair cells (OHCs) and is therefore considered responsible for cochlea's high sensitivity to sound waves. Echolocating bats use ultrasound for orientation and hunting. In this study, we obtained the complete *Prestin* coding sequences of 60 mammal taxa. Alignment results detected the same 3-bp deletion mutation (c.1833_1835del in exon 18) in two bat lineages, Pteropodidae and Emballonuroidea, and caused an amino acid deletion (p.Asp611del). These two bat lineages orient with vision and echolocation, separately, suggesting that the parallel deletion occurred independently after their split. Homology modeling of the protein structures indicated contrasting structural variations after the deletion of this amino acid. Estimation of the distributions of the surface electrostatic potential coincided with the structural variation. Our findings suggest the complexity of the echolocation in bats but functionality analyses are needed to illuminate it.

Key words: prestin, Chiroptera, parallel deletion, echolocation, evolution

Increased body mass supports energy compensation hypothesis in the breeding female Natal long-fingered bat *Miniopterus natalensis*

MARIËTTE PRETORIUS^{1, 2, 7}, TERESA KEARNEY^{1, 3, 4}, MARK KEITH^{1, 2}, WANDA MARKOTTER^{1, 5},
ERNEST SEAMARK^{1, 2}, and HUGH BRODERS⁶

¹*AfricanBats NPC, 357 Botha Avenue, Kloofsig, 0157, South Africa*

²*Mammal Research Institute, Faculty of Natural and Agricultural Sciences, University of Pretoria, Hatfield 0028, Private Bag x20, South Africa*

³*Ditsong National Museum of Natural History, PO Box 413, Pretoria, 0001, South Africa*

⁴*School of Animal, Plant and Environmental Sciences, Faculty of Science, University of Witwatersrand, Private Bag 3, Wits 2050, South Africa*

⁵*Department of Medical Virology, Faculty of Health Sciences, Centre for Viral Zoonoses, University of Pretoria, PO Box 323, Arcadia 0007, South Africa*

⁶*Department of Biology, University of Waterloo, 200 University Avenue W, Waterloo, Ontario, N2L 3G1, Canada*

⁷*Corresponding author: E-mail: mariette.pretorius@africanbats.org*

Lactation is one of the most energetically demanding periods in the life cycle of a small mammal. Classified as income breeders, hibernating small colonial insectivorous bats are hypothesised to compensate for the energetic demand of lactation by increasing daily food intake, which increases body mass. The Natal long-fingered bat *Miniopterus natalensis* is a colonial hibernating species in southern Africa for which energy compensation was hitherto unknown. We tested predictions of the energy compensation hypothesis using a wild population of *M. natalensis* during the parturition and maternity period of November–December in 2015–2017. The study was conducted at the Meletse Bat Research and Conservation Training Centre near Gatkop Cave, in Limpopo Province, South Africa. We weighed and categorised 2,707 *M. natalensis* females captured during evenings and mornings into one of four groups including not pregnant with a sclerotized nipple (NP-SC), not pregnant with a non-sclerotized nipple (NP-NSC), lactating with a sclerotized nipple (L-SC), and pregnant with a sclerotized nipple (P-SC). NP-NSC and NP-SC females were classified as non-reproductive, whilst L-SC and P-SC females were classified as active breeders. Results showed that females in the L-SC category were 6% heavier than females in non-reproductive categories (NP-NSC and NP-SC). Pregnant females were 25% heavier than non-reproductive females due, at least in part, to foetus mass, whilst the mean body mass did not differ between females in non-reproductive categories. Whilst the body mass of females in the NP-NSC, NP-SC and L-SC categories did not differ during evening captures, L-SC females showed the biggest mass increase between evening and morning captures. Proportions of females captured from reproductive categories differed among years, with a higher overall proportion of active breeders (70%) in 2017 than either 2016 (33%) or 2015 (31%). This may be related to inter-annual variation in climate and warrants further investigation. Our results suggest female *M. natalensis* were heavier, on average, during lactation and support the energy compensation hypothesis.

Key words: bats, body mass, energy compensation, lactation, *Miniopterus*, reproduction

Large dietary niche overlap of sympatric open-space foraging bats revealed by carbon and nitrogen stable isotopes

NITTAYA RUADREO¹, CHRISTIAN C. VOIGT^{2,3}, and SARA BUMRUNGSRI^{1,4}

¹*Department of Biology, Faculty of Science, Prince of Songkla University, Hat Yai, Songkhla, Thailand*

²*Department Evolutionary Ecology, Leibniz Institute for Zoo and Wildlife Research, Berlin, Germany*

³*Institute of Biology, Takustrasse 6, 14195 Berlin, Germany*

⁴*Corresponding author: E-mail: sara.b@psu.ac.th*

Sympatric bats engage in various strategies for dietary niche partitioning such as different microhabitat use; however, no previous study has yet looked at potential dietary niche partitioning in mammals foraging in a space void of any physical structure. Here, we used stable isotope ratios of carbon and nitrogen to investigate if three insectivorous bats of central Thailand, *Chaerephon plicatus*, *Taphozous melanopogon* and *T. theobaldi*, partition food resources when foraging in the open space of the lower boundaries of the troposphere. We quantified the isotopic dietary niches of these species and compared niche dimensions within the guild of open-space foraging bats and between this guild and the edge-foraging bat *Hipposideros larvatus*. Our results showed that stable isotope ratios of bats differed between wet and dry seasons. Consistently, open-space foraging bat species shared a similar isotopic composition in both seasons, which contrasted that of the edge-space foraging *H. larvatus*. Isotopic niche dimensions of open-space foraging bats were smaller than those of the edge-space foraging bat. Based on isotopic data, we inferred that open-space foraging bats foraged mostly on dipterans which may fly or drift to higher altitudes where these bats hunt. In contrast, *H. larvatus* included mostly beetles from C₄ food webs in their diet, highlighting that this species is an important predator of pest insects of C₄ crops, namely cane sugar and corn. Our study emphasizes that the unstructured aerosphere in which open-space foraging bats hunt insects may promote a large overlap in the diet of these species. We conclude that mechanisms other than trophic niche differentiation, such as the motion capacity of bat species, both in terms of covered distances and accessed altitudes may facilitate the coexistence of high-altitude foraging bats.

Key words: niche width, tropical bats, diet shifts, niche overlap, diet estimation

Trophic niche and diet of *Natalus mexicanus* (Chiroptera: Natalidae) in a tropical dry forest of Western Mexico

JOSÉ WILLIAMS TORRES-FLORES¹ and RICARDO LÓPEZ-WILCHIS^{1,2}

¹*Departamento de Biología, Universidad Autónoma Metropolitana Iztapalapa, Avenida San Rafael Atlixco No. 186, Col. Vicentina, Del. Iztapalapa, C.P. 09340, Ciudad de México, México*

²*Corresponding author: E-mail: rlw@xanum.uam.mx*

Trophic specialization is an evolutionary pathway of niche partitioning and one of the main pillars of diversification that enables species coexistence. One of the major challenges in understanding the evolution of Neotropical bats is the ability to successfully examine trophic specialization in species that are widely distributed and coexist with many other species in complex communities. In this study *Natalus mexicanus* is examined as an example of an insectivorous bat commonly associated in communities made up of hundreds or thousands of individuals of several species. We analyzed the diet and feeding patterns of *N. mexicanus* through fecal examination, direct observation, and availability of potential food sources. Our data show that *N. mexicanus* is a substrate insectivore that forages among vegetation, mainly picking insects from surfaces while hovering or flying slowly, also following a hunting strategy known as 'slow hawking'. In addition, this species has a special diet that is mainly composed of arachnids, a resource that is not commonly consumed by bats, allowing it to coexist with other species that have different feeding preferences.

Key words: ecomorphology, feeding habits, flight activity, Neotropical bats, dietary analysis, Arachnida, trophic specialization

Foraging habitat, home-range size and diet of a Mediterranean bat species, Savi's pipistrelle

MARINA KIPSON^{1, 11}, MARTIN ŠÁLEK^{2, 3}, RADEK LUČAN¹, MARCEL UHRIN⁴, EDITA MAXINOVÁ⁴, TOMÁŠ BARTONIČKA⁵,
MICHAL ANDREAS⁶, KAROLINA KIPSON⁷, ANA PUŠIČ⁸, DINA RNJAK⁹, LADISLAV NAĐO¹⁰, and IVAN HORÁČEK¹

¹*Department of Zoology, Faculty of Science, Charles University in Prague, Viničná 7, 128 44 Prague, Czech Republic*

²*The Czech Academy of Sciences, Institute of Vertebrate Biology, Květná 8, 603 65 Brno, Czech Republic*

³*Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Kamýcká 1176, Suchdol, 16521 Prague, Czech Republic*

⁴*Department of Zoology, Faculty of Science, P. J. Šafárik University in Košice, Moyzesova 11, 04001 Košice, Slovakia*

⁵*Department of Botany and Zoology, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic*

⁶*Department of Biology, Faculty of Science, University of Hradec Králové, Rokitanského 62, 50003 Hradec Králové, Czech Republic*

⁷*Brace Oruzec 20, 10360 Sesvete, Zagreb, Croatia*

⁸*Primorska 12, 10000 Zagreb, Croatia*

⁹*Geonatura Ltd. Consultancy in Nature Protection, Fallerovo šetalište 22, Zagreb, Croatia*

¹⁰*Institute of Forest Ecology, Slovak Academy of Sciences, L. Štúra 2, 960 53 Zvolen, Slovakia*

¹¹*Corresponding author: E-mail: marinakipson@gmail.com*

The Mediterranean is considered one of the richest biodiversity regions in Europe, and bats contribute to this species richness. Within the last two decades, certain bat species traditionally considered as representatives of the Mediterranean have spread northwards and colonized areas outside this region. In our study, we focused on ecological requirements of one of these bat species, the Savi's pipistrelle (*Hypsugo savii*). We used radio-telemetry and diet analysis to describe habitat use, home-range size and diet composition of reproductive females of Savi's pipistrelle in the traditional core of its distribution range in the Mediterranean region. Our results indicate that Savi's pipistrelle is able to fly long distances and utilize a wide range of habitats within its home-range, with affinities for particular habitats depending on its reproductive status. In particular, pregnant females favoured rocky pastures and forest areas, followed by meadows and riparian habitat, whereas the affinity for riparian habitat increased in lactating females, followed closely by meadows, forest and rocky pastures. The larger affinity for riparian habitats during lactation might indicate its importance for successful rearing of young, which could be influenced in the future by increasing droughts and water shortage in the Mediterranean region. Nevertheless, based on our radio-telemetry and diet analysis the species shows a high degree of flexibility, as an opportunistic forager that flies across large areas on a nightly basis, which may be a good predisposition for colonizing new areas.

Key words: Chiroptera, Mediterranean region, habitat affinity, *Hypsugo savii*, reproductive status, riparian vegetation, radio-telemetry

The itinerant Natterer: dynamics of summer roost occupancy by *Myotis nattereri* (Chiroptera, Vespertilionidae)

PETER G. SMITH¹ and PAUL A. RACEY^{1, 2, 3}

¹*School of Biological Sciences, University of Aberdeen, Tillydrone Avenue, Aberdeen, Scotland AB24 2TZ, United Kingdom*

²*Present address: Chapel Cottage, Prazegooth Lane, Cadgwith, Helston TR12 7LA, United Kingdom*

³*Corresponding author: E-mail: p.racey@abdn.ac.uk*

Natterer's bat *Myotis nattereri* is one of the least known European bats. Understanding its patterns of movement between roosts is an important aspect of assessing the relative value of different types of roost for conservation of the species. We determined patterns of movement of Natterer's bat between roosts by radio-tracking successive animals from the same colonies during summer (May to September). For one maternity colony comprising 65 adult females, the attic of a large mediaeval church was the main roost site, accounting for 88% of radio-located bat days. The two other maternity colonies tracked comprised about 35 adult females each and used from 15 to 25 roost sites, some containing multiple roosts. For these two colonies, up to six roost sites per colony accounted for about 80% of bat occupancy days in any one summer and for each colony, roost home ranges for roosts used by subgroups of at least two bats together covered 0.4 km². Although bats made frequent movements between roosts there was no apparent interchange between adjacent colonies and no overlap in the range used by adjacent colonies. Bats changed roosts every 3.0 days on average, moving 510 m (median) to an alternative roost. They departed late and returned early to roosts. Colonies assembled or disintegrated into larger or smaller groups occupying diverse roosts during summer, but there was high social cohesion between colony members. Bats that separated into subgroups from mid-summer (mid-July) onwards later roosted together again. Natterer's bat exhibits high behavioural flexibility in the type of roosts used: of two adjacent maternity colonies, one used mostly tree roosts and the other mostly buildings. However, both roosted mainly in roofs during early summer (late May to mid-July). Tree roosts were significantly preferred to those in buildings when ambient external maximum temperatures were $\geq 30^{\circ}\text{C}$ or mean temperatures fell below 14°C . Natterer's bat appears to depend on the availability of a number of roosts of different types. Parturition roosts, roosts in heavily timbered barns and roosts within core roosting areas, potentially up to 1.2 km distant from the parturition roost, should have highest conservation priority but conservation management should guard against any roost loss.

Key words: *Myotis nattereri*, behavioural flexibility, roosting behaviour, roost switching, radio-telemetry, roost temperature, summer roosts

Does light condition affect the habitat use of soprano pipistrelles *Pipistrellus pygmaeus* at the species northern extreme?

TORE CHRISTIAN MICHAELSEN^{1, 2, 3}, KNUT HELGE JENSEN¹, and GÖRAN HÖGSTEDT¹

¹*Department of Biology, University of Bergen, P.O. Box 7800, NO-5020 Bergen, Norway*

²*Nedre Hoffland 15, NO-6057 Ålesund, Norway*

³*Corresponding author: E-mail: michaelson@biometrika.no*

This study explores the hunting habitat and activity patterns of the soprano pipistrelle *Pipistrellus pygmaeus* in relation to insect densities and light conditions during summer at 62°N in western Norway. Here, the first soprano pipistrelles emerge at several thousand lux and are common in woodland at more than 1000 lux. In this study, bats tagged with transmitters emerged from their roosts on average one hour before sunset and were airborne for more than five hours each night. During the first hours they always hunted in woodland, but shifted to hunt above the fiord during the night. This shift occurred on average 2 h and 25 min after evening emergence and 1 h and 30 min after sunset. In addition to using radio telemetry, bat contacts over the fiord were counted using ultrasound detectors and car transects. Simultaneously, insects were collected using suction traps and light levels were measured. There was a highly significant effect of light intensity on the number of bats hunting along the fiord. Predictions based on a second order polynomial generalised linear model (GLM) shows that soprano pipistrelles will start to hunt above the fiord when light levels drop below approximately 25 lux. It also suggests a slight reduction of insects as bat numbers increase along the shoreline. The GLM model explains approximately 92% of the variation in the dataset. Ultrasound recordings show that soprano pipistrelles attack far more prey per effort near the shores compared to areas further away. The results found in this study strongly suggest that habitat selection is a trade-off between food energy intake and other factors, e.g. predation risk.

Key words: activity patterns, Chiroptera, emergence time, anti-predator behaviour, fiord, *Pipistrellus pygmaeus*, feeding buzzes, radio telemetry

Bat community responses to structural habitat complexity resulting from management practices within different land use types — a case study from north-eastern Germany

NICOLE STARIK^{1,4}, THOMAS GÖTTERT¹, EMANUEL HEITLINGER^{2,3}, and ULRICH ZELLER¹

¹*Systematic Zoology Division, Albrecht Daniel Thaer-Institute of Agricultural and Horticultural Sciences, Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany*

²*Department of Molecular Parasitology, Institute for Biology, Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany*

³*Research Group Ecology and Evolution of Molecular Parasite Host Interactions, Leibniz Institute for Zoo and Wildlife Research, Alfred-Kowalke-Straße 17, 10315 Berlin, Germany*

⁴*Corresponding author: E-mail: nicole.starik@hu-berlin.de*

In the present study we evaluated how management practices, structural habitat parameters and arthropod availability affect bat activity, species richness and species diversity (estimated by Shannon's diversity index H') in a cultural landscape composed by a mosaic of different habitats in Brandenburg (Germany). Over a study period of two years (2012–2013), a standardised acoustic monitoring was conducted on 12 sampling sites comprising different land use types in forests (pine, mixed and deciduous forest) and agricultural areas (arable land and grassland). The focus was on the effect of small-scale changes in structural habitat parameters resulting from management practices within one-and-the-same land use type. We applied a paired sampling design and compared two (forest) and three (agricultural areas) sampling sites (complexity categories) per land use type. An effect of structural complexity was tested using parametric and non-parametric analyses. Sampling sites differ in a complexity index derived from vegetation measurements related to: a) vertical vegetation structure (pine forests), b) tree species composition (mixed forests), c) tree age (deciduous forests), d) crop type (arable land), and e) management intensity (grassland). Within the pine and mixed forest, management practices leading to an increase in structural habitat complexity were associated with a significant increase in bat activity, species richness, and species diversity (H'). This effect is only partially explained by increased prey abundance. On grassland, increased bat abundance is associated with low-intensity management practices. This effect is explainable by an increase in arthropod abundance associated with structural complexity but no additional effect of structural complexity beyond that. On arable land, the difference in structural complexity among different crops (and not prey abundance) significantly affects bat communities. Our approach employed proxy measures of habitat quality to estimate which management practices within the study area theoretically result in suitable and available habitats to meet the requirements of local bat species. Thus, our findings have implications for forest and agricultural management. Even minor changes in silvicultural management (understorey development in pine monocultures and increased percentage of deciduous trees in mixed forests) may lead to a significant increase in forest habitat quality for bats. The findings also stress the importance of extensive management practices in grassland, as well as structure-rich crops on arable land to achieve a more environmentally sustainable farmland management.

Key words: agriculture, acoustic monitoring, bat activity, forest management, extensively managed grasslands

Beyond the Amazon forest: richness and abundance of bats in the understory of savannahs, campinaranas and terra firme forest

WILLIAM D. DE CARVALHO^{1, 2, 8}, LUIZ A. COSTA GOMES³, ISAÍ J. DE CASTRO⁴, ANA C. MARTINS⁵,
CARLOS E. LUSTOSA ESBÉRARD⁶, and KAREN MUSTIN⁷

¹*Programa de Pós-Graduação em Biodiversidade Tropical, Universidade Federal do Amapá, Rodovia Juscelino Kubitscheck, S/N, Jardim Marco Zero 68903-419, Macapá, Amapá, Brazil*

²*Laboratório de Ecologia, Departamento de Meio Ambiente e Desenvolvimento, Universidade Federal do Amapá, Rodovia Juscelino Kubitscheck, S/N, Jardim Marco Zero 68903-419, Macapá, Amapá, Brazil*

³*Laboratório de Mastozoologia, Departamento de Biologia Animal, Instituto de Ciências Biológicas e da Saúde, Universidade Federal Rural do Rio de Janeiro, BR 465, Km 7, 23890-000, Seropédica, Rio de Janeiro, Brazil*

⁴*Laboratório de Mamíferos, Instituto de Pesquisas Científicas e Tecnológicas do Estado do Amapá, Rodovia Juscelino Kubitscheck, Km 10, CEP 68912-250, Macapá, Amapá, Brazil*

⁵*Departamento de Zoologia, Instituto de Ciências Biológicas, Universidade de Brasília, Campus Universitário Darcy Ribeiro, 70910-900, Brasília, Distrito Federal, Brazil*

⁶*Laboratório de Diversidade de Morcegos, Departamento de Biologia Animal, Instituto de Ciências Biológicas e da Saúde, Universidade Federal Rural do Rio de Janeiro, BR 465, Km 7, 23890-000, Seropédica, Rio de Janeiro, Brazil*

⁷*Institute of Biological and Environmental Sciences, Zoology Building, University Aberdeen, Tillydrone Avenue, Aberdeen, AB24 2TE, Scotland, United Kingdom*

⁸*Corresponding author: E-mail: wilruoca@gmail.com*

The Amazon region is made up of a mosaic of important habitats scattered throughout the rainforests, which differ in vegetation structure, basal area, primary productivity, biomass and production of flowers and fruits. Consequently, species richness and abundance also vary between these habitat types, in part explaining the high levels of richness found in the Amazon region. Here, we sampled bats using mist nets in three Amazonian habitats to explore variation in richness, abundance and community composition between habitats and seasons, and test for variation in the number and composition of bats captured in different mist net shelves. Overall abundance was highest in Amazonian savannahs, which is probably due to these habitats being more complex at the landscape scale — being composed of areas of savannah interspersed with forest fragments, gallery forests and palm stands. Abundance was also higher in the rainy season in savannahs and terra firme forest, and in the dry season in campinarana. In all habitats, bats were most frequently captured between 0.7 and 2.4 m from the ground. These results have important implications for our understanding of the ecology of, and habitat use by bats in the Amazon, particularly in the less well-studied habitat types of Amazonian savannah and campinarana. In addition, knowledge of the distribution of bat captures between mist net shelves serves to highlight that nets need not be set so close to the ground to maintain sampling efficiency, which is important as it may help to reduce opportunistic predation events of individuals caught in the lowest mist net shelf.

Key words: Amazonian savannah, Brazil, guilds, phyllostomid bats, white-sand ecosystems

Long-term increase in hibernating bats in Swedish mines — effect of global warming?

JENS RYDELL^{1,5}, JOHAN EKLÖF², HANS FRANSSON³, and SABINE LIND⁴

¹*Biology Department, Lund University, SE-223 62 Lund, Sweden*

²*Nattbacka Natur, Krokdalsvägen 88, SE-517 34 Bollebygd, Sweden*

³*Store Mosse Nationalpark, SE-3357 74 Hillerstorp, Sweden*

⁴*Jönköpings kommun, SE-551 89 Jönköping, Sweden*

⁵*Corresponding author: Email: jens.rydell@telia.com*

We present the result of bat winter censuses in three old mines in southern Sweden from 1980 until present (2017). The Taberg and Kleva mines, each with about 1.5 km of accessible passages, have winter populations of 517 and 132 bats, respectively (maximum counts) belonging to six species, the highest numbers known in underground sites in Sweden. Ädelfors is less extensive and has fewer individuals (maximum 22). The two former sites were protected and gated in the 1980's while the third site still has no formal protection and is subject to disturbance. Generally Daubenton's bat *Myotis daubentonii* and the brown long-eared bat *Plecotus auritus* are common species and the numbers are stable. The whiskered and Brandt's bats *M. mystacinus/brandtii* and Natterer's bat *M. nattereri* have increased significantly, while the northern bat *Eptesicus nilssonii*, which is relatively rare in mines generally, has shown a slight but significant decline. At the species level the population trends conform well to those of the respective species in continental Europe and the British Isles. This suggests that there is a common factor behind the population changes across Europe. Although our data are very limited, the results question some previous explanations for the observed trends, but are in line with theoretical predictions based on global warming scenarios.

Key words: climate change, bat conservation, hibernation, population change, roost survey

Bat swarming in the eastern Palaearctic (Eastern Siberia)

DENIS KAZAKOV^{1,5}, ALEXANDRA SHUMKINA², ALEXANDER BOTVINKIN³, and OLEG MOROZOV⁴

¹*International Complex Research Laboratory for Study of Climate Change, Land Use and Biodiversity, Tyumen State University, 25 Lenin Street, 625003 Tyumen, Russia*

²*Federal State Budgetary Institution 'Zapovednoe Pribaikalye', 291b Baikalskaya Street, 664050 Irkutsk, Russia*

³*Department of Epidemiology, Irkutsk State Medical University, 1 Krasnogo Vosstania Street, 664009 Irkutsk, Russia*

⁴*Center of Children's Complementary Education and Evenkis' Folk Crafts, 2a Morozov Street, 671510 Bagdarin, Russia*

⁵*Corresponding author: E-mail: kazakov.denis.95@mail.ru*

Bat swarming in Siberia and the Russian Far East has not yet been studied. Therefore, the purpose of the present research was to obtain information about bat swarming (species composition, sex ratio and age structure) as it relates to mating at several sites in Siberia. The study of bat swarming was carried out in July–September 2015, 2016 and 2017 in the eastern Palaearctic at the entrances to three large karstic caves: Okhotnichya, Mehta and Dolganskaya Yama, located in the Baikal rift zone. We captured 1,604 bats belonging to seven species: *Plecotus ognevi*, *Murina hilgendorfi*, *Myotis petax*, *Myotis sibirica*, *Myotis ikonnikovi*, *Myotis [frater] longicaudatus* and *Eptesicus nilssonii*. In all swarming sites *P. ognevi* predominated (40–85%). The second most abundant species was *M. hilgendorfi* (except for Mehta Cave, where high numbers of *M. petax* were observed). In all the caves, males predominated (70–88%), except for Dolganskaya Yama Cave in September where the sex ratio was close to 1:1. Adult individuals were more numerous than juveniles, which reached the maximum proportion (30%) in Dolganskaya Yama Cave in September due to the inflow of juvenile females of *P. ognevi*. The maximum body mass and BCI_{vp} (body condition index taking into account observed to expected body mass) of adult males of dominant species were recorded in September for *P. ognevi* in Dolganskaya Yama Cave and *M. hilgendorfi* in Dolganskaya Yama and Okhotnichya caves. Based on the observations, it appears that the peak of mating of *P. ognevi* and *M. hilgendorfi* occurs in mid-August, when the ratio of males and females was 7:3. Moreover, in the case of *P. ognevi* the peak of mating is apparently more dependent on climatic conditions than in *M. hilgendorfi*. The abundance of species during the swarming season and hibernation in the same caves differed — *P. ognevi* and *M. hilgendorfi* occurred as singletons in winter, and *Myotis* spp. (mostly *M. sibirica*) predominated. Our results support the hypothesis that swarming is typical for bats of the temperate zone throughout the entire Holarctic (Europe, North America and Asia).

Key words: bats, mating, swarming, sex ratio, caves, Eastern Siberia

The behaviour and vocalisations of captive Geoffroy's horseshoe bats, *Rhinolophus clivosus* (Chiroptera: Rhinolophidae)

HANA PETERSEN^{1,*}, NIKITA FINGER^{1,*}, ANNA BASTIAN², and DAVID JACOBS^{1,3}

¹*Animal Evolution and Systematics Group, Department of Biological Sciences, University of Cape Town, Rondebosch, Cape Town, 7700, South Africa*

²*School of Life Sciences, University of KwaZulu-Natal, Durban 4001, KwaZulu-Natal, South Africa*

³*Corresponding author: E-mail: David.Jacobs@uct.ac.za*

Acoustic signals are important to the biology of animals, mediating crucial activities such as social interactions (communication) as well as orientation and foraging (echolocation). Many signals used in communication are vocal, which are especially important in nocturnal animals such as bats where social interactions occur in darkness. Despite this, little is known about the social calls and behaviours of echolocating bats. To better understand their social and acoustic behaviour, we compiled an ethogram and list of vocalisations for Geoffroy's horseshoe bat (*Rhinolophus clivosus*). We kept three non-contemporaneous and short-term captive groups to capture interactions and social calls using simultaneous video and audio recordings. The resultant ethogram was comprised of 40 unique types of behaviour, both social and non-social. Social calls ($n = 255$) were assigned to different call types by their frequency-time contour and categorised by their behaviours, situational categories and functional contexts (affiliative or agonistic). From the calls observed, four acoustically distinct call types were identified: (i) cascading/rising frequency-modulated (FM) calls ($n = 26$), (ii) oscillatory FM calls ($n = 140$), (iii) noisy screech calls ($n = 68$), and (iv) whistle calls ($n = 21$) (GLM: $F_{30, 711} = 24.28$, $P < 0.001$). Call types showed only weak associations with certain behaviours, situational categories or functional contexts. However, calls with specific acoustic attributes accompanied the behaviour of wing swat [discriminant function analysis (DFA) classification success: 76%; GLM: $F_{20, 108} = 4.12$, $P < 0.001$] and situational category of flight (DFA classification success: 82%; GLM: $F_{20, 136} = 2.97$, $P < 0.001$). An analysis of acoustic attributes across all call types showed weak associations with functional context (Affiliative DFA classification success: 6%). Only one acoustic parameter (peak frequency) had a slight significant difference between calls emitted during agonistic and affiliative interactions (GLM: $F_{10, 73} = 2.30$, $P < 0.05$; post-hoc unequal n : $P = 0.044$). In addition to the description of distinct call types, we provide evidence of transitional calls in this bat species in which a social call transitions seamlessly into an echolocation pulse. This study gives a first glimpse into the behaviours and social vocalisations produced by *R. clivosus*. Basic behavioural data such as these may facilitate the design of experiments that allow greater insight into the social organisation of bats.

Key words: social calls, captivity, ethogram, context-specificity, social behaviour, transitional calls

Function of distress calls in least horseshoe bats: a field study using playback experiments

XIU WU^{1,*}, YULAN PANG^{1,*}, BO LUO^{1,2,4}, MAN WANG¹, and JIANG FENG^{2,3}

¹*Key Laboratory of Southwest China Wildlife Resources Conservation of Ministry of Education, China West Normal University, Nanchong 637009, China*

²*Jilin Provincial Key Laboratory of Animal Resource Conservation and Utilization, Northeast Normal University, 255 Jingyue Street, Changchun 130117, China*

³*College of Animal Science and Technology, Jilin Agricultural University, Changchun 130117, China*

⁴*Corresponding author: E-mail: luob041@nenu.edu.cn*

Many social animals utter distress calls in the context of fear. These vocalizations may serve to attract audiences for help, warn individuals of danger, and confuse the predator. Here, we aim to assess the function of distress calls in free-living least horseshoe bats, *Rhinolophus pusillus*. We recorded distress calls from four allopatric colonies in mainland China. Playback trials, consisting of distress calls, silence, and noise, were presented to bats outside three bat roosts. *Rhinolophus pusillus* emitted long, harsh, broadband calls when under duress. Playback of distress calls induced a significant increase in bat passes at the loudspeaker in comparison with control trials. The number of recorded echolocation pulses increased 3.2–6.1 folds during playbacks of distress calls compared to playbacks of silence, and 2.9–5.2 folds compared to playbacks of noise. There was a positive association between bat passes and echolocation vocalizations. However, some bats delayed their emergence from the roost in response to distress call stimuli. Despite similar delayed responses, more bat passes were detected in the presence of allopatric distress calls than those from colony members. Overall, the results indicate that distress calls could attract and warn conspecifics in least horseshoe bats.

Key words: distress call, bat, predation risk, conspecific recruitment, alarm

Performance of hierarchical abundance models on simulated bat capture data

KATHRYN M. WOMACK-BULLINER^{1,4}, SYBILL K. AMELON², FRANK R. THOMPSON III², and JAYMI J. LEBRUN³

¹*Missouri Department of Conservation, Northeast Regional Office, 3500 S. Baltimore Street, Kirksville, MO 63501, USA*

²*U.S.D.A. Forest Service, Northern Research Station, 202 Natural Resource Building, Columbia, MO 65211, USA*

³*U.S. Fish and Wildlife Service, 5600 American Blvd. West, Suite 990, Bloomington, MN 55437, USA*

⁴*Corresponding author: E-mail: Kathryn.Womack@mdc.mo.gov*

The ability to accurately estimate abundance is crucial to ecologists, conservationists, and managers to provide insight on species status, population trends, and viability. Acoustic detection and occupancy modeling can provide an understanding of resource use for bats, but these methods do not estimate how many bats are in an area, or how these numbers change over time. In North America, there is a heightened need to estimate bat abundance and trends in response to white-nose syndrome (WNS) and other threats to bat populations. We assessed the performance of the N-mixture model for repeated count data and the general multinomial-Poisson model for removal sampling to estimate bat abundance from simulated mist-net capture data. We evaluated performance under varying numbers of sites and visits, detection probabilities (P), and population sizes. We simulated four scenarios with a total of 85 combinations of parameter values each containing 1,000 replications. We used the UNMARKED package in R to fit the N-mixture and removal models. We calculated relative bias (RB), mean absolute error (MAE), and mean absolute percent error (MA%E) from model estimates to evaluate model performance. Relative bias, MAE, and MA%E decreased as p and bat abundance increased for all models. The removal model outperformed the N-mixture model in all scenarios except when $P = 0.05$. The N-mixture model had low RB, MAE, and MA%E when bat abundance was ≥ 70 and $P > 0.5$, but in other scenarios, errors were large. The mean of estimates from the removal model were unbiased and RB, MAE, and MA%E were very low for most scenarios. Use of the removal model with data from repeated mist-net surveys may allow resource managers and conservationists to better quantify how resource management and landscape composition affect bat species abundance and overall populations.

Key words: N-mixture models, multinomial Poisson models, removal sampling, abundance

Fecal bacterial communities in insectivorous bats from the Netherlands and their role as a possible vector for foodborne diseases

JUDITH C. M. WOLKERS-ROOIJACKERS^{1,3}, KATHARINA REBMANN¹, THIJS BOSCH², and WILMA C. HAZELEGER¹

¹*Laboratory of Food Microbiology, Wageningen University & Research, Wageningen Campus, P.O. Box 17,
6700 AA Wageningen, The Netherlands*

²*Ad Hoc Zoogdieronderzoek, 6708 GA Wageningen, The Netherlands*

³*Corresponding author: E-mail: judith.wolkers-rooijackers@wur.nl*

Bats are commonly regarded as vectors for viruses, but little is known about bacterial communities in bats and the possible role of bats in the transmission cycle of foodborne diseases. To gain more insight, microbial communities in fecal samples from 37 insectivorous bats of different species from the Netherlands were investigated by polymerase chain reaction and denaturant gradient gel electrophoresis (PCR-DGGE). Subsequently, 10 samples from the following bat species: common pipistrelle (*Pipistrellus pipistrellus*; $n = 3$), Daubenton's bat (*Myotis daubentonii*; $n = 3$), serotine bat (*Eptesicus serotinus*; $n = 1$), whiskered bat (*Myotis mystacinus*; $n = 1$), Geoffroy's bat (*Myotis emarginatus*; $n = 1$) and Natterer's bat (*Myotis nattereri*; $n = 1$) were selected and used in bacterial 16S rDNA cloning and sequencing. The fecal microbiota in bats was found to be diverse with predominant bacterial genera *Carnobacterium*, *Serratia*, *Pseudomonas*, *Enterococcus* and *Yersinia*. The presence of opportunistic pathogens *Citrobacter freundii*, *Escherichia coli*, *Enterococcus faecalis*, *Serratia fonticola* and *Rahnella aquatilis* was also recorded. Based on cloning results, we found no proof that bats in the Netherlands are a major vector for the transmission of bacterial zoonotic diseases, although previous findings in literature reported isolation of foodborne pathogens from bats.

Key words: bats, microbial diversity, bacteria, DGGE

Ocular lesions and diseases in bats from Jalisco and Oaxaca, Mexico

CORNELIO SÁNCHEZ-HERNÁNDEZ^{1,7}, SILVIA S. ZALAPA², SERGIO GUERRERO², MARÍA DE LOURDES ROMERO-ALMARAZ³, LUZ M. SIL-BERRA⁴, and GARY D. SCHNELL^{5,6}

¹*Departamento de Zoología, Instituto de Biología, Universidad Nacional Autónoma de México, A.P. 70-153, Coyoacán, Ciudad de México, México*

²*Centro de Estudios en Zoología, CUCBA, Universidad de Guadalajara, C.P. 45200, Camino Ramón Padilla Sánchez No. 2100, Las Agujas, Zapopan, Jalisco, México*

³*Escuinapa No. 92 bis. Col. Pedregal de Santo Domingo, C.P. 04369, Ciudad de México, México*

⁴*Posgrado en Ciencias Biológicas, Instituto de Biología, Universidad Nacional Autónoma de México, A.P. 70-153, Coyoacán, Ciudad de México, México*

⁵*Sam Noble Oklahoma Museum of Natural History and Department of Biology, University of Oklahoma, Norman, OK 73072, USA*

⁶*Present address: 919 Yorkshire Drive, Breinigsville, PA 18031, USA*

⁷*Corresponding author: E-mail: cornelio@unam.mx*

Ocular diseases are common in pets and other domestic mammals, as well as in wild mammals, but there are few reports for bats. A review of multiple mortality events in bats and examination of bat carcasses from several species revealed that principal causes of death were traumas, bacterial infections, and attacks by domestic cats. Relatively little is known concerning ocular lesions or diseases in bats with only two papers reporting ocular anomalies. We describe ocular lesions or diseases detected in bats of Jalisco and Oaxaca, Mexico. From January 2008 through March 2017, we captured 8,718 bats, nine of these had ocular lesions or diseases. These nine were collected in five localities. Bats were captured with mist nets; six with ocular anomalies were released after recording the basic biological information and three were preserved as museum specimens. Eyes of the affected bats were photographed in the field. Of nine bats with ocular lesions or diseases, two had corneal opacity, four had eye injuries or infections, one had microphthalmia or nanophthalmia, and two had anophthalmia. No other evidence of trauma, disease, or reduced fitness was noted. The bats with anomalies were from two families (Phyllostomidae and Molossidae) and six species (*Desmodus rotundus*, *Glossophaga soricina*, *Artibeus jamaicensis*, *Artibeus lituratus*, *Sturnira parvidens*, and *Tadarida brasiliensis*). The paucity of reports of ocular anomalies in bats suggests that those with ocular problems have low survival probability in natural settings. However, given the small size of the eye in many bat species, the rarity of such reports could be in part due to field researchers missing such anomalies even when they occur. Also, we suspect that researchers at times encounter such anomalies but simply do not report their observations in the literature.

Key words: anophthalmia, Chiroptera, corneal opacity, eye injuries, microphthalmia, Molossidae, Phyllostomidae, ocular diseases

Sertoli cell efficiency of the Neotropical bats *Anoura geoffroyi*, *Artibeus lituratus* and *Myotis levis* (Mammalia: Chiroptera)

PEDRO I. M. VIANA¹, TALITA O. FARIAS¹, SONIA A. TALAMONI^{1,2}, and HUGO P. GODINHO¹

¹*Programa de Pós-graduação em Biologia de Vertebrados, Departamento de Ciências Biológicas, Pontifícia Universidade Católica de Minas Gerais, Avenida Dom José Gaspar, 500, Belo Horizonte, Minas Gerais, Brazil*

²*Corresponding author: E-mail: stalamoni@gmail.com*

Sertoli cells play an essential role in spermatogenesis, being determinant of male reproduction capability. In this study we determined and compared the Sertoli cell efficiency (SCE), i.e. the ratio of the number of round spermatids to the number of Sertoli cells, of three species of Neotropical chiropterans, *Anoura geoffroyi*, *Artibeus lituratus* and *Myotis levis*, and additionally we tested for correlations between SCE, the combined mass of the testes and epididymides (CMTE), and the body condition index (BCI), considering that both BCI and testis mass can influence gonadal function of males. For SCE determination, the number of round spermatids and Sertoli cells present in stage 1 of the cycle of the seminiferous epithelium were counted. The Sertoli cell efficiency (mean \pm 1 SD) was 4 ± 2.4 for *A. geoffroyi*, 4 ± 1.0 for *A. lituratus* and 6 ± 2.0 for *M. levis*. No significant variation was observed in SCE among the species, but *A. lituratus* exhibited a statistically significant correlation between CMTE and BCI. *Anoura geoffroyi* and *M. levis* exhibited significant positive correlations between SCE and CMTE, but not between SCE and BCI. Previous studies have shown that, unlike *A. lituratus*, *A. geoffroyi* and *M. levis* are subject to strong mating pressures, leading us to hypothesize that these findings may be related to differential mating pressures between species.

Key words: body condition index, chiropteran reproduction, epididymis mass, testicular mass

Specialization and modularity of a bat fly antagonistic ecological network in a dry tropical forest in northern Colombia

ADRIÁN A. DURÁN^{1, 2, 6}, ROMEO A. SALDAÑA-VÁZQUEZ³, GUSTAVO GRACIOLLI⁴, and
LAURA C. PEINADO⁵

¹*Grupo de Investigación en Zoología y Ecología Universidad de Sucre, Sincelejo — Sucre, Colombia*

²*Sistemática, Ecologia e Evolução de Hexapoda Neotropicais, Centro de Ciências Biológicas e da Saúde,
Universidade Federal de Mato Grosso do Sul, Campo Grande-MS, Brasil*

³*Laboratorio de Análisis para la Conservación de la Biodiversidad, Instituto de Investigaciones sobre los Recursos Naturales,
Universidad Michoacana de San Nicolás de Hidalgo, Avenida San Juanito Itzicuaró SN, Col. Nueva Esperanza,
C.P. 58330 Morelia, Michoacán, México*

⁴*Programa de Pós-Graduação em Ecologia e Conservação, Departamento de Biologia, Universidade Federal
de Mato Grosso do Sul, 79070-900 Campo Grande-MS, Brasil*

⁵*Departamento de Ecologia, Universidade Federal de Mato Grosso do Sul, 79070-900 Campo Grande-MS, Brasil*

⁶*Corresponding author: E-mail: adurandelaossa@gmail.com*

Ecological networks represent the energy flow and interactions among the species of an ecological community. Streblidae is a family of bloodsucking flies specialized in parasitizing bats, thus forming an ecological network. The purpose of this study was to investigate the specialization and modularity of a bat fly antagonist ecological network in a tropical dry forest in northern Colombia. Bat hosts were sampled by using mist nets, while bat flies were collected directly from the hosts by using entomological forceps. The network was built with the Bipartite package from R software. The sampling effort resulted in 270 bat flies recorded on 45 host individuals. The network showed a high specialization ($H_2^2 = 0.67$) and a low connectance ($C = 0.30$). *Paradyschiria parvuloides* was the most specialized fly ($d = 0.95$). The interactions exhibited a high modularity ($Q = 0.57$), with five modules. This study confirms the high specialization between bats and Streblidae flies, which is influenced by factors such as fidelity to the refuge and habitat, and host abundance.

Key words: flies, parasitism, Phyllostomidae, Streblidae

Parasitism of bat flies (Nycteribiidae and Streblidae) on bats in urban environments: lower prevalence, infracommunities, and specificity

GUSTAVO L. URBIETA^{1,4}, JAIRE M. TORRES², ELAINE A. CARVALHO DOS ANJOS³,
CRISTIANO M. ESPÍNOLA CARVALHO², and GUSTAVO GRACIOLLI¹

¹*Programa de Pós-Graduação em Biologia Animal, Laboratório de Sistemática, Ecologia e Evolução (LSEE), Instituto de Biociências (INBIO), Universidade Federal de Mato Grosso do Sul (UFMS), 79090-900, Campo Grande, MS, Brazil*

²*Programa de Pós-Graduação em Biotecnologia, Universidade Católica Dom Bosco (UCDB), Campo Grande, MS, Brazil*

³*Bolsista CAPES - Proc. Number 1218-13-1, University of Manitoba, Biological Sciences Building, Winnipeg, MB R3T 2N2, Canada*

⁴*Corresponding author: E-mail: gustavo.cx@hotmail.com*

Studies involving parasitism between ectoparasitic flies and bats are scarce for urban environments, which makes it difficult to find association patterns in these altered environments. Herein, we describe the bat flies community, and estimate the prevalence, mean intensity of infestation, infracommunities, and specificity of bat flies associations in urban remnants of Cerrado. We collected 371 bat flies of 14 species and 944 bats of 17 species. The most abundant species of bats were *Artibeus planirostris* ($n = 312$), *Artibeus lituratus* ($n = 197$), *Carollia perspicillata* ($n = 124$) and *Platyrrhinus lineatus* ($n = 110$). Regarding bat flies, *Megistopoda aranea* ($n = 148$) and *Trichobius joblingi* ($n = 118$) were the most abundant. The prevalence of bat flies ranged from 0.3 to 43.5% and the mean infestation intensity from 1 to 12 (mean general of 2.04). We found 16 bat flies infracommunities on the most representative hosts ($n > 30$). Concerning specificity, 71% of bat flies were associated with a single host species (monoxenic). Our results indicate that bats were most parasitized by a single bat flies species, and prevalence and specificity between bat flies and bats were lower in these urban environments.

Key words: fragmentation, Phyllostomidae, Cerrado, ectoparasite

Age-related changes in the teeth of two bat species: dental wear, pulp cavity and dentine growth layers

PAVEL GOL'DIN^{1,2}, LENA GODLEVSKA¹, and MARIA GHAZALI¹

¹*Schmalhausen Institute of Zoology, National Academy of Sciences of Ukraine, 15 Bogdan Khmelnytskyi Street, Kiev, 01030, Ukraine*

²*Corresponding author: E-mail: pavelgoldin412@gmail.com*

As bats are long-lived mammals, insight into the age of individuals is important for studies relating to population ecology and conservation biology, as well as longevity. Thus, there is a need to develop methods to estimate the age of bats, and teeth are excellent means to do so. The work detailed here involves an assessment of age-related changes and variation in tooth wear, dentine growth layers, and pulp cavity size in two bat species with differing life history strategies, i.e. *Nyctalus noctula* ($n = 149$) and *Eptesicus serotinus* ($n = 49$). Both the gross morphology and the histology of teeth in both species were found to display age-related variation. Morphological indicators like tooth wear and pulp-cavity size showed considerable variation at the individual level, and corresponding with broadly defined age categories. Dentine growth layering was consistent with presumed age and had annual growth layers in both species, along with accessory layers. Aspects of interpreting growth layers and tooth wear based on photographs and histological preparations associated with observer bias are important to consider, as are the sampling of multiple readings.

Key words: bats, age, teeth, growth layers, pulp cavity size, tooth wear

BOOK REVIEWS

WOINARSKI, J. 2018. A bat's end: The Christmas Island pipistrelle and extinction in Australia. ISBN 978-1-4863-0863-7, 266 pp. CSIRO Publishing, Clayton South, Victoria, Australia. Price AU\$59.99.

In the age of the Anthropocene and frequent references in the public and scientific literature to pending large-scale animal extinctions as our planet continues to be modified, this book provides such evidence for the Christmas Island pipistrelle, *Pipistrellus murrayi*. This species, which was endemic to the island, disappeared in late August 2009. Christmas Island is an Australian external territory, located in the eastern Indian Ocean, about 1500 km from its closest point to the Australian mainland and 350 km south of Java. Associated with different aspects of the island's management history and exploitation, introductions of different taxa, and a range of ecological calamities, at least two other endemic mammal species disappeared in the early 20th-century (*Rattus nativitatis* and *Rattus macleari*) and another has not been seen in nearly 40 years (*Crocidura trichura*).

It is appropriate to commence this review using the author's own words to explain the underlying message of this book, “[it] is an exploration of the shortcomings in research, monitoring, management and policy that led to the conservation management failure that is extinction” (p. 1). In order to provide the needed context to understand what went wrong, the first portion of the book include a well-written and interesting chapter on

conservation importance and challenges of islands, followed by a detailed history of environmental changes on Christmas Island. The next section summarizes what is known about *P. murrayi* and with a specific focus on historical distribution and different aspects of its natural history. The next two chapters examine the multiple faceted questions as to what happened to the bat, from the perspectives of the drivers of extinction and failings of management and policy at different levels, including governmental. Then a profile series of different government employees, administrators, managers, biologists, and conservationists that worked on the island in different manners related to the local natural environment and *P. murrayi*. The final chapter addresses the continued problems island ecosystems and their constituent species face and biodiversity conservation lessons.

The author has used non-technical language, often with poetic prose and considerable reflection, to allow non-biologists and biologists alike to understand the fate of *P. murrayi*. He is to be congratulated for bringing together all the details for this not so easy history to be told and understood. I recommend the book for people working on or interested in bat conservation, specifically to understand the different parameters that lead to the extinction of an island endemic bat, and as a vivid reminder of the delicate future of species with declining numbers and habitat.

STEVEN M. GOODMAN — *Field Museum of Natural History, 1400 South Lake Shore Drive, Chicago, Illinois 60605, USA; E-mail: sgoodman@fielduseum.org*