Three new insectivorous bat species records for the Mountain Zebra National Park, South Africa

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Received 14 February 2022. To author for revision 15 March 2022. Accepted 24 March 2022

INTRODUCTION

Sudies of bats occurring in arid and semi-arid regions are under-represented across the African continent relative to more mesic regions (Lisón *et al.*, 2019; Monadjem, Taylor, Conenna, & Schoeman, 2018). At a finer scale, river valleys are predicted to have relatively high bat species richness compared with adjacent areas in Africa, because habitat complexity has been predicted to be positively correlated with bat species richness (Herkt, Barnikel, Skidmore & Fahr, 2016). Riparian habitats are more diverse than adjacent habitats, with bat assemblages of the latter containing a subset of the former (Rautenbach, Whiting & Fenton, 1996; Monadjem & Reside, 2008; Taylor, Nelufule, Parker, Cory Toussaint & Weier, 2020). In addition, artificial water provision, such as impoundments, can also provide important foraging habitat for bats. For example, in the Western Cape Province of South Africa water body size was an important factor in positively contributing to the activity of a range of bat species (Sirami, Jacobs & Cumming, 2013).

Insectivorous bats, with their unique life histories, taxonomic stability, occupation of a relatively high trophic level, and overall sensitivity to environmental conditions, are especially good ecological indicators of environmental change (Jones, Jacobs, Kunz, Willig, & Racey, 2009). Consequently, the long-term monitoring of bat communities can provide important insights into environmental health, and the effects of climate change (Weier, Keith, Neef, Parker & Taylor, 2020). Moreover, since the effects of climate change on birds and mammals in Africa are expected to be more acutely felt in more arid regions because conditions will routinely surpass critical physiological thresholds (Ridley, Wiley, Bourne, Cunningham & Nelson-Flower, 2021), investigating the species richness and activity patterns of bats becomes a crucial research priority.

Protected areas and/or National Parks provide protection to plant and animal species that are not protected elsewhere and are thus hotspots of biodiversity. However, although bats are considered keystone species and bio-indicators for predicting the wider effects of climate change on ecosystems (Adams & Kwiecinski, 2018), they can be a challenging group of mammals to study (Parker & Bernard, 2019). My research attempts to address this critical knowledge gap and provide data on the bat populations of the Mountain Zebra National Park (MZNP) of South Africa, a semi-arid and an historically under-sampled locality with respect to insectivorous bats (Parker, 2021). I aimed to assess the overall species richness of insectivorous bats within the MZNP.

MATERIAL AND METHODS

Study site

The MZNP (32°18′S, 25°24′E) is a 21 412 ha South African National Park (SANParks) situated approximately 24 km from the town of Cradock in the Eastern Cape of South Africa. The park is found at a transition zone between the Nama-Karoo, Grassland and Albany Thicket biomes, and is characterized by a semi-arid climate (Mucina *et al.*, 2006). Mean monthly maximum and minimum temperatures in summer (September–March) vary from 6°C to 28°C and from –1°C to 20°C in the winter (April–August). The southern section of the park is mountainous with altitudinal peaks of up to 1960 m, whereas the northern section consists of lower lying areas ranging from 1000 m to 1500 m. The southern part of the park also has numerous doleritic intrusions, forming large, erosion resistant rocky outcrops. The MZNP is characterized by three broad vegetation types, the Eastern Upper Karoo (37% of the park), the Karoo Escarpment Grassland (53%) and the Eastern Cape Thicket (10%) (Mucina *et al.*, 2006). The Eastern Upper Karoo is characterized by either flat or gently sloping plains interspersed with rocky

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ISSN 2410-8200 [Online] — DOI: https://doi.org/10.3957/056.052.0017

areas and the dominant flora are dwarf microphyllous shrubs, such as the Karoo bitter bos (*Pentzia globosa*) and Karoo anchor bos (*Pentzia incana*). The Karoo Escarpment Grassland is characterized by low mountains and hills and is dominated by grasses, such as mountain wire grass (*Merxmuellera disticha*) and shrubs, such as *Euryops annuus* (Mucina *et al*., 2006). The Eastern Cape Thicket is prevalent on the steep sides of the escarpment and mountain slopes with the dominant flora being Karee (*Searsia lancea*) and olive (*Olea europea africana*) trees (Mucina *et al*., 2006). The seasonal Wilgerboom River traverses the park from the southern section, through the central area, before exiting in the north. Park management also supplies artificial surface water at multiple stations across the park for the wildlife throughout the year, with the largest artificial impoundment being the Doornhoek Dam, along the Wilgerboom River in the centre of the park.

Prior to the establishment of the park in 1937, only a few small to medium-sized antelope species were present and the species composition of the smaller (<300 g) mammalian fauna was unknown (Parker, 2021). However, at least 16 species of large mammal were re-introduced to the park in the 1950s and 1960s (Parker, 2021). Buffaloes (*Syncerus caffer*) were re-introduced in 1998, followed by black rhinoceroses (*Diceros bicornis bicornis*) and gemsbok (*Oryx gazella*) in 2002. Caracals (*Caracal caracal*) were the dominant predators in the park until cheetahs (*Acinonyx jubatus*) were re-introduced in 2007, brown hyaenas (*Parahyaena brunnea*) in 2008, and lions (*Panthera leo*) in 2013 (Parker, 2021). Despite some effort to document the smaller mammal species of the park during the 1970s and 1980s, shrews, golden and rodent moles, and bats remain understudied (Parker, 2021).

Acoustic sampling

Using a Song Meter (SM2) bat detector (Wildlife Acoustics, Inc., Maynard, MA, U.S.A.) recording passively throughout the night, and mounted on either suitable trees or structures 2–4 m above ground with the microphone angled at 45° to reduce the recording of echoes. Bat activity was monitored at two sites for two nights each in July 2013 (*i.e.* four nights in total), and at two sites (one being a new site) for two nights each in June 2014 (another four nights of sampling). Thus, a total eight nights of sampling, covering three sampling sites, was achieved across the two fieldtrips (Fig. 1). The bat detector was equipped with a new, omnidirectional and waterproof SMX-US microphone connected directly to a waterproof unit, which included two interchangeable flashcards for storing recordings. The unit was programmed to record at a 384 kHz sampling frequency with 16-bit sample resolution and only to record sounds above 12 dB, with a trigger frequency of 8 KHz. The bat detector was activated to record from sunset to sunrise to cover the dusk and dawn peaks in the nocturnal activity of bats (Parker & Bernard, 2019).

Analysis

Kaleidoscope Pro software version 5 (Wildlife Acoustics, Concord, MA, U.S.A.) was used to analyse and identify each bat call series. Kaleidoscope Pro can automatically cluster recordings based on the characteristics of each call series using a built-in classifier tool (Rydell, Nyman, Eklöf, Jones & Russo, 2017). This classifier tool, a comprehensive call reference library held by D.M.P. based on the echolocation calls of known bats, and published literature (Parker & Bernard, 2019; Monadjem, Taylor, Schoeman & Cotterill, 2020; Brinkley, Weier, Parker & Taylor, 2021) were used to identify each call series.

The classifier tool was used as an initial filter to speed up the sorting and subsequent final identification of each call series. All bat call recordings (n = 1403) were clustered into 13 initial clusters based on their call characteristics. Call characteristics used by the software to initially cluster the data included the total duration of the call (Dur) measured in milliseconds, the characteristic frequency (Fc) measured in KHz, the minimum call frequency (Fmin), and the maximum call frequency (Fmax) (Monadjem *et al*., 2020). Each of the individual bat call sequences within the 13 recognized clusters were then manually identified to species using the call reference library and the published literature (Parker & Bernard, 2019; Monadjem *et al*., 2020; Brinkley *et al*., 2021).

Recorded call sequences were only positively identified to species level if there was a sequence of three or more pulses recorded, to avoid misidentification of species due to possible noise, social calls or insufficient call statistics. If a call sequence could not be positively identified, it was excluded. The process for manual identification consisted of three phases and was deliberately conservative to avoid committing a Type I statistical error (Clement, Rodhouse, Ormsbee,

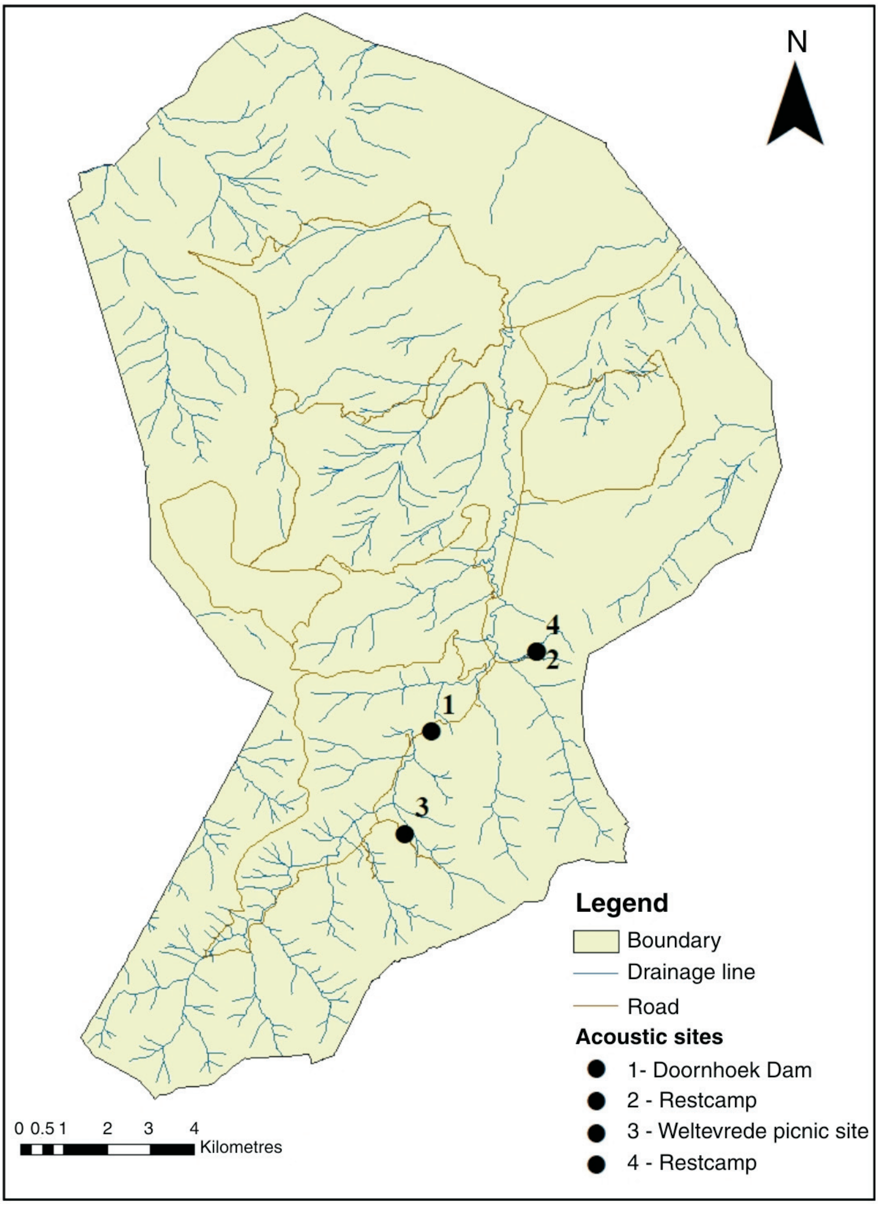

Fig. 1. The Mountain Zebra National Park, Eastern Cape, South Africa, showing the positions on the three sites used for the acoustic sampling of bats during July 2013 and June 2014.

Szewczak & Nichols, 2014; Parker & Bernard, 2019). For manual identifications in the first phase, I made use of the known ranges of the Fmin of southern African bats to putatively identify the call sequences to species. The second phase then used the known ranges of the Fc to corroborate the identifications made in the first phase. Only if a recording fell within the known ranges of the Fmin and the Fc were they retained for the final phase. The final phase corroborated the retained species assignments using the known ranges of the Fmax for southern African bats. Using this three-phase approach, a final total of 552 call sequences (*i.e.* 39% of the original 1403 recorded sequences), and their species assignments, were retained for further analysis. Each identified call sequence was assigned a foraging category (Monadjem *et al.*, 2020).

RESULTS AND DISCUSSION

Using acoustic monitoring at three sites during the austral winter of 2013 and 2014, a total of five putative bat species, representing three families, were recorded at MZNP (Table 1; Appendix A). More clutter-edge foraging bats (Vespertilionidae) were recorded compared to the open-air foraging bats (Emballonuridae and Molossidae) (Table 1).

A recent review of the mammals of the MZNP demonstrated that only three species (*Nycteris thebaica*, *Tadarida aegyptiaca* and *Laephotis capensis*) from three families (Nycteridae, Molossidae and Vespertilionidae) have been reliably recorded to be present in the park historically (Parker, 2021). The current acoustic assessment of insectivorous bat species richness at the MZNP has identified that at least five putative species from three families are likely present in the park (Table 1). *Taphozous mauritianus* (Emballonuridae), *Myotis tricolor* (Vespertilionidae) and *Scotophilus dinganii* (Vespertilionidae) therefore represent three additions to the checklist of mammals for the park. All three species have been collected as museum specimens in the vicinity of the MZNP (Monadjem *et al.*, 2020). In addition, the conservative approach that I used in my acoustic identifications makes it unlikely that these three species have been mis-identified. Although my study has identified three new insectivorous bat species present in the park, more intensive sampling, combining both live-capture and acoustic assessments, during the austral summer is recommended to detect any species that may have been missed by my acoustic-only approach (Parker & Bernard, 2019). For example, the low intensity and frequency modulated echolocation calls of *Nycteris thebaica* make it difficult to detect using bat detectors alone (Monadjem, Shapiro, Mtsetfwa, Reside & McCleery, 2017) and may explain why it was not recorded during my study. In addition, based on their known distributions and the available habitat in the park, other species likely present, but not detected, could include *Rhinolophus capensis*, *Rhinolophus clivosus*, *Miniopterus natalensis* and *Eptesicus hottentotus* (Monadjem *et al.*, 2020). Moreover, live-capture, and the subsequent release of positively identified individuals, can result in the generation of a site-specific reference call library that can assist in more confident identifications of species from acoustic data (Clements *et al.*, 2014; Parker & Bernard, 2019).

Much of South Africa is being affected by climate change with substantial increases in mean annual temperatures, accompanied by reductions in rainfall and increased desertification, being predicted (Ridley *et al.*, 2021). Thus, understanding bat ecology (including their diversity) is crucial, as bats are reliable indicators of the effects of climate disruption, especially in arid regions (Weier *et al.*, 2020). More research in the arid and semi-arid regions of southern Africa will likely yield additional records of hitherto undocumented bat species and a better understanding of the impacts of climate change.

This work was funded by Rhodes University. Thank you to the staff of MZNP for their support, all of the African Vertebrate Honours students who assisted during the fieldwork and two anonymous reviewers for their constructive comments.

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Table 1. Summary table of the five putative bat species identified at three sites within the Mountain Zebra National Park, South Africa, in 2013 and 2014. The total number of passes for each species is shown along with the means (±S.D.) of the three call characteristics used to identify the species (see text for details). Representative sonograms of the identified species are provided in Appendix A. ° = open-air forager and ᶜ = clutter-edge forager (see Monadjem *et al.*, 2020).

Species	Number of passes (%)	Fmin (KHz)	Fc (KHz)	Fmax (KHz)
EMBALLONURIDAE				
Taphozous mauritianus°	232 (42)	24.90 ± 3.84	26.48 ± 3.62	29.78 ± 5.25
MOLOSSIDAE				
Tadarida aegyptiaca°	217 (39)	22.26 ± 2.56	23.70 ± 3.33	26.33 ± 8.31
VESPERTILIONIDAE				
Myotis tricolor[c]	47 (9)	36.09 ± 9.29	39.55 ± 6.93	47.24 ± 26.00
Laephotis capensis[c]	41 (7)	36.25 ± 4.80	39.25 ± 3.51	45.09 ± 10.21
Scotophilus dinganii[c]	15 (3)	31.72 ± 2.70	35.05 ± 1.42	41.34 ± 3.48

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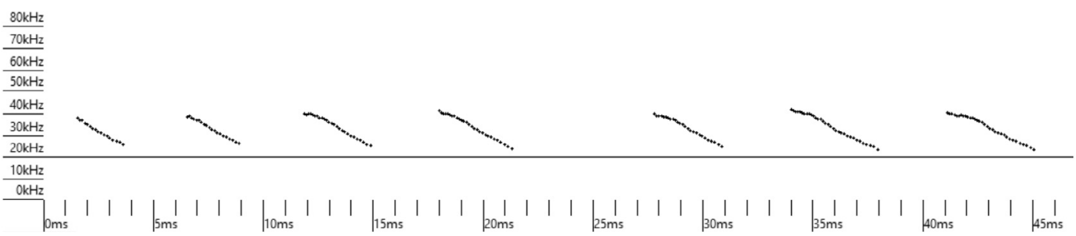
Responsible Editor: K. Madikiza

APPENDIX A

Representative sonograms of each species recorded during this study in the Mountain Zebra National Park, South Africa. The *x*-axis shows the length call; duration (ms) and the *y*-axis the frequency (KHz).

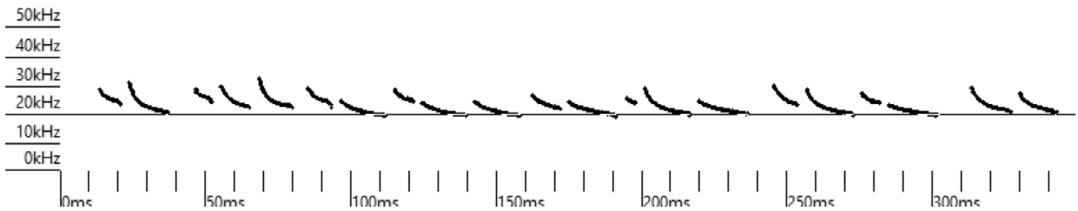
Emballonuridae

Taphozous mauritianus



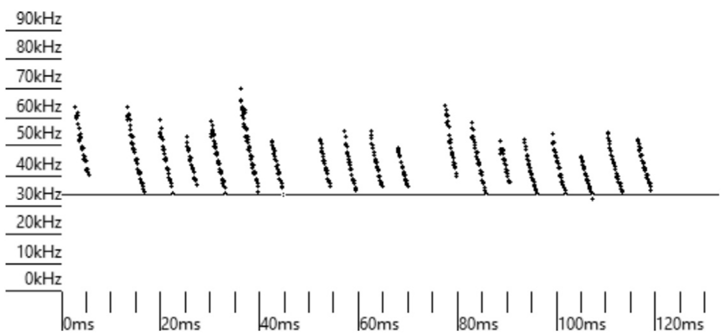
Molossidae

Tadarida aegyptiaca

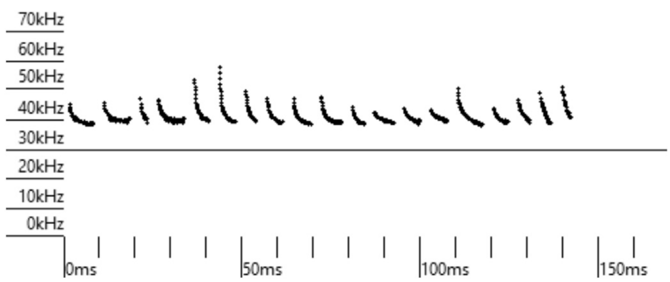


Vespertilionidae

Myotis tricolor



Laephotis capensis



Scotophilus dinganii