

NOTE



The use of swimming pools by bats on a game reserve in South Africa

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Abstract

While the use of anthropogenic resources by wildlife in degraded habitats has been frequently documented, the use of such alternative resources in natural and semi-natural habitats is not yet well understood. We explored the use of artificial water sources by bats in a semi-natural habitat by conducting acoustic monitoring surveys at swimming pools on Amakhala Game Reserve in the Eastern Cape of South Africa from 2018 to 2020. We identified 7 of 23 local species in 24,909 recorded activities associated with resource use at the swimming pools, including 1,374 feeding buzzes and 9,286 drinking buzzes. This study confirmed that bats were using swimming pools in the game reserve as a foraging and drinking resource and indicates that such anthropogenic features could be of value to bats and potentially other wildlife in natural and semi-natural habitats.

KEYWORDS

acoustic monitoring, Chiroptera, drinking behavior, Eastern Cape, foraging, resource use, thermal imaging, water source

The availability, accessibility, and quality of resources are fundamental factors influencing species abundance and distribution (Jochum et al. 2017, Penteriani et al. 2019, Buchholtz et al. 2021). To select resources, animals rely on a combination of learned and innate criteria to establish resource quality and, therefore, preference (Nielsen et al. 2013, Lillie et al. 2018). These criteria or cues can be visually perceived characteristics, such as color, size, and shape (Kheradmand et al. 2018), but they can also be auditory (Niu et al. 2019), olfactory (Sørensen et al. 2019), tactile (Goller et al. 2017), and magnetic (Nyqvist et al. 2020). For a resource to be considered available, it must be present and accessible. Landscape connectivity, physical barriers, artificial lighting, noise, and predation risk may

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deter or prevent wildlife from accessing a resource (Holloway 2018, Grande et al. 2020, Mourant et al. 2021). Furthermore, the availability of a preferred resource can be temporal (Amorim et al. 2018). Nystrom and Bennett (2019), for example, found that bats only drank at residential swimming pools when more natural water sources in a nearby park had dried up, and demonstrated that given the choice, bats preferentially selected more natural resources even when anthropogenic alternatives were readily available throughout the year.

The use of anthropogenic alternatives is often associated with highly modified and degraded environments, such as urban and suburban areas (Chamberlain et al. 2020). For example, rivers, streams, lakes, ponds, and even puddles are considered to be natural water sources for bats (Nelson and Gillam 2020); however, in urban environments when these resources are not readily available, bats can use artificial reservoirs, ornamental ponds, retention ponds, drainage ditches, cattle troughs, and residential swimming pools (Tuttle et al. 2006, Hall et al. 2016, Russo et al. 2017, Nystrom and Bennett 2019). The use of these types of water resources indicates that they meet the search criteria by which bats select their water sources, whether visual or acoustic.

While anthropogenic resources are clearly important to bats in urban and agricultural landscapes (Bergeson et al. 2020), the use of anthropogenic water resources in natural and semi-natural habitats is largely unknown and few studies to date have explored whether anthropogenic water features could improve or enhance such habitats for bats (Newton et al. 2017, Switalski and Bateman 2017). Our objective was to determine whether bats were using anthropogenic water sources in a natural or semi-natural habitat by conducting acoustic monitoring to explore the use of swimming pools by bats in a game reserve in South Africa.

STUDY AREA

We conducted this study on Amakhala Game Reserve, a privately owned 85-km² area in the Eastern Cape of South Africa (33°32'05.07"S; 26°05'13.05"E; Figure 1). At an elevation of 180–403 m, this region has a humid subtropical climate ranging from 16–26°C in the summer (December to February) and 7–20°C in the winter (June to August; Mahlalela et al. 2020). On average, annual precipitation in the area is 625 mm, albeit it with considerable annual variability. Typically, the region experiences monthly highs in August of >60 mm and lows in December of <35 mm; however, since 2015, the Eastern Cape of South Africa has been under severe drought with average rainfall decreasing to 425 mm over the preceding 6 years (Mahlalela et al. 2020, Archer et al. 2022).

The study area was originally converted to livestock farming in the early nineteenth century, but in 1999, it became an ecotourism-focused game reserve. Subsequently, the area has reverted back to subtropical thicket communities comprising spinescent shrubs, woody creepers, tall woody shrubs, geophytes, succulents, and various grass species (Smit et al. 2016, Gwate et al. 2018, Achieng et al. 2020, Duker et al. 2020). Since then, the property has brought in and actively managed a number of megaherbivore and carnivore species, including cheetah (*Acinonyx jubatus*), lion (*Panthera leo*), elephant (*Loxodonta africana*), Cape mountain (*Equus zebra zebra*) and plains zebra (*Equus quagga*), hippopotamus (*Hippopotamus amphibius*), South African giraffe (*Giraffa camelopardalis giraffa*), Cape buffalo (*Syncerus caffer*), and several species of antelope. In addition, there are a number of species from various taxonomic groups that have remained in the area or naturally colonized the reserve since its reversion, including bats.

Resources on the property for bats include roosting sites in trees and rock crevices, foraging opportunities along tree-lines, woodland patches, and riparian areas, and water resources, including the Bushman's River, which runs through the northeast portion of the property, and 35 brackish watering holes primarily in the southwestern portion of the reserve (Zengeni et al. 2016, Monadjem et al. 2020). In addition, 10 tourist accommodations occur within the game reserve, each with a footprint of about 0.01 km² with 1–13 closely spaced buildings depending on whether they are suites, lodges, or tented camps. Nine of these have swimming pools, which are available and potentially accessible to bats all year round (Figure 1). To determine if bats were using these as a water source, we conducted acoustic surveys at 2 of the swimming pools: Leeuwenbosch Country House and Woodbury Lodge. The pool at Leeuwenbosch Country House was a straight-edged, chlorine-treated pool with a 30-m² surface area, while Woodbury Lodge had 2 straight-edged, chlorine-treated pools <15 m from each other, one with a 12-m² surface area and the other covering 7 m².

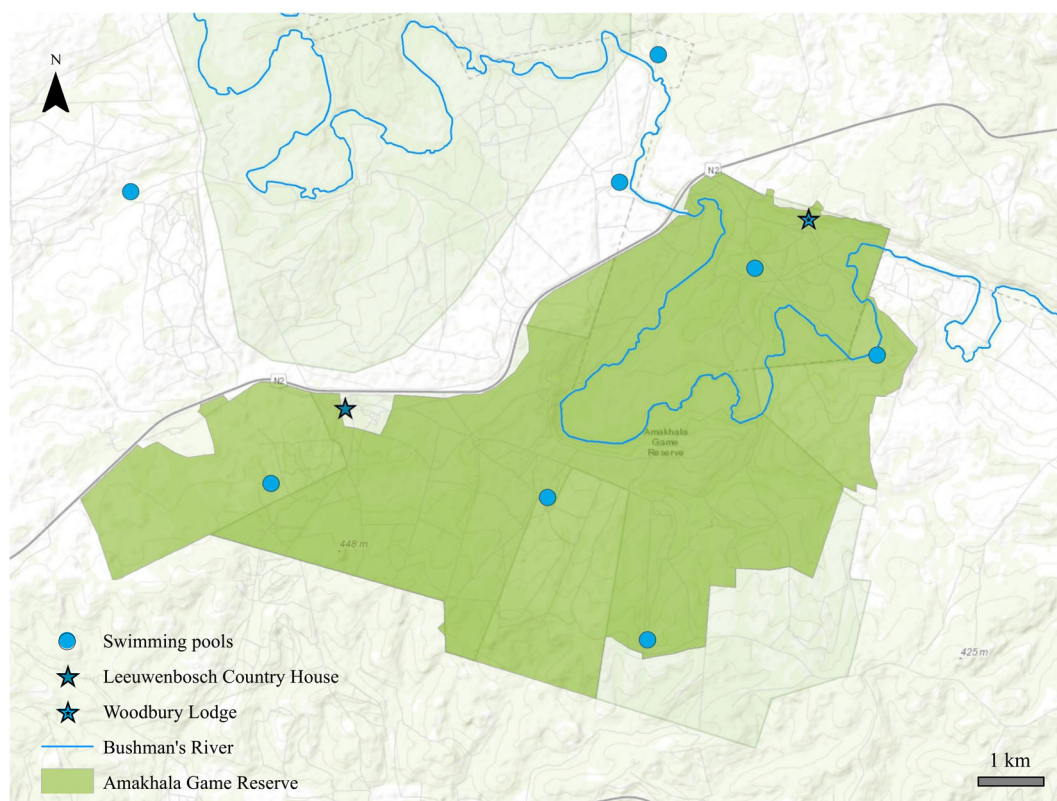


FIGURE 1 Amakhala Game Reserve and surrounding area in the Eastern Cape of South Africa, showing study sites (as stars) where we measured bat use in 2018–2020, locations of the other 8 tourist lodges with swimming pools, rivers, and the boundary of Amakhala Game Reserve.

METHODS

At the swimming pools, we deployed SM4BAT FS acoustic bat detectors with an external U2 ultrasonic microphone (Wildlife Acoustics, Maynard, MA, USA) from July 2018 to December 2020. We placed each detector close to the pool edge (<10 m) with the microphone angled toward the pool surface. At Woodbury Lodge, we selected the larger pool for the detector. We set detectors to record bat echolocation calls from dusk to dawn to trigger at frequencies between 10 kHz and 192 kHz to encompass the echolocation frequencies of 23 species that could potentially be present (Monadjem et al. 2020). We applied a 3-second delay between recordings and a gain threshold at 12.0 decibels (dB) with a trigger volume of 12.0 dB. Sound files were recorded in a 4-second standard wav file (.wav) format and saved at a sample rate at 256 kHz onto memory cards, which we retrieved monthly.

Once retrieved, we used SonoBat Scrubber software (version 4, Sonobat™, Arcata, CA, USA) to remove sound files containing noise only. We treated each remaining file with bat echolocation calls as a single sampling unit (i.e., bat pass). We then used Sonobat bat call analysis software (version 3.4, Sonobat™) to manually group the bat passes by activity by identifying the presence of distinct echolocation phases associated with resource use by bats: the approach phase and terminal buzz phase (Griffin et al. 1960). Approach phase activity demonstrated that a bat was either pursuing prey or approaching a static object, such as a roost or water surface to drink from, while the presence of terminal buzz indicated that a bat had caught or almost caught their prey, landed, or drank from the surface of water (Ratcliffe et al. 2013, Russo et al. 2016, Nystrom and Bennett 2019). We identified approach phase activity as an increase in and often erratic pulse rate and terminal buzzes as a rapid increase in pulse rate and

decrease in the interval between successive pulses (Hulgard and Ratcliffe 2016, Stidsholt et al. 2020). These activities are distinct from commuting or search phase calls, in which bats emit a series of pulses (or chirps) that coincide with the bats' downward wing strokes (Griffin et al. 1960).

To ascertain whether bats were using swimming pools as a foraging or drinking resource, we further separated terminal buzzes, where possible, into feeding buzzes (emitted by bats immediately before they capture aerial prey) and drinking buzzes (emitted as bats come in to drink from the surface of a water source; Russo et al. 2016, Lewanzik et al. 2019). We identified feeding buzzes as a sudden increase in pulse rate with the frequency range of the pulses abruptly shifting higher or lower collectively at the end of the sequence (Ratcliffe et al. 2013) and drinking buzzes as a sudden increase in pulse rate with the frequency range of the pulses remaining similar to the approach phase pulses often ending in an audible splash as the bat made contact with the surface of the water (Klopper et al. 2019). We classified all acoustic activity not directly related to resource use, including commuting and search phase activities (Griffin et al. 1960), as other and we did not consider these activities in the analysis. We also classified any buzzes that we could not categorize as either a feeding or drinking buzz as an undetermined buzz. A second reviewer verified all activity classifications to reduce misidentifications and we did not use any bat passes that could not be identified to an activity group in our analysis. Thus, we created 4 activity groups to determine resource use: approach phase only (i.e., no terminal buzz was present), feeding buzzes, drinking buzzes, and undetermined buzzes.

Once grouped, we used the automated identification classifier for South African bats in Kaleidoscope Pro Analysis Software (version 1.3.8, Wildlife Acoustics) to tentatively identify bat passes with terminal buzzes (feeding, drinking, undetermined buzzes) to species. We then manually verified species identifications using a key created from available call libraries, acoustic activity recorded from known bat species in the area, and other sources (Taylor 2000, Taylor et al. 2013, Monadjem et al. 2020). A second viewer confirmed all species identifications and we did not use any acoustic activity that could not be identified to species in the species-specific summaries described below. Once processed, we calculated the number of 1) bat passes, 2) approach phase calls, 3) terminal buzzes, 4) feeding buzzes, 5) drinking buzzes, 6) species-specific terminal buzzes, 7) species-specific feeding buzzes, and 8) species-specific drinking buzzes recorded.

We used the occurrence of all approach phase and terminal buzzes to confirm whether bats were using swimming pools at the lodges in Amakhala Game Reserve as a resource. We then used the occurrence of feeding and drinking buzzes, specifically, to confirm whether bats were using the pools as a foraging or drinking resource. To determine if the use of the pools as a resource was species-specific, we compared the average number of terminal buzzes per night recorded for each species. We only used data from survey nights in which the bat detector successfully recorded from dusk until dawn. We then compared the average number of feeding and drinking buzzes per night recorded for each species to determine if certain species used the pools more as a foraging or drinking resource.

RESULTS

We conducted the acoustic monitoring survey from 19 July 2018 to 14 December 2020 for 184 survey nights (which included 28 partial survey nights) with 2–5 full nights recorded per month each year (93 full nights at Leeuwenbosch, 61 at Woodbury Lodge). We recorded 125,182 bat passes. Across all survey nights, the number of calls ranged from 14 to 2,559 per night, with an average of 731.1 ± 659.4 (SD) per night. From the acoustic surveys at both swimming pool sites, we identified 24,909 resource use calls, of which 12,185 were approach phase calls, 1,374 were feeding buzzes, 9,286 were drinking buzzes, and 2,064 were undetermined buzzes. The number of resource use calls ranged from 0 to 731 per night, with an average of 136.3 ± 151.4 per night across the survey period. We identified 7 bat species at the pools, including Egyptian free-tailed (*Tadarida aegyptiaca*), Botswanan long-eared (*Laephotis botswanae*), Cape serotine (*Neoromicia capensis*), Natal long-fingered (*Miniopterus natalensis*), Cape horseshoe (*Rhinolophus capensis*), Geoffroy's horseshoe (*R. clivosus*), and lesser woolly (*Kerivoula lanosa*) bats.

TABLE 1 Summary of bat passes with terminal buzzes recorded by species at swimming pools in Amakhala Game Reserve in the Eastern Cape of South Africa from 2018 to 2021.

Bat species	Number of nights	Mean number of buzzes per night	SD
Cape serotine	163	39.25	50.60
Botswanan long-eared	137	23.75	19.72
Cape horseshoe	156	13.17	15.25
Natal long-fingered	133	6.98	7.35
Egyptian free-tailed	37	2.16	1.83
Lesser woolly	2	1.50	0.71
Geoffroy's horseshoe	5	1.40	0.89

TABLE 2 Mean number of feeding buzzes and drinking buzzes recorded for each species per night at swimming pools in Amakhala Game Reserve in the Eastern Cape of South Africa from 2018 to 2021.

Bat species	Feeding buzzes per night		Drinking buzzes per night	
	Mean number	SD	Mean number	SD
Cape serotine	7.46	8.20	35.19	46.59
Botswanan long-eared	2.50	3.72	23.00	19.34
Natal long-fingered	2.05	1.15	6.38	7.04
Egyptian free-tailed	2.16	1.83	0.00	0.00

Based on the terminal buzzes identified to species, Cape serotine most often used the pools as a resource, whereas Geoffroy's horseshoe and lesser woolly bats were recorded at the pool the fewest times (Table 1). We identified feeding buzzes for 4 of the 7 species: Egyptian free-tailed, Botswanan long-eared, Cape serotine, and Natal long-fingered bats. Among these species, we recorded Cape serotine foraging at the pools more often than any of the other 3 species (Table 2). As a drinking resource, we identified drinking buzzes for 3 species: Botswanan long-eared, Cape serotine, and Natal long-fingered bats. Among these species, we recorded Cape serotine and Botswanan long-eared bats drinking at the pools more often than Natal long-fingered bat (Table 2).

DISCUSSION

We obtained evidence for the use of swimming pools, as a foraging and drinking resource, by 7 different species of bats in a game reserve in the Eastern Cape Province of South Africa, confirming that bats will use anthropogenic water sources in a semi-natural to natural environment as a resource. More specifically, we determined that Botswanan long-eared, Cape serotine, and Natal long-fingered bats used swimming pools as a foraging and drinking resource, and Egyptian free-tailed bats used the pools for foraging only. While there are a number of studies that support our findings that bats use anthropogenic water sources, all these studies appear to have been conducted in habitats that are considered degraded (Ciechanowski 2015, Korine et al. 2016, Salvarina 2016, Nystrom and Bennett 2019, Agpalo 2020). Bats use such resources in a semi-natural to natural temperate environment based on our data.

Among the bat species using swimming pools as a resource, Botswanan long-eared and Cape serotine represented the 2 most commonly recorded in our study, comprising 30% and 60% of all terminal buzzes recorded,

respectively, while Egyptian free-tailed, Natal long-fingered, and Cape horseshoe bats visited the swimming pools at lower frequencies and Geoffroy's horseshoe and lesser woolly bats appeared to use the pools as a resource infrequently. We cannot be certain whether any or all of the 7 species recorded are common and abundant in Amakhala Game Reserve or its surrounding area, nor can we state that our results reflect their abundance in the area. Other acoustic and mist-netting surveys conducted in the province suggest that the Cape serotine bat is one of the most common species (Doty and Martin 2012, Moir et al. 2020), which does support our results for this species. Expanding acoustic monitoring throughout Amakhala Game Reserve and its surrounding area would potentially confirm species abundance and diversity, reveal whether the species using the swimming pools as a resource are the most abundant, and identify which species are not using the pools as a resource. Moreover, we acknowledge that our results may have underestimated resource use for species with high constant frequency echolocation calls. Resource use in Cape horseshoe, Geoffroy's horseshoe, and lesser woolly bats was low with no definitive drinking or feeding buzzes detected. Of the 7 species we recorded, these 3 had call frequencies >75 kHz. We speculate that our detection of these species may not necessarily have been associated with abundance, but rather the majority of their activity going undetected as a result of the high attenuation rate of their echolocation calls. In other words, the detectors may need to be placed <10 m from the pool to record their acoustic activity. Thus, we recommend that the rigor of acoustic monitoring surveys be assessed to confirm whether the foraging and drinking activity recorded acoustically is representative of the foraging and drinking undertaken by different species at the pools, especially those species with higher constant frequency echolocation calls.

Our study also indicates that these species are using the pools at the same time, as we recorded multiple species in the same sound files, demonstrating that these species were actively flying and potentially using the pools as a resource in proximity to each other. For example, in one instance we recorded Egyptian free-tailed, Botswanan long-eared, Natal long-fingered, and Cape serotine bats all at the same time. Such occurrences indicate that these species are not competing for resources with each other (Adams and Thibault 2006, Beilke et al. 2021) and supports a study by Adams and Simmons (2002), which reported that individual bats from 8 different species appeared to take turns drinking at a water resource. Instead, the results of our study suggest that the pools represent a reliable water source for at least 3 bat species. Moreover, while researchers reported that bats may not prefer a chlorine-treated swimming pool, this treatment does not deter bats from drinking at the pools and in some instances, bats may regularly use a pool as a primary water source (Nystrom and Bennett 2019, Agpalo 2020, Bennett and Agpalo 2022). Agpalo (2020) further reported that foraging activity, rather than drinking, was lower at chlorine-treated pools, which agrees with our result that foraging activity was recorded less frequently at the pools than drinking. Further studies that investigate the effects of chlorine-treatments on foraging bats and whether there are any health implications from drinking chlorine-treated water would pacify any concerns about the quality of swimming pools as a water resource for bats. To our knowledge, no studies have been published reporting any implications of chlorinated water sources to animals. Finally, Agpalo (2020) also demonstrated that other pool characteristics could dictate whether a pool is used by bats, such as size and shape. While we only surveyed 2 of the 9 swimming pools on the Amakhala Game Reserve, it would be useful to explore whether specific pool characteristics influenced the abundance and diversity of bats using them.

Our results indicate a need for future research to investigate why bats are using swimming pools in this semi-natural to natural environment. Landscape connectivity and the presence of natural and semi-natural water sources in proximity are likely to influence the frequency and diversity of bat species accessing a swimming pool (Rainho and Palmeirim 2011, Frey-Ehrenbold et al. 2013, Ancillotto et al. 2019, Agpalo 2020). Thus, we recommend further studies that explore whether the surrounding habitat is influencing bat activity and resource use at the swimming pools in Amakhala Game Reserve. Similarly, the quality and availability of natural and semi-natural water sources throughout the game reserve could be shaping the abundance and diversity of bats using the swimming pools. The Bushman's River, for example, can be an ephemeral source of water, as it had all but dried up following the drought that hit the Eastern Cape starting in 2015 (Mahlalela et al. 2020). Subsequently, the river and many of the watering holes were not available to bats throughout our study period from 2018 to 2021. Thus, unlike the natural and

semi-natural water sources located in Amakhala Game Reserve, swimming pools are available year-round and maintained at a constant quantity and quality. We recommend expanding acoustic monitoring surveys and deploying detectors at the natural and semi-natural water sources in the game reserve to compare usage by bats to that of the swimming pools. These types of studies can more effectively demonstrate the importance of anthropogenic resources in semi-natural environments.

MANAGEMENT IMPLICATIONS

Bats can and will use swimming pools as a foraging and drinking resource if they are available. Inclusion of anthropogenic alternatives could improve semi-natural habitats for bats and potentially other taxa, such as birds. None of the 7 species identified in this study are of conservation concern; however, continued habitat loss and land-use change in the region and across South Africa has led to the declines of many bat populations. Subsequently 17 species are listed as threatened, 5 species are listed as vulnerable including the Cape horseshoe, and 1 species is listed as critically endangered by the International Union for the Conservation of Nature (Doty and Martin 2012, Frick et al. 2020, International Union for the Conservation of Nature 2021). Our data provides insights into how anthropogenic features could enhance game reserves and other semi-natural habitats for bats. Of course, further research will be needed to determine what characteristics such features and surrounding area require to enable a range of species to use them. If managed effectively, there is the potential that such resources can positively influence species abundance and diversity and, in turn, aid conservation efforts.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ETHICS STATEMENT

This study adhered to relevant regulations and guidelines regarding the ethics of animal welfare (Texas Christian University Institutional Animal Care and Use Committee protocol 18-10).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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