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EXPEDITION REPORT

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Carnivores of the Cape Floral Kingdom: Surveying Cape leopards, caracals and other species in the fynbos mountains of South Africa

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Matthias Hammer (editor)
Biosphere Expeditions

Abstract

The fynbos biome of South Africa is a biodiversity hotspot renowned for its very high plant species richness, endemic birds and the presence of the Cape mountain leopard (*Panthera pardus*). Biodiversity monitoring across a range of faunal taxa was conducted in mountain fynbos habitat, together with a survey of tortoises into the arid karoo biome to the north. Studies were conducted for two weeks in October 2016, with the help of international citizen scientsts recruited by Biosphere Expeditions and based at Blue Hill Nature Reserve (Western Cape).

Camera-trapping during 2016 and early 2017 confirmed the presence of male leopard 'Strider', resident since 2015. It also captured a new female, suspected of being accompanied by a nearly fully-grown cub. Caracal and African wildcat were also recorded several times. Live-trapping efforts during the expedition were unsuccessful.

A historic capture of a female of the endangered and little known Hottentot buttonquail (*Turnix hottentottus*), a terrestrial bird endemic to the fynbos, was achieved by the expedition. Body metrics to instigate a telemetry study on aspects of the habits and life history of this species were taken. Further efforts to trap the species after the expedition were unsuccessful.

Trapping of small mammals using Sherman traps was undertaken for two nights; further trapping was prevented by cold weather. Species captured were striped field mouse (*Rhabdomys pumilio*), Cape elephant shrew (*Elephantulus edwardii*), African pygmy mouse (*Mus minutoides*) and Namaqua rock mouse (*Aethomys namaquensis*), the last a novel species for the study site. Capture rates were significantly higher during morning trap checks, suggesting strong nocturnal behaviour.

Bat surveys using Anabat and Echo Meter Touch recording devices revealed the presence of eight species: Egyptian free-tailed bat *(Tadarida aegyptiaca),* African pipistrelle (*Pipistrellus hesperidus*), Cape serotine (*Neoromicia capensis)*, Cape horseshoe bat (*Rhinolophus capensis*), Geoffroy's horseshoe bat (*Rhinolophus clivosus),* Hottentot serotine *(Eptesicus hottentotus)*, Zulu pipistrelle/Aloe bat (*Neoromicia zuluensis*) and Egyptian slit-faced bat *(Nycteris thebaica)*.

Tortoise mortalities associated with electrified and non-electrified fences were also studied and related to fence structure (mesh or strand) and open veld transects. All fence types had significantly higher tortoise mortalities than open veld transects with leopard tortoise (*Stigmochelys pardalis*) mortalities significantly higher along electric fences than non-electric fences, accounting for 56% of leopard tortoise mortalities. Angulate tortoise (*Chersina angulata*) mortalities were significantly higher along mesh fences than strand fences, but did not differ between electric and non-electric fences. Fencing strategies and their threat to tortoises are discussed and mitigation strategies suggested.

Opsomming

Die fynbos bioom van Suid Afrika is `n biodiversiteit 'kern area' bekend vir baie hoë plant spesie diversiteit, endemiese voëls, en die teenwoordigheid van die Kaapse berg luiperd (Panthera pardus). Die monitering van biodiversiteit oor `n reeks van fauna taksa was uitgevoer in berg-fynbos habitat, gesamentlik met `n opname van skilpaaie in die droeë karoo bioom na die noorde. Studies was uitgevoer oor twee weke in Oktober 2016, met behulp vanaf internasionale burgerlike wetenskaplikes, gewerf deur die 'Biosphere Expeditions' en gebasseer by Blue Hill Natuur Reservaat (Wes-Kaap).

Die gebruik van afgeleë kamera's gedurende 2016 en vroeg 2017, het die teenwoordigheid van `n mannetjie luiperd 'Strider' bevestig wat sedert 2015 die area bewoon. Die kamera's het ook `n nuwe wyfie afgeneem, waarvan vermoed word dat sy deur `n byna volgroeide welpie vergesel was. Die gebruik van vanghokke tydens die ekspedisie om lewende individue te vang, was onsuksesvol.

'n Wyfie van die bedreigde en onbekende Kaapse kwarteltjie (Turnix hottentottus), 'n grondvoël endemies aan die fynbos, was gevang tydens die ekspedisie; `n daad wat tot dusver onsuksesvol was. Liggaamsafmetings was geneem as die beginpunt van `n telemetriese studie op die aspekte van die gedrag en lewensgeskiedenis van hierdie spesie. Verdere pogings na die ekspedisie om nog individue van dié spesie te vang was onsuksesvol.

Die vasvang van klein soogdiere met behulp van Sherman lokvalle was oor twee nagte uitgevoer; verdere pogings was verhoed deur koue weersomstandighede. Spesies wat gevang was sluit in die gestreepte veldmuis (Rhabdomys pumilio), Kaapse klipklaasneus (Elephantulus edwardii), dwergmuis (Mus minutoides) en Namakwalandse klipmuis (Aethomys namaquensis), die nuutste spesie aangeteken vir die studie area. Aansienlik meer individue was teenwoordig in lokvalle tydens inspeksie in die oggend, wat sterk nagtelike gedrag aandui.

Opnames met die gebruik van 'Anabat' en 'Echo Meter Touch' klankopname toestelle het die teenwoordigheid van agt vlermuis spesies bevestig: Egiptiese losstertvlermuis (Tadarida aegyptiaca), Kuhl-vlermuis (Pipistrellus hesperidus), Kaapse dakvlermuis (Neoromicia capensis), Kaapse saalneusvlermuis (Rhinolophus capensis), Geoffroy se saalneusvlermuis (Rhinolophus clivosus), langstert-dakvlermuis (Eptesicus hottentotus), aalwyndakvlermuis (Neoromicia zuluensis) en gewone spleetneusvlerrnuis (Nycteris thebaica).

Skilpadsterftes in verband met geëlektrifiseerde en nie-geëlektrifiseerde heinings was ook bestudeer en verwant aan die struktuur van die heining (maas of strand) en oop veld lynopnames. Alle heining-tipes het aansienlike hoër skilpadsterftes gehad as die oop veld lynopnames, met bergskilpad-(Stigmochelys pardalis) sterftes aansienlik hoër met geëlektrifiseerde heinings as met nie-geëlektrifiseerde heinings en was verantwoordelik vir 56% van bergskilpadsterftes. Rooipens skilpad- (Chersina angulate) sterftes was aansienlik hoër by maas heinings as by strand heinings, maar het nie verskil tussen geëlektrifiseerde en nie-geëlektrifiseerde heinings nie. Beheining strategieë en hul bedreiging teenoor skilpaaie word bespreek en versagtende strategieë voorgestel.

Contents

Please note: Each expedition report is written as a stand-alone document that can be read without having to refer back to previous reports. As such, much of this section, which remains valid and relevant, is a repetition from previous reports, copied here to provide the reader with an uninterrupted flow of argument and rationale.

1. Expedition review

M. Hammer (editor)
Biosphere Expeditions

1.1. Background

Biosphere Expeditions runs wildlife conservation research expeditions to all corners of the Earth. Our projects are not tours, photographic safaris or excursions, but genuine research expeditions placing ordinary people with no research experience alongside scientists who are at the forefront of conservation work. Our expeditions are open to all and there are no special skills (biological or otherwise) required to join. Our expedition team members are people from all walks of life, of all ages, looking for an adventure with a conscience and a sense of purpose. More information about Biosphere Expeditions and its research expeditions can be found at www.biosphere-expeditions.org.

This report deals with an expedition to South Africa's Cape Floral Kingdom that ran from – 2–14 October 2016. The expedition focused on biodiversity monitoring of the fynbos and karoo habitat types occupied by two of Africa's iconic cats: the threatened Cape mountain leopard (*Panthera pardus*) and the caracal (*Caracal caracal*). The surveys feed into efforts to mitigate conflict with landowners by working with them to highlight conservation issues and thereby contribute significantly to cat survival and conservation. Whilst working in the unique biome of South Africa's Cape Floral Kingdom (fynbos) – a UNESCO World Heritage Site and the world's only biome contained within one country – the expedition also conducted a larger survey investigating the impacts of low-line electric fencing on tortoise mortality. Additionally, a baseline study of bat biodiversity was continued, with botanical records entered into the online database iSpot.

The ultimate goal of ongoing research at the study site is to develop a monitoring technique that will better inform landowners of the status of their wildlife and predatory cats, identify potential conflict areas, and use the knowledge gained to mitigate conflicts. To this end, the project's overall aim is to develop camera trap and transect monitoring techniques that will enable landowners to determine predator and prey densities on their land. The project also wishes to contribute to the biodiversity monitoring of the area through contribution to citizen science projects. To achieve all this, the expedition monitored the density, abundance, spatial distribution, home range size and habitat preferences of a known population of wildlife on a nature reserve using transect and camera trap techniques.

Almost all of Africa experiences some sort of human impact and the Cape Floral Kingdom (fynbos) is no exception. Much wildlife roams on understaffed, underfinanced and remote mountainous nature reserves where monitoring is difficult; or on private farmland where landowners have mixed attitudes to perceived problem animals such as leopard, caracal, jackal, baboon and bushpig. The Cape mountain leopard is one of South Africa's

Threatened Or Protected Species (TOPS), which restricts legal hunting, but the laws are almost impossible to enforce. There is a strong farming lobby pushing for greater control of ‘pest’ species and anecdotal evidence suggests that control by legal and illegal methods is widespread across the country.

Wherever humans and wildlife come together, conflicts tend to appear, and human–wildlife conflict has been identified as one of the biggest threats to biodiversity worldwide. Sound scientific knowledge is key to mitigating this conflict and to making wise management decisions that balance the need of humans, wildlife and the environment. We believe that knowledge is the key to conservation and is the most effective way to mitigate human–wildlife conflict.

The Cape Floral Kingdom is one of the world’s biodiversity hotspots and as such is a UNESCO World Heritage Site. It is dominated by a fire-driven ecosystem – the fynbos biome, which has unsurpassed botanical richness: 7,000 of the 9,000 plant species that are found here are endemic. It is in the flower-filled Cape Fold Mountains of South Africa that the Cape mountain leopard is found – a leopard half the size of the savannah leopards of Africa, but with home ranges twice the size. In 2008, the International Union for Conservation of Nature (IUCN) classified leopards as Near Threatened, stating that they may soon qualify for Vulnerable status due to habitat loss and fragmentation. Indeed, they are becoming increasingly rare outside protected areas.

1.2. Research area

At 1.2 million km^2 South Africa is the world's 25th largest country. It is incredibly biodiverse, with habitats ranging from forest to savannah, grassland, thicket, karoo, desert and fynbos. South Africa is also very rich in wildlife, and is a favoured Big Five safari destination.

Figure 1.2a. Flag and location of South Africa and study site.

An overview of Biosphere Expeditions’ research sites, assembly points, base camp and office locations can be found at [Google Maps](#).

The core of the study site is Blue Hill Nature Reserve (BHNR), a 2,300 ha CapeNature stewardship nature reserve with mountains ranging from 1,000 to just under 2,000 m and under the care of the Lee Family Trust. CapeNature is the Western Cape provincial conservation department in charge of the network of nature reserves of the Western Cape. The property was purchased in 2009 by Chris Lee, a retired geologist who has been awarded the Draper Memorial Award for contributions to South African geology. The land was previously used for cattle ranching, was incorporated into the local community conservancy in 2010 and officially declared a nature reserve in 2013. The Trust has an obligation to manage the land for biodiversity under a management plan administered by Eastern Cape Parks and Tourism Agency, the state organisation charged with managing the Baviaanskloof Mega Reserve.

Blue Hill lies on the western side of the massive Baviaanskloof Mega Reserve and wildlife is free to move between these protected areas. The Baviaanskloof area is one of outstanding natural beauty, owing to its spectacular landforms, a diverse array of plants and a wide variety of animals. The area is also part of the Cape Floristic Region World Heritage Site as of 2004.

1.3. Dates

The project ran for one two-week slot and was composed of a team of international research assistants, scientists and an expedition leader. Slot dates were 2 – 14 October 2016.

The date was chosen to coincide with spring and the period associated with the mildest climate, best plant flowering, mammal and bird breeding, as well as fewest mosquitoes.

1.4. Local conditions & support

Expedition base

The expedition team was based at Blue Hill, a former farmstead in a remote part of the mountains. Team members shared, on a twin bed basis, comfortable rooms with beds, linen and all modern amenities such as mains power, hot showers and WCs. There is also a communal building with a dining room and a lounge with sofas and a fireplace. All meals were prepared for the team and special diets could be catered for by prior arrangement.

Weather

Temperature data were taken from an on-site Davis Vantage-Vue weather station that recorded weather every 30 minutes during the expedition. The weather during the expedition was cool to warm, with a cold front arriving in the first and second weeks of the expedition. The average temperature was 11.7 ± 6 ºC, ranging from a low of 1.2 to a high of 27.8 ºC. Rainfall recorded was 0.8 mm.

Field communications

There was a landline telephone for receiving calls and (slow) internet/email access at base. Mobile phones and hand-held radios were used for communication between teams and around the study site. The expedition leader posted a diary/blog, mirrored on Biosphere Expeditions' social media sites such as Facebook and Google+.

Transport & vehicles

Team members made their own way to the assembly point in the city of George, Western Cape, in time. From there, onwards and back to George, all transport (4WD vehicles and mountain bikes) was provided for the expedition team. Expedition participants were trained in the use of the 4WD vehicles and thereafter drove them around the study site. Ford South Africa kindly provided two Ford Rangers for the expedition (see Fig. 1.9a).

Medical support and incidents

The expedition leader was a trained first aider, and the expedition carried a comprehensive medical kit. South Africa's healthcare system is of an excellent standard and the nearest doctor and public hospital are in Uniondale (45 km/45 minutes away). The nearest private clinic is in George (200 km / 2 hours from the site). Safety and emergency procedures were in place, but did not have to be invoked as there were no serious medical or other incidents. There were a couple of minor falls, which did not require any medical treatment.

1.5. Local scientist

Dr Alan Lee, the expedition's field scientist, was born in Zimbabwe but grew up in South Africa. He graduated from the University of Witwatersrand with an Honour's Bachelor's Degree in Botany and Zoology in 1996. While working and travelling from London he obtained a Diploma in Computing in 2001. He then commenced a period of seven years in Peru, first working for a volunteer project investigating impacts of tourism on Amazonian wildlife, and then from 2005 to 2010 undertaking a Ph.D. on the parrots of the Peruvian Amazon. Biosphere Expeditions part-financed and contributed data to the Ph.D. resulting in three peer-reviewed publications. In 2011 Alan set up the Blue Hill Escape guest establishment on the Blue Hill Nature Reserve with his wife, Anja, and parents Chris and Elaine Lee. In 2012 he was accepted as a postdoctoral research fellow at the FitzPatrick Institute of African Ornithology at the University of Cape Town to undertake an assessment of the status of the endemic birds of the fynbos, and maintains a position there currently as Research Associate. He is Editor-in-chief of Ostrich: Journal of African Ornithology and currently working with the SANBI Karoo Biogaps project, which is undertaking a comprehensive biodiversity study of the arid Karoo biome of South Africa.

1.6. Expedition leader

Craig Turner was born in Oxford, England. He studied biology, ecology and environmental management at Southampton, Aberdeen and London universities. Soon after graduating from his first degree, he left the UK for expedition life in Tanzania. Since then, he has continued to combine his interest in travel and passion for conservation, working with a wide range of organisations on projects and expedition sites in the Americas, Africa, Asia and the Pacific. He has managed expedition grant programmes for the Zoological Society of London, and is a frequent contributor to the 'Explore' conference held by the Royal Geographical Society (RGS). He is a Fellow of the RGS and the Linnean Society. Having visited and/or worked in more countries than years have passed, he now runs a small environmental consultancy with his partner, based in Scotland, where he splits his wildlife interests and work between the UK and overseas. He is ever keen to share his exploits, writing for several magazines, and is a published photographer.

1.7. Expedition team

The expedition team was recruited by Biosphere Expeditions and consisted of a mixture of ages, nationalities and backgrounds. They were (in alphabetical order and with country of residence): Jim Blomgren (USA), Andrew Dickson (UK), Scott Dutfield (press, UK), Jane Eades (UK), Vivien Hathaway (UK), Louise Larkinson (UK), Michael Lindemann (Germany), Christine Newell (UK), Ben Rees (UK), Anne Schroedter (Germany).

1.8. Expedition budget

Each team member paid a contribution of £1,790 per person per two-week slot towards expedition costs. The contribution covered accommodation and meals, supervision and induction, special research equipment and all transport from and to the team assembly point. It did not cover excess luggage charges, travel insurance, personal expenses such as telephone bills, souvenirs etc., or visa and other travel expenses to and from the assembly point (e.g. international flights). Details on how this contribution was spent are given below.

Income	£
Expedition contributions	15,860
Expenditure	
Expedition base includes all board & lodging	2,648
Transport includes transfers, car hire, fuel	554
Equipment and hardware includes research materials & gear etc. purchased in South Africa & elsewhere	1,255
Staff includes local and Biosphere Expeditions staff salaries and travel expenses	2,228
Administration includes miscellaneous fees & sundries	256
Team recruitment South Africa as estimated % of annual PR costs for Biosphere Expeditions	6,430
Income – Expenditure	**2,489**
Total percentage spent directly on project	**84%**

1.9. Acknowledgements

We are grateful to the volunteers, who not only dedicated their spare time to helping but also, through their expedition contributions, funded the research. Thank you also to Harry Lewis of the Landmark Foundation, and to all those who provided assistance and information. Expedition cooks Melda and Gurli also provided valuable botanical insights through their affiliations with SANBI's Custodians of Rare and Endangered Wildflowers (CREW) programme. Biosphere Expeditions would also like to thank members of the Friends of Biosphere Expeditions and donors for their sponsorship. Thank you to Chris, Elaine and Anja Lee for being such excellent hosts and making us feel at home at the expedition base. Thanks to Kougaview Game Farm for the entertaining game drive. Thanks to two reviewers for their helpful comments on drafts of this report. Finally, we would also like to thank [Ford South Africa](https://www.ford.co.za) for supplying the expedition with two invaluable Ford Ranger vehicles (see Fig. 1.9a. below).

Figure 1.9a. Ford Ranger vehicle in action during the expedition.

1.10. Further information & enquiries

More background information on Biosphere Expeditions in general and on this expedition in particular, including pictures, diary excerpts and a copy of this report, can be found on the Biosphere Expeditions website www.biosphere-expeditions.org.

Enquires should be addressed to Biosphere Expeditions at the address given on the website.

2. Leopard activity at Blue Hill Nature Reserve during 2016 and early 2017

Alan Tristram Kenneth Lee
University of Cape Town

During 2016 leopard and medium to large mammals continued to be monitored at Blue Hill Nature Reserve using motion sensor camera traps. This brief section simply serves as an update of activity and presents key photographs. Data for this period have yet to be entered and we thus have not yet quantified the number of captures for leopard, caracal and wildcat for this period. Comments are derived from observations made after quick reviews of photo folders of photo downloads in terms of presence and noteworthy observations.

Of concern was that the only leopard recorded by camera traps during 2016 was the resident male, named 'Strider', present since 2015. Strider made his presence known on several occasions, and proved to be a very photogenic individual (Figure 4.1). He has only ever been captured on camera at night. His presence was recorded at all camera trap locations (East Road, South Road and close to Blue Hill Escape). Prior to Strider, the last male leopard to be recorded at Blue Hill was 'Scarface', a leopard recorded only once at Blue Hill. Scarface had been previously trapped by the Landmark Foundation over 60 km east of Blue Hill in the heart of the Baviaanskloof Nature Reserve.

Due to extended periods of absence, as may be associated with patrols of a very large territory, there were concerns about the safety of Strider, as leopard persecution has been well documented for this region. As a result, trapping efforts to fit a satellite collar were made during October 2016. A walk-through cage was placed at a scratch-tree, where he was recorded on several occasions. However, these efforts were unsuccessful (as all previous efforts have also been).

On a brighter note, in February 2017, a new leopard, presumed to be female, was recorded for the first time (Figure 4.2). We suspect, but cannot yet confirm, that this female is accompanied by a nearly full-grown cub. On 6 February 2017, two leopard camera trap capture events occurred, close together in time at two locations. However, photos were insufficient to determine identity and could represent captures of the same individual (see Fig. 2.5).

Caracal and African wildcat were also recorded on a number of occasions. One caracal was reported to have been killed on a nearby farm towards the end of 2016 and predator control activities are ongoing. However, at least one caracal was still present at Blue Hill after this event.

A selection of other wildlife from the camera traps at Blue Hill Nature Reserve can be seen at www.facebook.com/bluehillnaturereserve/

Figure 2a. Strider posing (and smiling) for the camera on the East Road.
The early evening light means the background is still fairly well lit.

Figure 2b. A new leopard, presumed to be a female and tentatively named Lina.

Figure 2c. A male caracal, maybe off to find some sunlight in order to warm up.

Figure 2d. The leopard scratch tree with an African wildcat.

Figure 2e. The leopard scratch tree with Strider, looking well-fed in this picture.

Figure 2f. New leopard, possibly Lina.

3. Hottentot buttonquail (*Turnix hottentottus*) capture: a first-ever for South Africa's ringing database

Alan Tristram Kenneth Lee
University of Cape Town

3.1. Introduction

The Hottentot buttonquail *Turnix hottentottus* is one of 18 species of buttonquail, a group of cryptic, small, terrestrial birds probably best known for their polyandrous breeding systems (Debus and Bonan 2016). Hottentot buttonquail is considered to be endemic to the fynbos biome of South Africa (Taylor et al. 2015), which is a fire-driven Mediterranean-type ecosystem (Cowling et al. 1997). It is the only *Turnix* reported to be reported from the fynbos.

Remarkably little is known about the Hottentot buttonquail. It is, like other buttonquails, assumed to be polyandrous (Dean 2005). There is distinct sexual dimorphism, with birds described as males generally uniform and pale, but females having contrasting white belly and chestnut, reddish brown chest and face (Arizaga et al. 2011). Little is known about their ecology.

Taxonomically the species was considered conspecific with the black-rumped buttonquail *Turnix nana* (Dowsett and Dowsett-Lemaire 1993), while Sibley & Monroe (1990) suggested the two taxa were separate species. The latter taxonomic treatment is supported by their allopatric ranges, as well as differences in habitat preference and plumage (Dean 2005). They are currently accepted by BirdLife International (2016) as of 2014; BirdLife South Africa, which never previously recognised the grouping (Lotz 2013); and the International Ornithologists' Union (Gill and Donsker 2014). The systematic position of Turnicidae has been much debated (Zelenkov et al. 2016) and they are currently allied with the Charadriiformes, i.e. the order of waders and gulls (Burleigh et al. 2015).

From a conservation perspective, the species has variously been described as 'on the brink of extinction' (Brooke 1984); 'possibly extinct' (Debus 1996); and 'possibly critically endangered' from c2010 - 2013 (Lotz 2013). However, at the same time it was classified as 'Least Concern' globally, while lumped with *T. nanus* (BirdLife International 2004), and as of 2014 as 'Endangered' both globally (BirdLife International 2016) and nationally (Taylor et al. 2015). The most recent listings were partly based on an extrapolation by Lee (2013) of a density estimate provided by Fraser (1990) to a possible global population of 400 individuals. In addition, the rarity of records from the ongoing South African Bird Atlas Project (SABAP2) was highlighted. By contrast, a survey in 1994 by Ryan and Hockey (1995) on the Cape Peninsula suggested that area alone may hold 350 (100-560) birds, making it one of the most common bird species in restionaceous fynbos. Thus informed decisions requiring population size, population trend and range, as well as on the conservation status and for species management purposes, have been hampered by a general lack of knowledge of this species.

3.2. Methods

Study area

The fynbos biome (fynbos, also known as the Cape Floral Kingdom/Cape Floristic Region) comprises one of only six floral kingdoms in the world and is contained entirely within the political boundaries of South Africa, where it is mostly restricted to the Western and Eastern Cape provinces of the Cape Fold Belt. Owing to its exceptional plant species richness and high level of endemism, as well as high levels of animal diversity and endemism, it is recognised as one of the world's 25 biodiversity 'hotspots' (Myers et al. 2000). The biome takes its name from 'fynbos' (Afrikaans for 'fine bush'), the dominant vegetation type in the biome. The other two main vegetation types are 'renosterveld' (Afrikaans for 'rhino bush') and 'strandveld' (Afrikaans for 'beach bush'). Vegetation is dominated by three characteristic families: Proteaceae, Ericaceae and Restionaceae. All the fynbos experiences at least some winter rainfall. In the western fynbos rainfall is mostly restricted to the winter months, while in the east summer rainfall becomes more important. The fynbos is a fire-driven ecosystem, with most plant species adapted to an intermittent fire regime (6 – 40 years). Conversion to agriculture, urbanisation and the invasion of a variety of alien plant types all pose major conservation threats to the area.

Attempts at trapping took place at the Blue Hill Nature Reserve (BHNR) (Fig. 2.1) on the western border of the Baviaanskloof Nature Reserve, Western Cape, South Africa. The 2230 hectare BHNR lies between 1,000 and 1,530 metres above sea level (m asl) in fynbos. The reserve falls into an aseasonal rainfall region, with annual informal records from the closest town, Uniondale (40 km distant, 730 m asl), for the 1965 – 1997 period 344 ± 102 mm (Lee and Barnard 2013). The property that forms the reserve was acquired by the Lee Family Trust in 2009 and they initiated a partnership with CapeNature, the Western Cape provincial agency in charge of protected areas, to convert the land to a stewardship nature reserve. This process was completed in 2013 with the land now managed for biodiversity. Prior to 2009, use of the land had been for agricultural purposes, mostly stock farming of cattle and sheep.

Trapping efforts

On three days from 5 – 7 October 2016, 133 metres of net were erected along existing vehicle tracks at locations where Hottentot buttonquail had previously been encountered by the author at BHNR. At each location, teams of observers of between 5 and 11 citizen scientists, along with the author, walked abreast in flush attempts to drive birds towards the nets. As general bird capture rates with mist nets are highest in the early morning, in order to avoid incidental bycatch, these trapping efforts were conducted from 08:00.

3.3. Results

At 09:00 on 5 October 2016 a Hottentot buttonquail was flushed, but did not fly into the net until subsequent flush efforts were made. The bird eventually flew into the net and was successfully retrieved. The female adult Hottentot buttonquail weighed 61.1 grams, being heavier than expected and with a thicker than expected tarsus and was fitted with a 3.5 mm ring with identification number CA28546 on the right tarsus in accordance with SAFRING guidelines (De Beer et al. 2001). Other pertinent measurements included wing length of 85 mm, tail of 40 mm, tarsus of 21.7 mm and culmen of 11.3 mm. No primary, head or body molt were observed, and there was no brood patch.

The location was 23.428130E, 33.608180S. The bird was released in good condition. A flush survey in the area in the subsequent week flushed another buttonquail of unknown age and sex in the same area (not captured).

Trapping efforts on 6 and 7 October 2016 resulted in no further captures using the same protocol, although a buttonquail was observed at 23.437920E, 33.628724S prior to erecting nets. These were the only two locations at which buttonquail were observed during the expedition period (4 – 16 October 2016), although flush survey lines were conducted across the reserve during this period.

Efforts to capture Hottentot buttonquail using call-back lures during the last week of January 2017 resulted in no sightings or captures.

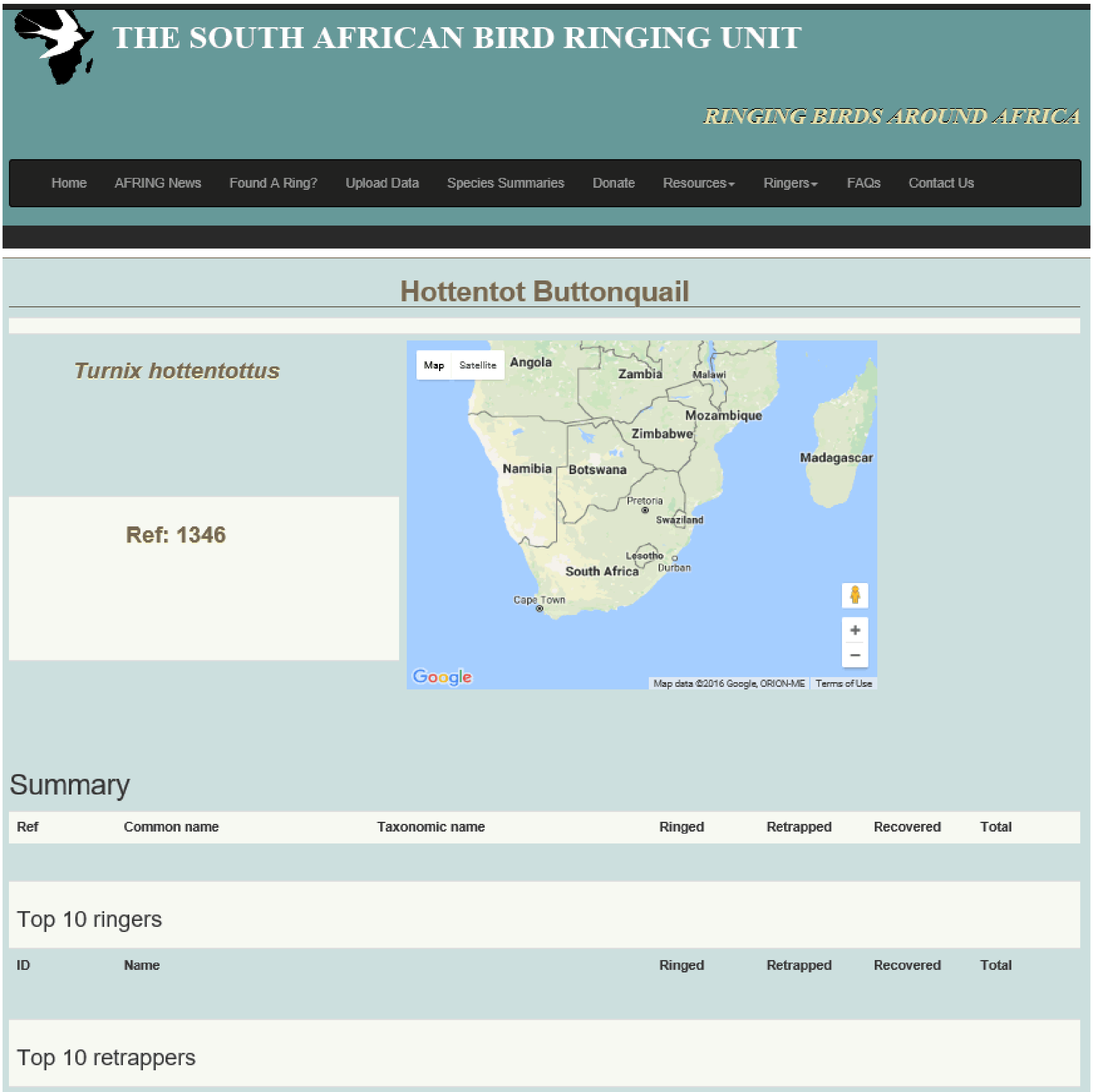

Figure 3.3a. Before: a screen capture of the SAFRING database for the Hottentot buttonquail prior to this expedition, showing no entries.

Figure 3.3b. During: The adult female buttonquail successfully captured and released at Blue Hill Nature Reserve (see also video of the capture event).

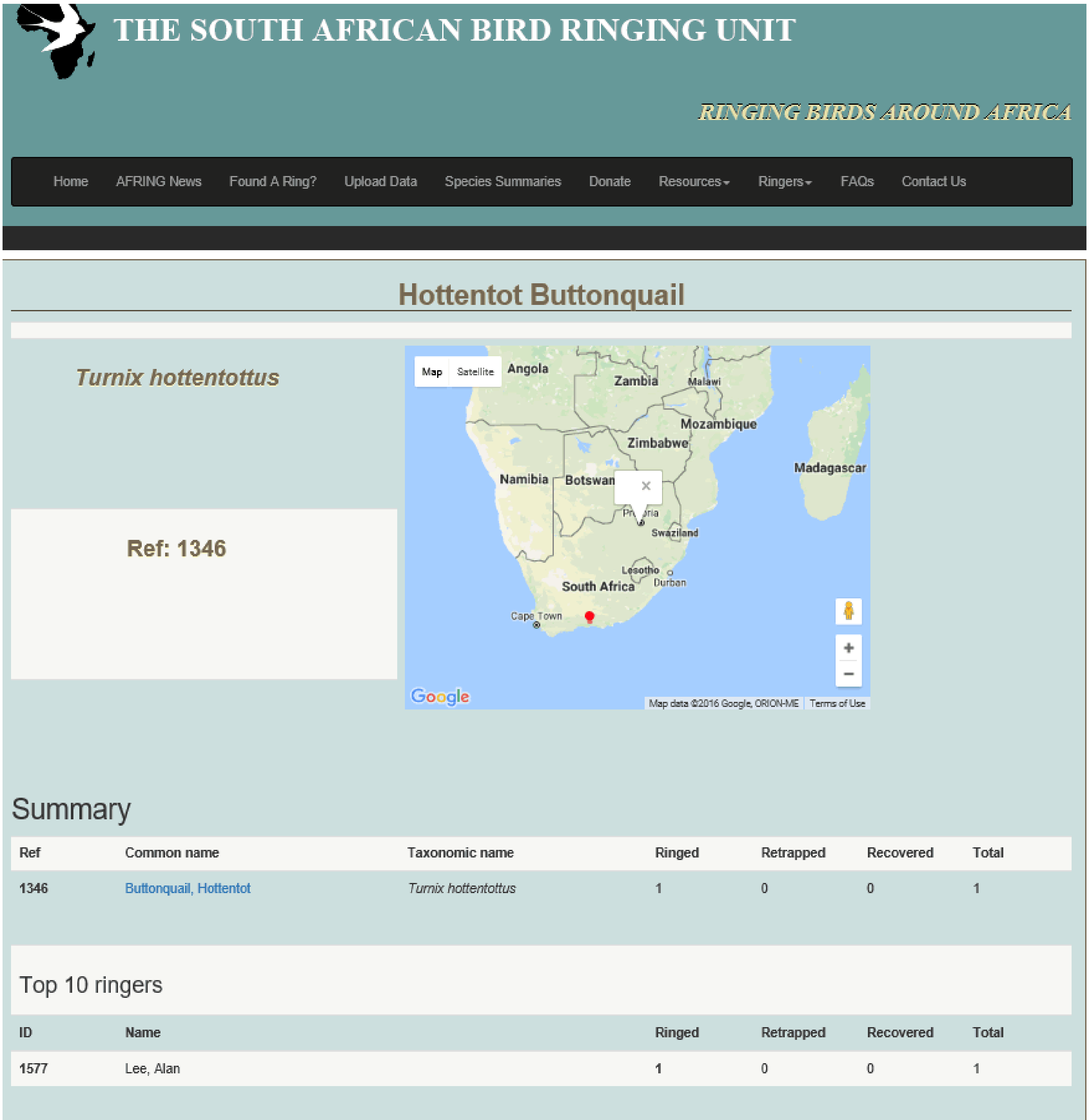

Figure 3.3c. After: Red pin indicates location of the first record for the Hottentot buttonquail in the SAFRING database.

3.4. Discussion

This exciting first-ever live capture and release of a Hottentot buttonquail needs to be put in the context of ringing efforts across the biome and at Blue Hill Nature Reserve. According to the last comprehensive report from SAFRING (Paijmans and Oschadleus 2015), ringing effort for the 2006-2013 period in the Western Cape, i.e. the range of the Hottentot buttonquail, resulted in 95 670 captures of 308 species of bird, obviously none of which was a Hottentot buttonquail. As of March 2017 at Blue Hill Nature Reserve, where ringing commenced in 2011, there have been over 5087 birds captured of 82 species. All seven bird species endemic to the fynbos biome have now been ringed at Blue Hill Nature Reserve.

However, it is clear that significant efforts are needed to catch this mostly terrestrial bird, requiring a lot of manpower for erecting the long lines of nets, as well as effort to flush the birds. To this end the assistance from Biosphere Expeditions citizen scientists has proved extremely useful.

Conclusions and future research

Still next to nothing is known about the Hottentot buttonquail: daily activity patterns, diet and breeding patterns have been inferred from other buttonquail species, but have still to be confirmed. Patterns of territoriality and migration are still only matters of speculation. How closely related this species is to black-rumped buttonquail *Turnix nana* also needs to be ascertained. There is thus much that needs to be done better to understand this Endangered species found only in the fynbos biome, South Africa.

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4. Small mammal capture rates: getting high matters in transitional fynbos

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4.1. Introduction

Rodents play an important role in fynbos plant ecology, ranging from flower pollinators to seed predators and seed dispersers (Vlok, 1995, Midgley et al., 2002, Biccard and Midgley, 2009). They are also an important food source for a variety of animals, from snakes, to raptors, to cats. A previous study of rodent diversity and capture rates from the Baviaanskloof (Bond et al., 1980) concluded that species composition varied according to altitude and aspect, with a total catch of six rodent and two shrew species, and found correlations between abundance of rodent species and vegetation structure and the cover of rock and bare soil.

In this study, we build on baseline surveys conducted during 2015 by Biosphere Expeditions (Lee, 2016), by conducting a further two nights of small mammal trapping at Blue Hill Nature Reserve.

4.2. Methods

The study area and site are as described in chapter 3 of this report.

Small mammal abundance from Sherman traps

In order to sample small mammal abundance, we created three Sherman trapping arrays at BHNR based on guidelines from Manley et al. (2006, Chapter 5: Small Mammal Monitoring). Traps were baited with peanut-butter and a commercial mixed bird food or bread. Traps were placed in sheltered locations near rocks or under bushes and checked twice a day (morning and evening). Trapped animals were photographed if necessary (for identification), were weighed and then released.

Sampling was conducted from 8 to 14 October 2016 in the following manner: 50 traps were placed along four routes (two routes of opposing aspect (north or south) in each array with 25 traps each spaced at approx. 25 metre intervals). Sampling was conducted over three nights on the first array and then moved to the second array for a further three nights. Arrays were positioned along an altitudinal gradient at each array, on north- and south-facing slopes in fynbos. This sampling took place approximately 16 years since the last fire. Sampling was conducted at a third survey array on the nights of 11 and 12 October 2016, but further activity had to be abandoned due to cold weather.

Due to low capture rates within species, all captures were pooled to examine the influence of aspect and altitude on rodent capture rate. Binomial logistic modelling was used for capture vs non-capture from each trap check, keeping the individual trap location as a random effect. For modelling, the lme4 package (Bates et al. 2013) was used and p values were obtained using the lmerTest package (Kuznetsova et al., 2013) in R. The 'step' function from lmerTest was used to check for alternative explanatory models by Aikake Information Criterion (AIC), but the full model was retained as the best model.

4.3. Results

Small mammal abundance from Sherman traps

Capture success along the Sherman trap arrays was low: 7% (48 captures from 700 checks across 150 trap positions), with at least one confirmed recapture and one suspected recapture. Identifiable species were: striped field mouse *Rhabdomys pumilio* (n=9); Cape elephant shrew *Elephantulus edwardii* (n=5); Namaqua rock mouse *Aethomys namaquensis* (n=24) and African pygmy mouse *Mus minutoides* (n=1). There was uncertainty regarding the identification for nine individuals, which most closely resembled the Namaqua rock mouse, but might also have been Cape spiny mouse *Acomys subspinosus* (Table 4.3a). It is possible that species identified as Namaqua rock mouse also included the latter species.

Table 4.3a. Rodent species capture totals from Sherman traps, with mean and standard deviation (SD) of mass.

Species	n	Mean (g)	SD
Striped field mouse *Rhabdomys pumilio*	9	43.44	15.29
Cape elephant shrew *Elephantulus edward*ii	5	58.44	5.27
Namaqua rock mouse *Aethomys namaquensis*	24	53.66	5.44
African pygmy mouse *Mus minutoides*	1	21.10	NA
Unidentified	9	41.31	15.93

Capture rates were significantly higher during morning trap checks ($t = -6.2$, $p < 0.01$) suggesting strong nocturnal behaviour among this population of small mammals. Both altitude and aspect were significant predictors in a model of capture probability (Table 4.3b), with capture rates highest on flat terrain, and with a tendency for higher capture rates on the north-facing slopes. However, the number of sites classified as 'flat' was low (6%, 9 of 150). Capture rate decreased with increasing altitude, as illustrated in Figure 4.3a. No other small mammals or taxa other than rodents were captured.

Table 4.3b. Model output of variables influencing the probability of finding a rodent in a Sherman trap at BHNR. PM represents results of checks conducted at the end of the day, where capture rates were lower compared to early morning checks after night-time activity. Aspect (N and S) are presented relative to the intercept of 'no aspect'.

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	0.642	0.166	165	3.863	0.000
Altitude	0.000	0.000	163	-2.289	0.023
PM	-0.109	0.018	544	-6.138	0.000
Aspect N	-0.122	0.049	167	-2.500	0.013
Aspect S	-0.147	0.050	166	-2.953	0.004

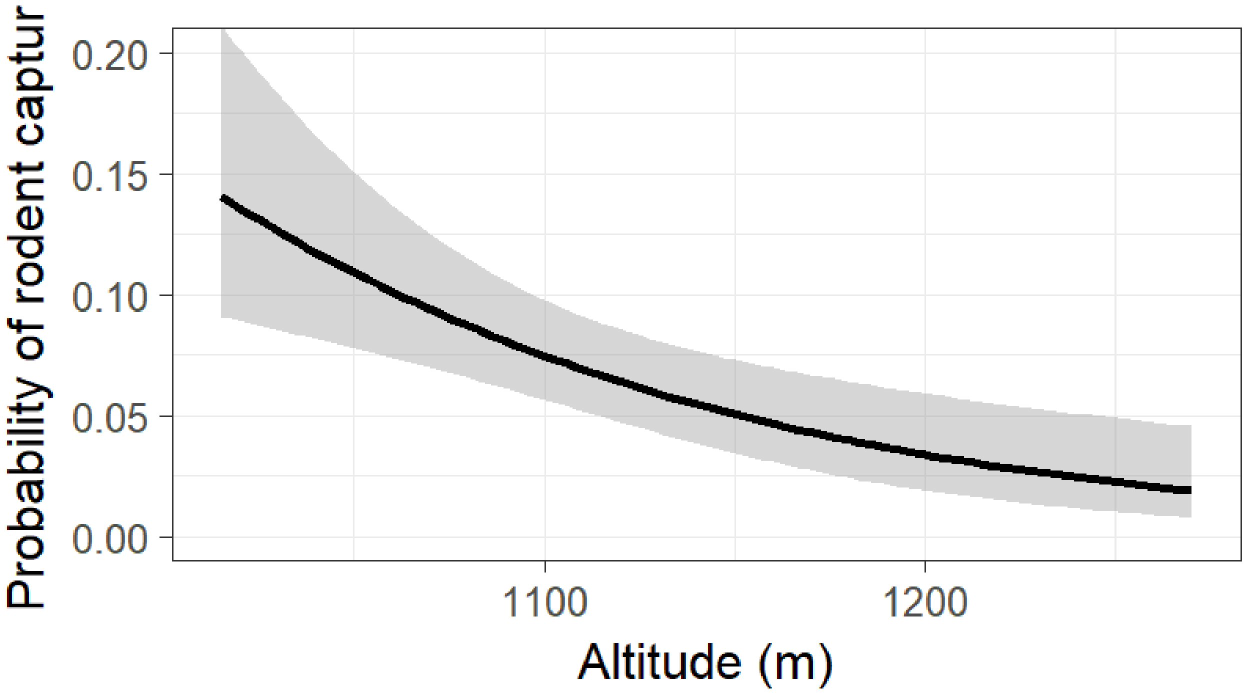

Figure 4.3a. Rodent capture probability across three trapping arrays at BHNR, illustrating the influence of altitude. Note: capture probabilities are low at all altitudes. Grey shading represents standard error

4.4. Discussion

Small mammal abundance from Sherman traps

The results presented in this report represent the first formal small mammal surveys at BHNR. While three of the species recorded were known to be present, the capture of several Namaqua rock mouse presented a novel species for the BHNR list. However, close attention needs to be paid to species identification in future trapping efforts.

Capture rates were low and decreased with increasing altitude, corroborating previous findings (Bond et al. 1980). While there was no clear difference between north- and south-facing slopes, which have radically different vegetation at this site, sites with no quantifiable aspect (flat) had the highest capture rates. South-facing slopes at Blue Hill Nature Reserve at the trap locations are dominated by *Protea* species, with north-facing slopes dominated by *Aspalathus*, *Restio*, and *Aloe* species (Lee and Barnard, 2013). *Protea* are serotinous and retain their seeds on the plant until a fire, and such slopes would be expected to have lower food availability for this granivore community; while the habitat on north-facing slopes is dominated by plants that release their seeds on an annual basis.

More attention needs to be paid to the role of plant composition at trap locations in future trapping efforts. Low capture rates mean that a large effort will be required to obtain meaningful results.

Conclusions and future research

Future expeditions should attempt to repeat surveys at previously sampled trap sites in order to explore temporal changes in capture rate. More attention needs to be paid to the variables at each trap position, including percentage of rock cover and dominant plant types, following Bond et al. (1980). In addition, in order to make this research novel, the possibility of extending the sampling sites to include fynbos of different ages (time since fire) should be explored. Understanding how vegetation and topography influence rodent abundance and biomass will substantially assist in understanding the predicted movements of their predators in the landscape.

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5. Tortoise mortality along fences in the southeastern Karoo, South Africa

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5.1. Abstract

Fencing, particularly electric fencing, is widely used across South Africa for livestock and game ranching practices. Recent studies found that leopard tortoises (*Stigmochelys pardalis*) are more prone to dying from electrocution along electric fences than any other taxa. However, no studies have quantified tortoise mortality along non-electric fences or assessed the impact of fence structure. With South Africa being home to more tortoise species than anywhere else in the world, this is a primary conservation concern.

This study quantifies tortoise mortalities associated with electrified and non-electrified fences and relates these rates to fence structure (mesh or strand). Open field transects are used as controls to estimate background mortality. This study also reports the distribution and abundance of different fence types along 2,200 km of roads in the southeastern Karoo, allowing the cumulative impacts of different fence types to be estimated.

All fence types had significantly higher tortoise mortality rates than open field transects. Leopard tortoise mortalities were significantly higher along electric fences than non-electric fences. Despite comprising only approximately 4% of all roadside fencing, electric fences accounted for 56% of leopard tortoise mortalities. This study validates the concerns regarding increased electric fence use in the future and the potential impact on leopard tortoises. When considering the relative abundance of fence types and their associated mortalities, the total number of leopard tortoise mortalities along electric and non-electric fences are comparable.

Angulate tortoise (*Chersina angulata*) mortalities were significantly higher along mesh fences than strand fences, but did not differ between electric and non-electric fences. Angulate tortoises appear to wedge themselves in mesh fences and are unable to escape.

This study highlights the current threat of non-electric fencing on tortoises, as no similar studies have previously been conducted. These additional tortoise mortalities should be considered alongside other emerging threats when investigating the longevity of these tortoise populations, not only in the Karoo, but globally. The implementation and practicality of previously suggested mitigation strategies are discussed and alternative mitigation strategies are suggested.

5.2. Introduction

South Africa is the most species-rich tortoise region in the world, with 14 species from five genera (Branch et al. 1995, Alexander & Marais 2007). Tortoises face many threats that have led to decreasing populations, such as exploitation for the pet trade, road mortalities, habitat transformation from farming activities, encroachment of urban sprawl, establishment of invasive alien vegetation, increased fire frequency and pollution (Branch et al. 1995, Alexander & Marais 2007, Watson et al. 2008). The local increase in pied crows (*Corvus albus*) across parts of South Africa (Cunningham et al. 2016 Joseph et al. 2017) has resulted in increased predation on juvenile and small tortoises (Fincham & Lambrechts 2014, Loehr 2017). Electric fences are an emerging threat to tortoises as they are more prone to dying from electrocution along electric fences than any other taxa (Beck 2010).

Fencing types and threats

Electric fencing is increasingly being used across South Africa due to an increase in livestock farming and game ranching (Beck 2010, Brandt & Spierenburg 2014, Pietersen et al. 2014, Taylor & van Rooyen 2015, Farber 2016), as they deter predators and other problem animals that threaten livelihoods (Burger & Branch 1994, van Niekerk 2010, Kesch et al. 2014). However, there are few national regulations regarding fence type, structure and abundance, although localised policies may be found (e.g. Cape Nature 2014), but these are difficult to implement and regulate in remote areas. Thus, the environmental impacts of both electrified and non-electrified fencing are of great concern as more fences continue to be erected.

A common feature of an eclectic fence is an offset, single low-lying (30-300 mm) electrified strand that prevents problem animals from digging underneath fences (Burger & Branch 1994, Beck 2010; Pietersen 2013). Regardless of whether a fence is electrified or not, fences primarily comprise of either a diamond-shaped mesh or horizontal strands that run between fence poles (Fig. 5.2a).

Given the increased use of electric fencing, Beck (2010) tried to quantify the number of animals killed by electric fences across South Africa. He found individuals from 33 species that had died as a direct result of electric fencing. Reptiles had an order of magnitude higher mortality rate than mammals, with reptile mortality rates up to 2.15 individuals/km/yr (mean = 0.475 individuals/km/yr). Leopard tortoises (*Stigmochelys pardalis*) comprised 91% of all reptile mortalities. Beck's (2010) results corroborated findings of a previous study (Burger & Branch 1994) that investigated tortoise mortalities along electric fences in the Thomas Baines Nature Reserve, South Africa. Both South African studies related high mortalities of leopard tortoises to their behaviour, their large size, wide distribution and reaction to electrocution. All tortoise mortalities were a direct result of tortoises coming into contact with a single, low-lying electric strand. When tortoises touch an electrified strand, they adopt their natural defense strategy and retract their limbs and head into the carapace. They then remain part of the circuit and thus become trapped (Burger & Branch 1994, Todd et al. 2009; Beck 2010), eventually dying of electrocution, dehydration or overheating (from exposure to the sun), or a combination of all three (Burger & Branch 1994).

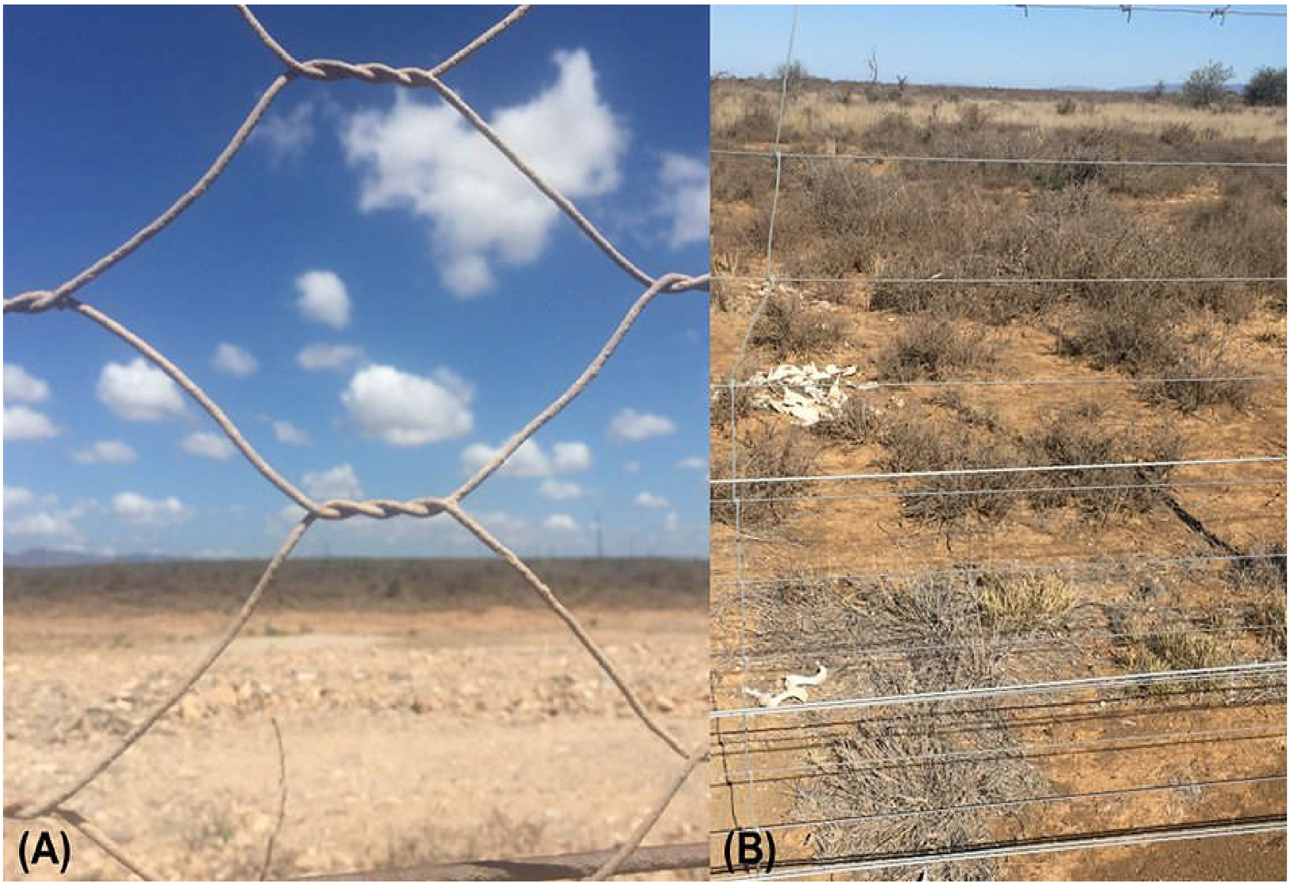

Figure 5.2a. Common fence types found in the area (A) mesh and (B) strand.

Other tortoise species also are killed by electric fences, including angulate tortoise (*Chersina angulata*), Kalahari Tent Tortoise (*Psammobates oculiferus*) and Lobatse hinged tortoise (*Kinixys lobatsiana*) (Burger & Branch 1994, Beck 2010), suggesting that all tortoise species could be at risk if the electric strands are low enough.

Beck (2010) cites two primary mitigation strategies to reduce tortoise mortalities: (a) raising the height of the electric strand and: (b) building rock aprons along electric fences (rocks packed against the fence to prevent problem animals from digging beneath fence and maintain fence integrity) in order to prevent tortoises from reaching the electric strand.

Some studies conducted in the United States investigated desert tortoise (*Gopherus agassizii*) responses to various barriers, including mesh fences (Ruby et al. 1994) and found that the most effective tortoise barrier was a mesh screen fine enough to exclude a tortoise's head. No studies in South Africa have reported any tortoise mortalities along non-electric fences. It is not known if non-electric fences have any associated tortoise mortalities or whether fence structure (i.e. mesh or strand) has any role. The mortality rates reported by Burger & Branch (1994) and Beck (2010) were also not compared to natural mortality rates.

The Karoo region and tortoises

The Karoo is the most species-rich tortoise region in South Africa, with four genera of tortoises comprising nine species, of which six are endemic to the region (Branch et al. 1995, Branch 1998; Milton et al. 1999). The leopard tortoise is the largest (with exceptional individuals reaching lengths of 750 mm and masses of 40 kg), most abundant and widespread tortoise across South Africa (Alexander & Marais 2007). In addition, leopard tortoises produce notably more offspring than other tortoises found in the region. Of the tortoises found in the southeastern Karoo, only leopard tortoises have been assessed by the IUCN and are listed as Least Concern (IUCN 2017). Angulate tortoises may be locally abundant, with exceptional individuals reaching lengths of 300 mm and masses of 2 kg (Alexander & Marais 2007). Of the three tent tortoise species, only the Karoo tent tortoise (*Psammobates tentorius*) occurs in the southeastern Karoo in low densities (Alexander & Marais 2007). Finally, of the five species of padloper tortoise (all of which are endemic to South Africa), two occur in the southeastern Karoo: the parrot-beaked padloper (*Homopus areolatus*) and the rare Karoo padloper (*H. boulengeri*) (Alexander & Marais 2007).

The Karoo exhibits all the problems mentioned above regarding increased fencing (Brandt & Spierenburg 2014, Farber 2016). The Karoo stretches across multiple provinces, making it difficult to monitor and regulate at a provincial level. Although landowners appreciate the threat posed to tortoises by electric fences, little has been done to address the issue. The problem recently received media attention to raise awareness to the public and generate pressure for change (Watson et al. 2008, Farber 2016).

The study

This study quantifies tortoise mortalities associated with electrified and non-electrified fences and relates these rates to fence structure. Open field transects are used as controls to estimate background mortality. The implementation of mitigation strategies and their effectiveness is investigated. This study also reports the distribution and abundance of different fence types in the southeastern Karoo, allowing the cumulative impacts of different fence types to be estimated. This study also aims to raise awareness and inform a code of best practice not only to reduce tortoise mortality, but also to meet the needs of game ranchers and livestock farmers. Recommendations can be adapted into fencing policies to benefit landowners and tortoises.

5.3. Methods

Study area

The study was conducted during October and November 2016 in the southeastern Karoo between Calitzdorp and Kleinpoort (Fig. 5.3a). The study area was primarily situated in the Nama Karoo Biome, although some areas extended into Succulent Karoo and drier areas of Albany thicket and fynbos biomes. However, many areas are transformed from natural vegetation due to overgrazing by livestock (Hoffman et al. 1999, Milton et al. 1999). Annual rainfall varies between 120 - 200 mm, with March generally being the wettest month (20 - 30 mm) and June being the driest (0 - 12 mm), but this varies regionally. The area suffered a drought in 2016. January and February are the hottest months, with average daily maxima temperatures of 30 - 33 °C and minima of 14 - 16 °C. June and July are the coldest months with average daily maxima temperatures ranging from 18 - 20 °C and minima from 3 - 6 °C.

Data collection

Tortoise encounter survey

Transect data were collected in relation to fence type in order to identify what factors predicted the presence of tortoises along fences. This was based on live tortoises and the standing stock of dead tortoises along fences. A mortality rate of individuals/km/yr could not be measured, as there was not enough time to clear carcasses and re-check areas after a reasonable interval. Instead, we measured the probability of finding a tortoise and the average number of tortoises along a 1 km length of fence. Transects along different fence types were walked, as well as transects in open field (control) within the study area. Fences away from road verges were not included for data consistency reasons and due to time restrictions, because obtaining permission from every landowner for such a large area would be impractical. Transect distances were ideally 1 km long, but were occasionally shortened if, for example, a fence type changed.

The following information on fence presence and design were recorded at 100 m intervals, as well as at each tortoise found during a transect: the structure of the fence (i.e. mesh or strand); presence of electrified strands; where these were present, the height of the lowest electric strand. Fence types were categorised into the following groups: No fence (open field control), Electric mesh, Electric strand, Mesh (non-electric) and Strand (non-electric). If a rock apron was present, it was recorded. A rock apron was recognised if there were rocks packed together with no observable gaps to a height of at least 5 cm and extended for 5 m either side from the data point.

The following measurements were taken for all tortoise encounters along transects: species identity (based on scutes and carapace shape), standard carapace length (SCL) and carapace height. For tortoises found on an electric fence, the electric strand height was recorded at the point of contact and when the point of contact could not be estimated, the reading was made where the fence was closest to the carcass. The top three scutes (Fig. 5.3b) were measured due to their distinctive shape, which allowed them to be easily identified amongst partial tortoise remains.

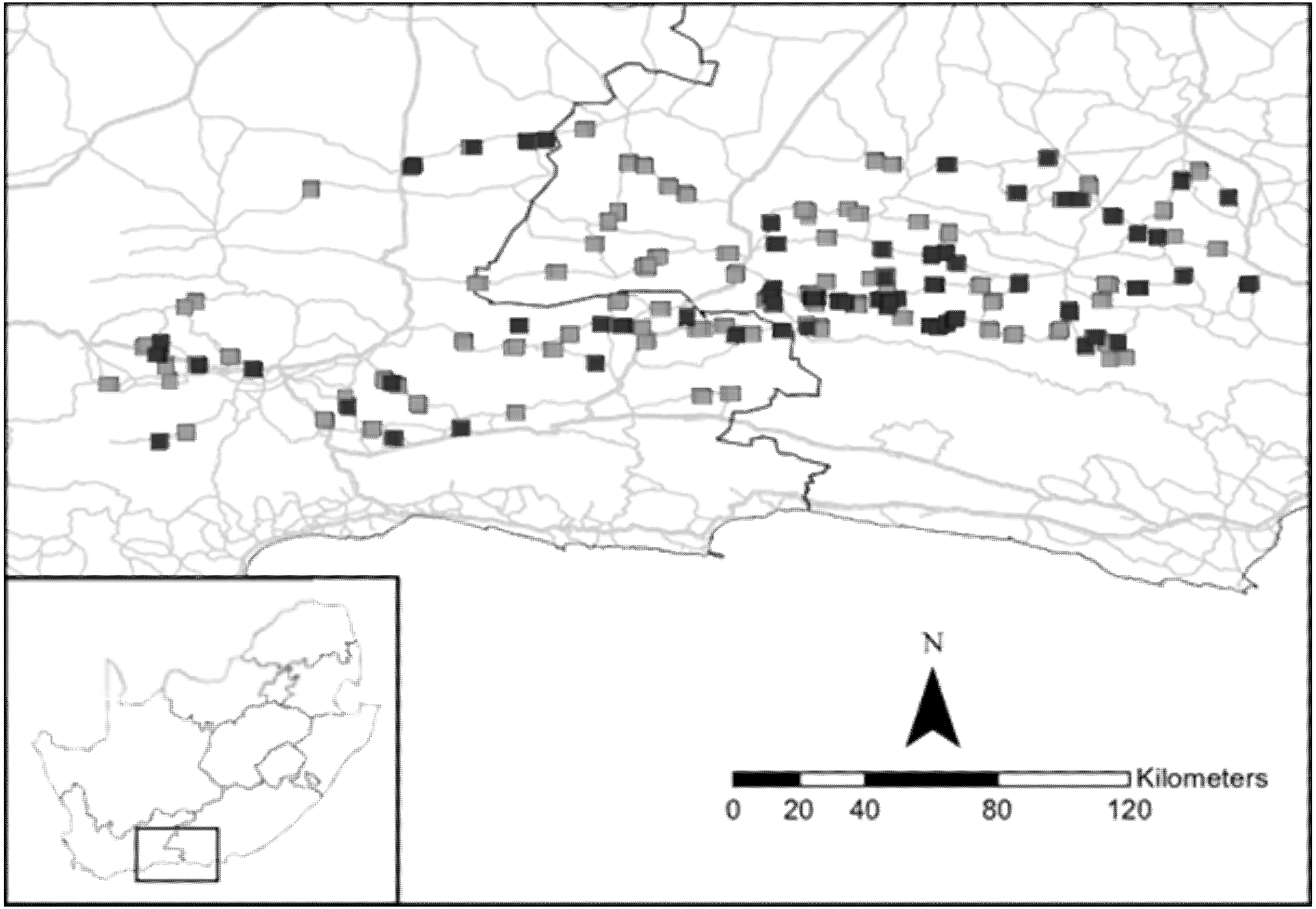

Figure 5.3a. Map of study area showing location of transects. Black squares indicate points where dead tortoises were found and grey squares indicate transect points where live tortoises were found.

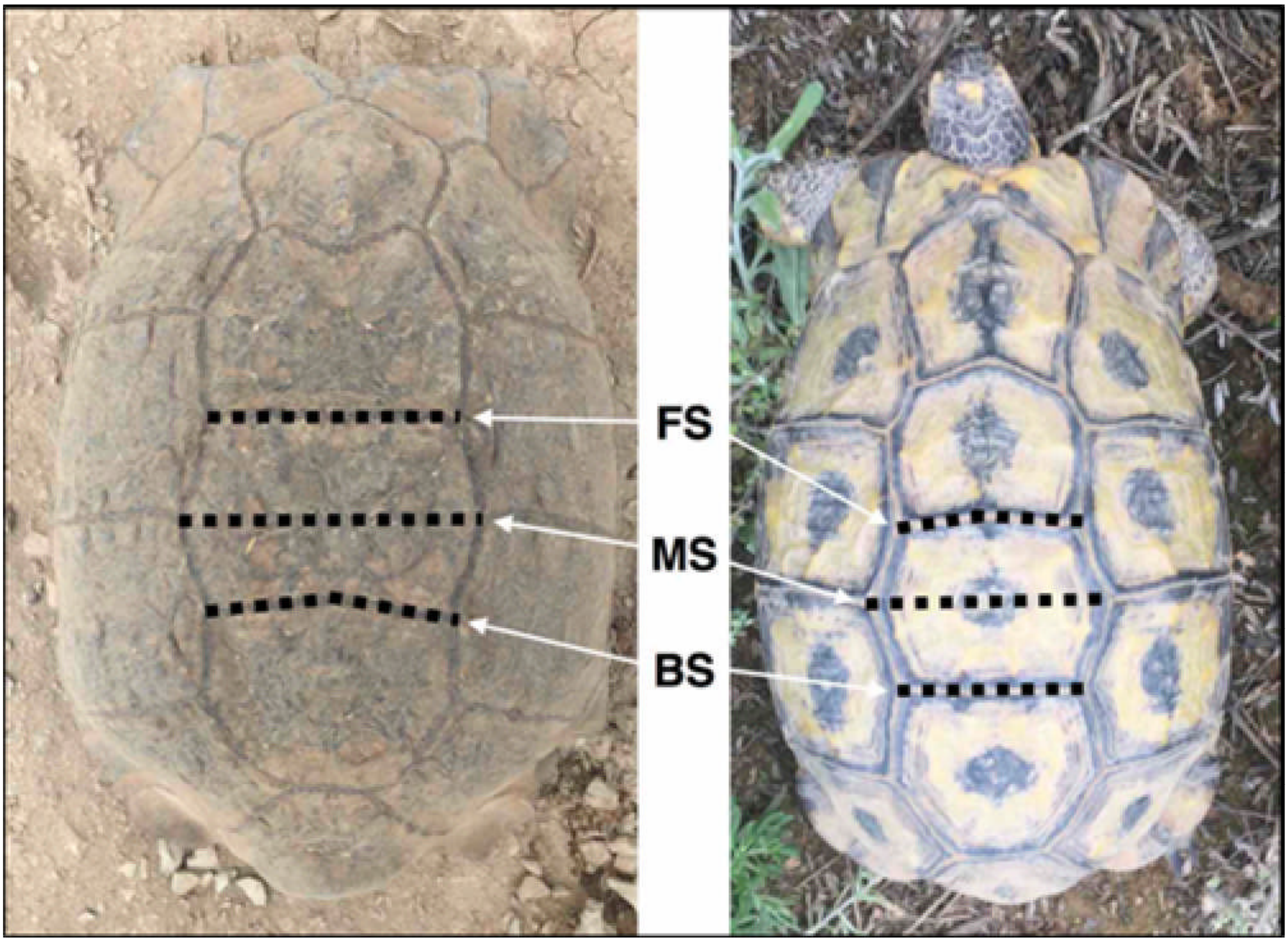

Figure 5.1b. Dashed lines show the lengths recorded of the top three carapace scutes for leopard tortoises (left) and angulate tortoises (right). Relevant scute codes indicated by arrows (FS = length along the edge between the top front scute and top middle scute, MS = length of middle scute, BS = length along the edge between the top back scute and top middle scute).

Spatial distribution of fences

Fence distribution data were collected to sample the distribution and abundance of different fence types in non-urban environments. Data points were collected every 5 km along public roads (for both sides of the road) across the study area (Fig. 5.3a). The same information on fence presence and design described above were recorded, except the height of the lowest electrified strand (due to time constraints).

Additional information

For any incidental tortoise encounters (not on a transect), the fence presence/design and tortoise encounter information as described above were recorded. Behaviour of live tortoises was categorised as follows: Resting (inactive), Trapped on fence, Drinking, Feeding, Mating and Walking. In addition, temperature was recorded with a hand-held Kestrel device for all incidental encounters. Live tortoises found trapped on a fence were removed by hand or using a wooden pole to push them. Finally, any personal field observations and informal conversations with landowners regarding tortoises, land-use, and wildlife conflict were noted.

Data analyses

Tortoise mortality along fence types

Generalized linear models (GLMs) were used to model the probability of finding a tortoise and the average number of tortoises found along a 1-km transect. An offset of transect length was included to account for varying transect distances. For probability models, a binomial distribution and a logit-link function were specified. For average number of tortoises along a 1-km transect, a negative binomial distribution and a logit-link function were specified. Significance was set at 0.05 for all analyses.

Estimated number of tortoises killed

The total number of tortoise mortalities along the roads surveyed was estimated, assuming that the relative proportions of each fence type (measured every 5 km) were representative of fences along the roads sampled. The relative proportions of each fence type were multiplied by the total length of roads surveyed to estimate the total distance of each fence type in the study area. This was multiplied by the average density of dead tortoises (from the GLMs for each species and fence type to estimate the total number of dead tortoises).

Patterns of tortoises killed

Regression models were fitted to predict carapace heights from SCL and scute lengths for each species. All regressions were significant (Appendix I, Figs. S1 and S2). For broken-down carcasses where carapace heights could not be measured, heights were calculated using regression equations (Appendix I, Table S1) Regression equations that showed the strongest correlation were used if multiple opportunities presented themselves to calculate carapace height (e.g. if multiple scutes were found).

The impact of electric strand height relative to carapace height of dead tortoises was investigated. Carapace heights of dead tortoises found along electric fences were scored as taller or shorter than the electric strand. The null hypothesis that electric strand height has no impact on size of tortoise killed predicts an equal distribution of tortoises that are taller and shorter than the electric strand. A chi-squared test (with Yates' correction for continuity) was used to test the significance between observed and predicted (null) frequencies.

Measurements where the electric strand height was above 400 mm were removed because they were not serving a functional purpose against problem animals (most of these were in dips of river beds). The heights of electric strands and tortoise carapace heights (of each species) were not normally distributed. Thus, a non-parametric Wilcoxon test was used to test for significant differences between: electric strand heights where dead tortoises were found against those recorded every 100 m; carapace heights of dead tortoises found along electric fences against all other tortoises (live and dead tortoises not found along electric fences); and carapace heights of dead tortoises found along electric fences against electric strand heights measured every 100 m.

5.4. Results

Fence type abundance

The fence distribution data consisted of 442 points spanning approximately 2,200 km, each with information for both sides of road (884 points in total). Electric fences were found to be uncommon in the southeastern Karoo (relative proportions: electric mesh = 0.010, electric strand = 0.033) compared to non-electrified fences: mesh (0.604) and strand (0.258; Fig. 5.4a). The proportion of road verges lacking fencing (0.095) was more than double the proportion with electric fencing (0.043). Mesh fence proportions were higher than strand fences for both non-electric and electric fences. Rock aprons were uncommon, being present on only 7.2% of fences.

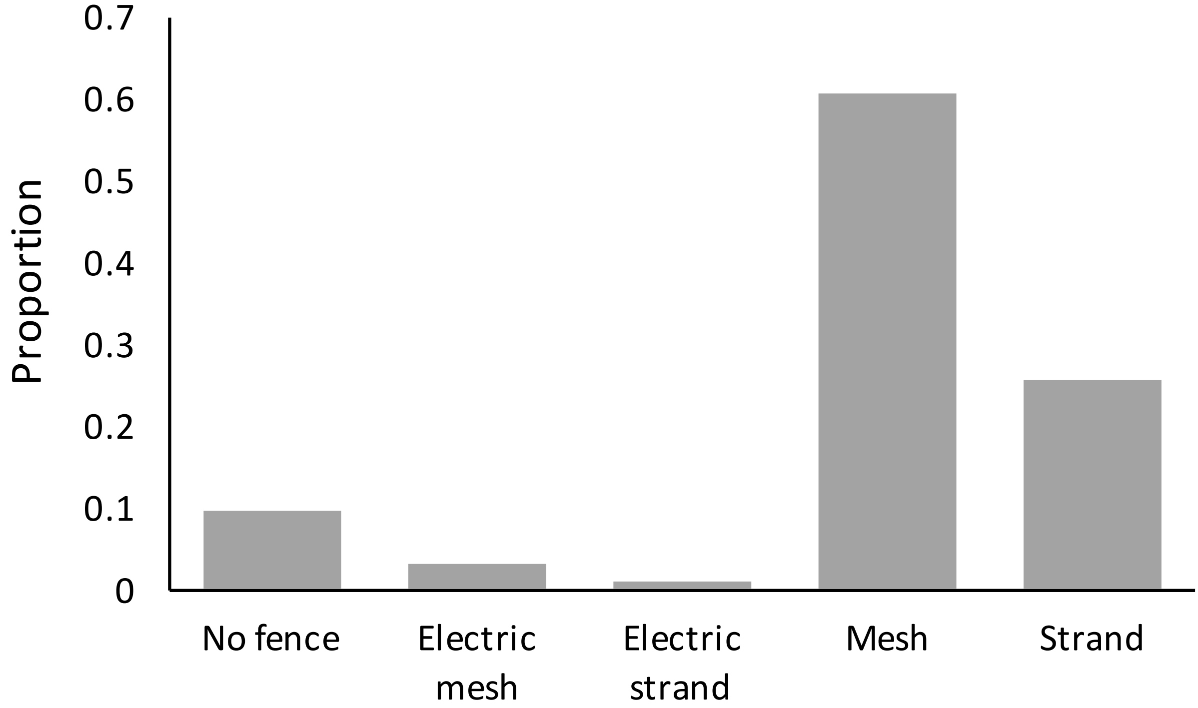

Figure 5.2a. Proportion of fence types from points recorded every 5km along major and minor public roads, spanning approximately 2200 km in the southeastern Karoo.

Tortoise presence along fences

Transect data used in analyses comprised of 189 transects covering 163.85 km (Appendix I, Fig. S3). A total of 403 tortoises were found on transects, only 40 of which were alive (Fig. 5.4b). Leopard tortoises were most commonly found (344 individuals, 35 alive), followed by angulate tortoises (54 individuals, 5 alive) and tent tortoises (5, all dead). Thus, many of the analyses could only be carried out for leopard tortoises.

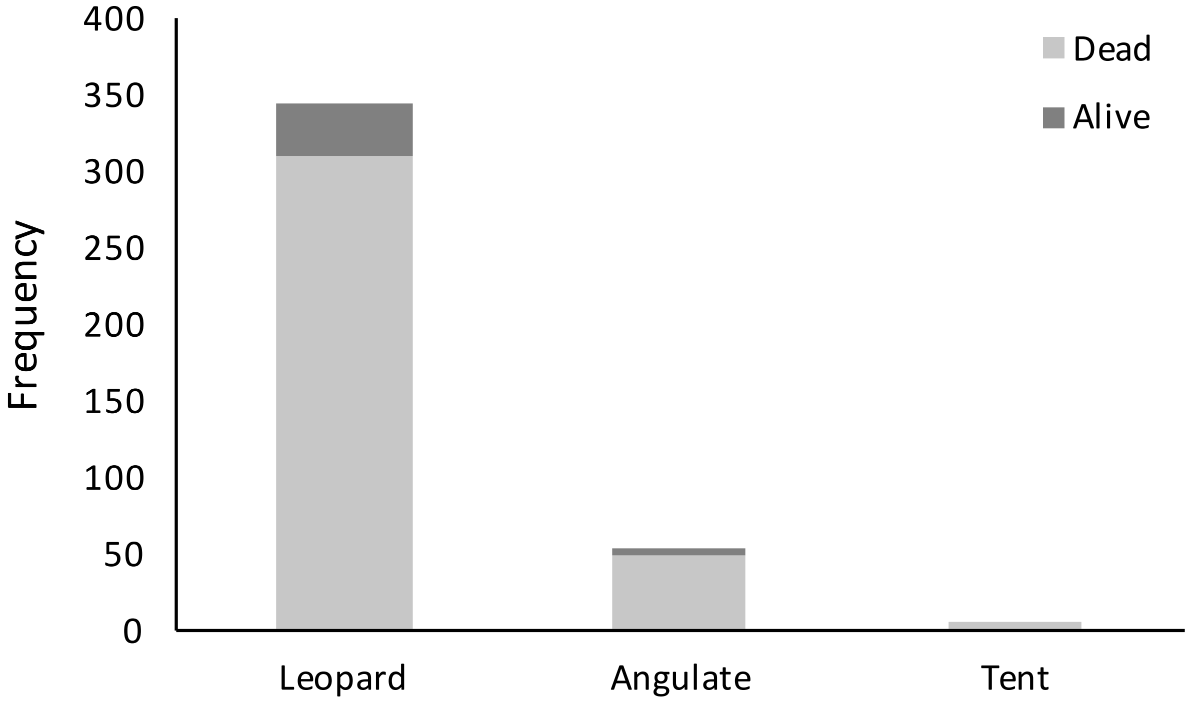

Figure 5.4b. Frequency of encounters of different tortoise species along walked transects in the southeastern Karoo.

The GLMs show that the probability of finding a dead leopard tortoise on an electric fence was significantly higher than finding a dead angulate tortoise, with no significant difference between non-electric fences (Fig. 5.4c(A)). Similar patterns are seen in the average number of dead leopard and angulate tortoises found per km (Fig. 5.4c(B)). The probability of finding a dead leopard tortoise on an electric fence was significantly greater than on a non-electric fence (Fig. 5.4c(A)). Electric mesh fences had a significantly higher probability of having a dead leopard tortoise than electric strand fences, but there was no difference between these fence types when they were not electrified. All fences had significantly higher probabilities of a dead leopard tortoise than open field transects. Similar patterns were found for the average number of leopard tortoises, with the only exception being a significant difference between the two non-electric fences ((Fig. 5.4c(B)). A notable observation is the two transects with the highest number of mortalities (54 dead tortoises in 1 km and 45 dead tortoises in 0.7 km), which were conducted on opposite ends of a single property (approximately 20 km apart), which had electric mesh fences.

No dead angulate tortoises were found along electric strand fences or in open field transects, and there was no significant difference between the probability of a dead angulate tortoise between electric mesh and non-electric mesh fences (Fig. 5.4c(A)). However, both mesh fence types showed a greater probability of finding a dead angulate tortoise than a strand fence. Similar patterns were found for the average density of angulate tortoises (Fig. 5.4c(B)). GLMs could not be run for tent tortoises due to a lack of data (n = 5); four dead tent tortoises were found along non-electric mesh fences and one was found dead in open field.

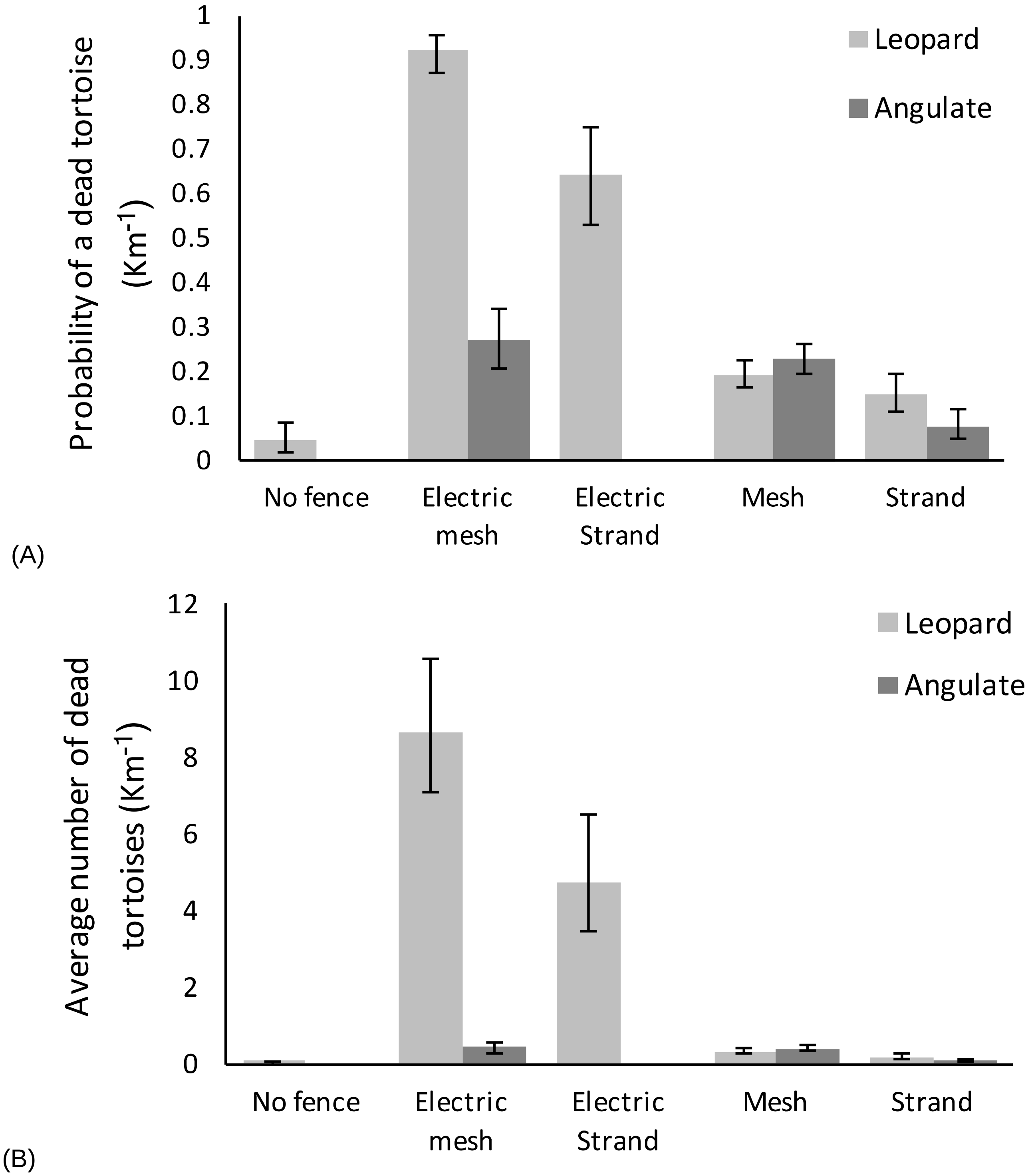

Figure 5.4c. (A) Probability of dead leopard and angulate tortoise occurrence per kilometre for each fence type. (B) Average number of dead leopard and angulate tortoises per kilometre of fence type. Error bars indicate 95% confidence intervals, thus where there is no overlap, results are significantly different.

Estimated number of tortoises killed

The estimated number of dead leopard tortoises across the 2,200 km of roads surveyed was approximately 1,300 individuals, with 56% of these mortalities along electric fences and 43% along non-electric fences (Table 5.4a). Less than 1% of leopard tortoise mortalities were predicted to be on unfenced areas. The estimated number of dead angulate tortoises was approximately 630 individuals, with 93% of mortalities along mesh fences and 7% along strand fences (Table 5.4b).

Table 5.4a. Estimate of the number of dead leopard tortoises for each fence type along 2,200 km of road sampled in the southeastern Karoo.

Fence type	Proportion fence type	Length of fence surveyed (km)	Dead leopard tortoises per km	Estimated number of dead leopard tortoises
No fence	0.095	209.0	0.04	9
Electric mesh	0.033	72.6	8.67	629
Electric Strand	0.010	22.0	4.74	104
Non-electric mesh	0.604	1328.8	0.33	445
Non-electric strand	0.258	567.6	0.20	112

Table 5.4b. Estimate of the number of dead angulate tortoises for each fence type along 2,200 km of road sampled in the southeastern Karoo.

Fence type	Proportion of fence type	Length of fence surveyed (km)	Dead angulate tortoises per km	Estimated number of dead angulate tortoises
No fence	0.095	209.0	0	0
Electric mesh	0.033	72.6	0.43	31
Electric Strand	0.010	22.0	0	0
Non-electric mesh	0.604	1328.8	0.42	557
Non-electric strand	0.258	567.6	0.08	44

Patterns of tortoises killed

Significantly more dead leopard tortoises were taller than the electric strand where they were found ($\chi^2 = 48.9$, df = 1, $p < 0.001$), with 93 being taller and 19 being shorter (Figure 5). The same test could not be run for angulate tortoises due to the small dataset (n = 5). However, all angulate tortoises were shorter than the electric strand where found and carapace heights ranged from 60 – 100 mm.

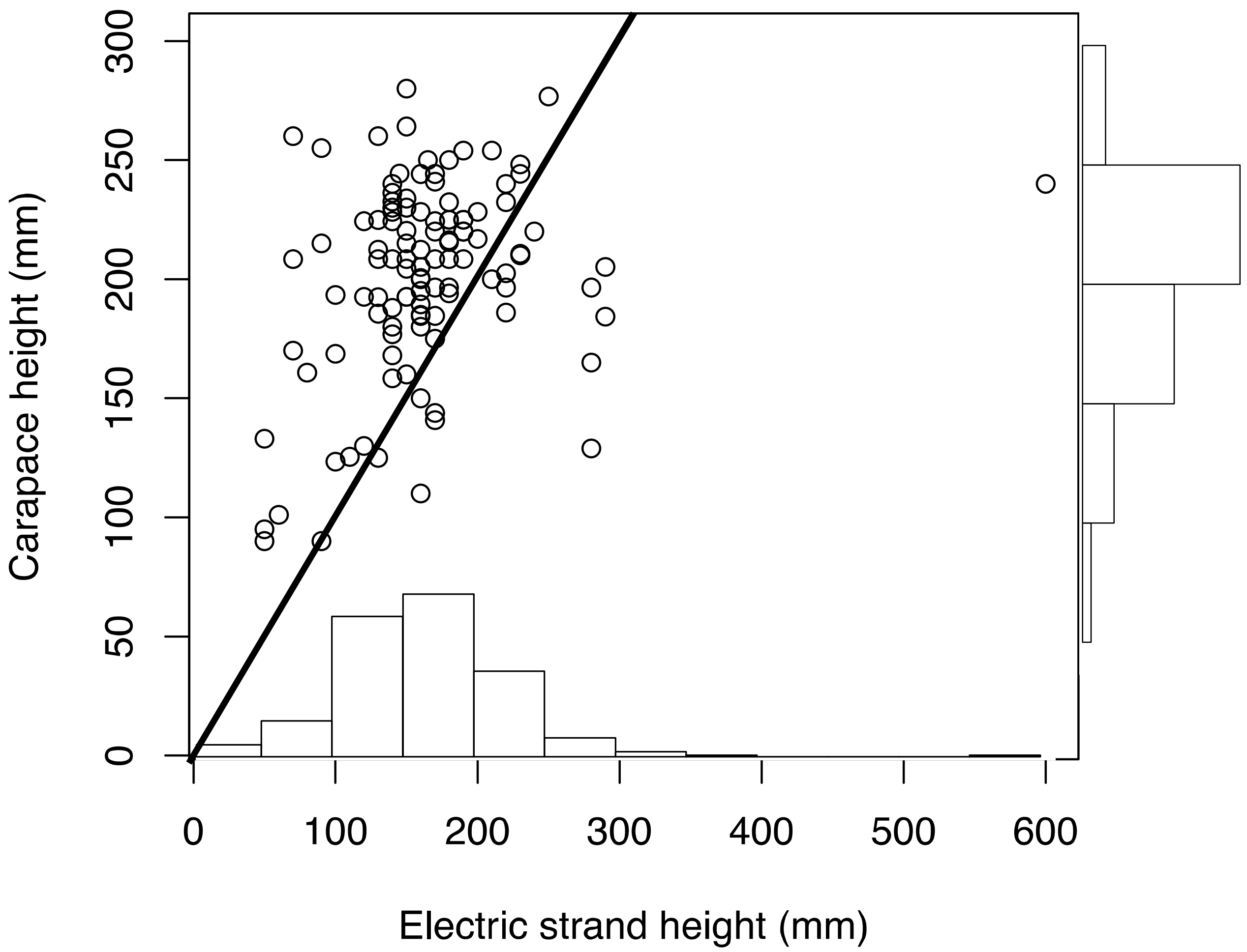

Figure 5.4d. Plot showing carapace heights of dead leopard tortoises found alongside an electric fence with respective electric strand heights (circles). Bars highlight distribution of points as data is heavily grouped. Line plotted is where carapace heights equals strand height (*x* = *y*).

The electric strand heights with dead leopard tortoises were significantly lower compared to the electric strand heights measured every 100 m along transects (W = 48272, p = 0.025; Figure). However, when outliers > 400 mm high were removed, the result was not significant (W = 45298, p = 0.084). The carapace heights of leopard tortoises found dead next to an electric fence were not significantly different from those of tortoises found elsewhere (dead and alive from transects and incidental data which were not on electric fences) (W = 4930.5, p = 0.100; **Error! Reference source not found.**). In all cases, small tortoises size classes were poorly represented. The carapace heights of leopard tortoises not found on electric fences were significantly higher than electric strand heights measured every 100 m along transects (W = 9125, p-value = <0.001). This is reflected in the interquartile ranges (carapace heights = 190 - 235 mm, electric strand heights = 140 - 220 mm) (Figs. 5.4e & f). The same tests described above could not be run for angulate tortoises due to lack of data (only 5 dead animals), but all were shorter than the electric strand where they were found. Of all the angulate tortoises found, carapace heights ranged between 60 – 100 mm, with SCL ranging from 80 – 200 mm.

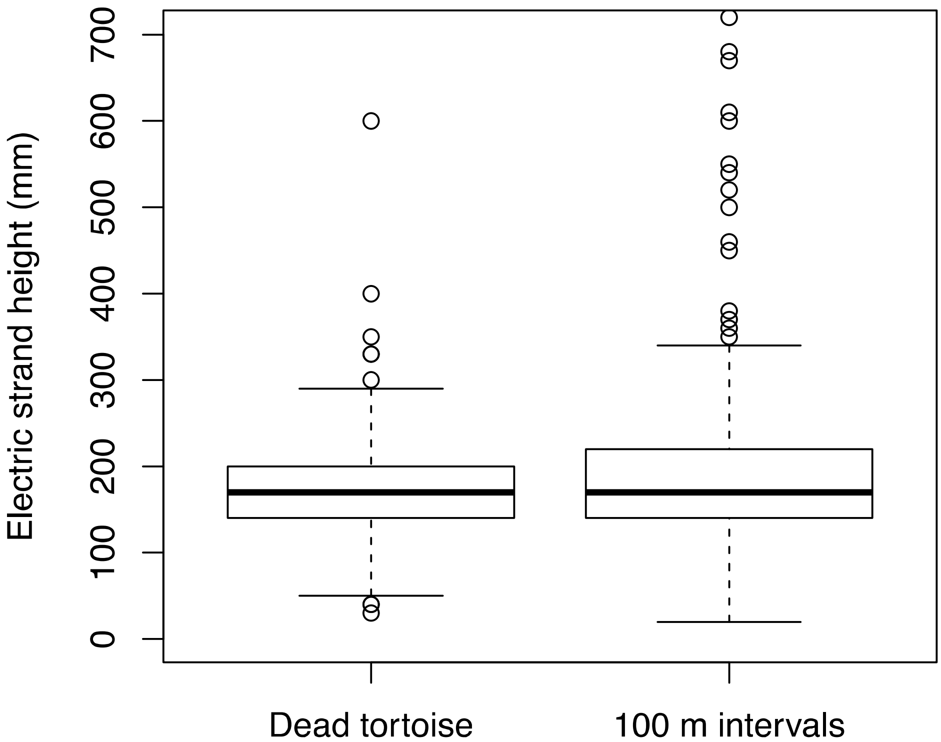

Figure 5.4e. Boxplot of electric strand heights measured where dead leopard tortoises were found at 100 m intervals along transects. Boundaries of box indicate 25% and 75% quartiles, thick line indicates median, bars represent maximum and minimum values and circles represent statistical outliers. No significant difference exists when outliers above 400 mm are removed (W = 45298, p-value = 0.08427).

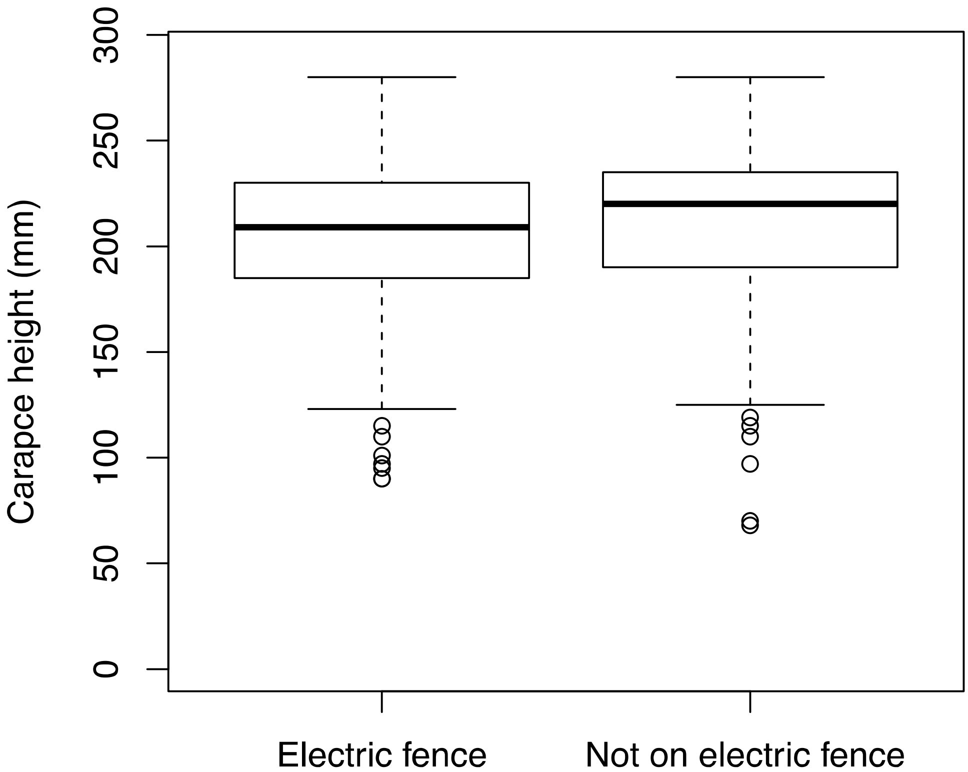

Figure 5.4f. Boxplot of leopard tortoise carapace heights of found dead on electric fence transects and all other leopard tortoises recorded not on electric fence (incidental and transects data). Boundaries of box indicate 25% and 75% quartiles, thick line indicates median, bars represent maximum and minimum values and circles represent statistical outliers. No significant difference exists (W = 4930.5, p-value = 0.1002).

5.5. Discussion

Tortoise mortalities along fences

Leopard tortoises

Our findings corroborate those of previous studies (Burger & Branch 1994, Beck 2010); that leopard tortoises are more heavily impacted by electric fencing than other species. This underlines the danger to leopard tortoises of increased electric fencing. Mortality along electric mesh fencing was higher than electric strand fences, possibly because the mesh is more of a barrier to the tortoise making it harder to escape. In addition, this study highlighted the threat posed to large tortoises and hence the importance of the height of the lowest electric strand. In order to remain part of the circuit once the tortoise retracts its legs, the tortoise's carapace height needs to be taller than the height of the electric strand, thus making larger tortoises more prone to electrocution. However, the size distribution of tortoises found along electric fences was not significantly different to all other leopard tortoises found. This is a result of the distribution of electric strand heights being significantly lower than the carapace heights, thus placing the majority of leopard tortoises in this study area at risk of electrocution.

Leopard tortoise mortality rates along non-electric fences appear to be higher than natural mortality rates estimated from open field transects. However, the cause of death of these large leopard tortoises along non-electric fences could not be determined (example in Fig. 5.5a). These previously unaccounted leopard tortoise mortalities along non-electric fencing should potentially be recognised as an additional threat to leopard tortoises, and may also explain the dead tortoises on electric fences where carapace height was shorter than the electric strand (Fig. 5.5a).

Despite forming only approximately 4% of all roadside fencing, electric fences account for 56% of leopard tortoise mortalities. This study validates the concern for increased electric fence use in the future and the potential impacts on leopard tortoises as voiced by Beck (2010) and Farber (2016). Although non-electric fences had significantly fewer leopard tortoise mortalities per km, the predominance of non-electric fencing (specifically mesh fencing) makes them a comparable threat (43% of mortalities) to electric fencing, considering current fence distribution.

The threat posed by fencing may extend to the ecosystem as the ecological role these tortoises play is reduced or lost. Milton (1991) found that leopard tortoises eat 75 species of grasses, succulents and forbs belonging to 26 plant families. Germination trials suggest that leopard tortoises disperse seeds of Aizoaceae, Chenopodiaceae, Crassulaceae, Cyperaceae, Fabaceae, Poaceae and Scrophulariaceae and could thus play an important role in shaping the unique flora found in the Karoo (Milton 1991). In addition, many of the succulents that leopard tortoises eat are avoided by sheep, goats and indigenous antelope as they are unable to metabolise the toxins in these plants (Milton 1991, Milton et al. 1999).

Figure 5.5a. A large dead leopard tortoise against a mesh fence with no obvious cause of death.

Angulate tortoises

Although it is possible for angulate tortoises to be electrocuted, they are generally small enough to pass under the lowest electric strand or to drop below the level of the strand when they retract into their shells after being electrocuted. The largest angulate tortoise heights (100 mm) are well below the interquartile range of the electric strand heights measured (140 – 210 m) making electrocution a rare occurrence. Angulate tortoises are also less likely to be affected by strand fences as their smaller size allows them to pass through more easily than the larger leopard tortoises.

Angulate tortoises appear to be more affected by the mesh structure of fences, rather than the electrified strand. When an angulate tortoise tries to pass through the mesh, it becomes trapped if the mesh size is slightly smaller than the tortoise’s body height (Fig. 5.5b). Once wedged in the mesh, they lack the strength to escape. The same issue is likely to affect other small tortoise species and young leopard tortoises. For example, all but one dead tent tortoise were found along mesh fences.

Approximately 64% of all roadside fences have mesh structures and account for 93% of angulate tortoise mortalities, thus the associated mortalities of angulate tortoises and possibly other small tortoises should be considered. Data were deficient for angulate tortoises along some fence types, as none were found, so the need for future studies to build on this dataset is vital in order to fully understand the impact of fencing. This is even more relevant when considering the rarer tortoise species.

Although the estimated number of dead angulate tortoises likely to be found (630) along the 2,200 km of roads sampled is considerably lower than leopard tortoises (1,300), it does not mean that they can be disregarded. On the Tembani and Mimosa farms in the Eastern Cape, angulate tortoises have lower population densities than leopard tortoises (Mason et al. 2000). Furthermore, this may be an underestimate as smaller tortoises are not as easily found compared to large leopard tortoises, so the relative threat of mesh fencing on angulate tortoise may be underrepresented.

Other tortoise species

Only five tent tortoises and no padloper tortoises were found. Although these tortoises are known to be rare and occur in low abundances (Alexander & Marais 2007), it was expected that a few would be encountered. However, concern has been raised about increased avian predation on these smaller tortoises and the resulting impacts on their populations (Fincham & Lamberts 2014, Loehr 2017). The roles these tortoises play in the ecosystem is not yet fully understood, but may be similar to leopard tortoises.

Causes of mortality of other tortoise species

This study investigated the probability of finding tortoises along fences and found that fences do indeed pose a threat. It is likely that some mortalities were not caused by fences (e.g. natural deaths, vehicle accidents, predation). Considering that most tortoise carcasses were found on or within 0.5 m of the fence and given potential disturbance by scavengers or people, it is likely that the fence had an impact whether it be direct (previously discussed) or indirect.

Figure 5.5b. Angulate tortoise trapped in a mesh fence without (A) and with a rock apron (B).

Farber (2016) reported concern for tortoises unable to cross fences to access resources. Fences separate different land practices, which may differ in vegetation (Figure 5 5.5c) creating an incentive for tortoises to attempt to cross fences. Other incentives include access to water (Milton 1992, Milton et al. 1999, Farber 2016), which is important to consider given recent droughts in the area. Some tortoises may also have been trying to gain access to mates as it was breeding season. Tortoises will walk along fences (
Figure 5. 5.5d) where they are likely to be killed by the fence or by another cause (Burger & Branch 1994, Ruby et al. 1994, Milton et al. 1999, Beck 2010), until they find a way through. This raises questions of a fence's permeability. Leopard tortoises were observed to have squeezed between strands of some fences or to make use of holes in fencing caused from problem animals (
Figure 5.).

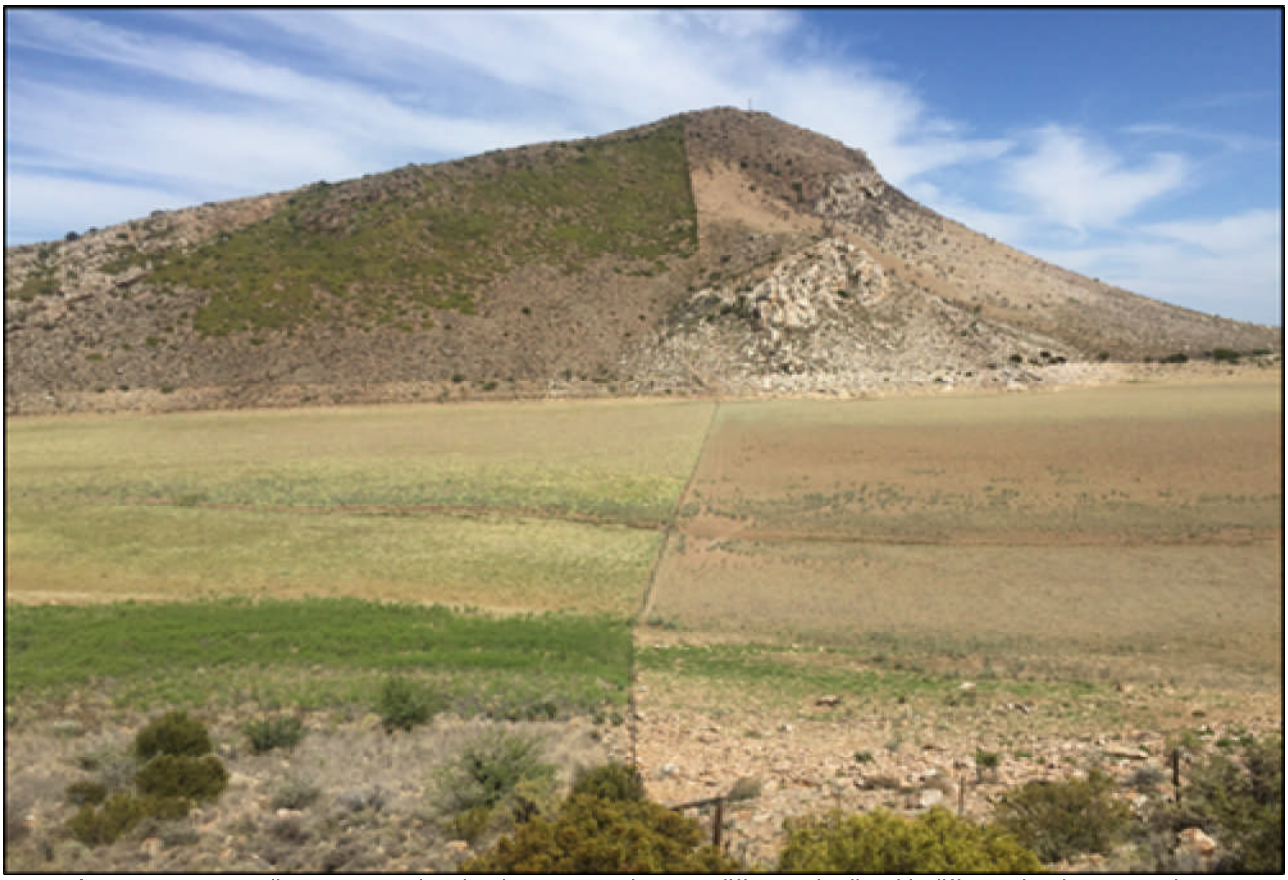

Figure 5.5c. Fenceline contrast showing how vegetation can differ markedly with different land-use practices.

All fences walked in this study were along roads, so mortality rates as a consequence of road accidents, which are common in the Karoo (Milton et al. 1999), also need to be considered. However, road type was not statistically significant in describing presence of tortoises. Road verges were often large, with distances between the fence and road often exceeding 2 m. Most carcasses found were closer to the fence than the road and carcasses were found on both sides of fences, although this may be partly due to greater observer vigilance along the fence line. In addition, road collisions often occur at high speed resulting in the tortoise carapace being broken apart. The clustering of carcass fragments and intact carcasses recorded indicate that road collisions were an unlikely cause of death for the majority of carcasses found. However, these variables should be accounted for in future studies.

Figure 5.5d. Three leopard tortoises walking along a fence where vegetation has been cleared.

Figure 5.5e. A hole in a fence caused by problem animals that tortoises can use to cross the fence.

Suggested mitigation strategies

Electric strand height

By raising the minimum height of the electrified strands to at least 200 - 250 mm, unintentional animal mortalities including those of tortoises may be reduced (Burger & Branch 1994, Beck 2010). Although this will not prevent all mortalities, significantly fewer leopard tortoises were found killed by higher strands (Beck 2010). All other South African chelonian shell heights are lower than 200 mm (Burger & Branch 1994, Alexander & Marais 2007), thus would be safe from electrocution. However, raising electrical strand height is impractical from the perspective of problem animal control as the low-lying electric strand is what prevents animals from digging under the fence. Burger & Branch (1994) describe the effectiveness of their strand height suggestion at deterring porcupines and bushpig, but do not mention jackal, which are renowned for digging under barriers (Kesch et al. 2014). Thus, this suggestion is poorly implemented (the median strand height is 170 mm) and has created tension between farmers and conservationists (Pietersen et al. 2014, Woodroffe et al. 2014).

Rock aprons

Rock aprons are used to prevent animals digging under fences as rocks will fall into the place of dispersed soil (Beck 2010). It is also thought that they may prevent tortoises from coming into contact with electrified strands as tortoises are unable to climb over rocks (Beck 2010). Although Beck (2010) did not directly investigate the effectiveness of rock aprons in preventing tortoise and other animal mortalities, he did note that only a single chelonian mortality was recorded at Pilanesberg National Park. He attributed this low mortality rate to the rock-packed apron and concluded that rock-packed aprons may be a viable and more eco-friendly mitigation strategy than electric strands. However, rock aprons were poorly implemented in the southeastern Karoo as they were only present on 7% of fences.

In this study rock aprons did not have a significant affect in describing the presence or absence of dead tortoises, and individual observations made contradict Beck's (2010) conclusions. In cases where tortoises climb rock aprons, the effective electric strand height is lowered, effectively placing tortoises that were initially shorter than the electric strand at risk of electrocution (Fig. 5.4f). If a tortoise does manage to pass the rock apron, there is a risk of the tortoise becoming trapped between the fence and the rock apron (Fig. 5.5f). A rock apron may also hinder an angulate tortoise's ability to escape a mesh fence (Fig. 5.5f). Additionally, rock aprons are openly acessible for crows to drop juvenile tortoises on as they attempt to break their carapace (Branch 1998). We thus contradict Beck's (2010) conclusions and find no evidence that rock aprons are an effective mitigation strategy.

Figure 5.5f. Rock aprons may cause additional tortoise mortalities by (A) effectively lowering the electric strand height as tortoises climb the rocks, (B) by trapping smaller tortoises between rock and the fence (arrow indicates tortoise position).

Fence design

Results indicate that strand fences have fewer tortoise mortalities than mesh fences. However, strand fences are more permeable than mesh fences, not only for tortoises, but also for predators and problem animals, which explains why mesh fences are more widely employed, despite their greater input costs. A study by Ruby et al. (1994) investigating desert tortoise responses to barriers found that the most effective fence type was a screen mesh with openings small enough to exclude a tortoise's head. The same mitigation strategy could be applied to South African fences, which would prevent angulate and similar tortoises becoming trapped in mesh fences. However, the extra metal in the fence may prove costly. Conversely, a fence with larger openings such as 150 mm tall would allow angulate tortoises (maximum height found 100 mm, but angulates found in this study were smaller than expected) and other small tortoises to pass through freely whilst still being small enough to prevent problem animals from squeezing through.

Conclusions

Fencing of all types have associated tortoise mortalities, with leopard and angulate tortoises being affected differently. Until now, the impact of non-electric fencing has been largely overlooked, despite the estimate of numbers of tortoises killed being comparable to electric fencing (given the relatively small proportion of electrified fences). Previously suggested mitigation strategies are unlikely to be practical for landowners and have thus been poorly implemented. Mitigation strategies should be developed in conjunction with landowners if they are to be successful and the effectiveness of suggested mitigation strategies needs to be investigated. Considering the numerous negative effects of fencing, not only on tortoises, installing fencing should be an action of last resort when all other options have been exhausted (Woodroffe et al. 2014). With global fence use increasing around the world (Sudip 2016) and tortoises being so widespread (Alexander & Marais 2007, van Dijk et al. 2014), the suggestions from this study extend beyond the Karoo.

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6. Blue Hill bat survey

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6.1. Introduction

Bats are an essential component of any ecological community providing vital ecosystem services including insect control, seed dispersal and pollination. Bats are often overlooked during simple biodiversity surveys due to their nocturnal habits and the specialised equipment needed to record or identify them.

During the Biosphere Expeditions South Africa expedition in 2015 a pilot bat survey using ultrasonic acoustic detectors was undertaken to assess what species were present in a small area of the Blue Hill Nature Reserve area (BHNR). This short study (Lee et al. 2016) confirmed the presence of at least five species, including:

Egyptian free-tailed bat *(Tadarida aegyptiaca)*
African pipistrelle (*Pipistrellus hesperidus*)
Cape serotine (*Neoromicia capensis)*
Cape horseshoe bat (*Rhinolophus capensis*)
Hottentot serotine *(Eptesicus hottentotus)*

Following the 2015 pilot bat survey, a more expansive survey was undertaken in October 2016 to assess species composition at BHNR.

6.2. Methods

The principal aim of the bat surveys completed in October 2016 was to provide baseline information with respect to bat species and activity within the site. The surveys had the following specific objectives: (1) to confirm the likely presence or absence of any bat roosts and assess their likely usage and (2) to identify which bat species are present within or adjacent to the site and their levels of activity.

The data presented here focus on species presence and actual roost locations, as activity data at each of the static survey locations are still to be analysed.

Static Surveys

All static surveys reported here were run as 'overnight' surveys: The Anabat units were deployed each afternoon and programmed to commence recording 30 minutes before sunset until one hour after sunrise. Surveys were completed using two Anabat Express detectors to record bat echolocations as 'bat passes' (where a bat pass is defined as a sequence of greater than two echolocation calls made as a single bat flies past the microphone[1]).

[1] http://www.bats.org.uk/nbmp_tutorials/tutorial26.html

The surveys were carried out in accordance with the standard methodology (BCT 2016), and bat calls were analysed according to standard parameters (Parsons and Jones 2000, Monadjem et al. 2010, Russ 2012). All calls were analysed by the author[23]. Details of survey locations are given in Table 6.2a and Figure 6.2a. Surveys were undertaken at 'static' locations, 500 m, 1000 m and 1500 m from the expedition base, along the north, east and south roads. The detectors were attached at fixed points, 1-3 m above ground level and a total of 18 survey nights were completed across the nine locations (Table 6.2a).

Table 6.2a. Survey types and locations. See Fig. 6.2a below for locations.

Site no.	Description	Survey type	Number of surveys
1	North Road 500 m	Overnight	2
2	North Road 1000 m	Overnight	2
3	North Road 1500 m	Overnight	2
4	East Road 500 m	Overnight	2
5	East Road 1000 m	Overnight	2
6	East Road 1500 m	Overnight	2
7	South Road 500 m	Overnight	2
8	South Road 1000 m	Overnight	2
9	South Road 1500 m	Overnight	2

Transect surveys

Time- and distance-limited walking transects were also tested. Volunteers completed a walked transect from the expedition base to 1000 m along each of the roads and returning to the start point within one hour. Transects were completed between 20:00 and 21:00. The detectors used were again the Anabat Express units (in 'Transect' mode) and an Echo Meter Touch connected to an iOS device (e.g. iPad). Use of the Echo Meter Touch allowed South African Classifiers (Beta version) to be used, which permitted automatic identification of the species to be tested.

Cave surveys

A daytime inspection of a series of neighbouring caves along the south road (Figure 6.2a, target note CS) was undertaken. An internal inspection of the cave areas (where safe to enter) was conducted following best practice survey techniques as outlined by the Bat Conservation Trust (BCT)[4]. Cave walls, ceilings and exposed surfaces were checked for signs of use by bats including (1) bat droppings (size of droppings grouped into small, medium or large to signify type of bat that may be present), (2) feeding remains (certain bat species often eat the bodies and leave the wings of invertebrate prey including moths, butterflies and larger flies such as lace wings), (3) bat corpses and (4) sightings.

[2] A sample call library was kindly provided by Dr. Sandie Sowler.
[3] A sample call library was kindly provided by Joel Avni.
[4] Collins J (ed.) (2016) Bat Surveys for Professional Ecologists: Good Practice Guidelines (3rd edn) (published by Bat Conservation Trust, London)

Figure 6.2a. Location of the static bat surveys (1-9) around BHNR.
Walked transects were completed to locations 2, 5 and 8 from the base.

Data analysis

The data collected from Anabat bat detectors were analysed and interpreted using AnalookW software. Calls were also compared to a known library of calls[5], to facilitate accurate identification. Data collected on the Echo Meter Touch unit were automatically identified, based on available classifiers.

Constraints and limitations

It should be noted that lack of evidence of a particular bat does not necessarily preclude it from being present at a later date. In relation to use of habitats or roost sites by bat species, use of a particular area of land can vary not only on a seasonal basis, but also from day to day. Whilst activity surveys are used to provide an estimate of the likely importance of a given area of land for bats, due to the highly mobile nature of bats it is not possible to accurately determine the exact numbers of bats when using standard non-intrusive survey methods.

[5] Two sample libraries (above) were used to aid identifications.

Other constraints to be aware of are:

(1) The echolocation used by some bats is very quiet and difficult to detect. Some species may have been present without registering on the bat detectors used during the activity survey due to the nature of their echolocation.

(2) The recording system employed by Anabats can only respond to the signal with the highest intensity at any time. As the signal from some bat species (such as pipistrelles) will nearly always be more intense than that of other bat species (such as *Myotis* bats), it is possible that some bat signals were not recorded. As a result, some bat activity may have been under-recorded.

(3) The height at which Anabats were positioned may have limited the recording of some bat activity across all stations.

(4) The identification of bats in the genus *Myotis* to species level based on recorded echolocations is not always possible with a high degree of confidence[6]. This is due to the similarity and overlap in characteristics between myotid bats and the calls they make, together with the ability of these bats to emit different calls in different habitats and situations. Techniques are being developed to assist with the identification of these bats from recordings, such as the use of 'slope' in the AnalookW program designed for use with Anabat CF detectors. The Slope Display shows the instantaneous slope of each displayed call on a scale of -1000 to 1000 Octaves Per Second (OPS). Comparison of slope between myotids and a library of known calls was used to assist with identification.

(5) The South Africa classifiers used by the Echo Meter Touch are still in development, and consequently not all species were represented at the time of the surveys. The Auto-ID feature does not include every possible bat for each of the covered regions. Therefore, if a bat that is not included is recorded, it will be identified by the app as a species with a similar echolocation call type.

6.3. Results

At least eight species of bat were identified during the static surveys (Table 6.3a, Figs. 6.3a-h). Two species, the Egyptian free-tailed bat and the African pipistrelle were again recorded at all of the sites, whereas the Hottentot serotine and Egyptian slit-faced bat were recorded at just two locations. Geoffroy's horsehoe bat, Hottentot serotine and the Egyptian slit-faced bat were recorded on the north road, and never on the east road.

The Egyptian slit-faced bat, Geoffroy's horseshoe and the Zulu pipistrelle are new records for BHNR, not previously recorded in the 2015 study.

[6] BCT guidelines recognise that *Myotis* bats can only be identified with a low degree of confidence to species level, as set out in section 6.4.3 of the guidelines.

Table 6.3a. Species records by site for the static surveys.

Species	North Road			East Road			South Road			Species total
	1	2	3	4	5	6	7	8	9	
Egyptian free-tailed bat *(Tadarida aegyptiaca)*	Y	Y	Y	Y	Y	Y	Y	Y	Y	9
African pipistrelle (*Pipistrellus hesperidus*)	Y	Y	Y	Y	Y	Y	Y	Y	Y	9
Zulu pipistrelle *(Neoromicia zuluensis)*	Y	Y	Y	Y	Y	N	Y	Y	N	7
Cape serotine (*Neoromicia capensis)*	N	Y	Y	Y	Y	Y	Y	Y	Y	8
Cape horseshoe bat (*Rhinolophus capensis*)	Y	Y	N	Y	N	N	Y	Y	Y	6
Geoffroy's horseshoe bat (*Rhinolophus clivosus)*	Y	Y	Y	N	N	N	N	Y	N	4
Hottentot serotine *(Eptesicus hottentotus)*	Y	Y	N	N	N	N	N	Y	N	3
Egyptian slit-faced bat *(Nycteris thebaica)*	N	N	Y	N	N	N	N	Y	Y	3
Site total	7	7	6	4	4	4	4	8	5	

Transect surveys

The transects confirmed the presence of several of the species recorded in the static surveys, and, using the Echo Meter Touch, also indicated the potential presence of the following species:

Roberts's flat-headed bat (*Sauromys petrophilus)*
Little free-tailed bat (*Chaerephon pumilus*)
Natal long-fingered bat (*Miniopterus natalensis)*
Hildebrandt's horseshoe bat (*Rhinolophus hildebrandtii)*
African yellow bat (*Scotophilus dinganii)*
Dent's horseshoe bat (*Rhinolophus denti*)

Due to incomplete lists of species currently available on the South African Classifiers, confirmation of the actual presence of these species would require further analysis of the calls recorded.

Cave surveys

The cave roost of Cape horseshoe bats (identified in 2015) was again inspected and was confirmed as an active roost. Adjacent to (and south of) this, are a series of small cave entrances that were also inspected. Evidence of bats (via droppings) was confirmed in two of these caves, with a corpse (of a Cape horseshoe bat) located in one entrance. Based on a comparison of droppings between each of the caves, the caves are all believed to support roosts of this species. They may support multi-species roosts, but this would need to be confirmed via additional surveys.

Example sonograms from static surveys

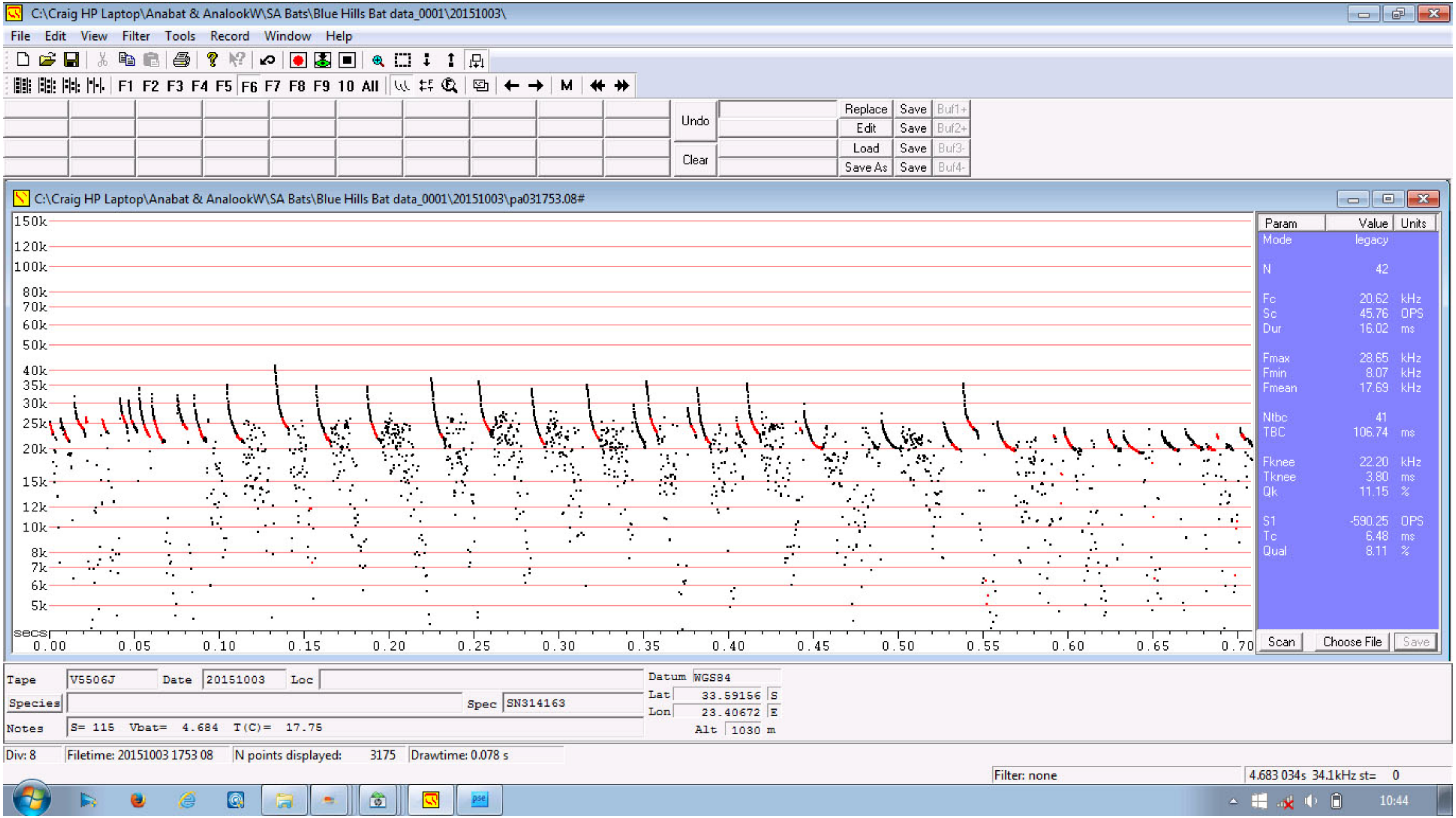

Figure 6.3a. Egyptian free-tailed bat *(Tadarida aegyptiaca).*

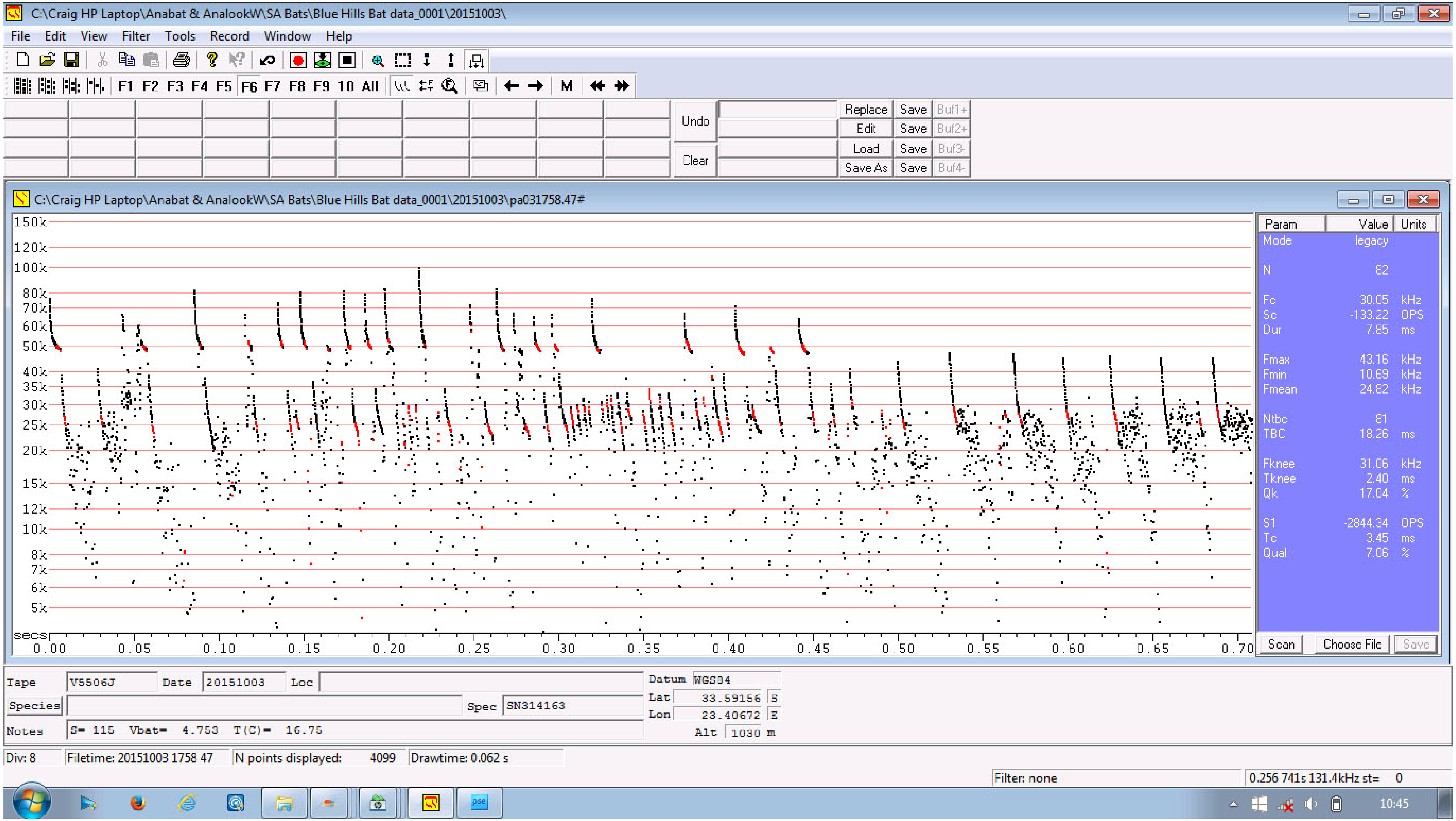

Figure 6.3b. African pipistrelle (*Pipistrellus hesperidus*), with Egyptian free-tailed below.

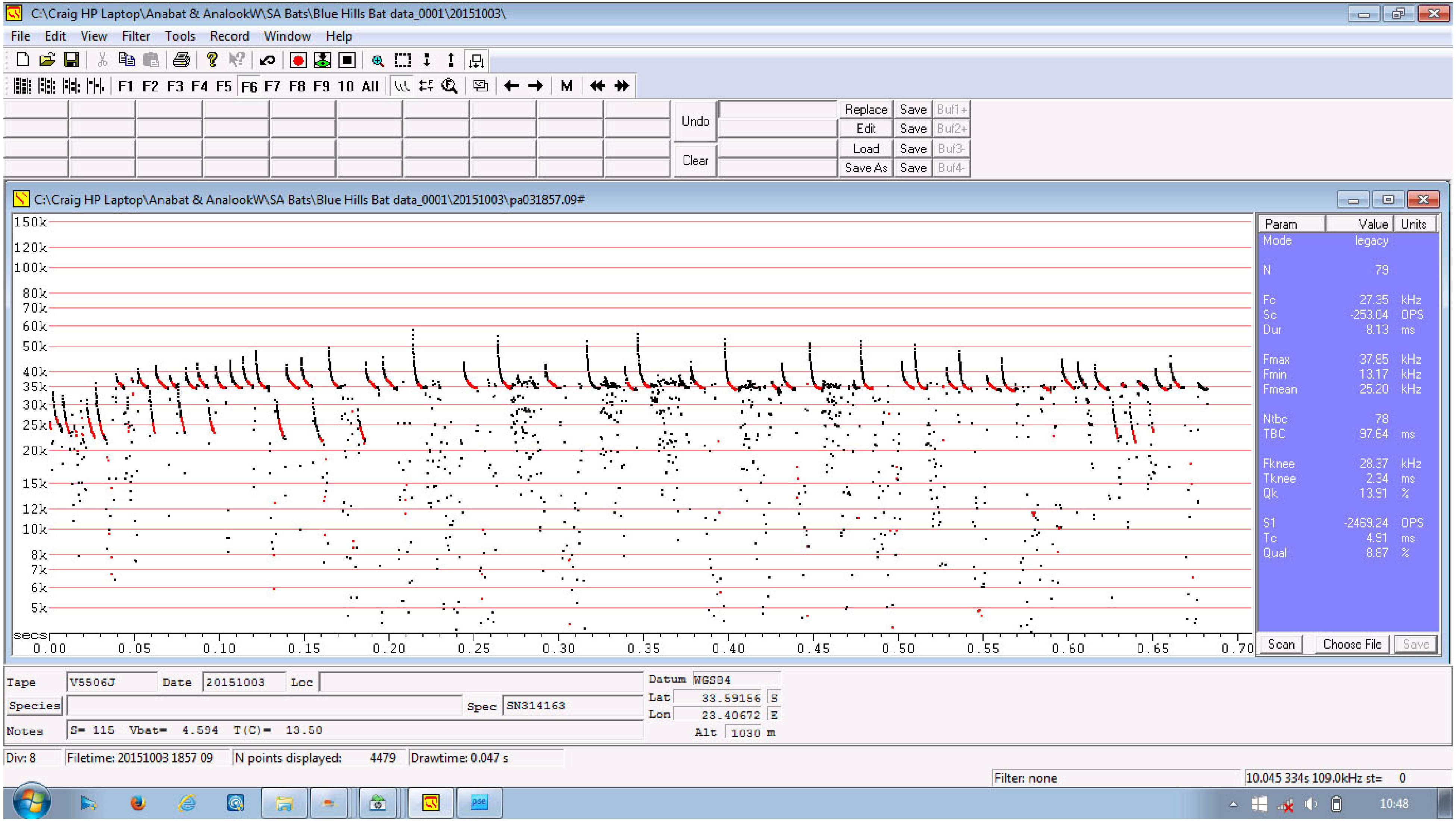

Figure 6.3c. Cape serotine (*Neoromicia capensis).*

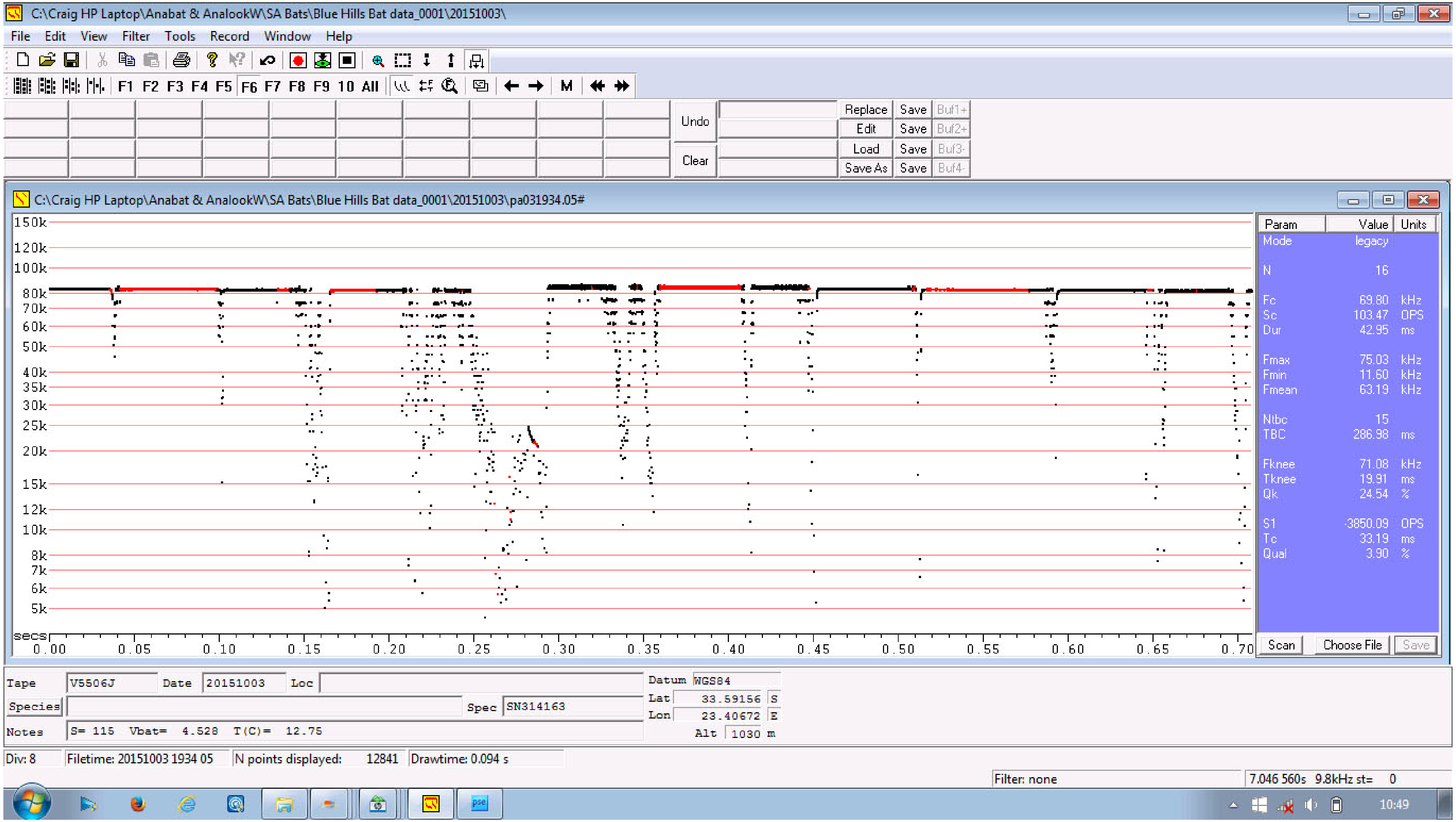

Figure 6.3d. Cape horsehoe bat (*Rhinolophus capensis*).

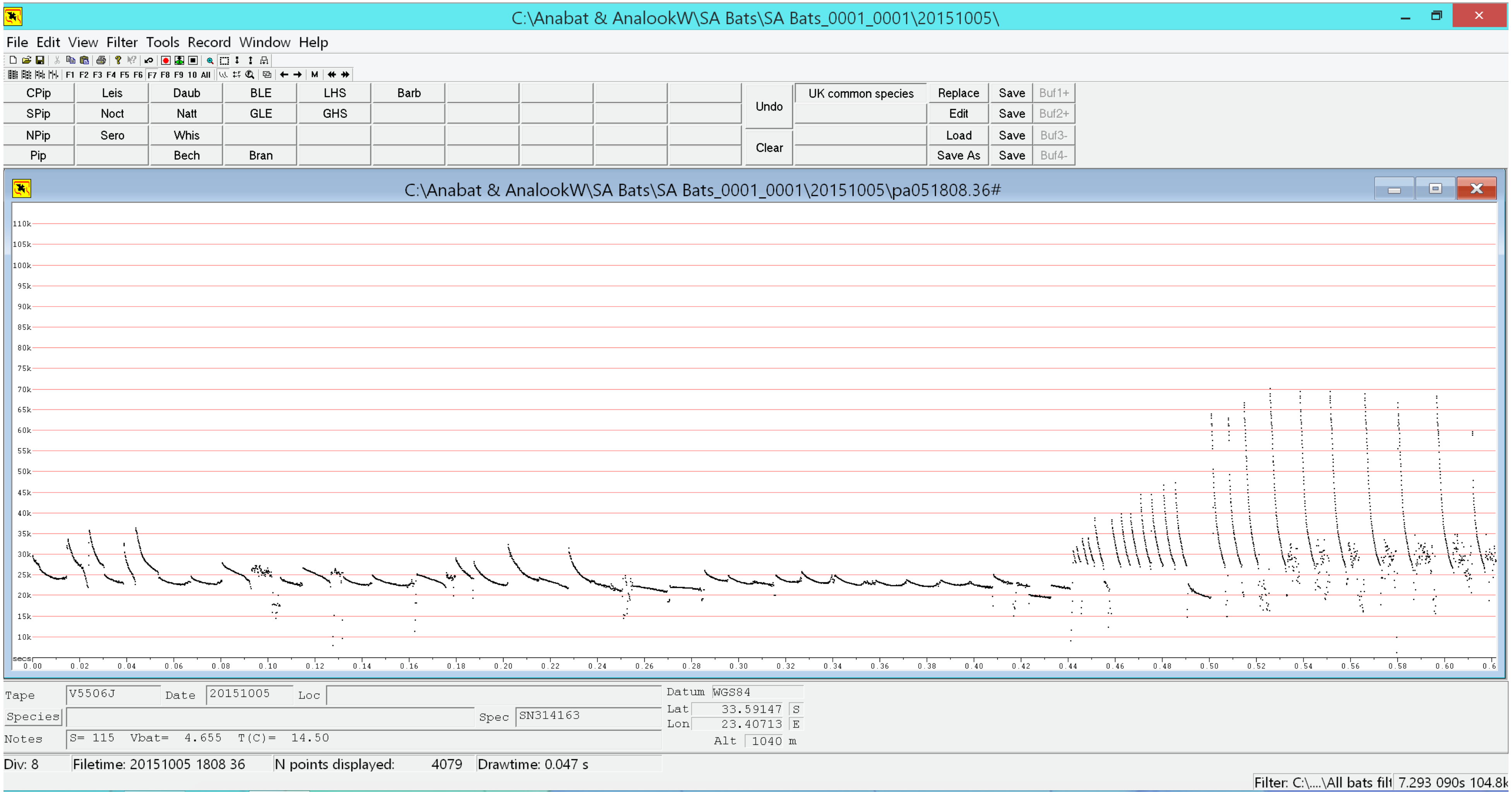

Figure 6.3e. Hottentot serotine *(Eptesicus hottentotus)*, with Egyptian free-tailed bat.

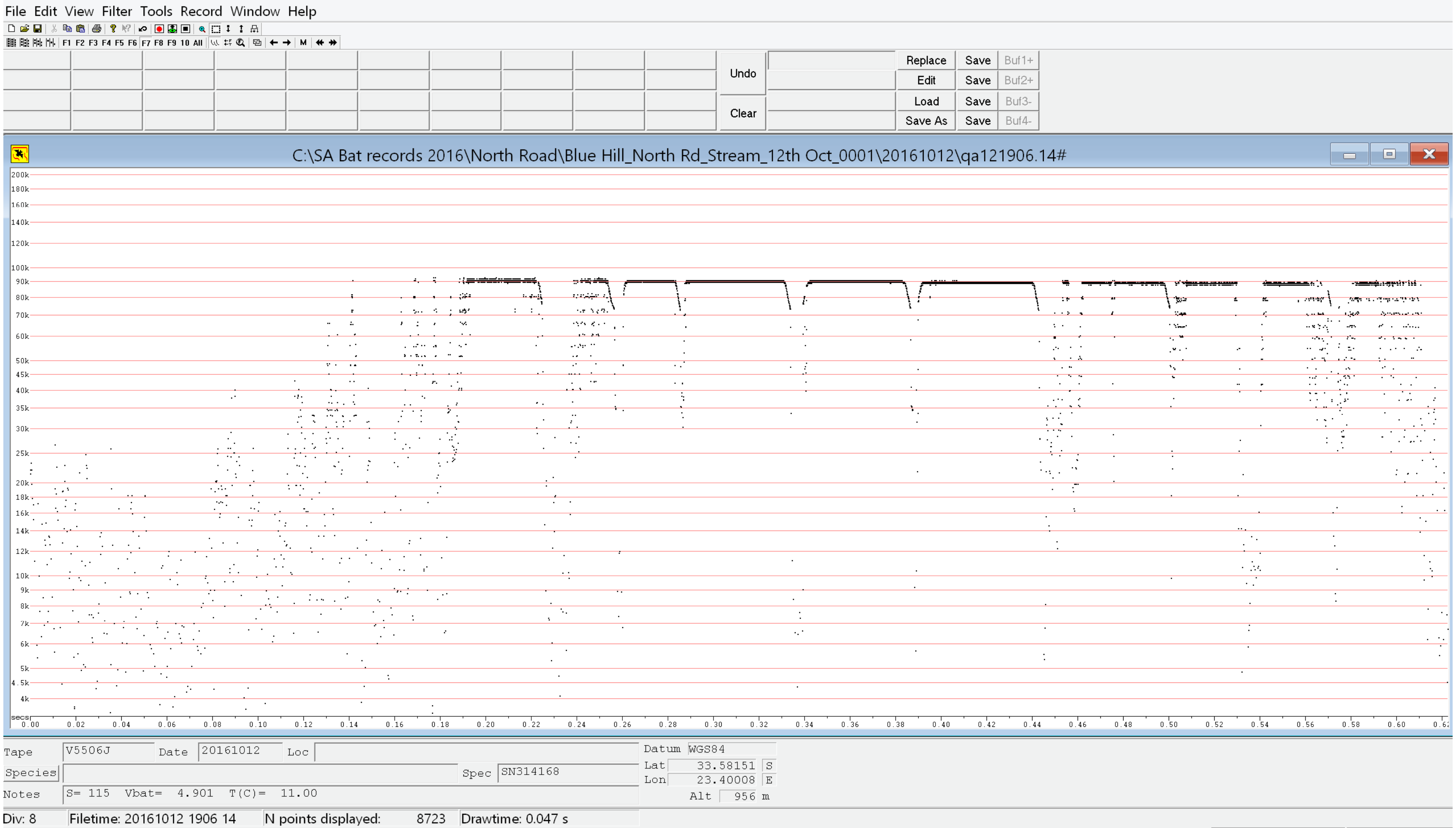

Figure 6.3f. Geoffroy's horseshoe bat (*Rhinolophus clivosus):*

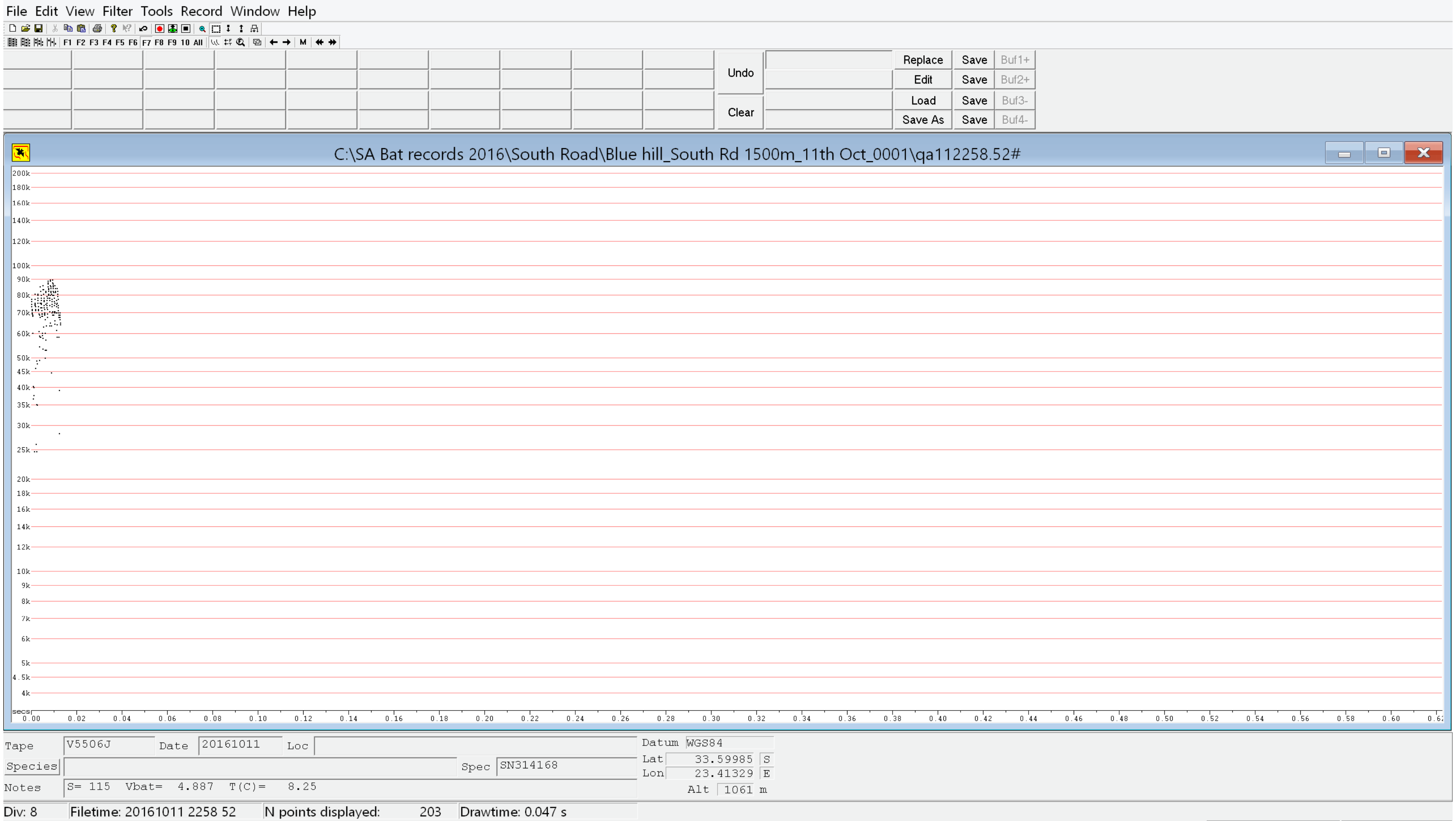

Figure 6.3g. Egyptian slit-faced bat *(Nycteris thebaica).*

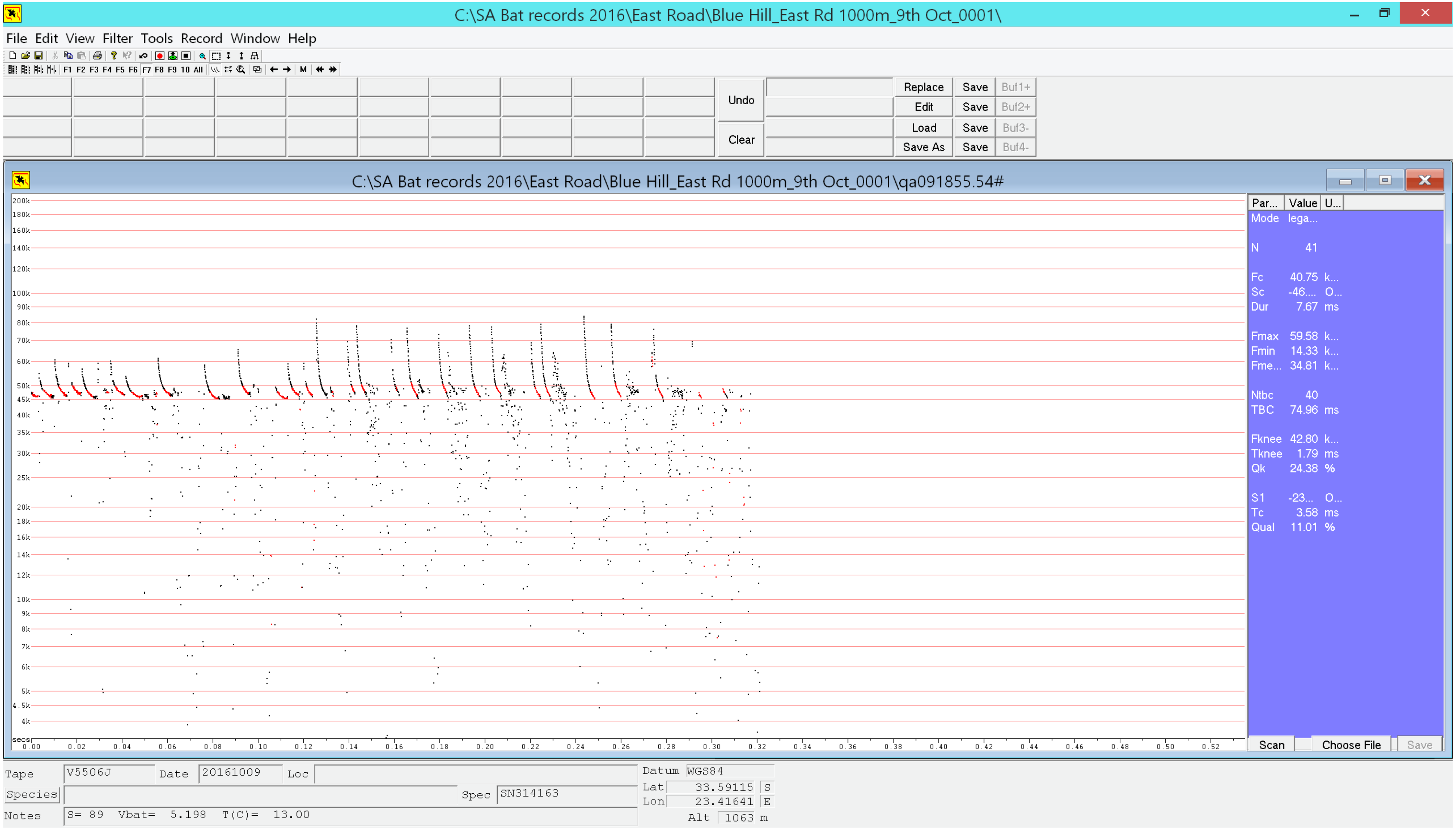

Figure 6.3h. Zulu pipistrelle *(Neoromicia zuluensis).*

6.4. Discussion

The current literature indicates at least 56 known species of bat from Southern Africa, and at least 14 species have known distributions that would coincide with the survey area[7].

The previous short pilot study (Lee et al. 2016) confirmed the presence of at least five species within a small area of the BHNR. The more extensive static survey of this study has confirmed the presence of three additional species, recording eight in total.

A greater diversity of bat species was recorded on the north and south roads compared to the east road. This probably reflects the overall differences in habitat diversity. Further analysis of the activity levels would help better resolve relationships between particular species and habitat types.

A brief summary for each species recorded in the static surveys is given below.

Egyptian free-tailed bat *(Tadarida aegyptiaca):* A broadly distributed species, the range of the Egyptian free-tailed bat extends throughout Africa and the Arabian Peninsula, to India, Sri Lanka and Bangladesh. Classified as Least Concern (LC) on the IUCN Red List.

African pipistrelle (*Pipistrellus hesperidus*): This species has been recorded over much of sub-Saharan Africa. It ranges from the Cape Verde Islands, to Liberia and Côte d'Ivoire, to Nigeria, Cameroon and Equatorial Guinea (Bioko), western Democratic Republic of the Congo, southern Sudan, Ethiopia, Eritrea and Somalia, into Kenya and Uganda, Rwanda, Burundi, Tanzania, Malawi, Mozambique, Zambia, Zimbabwe, and Angola, being found as far south as eastern and southern South Africa and possibly Swaziland. Listed as Least Concern on the IUCN Red List in view of its wide distribution, presumed large population, and because it is unlikely to be declining fast enough to qualify for listing in a more threatened category.

Cape serotine (*Neoromicia capensis):* This species is widespread over much of sub-Saharan Africa. It has been recorded from Guinea Bissau in the west, to Somalia, southern Sudan and Eritrea in the east, ranging south to most of South Africa. Listed as Least Concern on the IUCN Red List in view of its wide distribution, presumed large population, and because it is unlikely to be declining fast enough to qualify for listing in a more threatened category.

Cape horseshoe bat (*Rhinolophus capensis*): This species is endemic to South Africa. It is restricted to the coastal belt of the Northern Cape, the Western Cape and the Eastern Cape of South Africa, as far east along the coast as the vicinity of East London. Listed as Least Concern on the IUCN Red List.

Geoffroy's horseshoe bat (*Rhinolophus clivosus):* This species is widespread in North, East and southern Africa, and also in parts of southwest Asia, including western and southeastern areas of the Arabian Peninsula. In North Africa it has been recorded in Algeria, Libya and Egypt; in East Africa, it ranges from Sudan in the north, through all East African countries to Malawi in the south; in southern Africa, it is present in Mozambique and Zambia in the north, ranging southwards into South Africa, Namibia and southern Angola. Listed as Least Concern on the IUCN Red List.

[7] www.iucnredlist.org

Hottentot serotine *(Eptesicus hottentotus):* This largely Southern African species ranges from southern Angola in the west, through parts of Namibia, South Africa, southern Lesotho, Botswana, Zimbabwe, Mozambique, Malawi and Zambia, with a single record as far north as southwestern Kenya. Although this species is considered to be sparsely distributed, it is locally common in part of the ranges, such as Zimbabwe but is thought to be rarer elsewhere (e.g. South Africa). Listed as Least Concern on the IUCN Red List.

Zulu pipistrelle/Aloe bat (*Neoromicia zuluensis*): This species is widespread in east and southern Africa. The eastern distribution ranges from Ethiopia and south Sudan to Uganda and Kenya. The southern range extends from Zambia and southern parts of the Democratic Republic of the Congo to southern South Africa, and from eastern Angola to central Zambia and Zimbabwe. Listed as Least Concern on the IUCN Red List.

Egyptian slit-faced bat *(Nycteris thebaica)*: Broadly distributed across savanna and riparian zones. Mostly found in sub-Saharan Africa; also found in Morocco, Libya, Egypt (primarily down the Nile River valley, but also into Sinai) and the Middle East (Israel, Palestine and Jordan). Listed as Least Concern on the IUCN Red List.

Transect surveys

Bats vary their echolocation calls in response to a wide variety of needs and no automated call identification system can achieve 100% accuracy in identifying species. As such, the reliability of species recordings in addition to those in the static surveys needs careful consideration. The built-in Auto-ID feature suggests the two most likely bat species for each recording, but the Auto-ID feature (particularly for South Africa) does not include every possible bat for each of the covered regions. Therefore, if a bat that is not included on the database is recorded, it will be identified by the app as a species with a similar echolocation call type. Thus mistaken identification is probable.

This probably explains the records for Hildebrandt's horseshoe bat (*Rhinolophus hildebrandtii)* and Dent's horseshoe bat (*Rhinolophus denti*), neither of which have previously been recorded in this part of South Africa[8]. The detector most likely heard the Cape horseshoe bat, which was not listed on the app at the time of the surveys.

Roberts's flat-headed bat (*Sauromys petrophilus)* and the Little free-tailed bat (*Chaerephon pumilus*) have both been recorded in the western Cape (Jacobs & Fenton 2001) and the Natal long-fingered bat (*Miniopterus natalensis)* and African yellow bat (*Scotophilus dinganii)* have known distributions[9] to indicate that their presence is possible. Further analysis of the existing calls and additional surveys would be likely to confirm the presence (or otherwise) of these four species.

The data recorded will be provided to Wildlife Acoustics to assist in development of the species classifiers for South Africa.

[8] www.iucn.org

Cave surveys

Additional cave roosts of the Cape horseshoe bat were confirmed. These caves may support more than one species and would warrant focussed audio-visual surveys to confirm species presence.

Conclusion

Additional surveys in multiple locations, following standardised protocols have clearly revealed yet more species (than the 2015 pilot study), increasing from five to eight, with a further four to be confirmed. The surveys have begun to better illustrate bat usage of the wider landscape and habitat features, which will become clearer as activity data are processed. A greater diversity of species has been located along the north-south roads, where there is a greater diversity of habitats likely to support bats.

The spatial range of the surveys should be extended in 2017 to include:

- Multi-night static surveys at multiple locations, beyond the roads and covering a wider range of habitats, altitudes and times of year.
- Cave entrance surveys, using static (daytime) deployment to assess roost locations and level of activity.
- Multiple transect surveys along existing tracks using Anabats and Echo Meter Touch detectors.

6.5. Literature cited

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Appendix I: Further tortoise data

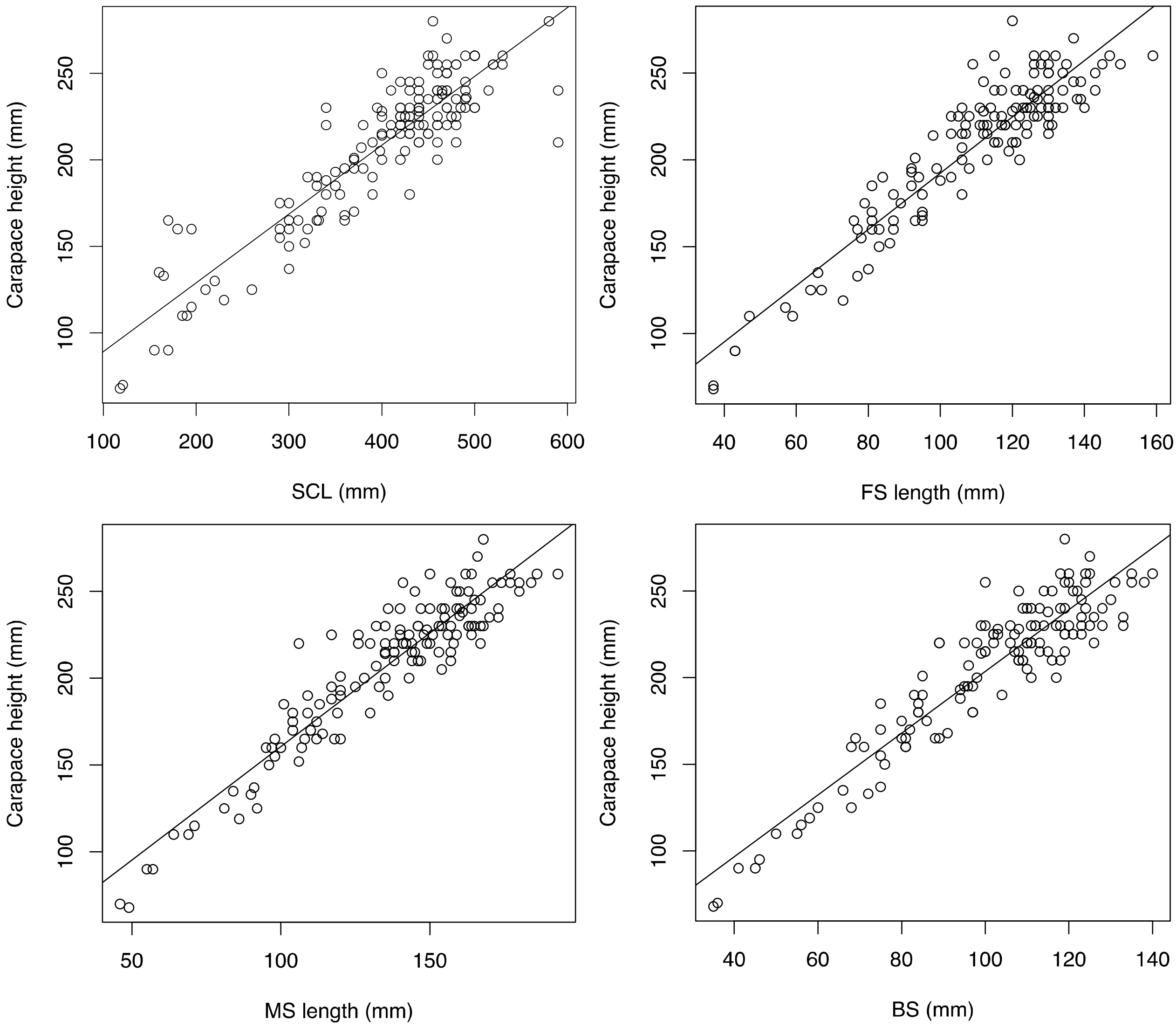

Figure S1: Leopard tortoise scute lengths and SCL regressions against carapace height

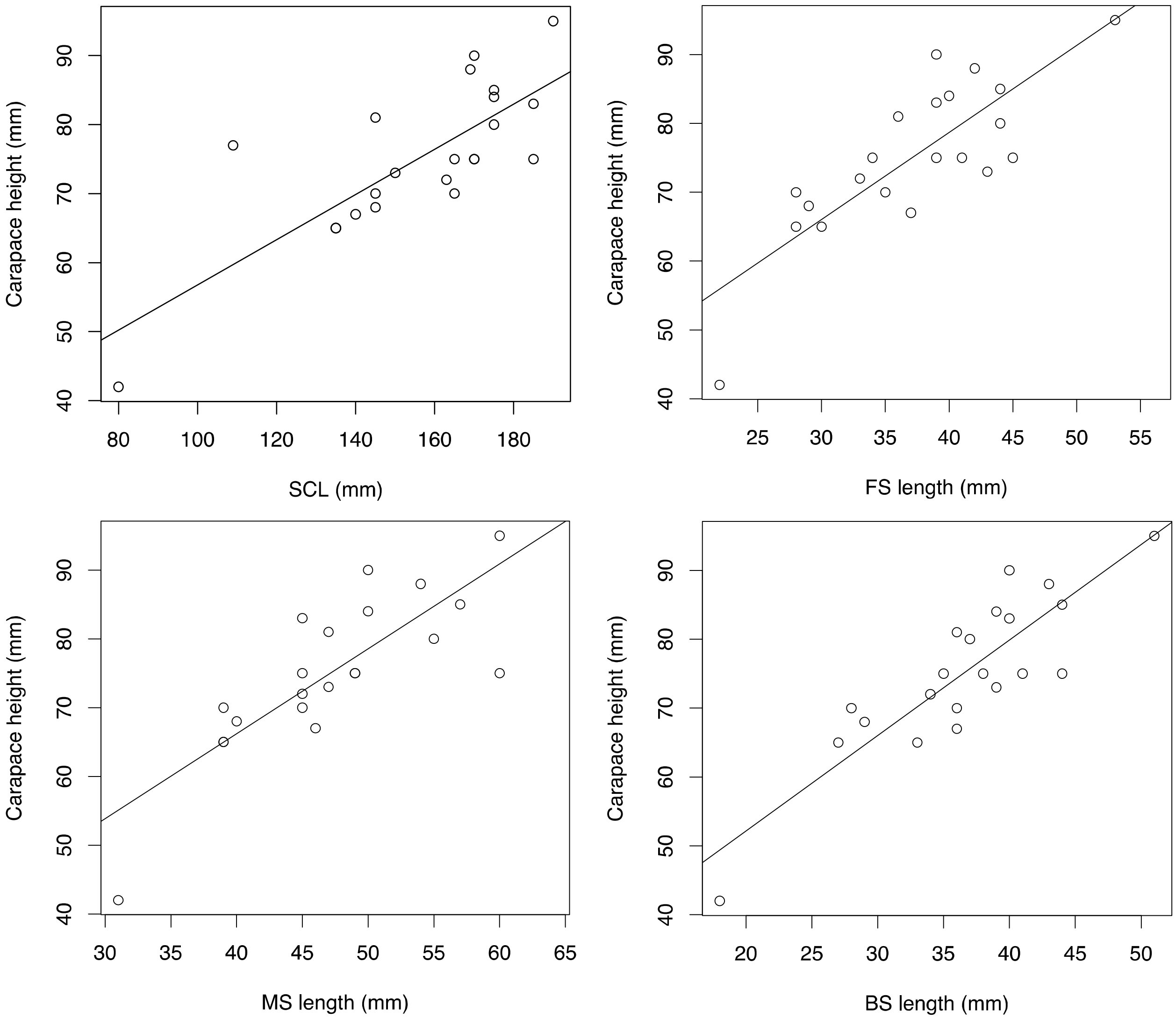

Figure S2: Angulate tortoise scute lengths and SCL regressions against carapace height

Table S1: Scute lengths and SCL regression equations used to predict height of tortoise carapaces.

Measurement	Equation	SE	R^2	Adjusted R^2	F	df	p
Leopard SCL	y = 0.397*x* + 49.42	0.016	0.808	0.807	636.70	151	<0.001
Leopard FS	y = 1.620*x* + 30.34	0.057	0.854	0.853	794.80	136	<0.001
Leopard MS	y = 1.306*x* + 30.04	0.044	0.867	0.866	877.60	135	<0.001
Leopard BS	y = 1.781*x* + 25.38	0.063	0.858	0.857	804.00	133	<0.001
Angulate SCL	y = 0.327*x* + 23.99	0.060	0.602	0.582	30.24	20	<0.001
Angulate FS	y = 1.265*x* + 28.09	0.212	0.652	0.634	35.66	19	<0.001
Angulate MS	y = 1.236*x* + 16.74	0.208	0.650	0.631	35.20	19	<0.001
Angulate BS	y = 1.386*x* + 24.44	0.181	0.755	0.742	58.49	19	<0.001

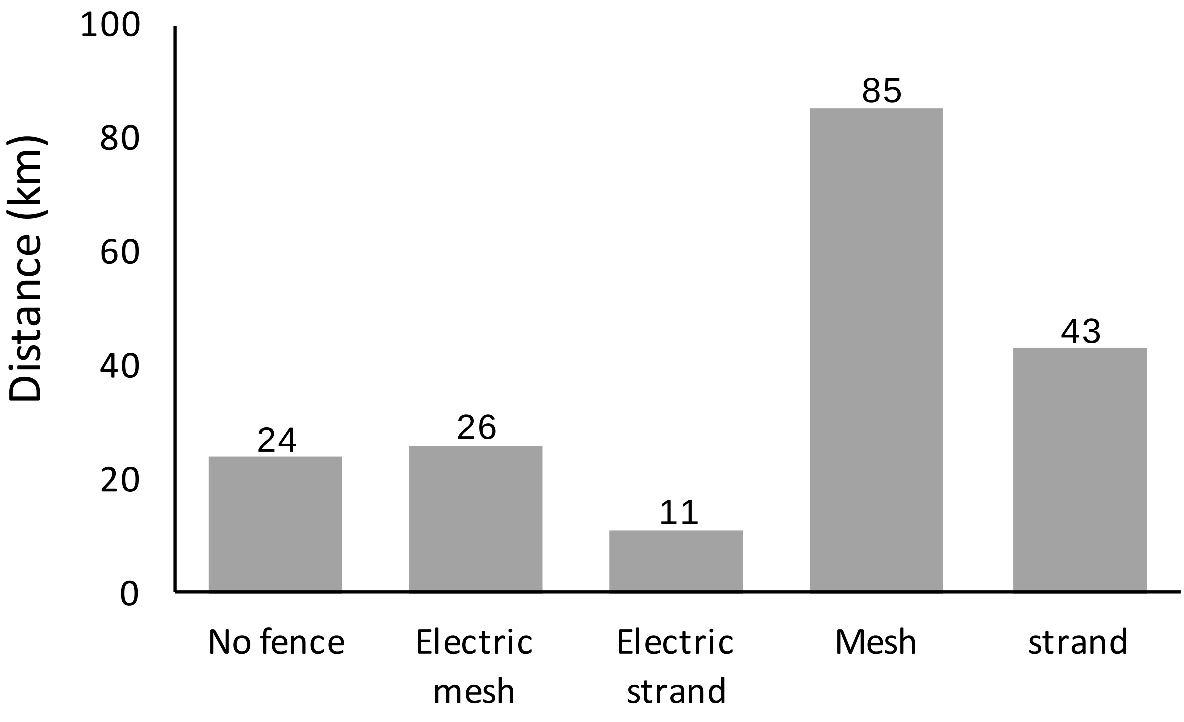

Figure S3: Distances of fence types used in analyses. Numbers of above bars indicate the number of transects.

Appendix II: Expedition diary and reports

A multimedia expedition diary is available at https://biosphereexpeditions.wordpress.com/category/expedition-blogs/south-africa-2016/.

All expedition reports, including this and previous expedition reports, are available at www.biosphere-expeditions.org/reports.