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Aspects of the home range ecology of the leopard tortoise in the semi-arid central Karoo: An area threatened with fracking

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ABSTRACT

Whilst fracking is used globally, impact studies on wildlife are limited. The semi-arid Karoo, South Africa, a large ecosystem with a high degree of endemism, is targeted for fracking. We investigated how adult leopard tortoises (*Stigmochelys pardalis*) use their environment by determining individual and seasonal variation in home range and effects of weather factors on these pre-fracking. Data were obtained from Global Positioning System (GPS) transmitters placed on leopard tortoises (n = 11) on private livestock farms near Beaufort West, South Africa for a year. Kernel density estimation (KDE) was used to estimate home range. Individuals had a mean (±SE) home range of 121.86 ± 28.12 ha, (range 40.53–258.52 ha) with a core area of 76.55 ± 17.33 ha (range 21.22–83.89 ha). No difference was found between annual male and female home ranges. Two telemetered individuals were excluded from analysis because they exhibited apparent nomadic behaviour. Several individuals did not visit permanent water sources, possibly suggesting that dietary water intake was sufficient. Generalised Linear Mixed Models were used to explain monthly home range estimates (95% KDE_{href}) in regards to biologically significant predictor variables. A single top model ($\Delta AIC_c < 2$) was produced, indicating importance of individual variability (sex, body mass) and weather (temperature, rainfall) variables. Our results provide baseline data pre-fracking in the region, and as such, should be repeated following commencement of fracking.

1. Introduction

Most protected areas (PAs) are generally well-managed and well-researched in southern Africa (SANParks, 2013), however, there is an increasing need to further understand ecosystems that do not fall into PAs. The increase in human population has resulted in loss and degradation of naturally existing environments. Across the world, land is cleared to provide important human resources, including housing, agriculture, and energy production. The change in land use outside PAs for fuel and energy can heavily impact threatened species (Reimer and Snodgrass, 2009). Furthermore, interpretation of movement ecology and home range estimations of these species can be important in aiding successful management decisions, especially in areas of land use change (Hebblewhite and Haydon, 2010).

Burt (1943), originally defined 'home range' as the '*area traversed by the individual in its normal activities of food gathering, mating and caring*', though further definitions and analytical methods have advanced our understanding of how animals occupy and use their spatial environment. As animals explore their environment they build and continuously update a cognitive map (Gautestad, 2011). It has been proposed that the best estimate of animal's home range are areas within this cognitive map that are updated more regularly (Powell and Mitchell, 2012). Technological advances and improvements in statistical models have allowed a greater understanding of the utilisation of environments by animals. For example, Kernel Density Estimation (KDEs), a nonparametric statistical technique which utilises probability density functions to estimate home range (Worton, 1989), can also be used to investigate habitat use (Seaman and Powell, 1996).

South Africa, with its variety of habitats and ecosystems, is home to at least thirteen terrestrial tortoise species—~24% of the world's 53 extant species (Hofmeyr et al., 2014; Turtle Taxonomy Working Group, 2014)—and is considered a centre of endemism for Testudinidae (Branch et al., 1995). The Karoo biome, a semi-arid desert covering much of the Northern, Eastern and Western Cape Provinces, has a high tortoise diversity with eight species occurring in the region (Hofmeyr et al., 2014; Turtle Taxonomy Working

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Group, 2014). In some areas, up to five species coexist: leopard tortoise (*Stigmochelys pardalis*), angulate tortoise (*Chersina angulata*), tent tortoise (*Psammobates tentorius*), Karoo padloper (*Homopus boulengeri*) and greater padloper (*H. femoralis*) (Hofmeyr et al., 2014).

As with other major ecoregions, many parts of the Karoo are highlighted as potential sites for hydraulic fracturing (fracking) (Le Maitre et al., 2009): a process to collect shale gas using injection of a pressurised fluid mixture deep into the earth (Bažant et al., 2014; De Wit, 2011). Fracking has been used successfully in many parts of the world, however, studies on their implications on wildlife are limited. Potential impacts of fracking on the water-scarce Karoo ecosystem is currently unknown. Perhaps the greatest concern is the potential environmental contamination and degradation due to highly saline wastewater discharge entering into naturally-existing freshwater systems, as shown in North America (Schmidt, 2013). Many communities and ecosystems within the Karoo rely on existing water sources. Contamination of water sources could greatly impact local communities (Mash et al., 2014) and fauna and flora. This could reduce regional biodiversity, as the Karoo is a centre of endemism for birds and reptiles (Branch et al., 1995; Dean, 1995). The South African National Biodiversity Institute (SANBI) is currently undertaking systematic surveying to fill biodiversity information gaps to support development decision making with regards to fracking operations (SANBI, 2016).

The leopard tortoise is listed as a species of "Least Concern" both internationally, by the International Union for Conservation of Nature (IUCN) (Turtle Taxonomy Working Group, 2014), and regionally, by the South African Reptile Conservation Assessment (SARCA) (Hofmeyr et al., 2014). The leopard tortoise is ecologically the best-studied African tortoise species, owing to relative abundance, distribution, and relative ease of locating wild individuals. Previous home range studies have shown variability in results, with tracked individuals in the Nama-Karoo, Northern Cape (McMaster and Downs, 2009) and Addo Elephant Park region, Eastern Cape (Mason and Weatherby, 1996) showing much larger home range sizes than populations studied in Swaziland (Monadjem et al., 2013). This difference has previously been attributed to resource (vegetation/water) availability: animals are expected to travel further and cover larger areas when resources are scarce (Monadjem et al., 2013). The aforementioned studies also found variation between sexes. For example, females had significantly larger home ranges than males in the Northern and Eastern Cape Provinces (Mason and Weatherby, 1996; McMaster and Downs, 2009): a trait not shown in Swaziland (Monadjem et al., 2013). Individuals within these studies also displayed great variability in home range size and habitat use, regardless of sex or size. Such individual variation has been identified in other taxa with animals in similar environments exhibiting varying dietary preferences, sociality, and responses to environmental conditions (McMaster and Downs, 2013b; Pagani-Núñez et al., 2016; Pinter-Wollman et al., 2013). It is important to note that longevity of study, survey methodology, project funding and statistical techniques differed between these studies, and may account for some observed differences.

As with many taxa, home range analyses on tortoises have been conducted with the intent of further understanding their ecology (Slavenko et al., 2016). We investigated home range of leopard tortoises over 12 months on private livestock farmland in the Central Karoo, using Global Position System (GPS)-Global System for Mobile Communications (GSM)/Ultra High Frequency (UHF) telemetry techniques and estimation statistics. Such information is useful to guide management decisions for the species, whilst the methods and analysis are easily transferable to other tortoise species, including those that are currently listed as vulnerable (Hofmeyr et al., 2014; Turtle Taxonomy Working Group, 2014). Considering the region is targeted as a centre for fracking, we present our methodology and results as baseline data in a pre-fracking era for the region. We predicted that home range estimates of leopard tortoises in the Central Karoo would be comparable to those in Nama-Karoo and the Addo region, due to similarities in habitat and average adult body mass of tortoise populations. We predicted that females would exhibit a larger home range size, as has been shown in previous studies in western populations, due to differing resource requirements (e.g. egg-laying habitat). As with previous studies of home range in tortoises (Hailey and Coulson, 1996; Mason and Weatherby, 1996; McMaster and Downs, 2009; Monadjem et al., 2013), we expected individual and seasonal variation. We expected this individual variation to reflect of individual habitat use and foraging.

2. Materials and methods

2.1. Study area

The Karoo is a large area covering approximately 37 million ha (Vorster and Roux, 1983), with northern and western areas typically arid, and remaining areas semi-arid. Rainfall in the Central Karoo is generally low, and unpredictable and unreliable in terms of quantity and timing (Mucina et al., 2006). Mean daily ambient temperatures frequently surpass 30 °C in summer, when plants and animals are under severe heat and desiccation stress (Mucina et al., 2006; Vorster and Roux, 1983). Furthermore severe frost events can occur during winter (Muller et al., 2016). The result is that vegetation is adapted, wide-ranging, and typically of low levels of endemism, with much of the flora also occurring in surrounding biomes (Hilton-Taylor, 1987).

The study area consisted of three private mixed livestock farms surrounding Nelspoort and Beaufort West, Central Karoo, Western Cape, South Africa: Baakensrug (32 °13S, 23 °11E), Kamferskraal (32 °14S, 23 ° 2E), and Elandsfontein (32 °18S, 22 ° 54E) (Fig. 1). These farms utilise aspects of holistic resource management, using rotational intensive grazing of livestock (sheep, goats, cattle), aimed at reducing selective grazing and subsequent desertification of their lands (Savory, 1991). Distinct boundaries between the farms exist in the form of mountains, roads, and fencing (pers. obs.). Each farm uses gates and various types of agricultural fencing to separate pastures, which vary greatly in size. These fences have varying levels of restriction to tortoises; from little (e.g. low tensile wire fence) to full (e.g. chain-link fence).

2.2. Fieldwork

Adult leopard tortoises were initially located by walking morning and evening transects within study areas during November and December 2014. Transect locations were determined using the 'Create Random Points' tool in ArcGIS 10.3.1 (ESRI, CA, USA). Most of these were away from croplands, buildings and manmade watering points, to buffer effects of anthropogenic environments. Haglöf Mantax Blue callipers (Haglöf, Långsele, Sweden) were used to measure straight carapace length (SCL), straight carapace width (SCW) and straight carapace height (SCH), whilst digital hanging scales (Pesola, Schindellegi, Switzerland) were used to measure mass (to nearest ± 0.1 kg). Geolocation was recorded using a Garmin eTrex 10 Worldwide Handheld GPS Navigator (Garmin, Schaffhausen, Switzerland). We had ethical clearance from the University of KwaZulu-Natal Ethics Committee (020/15/animal).

Unique GPS-GSM/UHF transmitters (Wireless Wildlife, Pretoria, South Africa) were attached to the carapace of adult tortoises