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Multi-species occupancy modelling of a carnivore guild in wildlife management areas in the Kalahari

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ABSTRACT

Populations of large carnivores are declining at a rapid rate, primarily resulting from land use change due to increasing human pressure. Such changes can restrict available habitat for many species, particularly wide-ranging large carnivores. In Botswana, aside from protected areas, large tracts of land are set aside as wildlife management areas (WMAs). Wildlife management areas are important regions of habitat for many species and can serve as buffer zones between protected areas and agro-pastoral land, while allowing communities to utilise resources. It was hypothesised that land use type surrounding WMAs, human settlements and prey availability might affect carnivore distribution patterns. We conducted a camera-trap study with 96 stations in two WMAs in the Ghanzi district and used a Royles-Nichol multi-species occupancy model to test which factors influenced habitat use for nine carnivore species. Detection probability was low across all species, whereas occupancy varied substantially. Lion occurrence was highest close to protected areas, whereas leopards and brown hyaena occurred closer to commercial farms. Black-backed jackal and caracal had high occurrence probabilities near both protected and commercial farming areas. Settlement locations and wild prey availability did not strongly influence occurrence of any species, although black-backed jackals had higher occurrence in areas with high livestock frequency. As pressure for land continues to increase, available habitat for wildlife is reduced and wide-ranging species like carnivores are vulnerable to edge effects. The WMAs provide vital habitat for carnivores and can be used to improve livelihoods for communities, whilst maintaining biodiversity in the Kalahari.

1. Introduction

Populations of large carnivores are declining at a rapid rate, primarily as a result of land use change (Di Minin et al., 2016). Increasing human population growth and intensity of land use often results in habitat loss and threatens these carnivores (Ripple et al., 2014). In southern Africa, populations of large carnivores such as cheetah (*Acinonyx jubatus*), African wild dog (*Lycaon pictus*) and brown hyaena (*Parahyaena brunnea*) primarily exist in areas outside of protected areas (RWCP and IUCN/SSC, 2015; Durant et al., 2017; Winterbach et al., 2017), and is often considered a result of avoidance of larger predators like lion and spotted hyaena (Durant, 1998, 2000). This in turn increases the risk of human-wildlife conflict (Ripple et al., 2014), often resulting in persecution with the potential to further reduce population numbers. As most protected areas (PA) are rarely connected, landscape level approaches to conservation are needed, often incorporating areas that are utilised by people (Glennon and Didier, 2010).

Botswana still holds some of the largest populations of large African carnivores and provides vital zones of connectivity with neighbouring countries (Winterbach et al., 2014). Despite this, pressure for land for agro-pastoral activities is increasing and primarily wildlife based areas have been converted for agricultural purposes over the past few decades (Dougill et al., 2016). Botswana hosts several large PAs (National Parks, Game Reserves and Forest Reserves), and a number of wildlife management areas (WMA) were set aside in the 1980s. In WMAs, wildlife is the primary form of utilisation, but other activities like maintaining livestock are allowed, provided they do not negatively impact on wildlife populations (Parry and Campbell, 1990). They can be seen as multi-use areas for both conservation of wildlife and providing sustainable resources for communities residing within these areas (Twyman, 2001). Wildlife management areas provide suitable habitat for many species and are also important buffer zones that can serve as a refuge for wildlife. Most WMAs are found alongside PAs, therefore creating a soft-boundary between PAs and pastoralist areas, which is important for reducing human-wildlife conflict (Jones, 2008). Although maintaining WMAs is a vital aspect of wildlife conservation in Botswana, southern WMAs in the Kalahari tend to support lower wildlife biomass than those in the north due to lower abundance and diversity

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(Parry and Campbell, 1990). This makes them potentially less valuable for tourism and less economically valuable for communities (Aarntzen, 2003; Mulale and Mbaiwa, 2012). However, communities can still benefit from these areas by sustainably harvesting local resources whilst maintaining important cultural and symbolical value (Twyman, 2000). Furthermore, low rainfall areas such as those in the Kalahari are also vitally important for many arid adapted species of herbivores and carnivores and show important differences in ecological structure to wetter areas (Durant et al., 2014; Mills, 2015). As carnivores can serve as important sentinel species (i.e. represent an areas condition) and are vulnerable to management practices (Sergio et al., 2008), comprehensive studies of these species in WMAs is needed in the Kalahari, as these areas represent a transitional point in the environmental gradient between high and low human intensity.

Recent studies have shown that carnivore distributions are most affected by small prey biomass and distance to PAs (Burton et al., 2012; Rich et al., 2017a). At the edges of PAs, or where wildlife areas intersect with human activity, edge effects can drastically affect a species propensity toward extinction, especially for wide-ranging species like large carnivores (Woodroffe and Ginsberg, 1998). However, carnivore species may vary in their response to human activities and proximity to PAs (Burton et al., 2012). Some species may prefer human occupied areas like farms, as a way to avoid inter-specific competition with more dominant species (Linnell and Strand, 2000) which, are usually eradicated in farming areas. These areas may also be favourable due to increased access to water, from the implementation of boreholes to water livestock, which may also increase wild prey abundance. However, natural prey biomass may also vary due to the potential effects of hunting and competition with livestock in pastoral areas. For example, high stocking rates are negatively correlated with some large herbivore species (Blaum et al., 2009). As WMAs in Botswana are often surrounded by different land use types with varying levels of human activity, this inevitably also leads to variable prey abundance. Land use type and prey availability are therefore key factors that may affect the distribution of carnivores and may be community- or species-level specific.

Multi-species occupancy models (MSOMs) are particularly useful for assessing biodiversity through measures of species richness and community- or species-specific effects of occupancy and habitat use (Kéry and Royle, 2008). These models can also be useful to model data from rare species, such as some large carnivores, as coefficients are modelled through community-level parameters, rather than independently for each species (Broms et al., 2016). Furthermore, occupancy models with imperfect detection can be used to account for heterogeneity in both occupancy and detection probability due to different site-specific covariates (MacKenzie et al., 2006; Royle and Dorazio, 2008). In this study, our objective was to determine the role of anthropogenic pressure and prey availability on the distribution and habitat use of medium and large carnivores in WMAs of the Kalahari. Our aim was to develop a MSOM using camera trap data for a carnivore guild incorporating species most implicated in human-wildlife conflict for this area (Selebatso et al., 2008). We hypothesised that occupancy would be positively affected by increasing distance from areas of high human activity. We also predicted that natural prey availability would be positively associated with higher occupancy probabilities for all species.

2. Methods

2.1. Study area

To assess the distribution of carnivores in WMAs and the effect of land use on distribution, we conducted a camera trap study in the Okwa WMA in the Ghanzi District of western Botswana (Fig.1), covering an area approximately 15,290 km^2. The Okwa WMA (comprised of two WMAs - GH3 and GH10) is surrounded by four land use types; a large protected area (PA) to the east; commercial cattle and game farms (CF) to the north-west; communal grazing areas (CG) and another WMA to the south and west (Fig. 1). Within the study area, several villages with associated cattle posts are present, comprising a population of roughly 2000 people, with the majority Basarwa (Bushmen/San) (Twyman, 2001). In each village there are several bore holes for people and small numbers of livestock are permitted within a designated zone within the WMA (Twyman, 2001). The habitat is fairly homogenous and made up primarily of low tree and shrub savannah characterised by *Terminalia sericea* and *Loncocarphus nelsii* (Cole and Brown, 1976). The substrate is primarily hardveld and natural pans accumulate water during the rainy season, but during the study period surface water was not present. Rainfall is approximately 400 ml annually in this region (Cole and Brown, 1976) but can be highly variable.

2.2. Camera trap survey

The study area maintains a limited sand road network, making much of the area inaccessible. Due to the thick habitat, camera trap locations were limited to roads. Although placements on roads is considered non-random sampling (Wearn et al., 2013), roads lightly travelled are commonly used by species of large carnivore (Stander, 1998; Abrahms et al., 2016) and would therefore increase detection probabilities in this area. We note that the survey was constrained particularly in the centre of the sampling area, however we still covered a gradient of the range of values of our covariates of interest. We identified a total of 96 camera stations (Fig. 1) by placing a 5 × 5 km grid over the study area and placing cameras on the road nearest to central point of each grid. We chose 5 km spacing as we focussed specifically on medium and large carnivores, which are generally wide-ranging, in an attempt to ensure independence at sampling sites and reduce spatial auto-correlation. We placed one infrared camera trap (Bushnell Aggressor or Bushnell Trophy Cam) per location mounted on wooden poles or trees, approximately 60 cm from the ground. Cameras were programmed to record a burst of 3 photos separated by 30 s intervals. Due to a limited number of cameras, the study was divided into two survey areas and were run in succession. Cameras were set to run for a minimum of 30 days for each area, with the entire study period completed from October-early December. Cameras were checked every two weeks to change batteries and download photos.

2.3. Covariates

We hypothesised that two main factors would influence the distribution of carnivores in this area, those being anthropogenic influences related to land use intensity and settlement locations, and those related to available prey resources. The effect of anthropogenic impacts we tested were distance to three different land use categories: protected (PA), fenced commercial farming (CF) and unfenced communal grazing (CG) areas, as well as distance to villages (VL) within the WMAs or surrounding areas. Camera stations, land use types of the district and villages were mapped in ArcGIS (10.4, ESRI). Distance to nearest village and each land use type were calculated in ArcMap for each camera station. We used prey capture frequency as an index of prey availability from three prey groups: large prey (LP) > 100 kg (kudu *Tragelaphus strepsiceros*, eland *Taurotragus oryx*, blue wildebeest *Connochaetus taurinus*, red hartebeest *Alcelaphus buselaphus* and gemsbok *Oryx gazella*), small prey (SP) 2-70 kg (grey duiker *Sylvicapra grimmia*, steenbok *Raphicerus campestris*, springbok *Antidorcas marsupialis*, warthog *Phacochoerus africanus*, springhare *Pedetes capensis* and cape/scrub hares *Lepus capensis/saxatilis*) and livestock (LV) (cow *Bos indicus*, donkey *Equus asinus*, horse *Equus caballus*, sheep *Ovis aries* and goat *Capra hircus*). For each prey group, we summed the total number of detections per camera station using a 60 min period of independence per species using software described in Harris et al. (2010) for the entire sampling period. To account for different numbers of sampling occasions per location (e.g. camera failure), we divided the number of