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Distribution update

Occupancy and range extension of the Cape fox in northern Botswana

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Abstract

The Cape fox resides in open and arid environments throughout the central and western regions of Southern Africa. The Cape fox is nocturnal and generally difficult to observe, making camera traps an ideal method for estimating its distribution. We used camera trapping and hierarchical occupancy models to estimate the distribution of the Cape fox in Ngamiland District of northern Botswana, an area where the species was previously undocumented. We deployed 221 camera traps across a 550km² area between February and July 2015. We included percent cover of mopane shrub and woodlands and road density as covariates for Cape fox occupancy probabilities, and vegetative thickness surrounding the camera stations as a covariate for Cape fox detection probabilities. Our hierarchical occupancy models were then analysed using a Bayesian framework. We photographed Cape fox on 27 occasions, resulting in an overall mean probability of occupancy of 0.31 (*SD* = 0.105). Cape fox occupancy was negatively related to mopane cover and road density, and the probability of photographing a Cape fox was positively related to vegetative thickness. To our knowledge, this is the first confirmed documentation of the Cape fox north of Maun, Botswana. The presumed range extension of the Cape fox into northern Botswana may be a consequence of observed climate change in the Kalahari, which has resulted in increasingly open and arid environments that are more suitable for the Cape fox.

Introduction

The Cape fox (*Vulpes chama*; Figure 1) is a canid classified as a species of least concern. It is common throughout its range in the central and western regions of Southern Africa (Skinner and Chimimba 2005). In Botswana, its range extends as far north as Lake Ngami and the Boteti River just south of Maun and then continues in a northwest direction (Smithers 1971). The species experienced range-wide declines in the 1980s, but populations are currently thought to be stable and in some areas, extending as semi-arid vegetation expands through desertification (Stuart and Stuart 2004).

The Cape fox generally occupies open environments such as grasslands and arid scrub (Stuart and Stuart 2004). In the Western Cape, however,

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it has expanded into areas with denser vegetation (Skinner and Chimimba 2005) and has been found to occupy agricultural areas (Smithers 1971).

Figure 1. Cape fox photographed during a camera trap survey in Ngamiland District, Botswana, 2015.

In South Africa, the mean annual home range size of the Cape fox was estimated to be from 9 to 28km² depending on black-backed jackal *Canis mesomelas* abundance (Kamler et al. 2012; 2013). The typical food items of Cape fox include small species such as small mammals, birds, insects, arachnids, reptiles and wild fruits (Smithers 1971; Klare et al. 2014). One of the primary competitors and predators of the Cape fox is the black-backed jackal (Kamler et al. 2012; 2013). In northern Botswana, large carnivores also likely compete with and prey on Cape fox (Stuart and Stuart 2004).

The Cape fox is difficult to observe due to its generally nocturnal, elusive and solitary foraging behaviour. As such, camera trapping techniques are an ideal method for estimating Cape fox distributions because they collect data over large areas in a time- and cost-effective manner, operate 24 hours/day, and generally have high detection rates (O'Connell et al. 2006). Our objective was to use camera trapping and hierarchical occupancy models (Dorazio and Royle 2005) to estimate the distribution of Cape fox in a portion of Ngamiland District, Botswana.

Methods

Our study area (ca 550 km²; 19°31'S, 23°37'E) in northern Botswana included the eastern section of Moremi Game Reserve, wildlife management areas NG33/34, and part of the livestock grazing areas of Shorobe (Figure 2). Vegetation cover included mopane *Colophospermum mopane* shrub and woodlands, floodplains/grasslands, acacia woodland savannas and mixed shrublands (e.g. *Lonchocarpus nelsii* and *Terminalia* spp.).

We deployed Panthera v4 incandescent-flash and Bushnell TrophyCam infra-red camera traps at 221 locations across 550km² between February and July 2015. We used 5km² grid cells to guide the placement of cameras and ensure systematic coverage of the entire study area. To increase our probability of photographing wildlife, we placed cameras on sand roads. Many wildlife species often use lightly-travelled roads as movement corridors (Forman and Alexander 1998). We deployed two camera stations within each grid cell, one on the sand road closest to the predetermined centre point of each grid cell and the second on the road closest to a predetermined random point within each grid cell. We used a block system for camera deployment where we divided our study area into five, ~110km² sub-areas and sequentially sampled each area for 30 nights. We deployed an average of 44 camera stations (two cameras/station) within each sub-area. We checked cameras every five to ten days to download photos, replace batteries and ensure cameras were still operational.

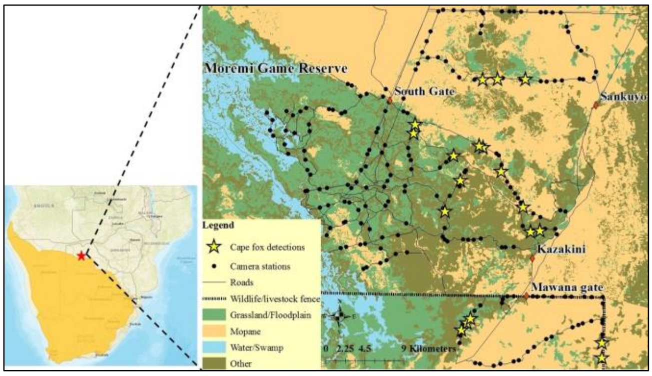

Figure 2. Current range of the Cape fox, location of our camera trap survey in Ngamiland District, Botswana, 2015 and camera stations where a Cape fox was photographed.

We hypothesized the spatial distribution of Cape fox would be influenced by land cover and road density. We calculated percent cover of the dominant land covers, floodplains/grasslands and mopane shrub and woodlands (Bennitt et al. 2014), within a 1km radius buffered area surrounding each camera station. Floodplains/grasslands and mopane were highly correlated (Pearson r = -0.67) so we only retained mopane cover for our analyses. To calculate road density, we georeferenced all gravel and four-wheel drive sand roads within our study area, created a raster layer representing km of road/km² in ArcMap 10.3.1 (ESRI, CA, USA), and calculated the mean road density within a 1km buffered area surrounding each camera station. Given that the Cape fox generally occupies open environments (Stuart and Stuart 2004), we also hypothesized the thickness of the vegetation surrounding the camera station may influence the probability of photographing a Cape fox. To measure vegetation thickness, we took two photographs at knee height, one pointed at 90° and the other at 270° in relation to the road. We took these photographs at the camera station, 50m up the road, and 50m down the road for a total of six photos/station. We then digitally placed a 13x15 grid over each photo and counted the number of grid cells that were ≥ 50% covered by forbs, shrubs or trees. We divided this count by the total number of grid cells and used the mean value across the six photographs as our estimate of relative vegetative thickness for the respective camera station.

We estimated the occupancy of Cape fox using hierarchical occupancy models (Dorazio and Royle 2005). Specifically, we linked detection and occupancy by incorporating models that specified the state process, whether a site was occupied and the observation process, whether the species was detected, conditional on the site being occupied (Dorazio and Royle 2005). Distinguishing the true absence of the Cape fox (i.e. not occupied) from areas where the Cape fox was present but not photographed (i.e. not detected) requires spatially or temporally replicated data (MacKenzie et al. 2002). Therefore, we treated consecutive trap days as repeated surveys at each camera station. The probability of detection is therefore an estimate of the proportion of trap nights on which the Cape fox will be photographed given that it is present at the site during the study. We standardized mopane cover, road density and vegetative thickness to each have a mean of 0 and standard deviation of 1. We then incorporated these site-level characteristics using a generalized linear mixed modelling approach to estimate occurrence and detection probabilities (Dorazio and Royle 2005).

Results

We recorded Cape fox on 27 occasions during our 6,607 trap nights (Figure 1). The Cape fox was photographed at 19 different camera stations (Figure 2) with one to seven detections/camera ($\bar{x}$ = 1.4, SD = 1.39). We detected Cape fox over a 95km² area with distances between detections ranging from 0.5-35.0km (Figure 2). The overall mean probability of occupancy was 0.31 (SD = 0.105) with camera station-specific estimates of occupancy ranging from 0.01 to 0.82. We found the probability a Cape fox occupied an area to be negatively related to mopane cover and road density (Table 1). The probability of photographing a Cape fox was low across all camera stations ($\bar{x}$ = 0.02; *SD* = 0.007) but found to be higher in areas with thick vegetation (Table 1).

Table 1. Mean ($\bar{x}$), standard deviation (*SD*) and 95% credible interval (95% *CI*) estimates for the covariates hypothesized to influence Cape fox occupancy (β) and detection (*P*) probabilities in Ngamiland District, Botswana, 2015. Covariates include percent cover of mopane shrub and woodlands, density of roads, and relative thickness of vegetation.

Covariate		$\bar{x}$	*SD*	*95% CI*	
β_1	mopane	-1.90	1.010	-4.411	-0.554
β_2	roads	-2.06	1.036	-4.581	-0.546
P_1	vegetation	0.97	0.264	0.461	1.490

Discussion

We estimated the Cape fox had a mean occupancy probability of 0.31 (*SD* = 0.105) in our study area in Ngamiland District, Botswana, an area where the species was previously undocumented. We photographed the Cape fox over a 95km^2 area with a maximum distance of 35km separating photographic detections. In South Africa, the mean annual home range size for Cape fox can be up to 28km^2 (Kamler et al. 2012). If home range sizes are comparable in Botswana, then it is unlikely our photographs were of a single animal. Cape fox occupancy probability declined with increasing cover of mopane wood and shrublands (Table 1). This supports past studies that found Cape fox prefers open environments (Stuart and Stuart 2004; Kamler et al. 2012). We also found that Cape fox occupancy probability declined with increasing road densities (Table 1). A study in South Africa found the Cape fox was detected by camera traps placed at water sources but not by camera traps placed on roads (Edwards et al. 2016). If the Cape fox generally avoids roads, then our sampling design may have resulted in their true occupancy being underestimated.

We documented a range extension of the Cape fox in northern Botswana, as our records were ~100km farther north than that previously reported for this species (Smithers 1971). Range extensions of the Cape fox during previous decades were reported in the southern part of their distribution (Stuart and Stuart 2004), but our data are the first to document their range extension in the northern part of their distribution. The presumed range extension of the Cape fox in northern Botswana may be a consequence of Botswana becoming hotter and drier (Ringrose et al. 2002) and the projected effects of this changing climate including increased rates of deforestation and degradation of woodlands (Collins et al. 2013). In north-central Botswana specifically, where our study took place, vegetative cover is changing from tree and shrub savanna to more shrub and bush savanna (Ringrose et al. 2002). The desiccation of northern Botswana combined with the shifts in vegetation structure may lead to an increasingly open and arid environment that is more suitable for the Cape fox (Stuart and Stuart 2004). The expansion of the Cape fox's range suggests the projected impacts of climate change on species distributions may already be taking place in Botswana. As aridity in southern Africa likely increases in coming decades (Collins et al. 2013), we predict the Cape fox may continue expanding its range across the region.

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Biographical sketches

Lindsey Rich is a PhD candidate in Wildlife Conservation at Virginia Tech, working in collaboration with the Botswana Predator Conservation Trust. Her research is focused on population dynamics, carnivore ecology and community ecology and aims to inform the effective management and conservation of wildlife.

Marcella Kelly is a Professor at Virginia Tech, focused primarily on carnivore population ecology, management and conservation. She uses emerging techniques such as camera trapping, genetic sampling, molecular scatology and GPS-collaring to estimate parameters including population densities, genetic diversity and habitat selection.

David Miller is an Assistant Professor at Penn State University, where he works with a range of taxa, including amphibians, birds, snakes and mammals. His research focuses on the application of novel quantitative approaches and population and community ecology principles to inform management of wildlife populations.

"Tico" McNutt is the founder and director of the Botswana Predator Conservation Trust (BPCT), one of the longest running conservation research projects in Africa. BPCT aims to preserve Africa's large predators and their habitats by using scientific inquiry to better understand the behaviour and communication systems of these animals.

Hugh Robinson is the director of the landscape analysis laboratory at Panthera. His research focuses include predator-prey dynamics, population dynamics, habitat use and large carnivores.