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Short Note

Status and density of the threatened Kori Bustard *Ardeotis kori* in a woodland savanna

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Many grassland habitats have disappeared or undergone substantial change worldwide and many obligatory grassland animal species have populations that are at risk of extinction. The Kori Bustard *Ardeotis kori* is the largest flying bird native to Africa and an open savanna specialist, but no research on the population ecology of the Kori Bustard in Namibia has been published in the last 30 years. Using distance sampling from driven transects, we estimated 0.34 ± 0.1 birds km^{-2} in the 2021–2022 calendar year, which projects a population of <200 (~196) Kori Bustards for the 576 km^2 study area. We found no significant variation in density estimates among seasons from 2016 to 2021. A nationwide status survey and investigation of potential limiting factors, including analysis of survival rates and connectivity between populations, will be important undertakings to better inform conservation strategies for this imperilled species in Namibia and in other range countries with data deficiency.

Statut et densité de l'outarde kori *Ardeotis kori*, espèce menacée, dans une savane arborée

Une grande partie des habitats de prairie du monde entier ont soit disparu soit subi des changements substantiels, ce qui a emmené à que de nombreuses espèces animales adaptées aux prairies ont des populations menacées d'extinction. L'outarde kori *Ardeotis kori* est le plus grand oiseau volant d'Afrique et un spécialiste des savanes ouvertes. Aucune recherche sur l'écologie de la population d'outardes kori en Namibie n'a été publiée au cours des 30 dernières années. En utilisant un échantillonnage à distance à partir de transects en voiture nous avons estimé 0.34 ± 0.1 oiseaux km^{-2} pour l'année civile 2021–2022, ce qui projette une population de <200 (~196) outardes kori pour notre zone d'étude de 576 km^2. Nous n'avons pas trouvé de variation significative dans les estimations de densité entre les saisons (2016–2021). Une enquête nationale sur le statut de l'espèce et l'étude des potentiels facteurs limitants, y compris des analyses de survie et de la connectivité entre les populations, seront des entreprises importantes pour mieux informer les stratégies de conservation de cette espèce en danger en Namibie et dans d'autres pays de l'aire de répartition où les données sont insuffisantes.

Keywords: density estimation, distance sampling, grassland, Namibia, Otididae, population size, transect data

Supplementary material: available online at https://doi.org/10.2989/00306525.2023.2248395

The bustard family (Otididae) is known to include many species of conservation concern (Collar 1996; Silva et al. 2023). Out of 26 species, 15 are listed as either Near Threatened, Vulnerable, Endangered or Critically Endangered (Anderson et al. 2001; Scott and Scott 2020; Shaw et al. 2021; Uddin et al. 2021; Ram et al. 2022) and 11 as Least Concern (Birdlife International 2023). Habitat loss through conversion to crops and expansion of human settlements have altered foraging and safety refugia for many populations within the bustard family. Anthropocene-driven bush encroachment (Atkinson et al. 2022) and powerline-caused mortality also negatively impact some populations (Uddin et al. 2021; Bernardino et al. 2022; Silva et al. 2023).

The Kori Bustard *Ardeotis kori* is the largest flying bird in southern and eastern Africa (Stevenson and Fanshawe 2002). Morphometry (Maloiy et al. 1987), the natural history of the species (Allan and Osborne 2005), habitat use (McCollum et al. 2018), body size variability (Hallager 2003) and behaviour (Lichtenberg and Hallager 2008), including courtship displays (Osborne and Osborne 1998) and parental care (Mwangi 1998; Hallager 2003), have been addressed in literature reviews for the species. However, most Kori Bustard populations are data deficient

and likely under severe threat (Senyatso et al. 2013), requiring the collection and analysis of baseline information that can assist with threat mitigation. In particular, research on the population ecology of the Kori Bustard in Namibian farmlands is lacking, hindering projections of population growth, risk assessment, habitat-suitability analysis and conservation efforts.

The Cheetah Conservation Fund (CCF) field base in Namibia has extensively monitored wildlife on Namibian farmlands for the last 30 years, mainly focusing on large carnivores and their prey base. From 2016 onwards, vehicle transects have been driven systematically on an annual basis across seasons, recording animal data, mainly focusing on estimating ungulate population trends and carrying capacity of large carnivores. Through this long-term collection of data, we also obtained observations of Kori Bustards in a distance-sampling framework, to facilitate density estimation of this species in a woodland savanna. Our study is the first in the last 30 years in Namibia to estimate the population size (Osborne and Osborne 1998) of this Near Threatened species (BirdLife International 2023). Documenting the status of lesser-known species typical of grassland ecosystems is a conservation priority since grassland systems and component species are being affected by human activities on a global level (Jhala et al. 2021).

Our study was conducted in a woodland savanna of north-central Namibia on property owned by the Cheetah Conservation Fund (576 km^2), subdivided into a wildlife reserve and mixed-use farms (wildlife and livestock) (Figure 1). The study area experiences three seasons: cold-dry (May–August), hot-dry (September–December) and hot-wet (January–April) (Nghikembua et al. 2020, 2021). We used the habitat-stratified conventional distance-sampling method (Thomas et al. 2010) to estimate the density of Kori Bustards sighted along transects (Figure 1) in 2021–2022. From July 2021–April 2022, we drove 10 transects (19.2 ± 4.04 km) two times per season (two replicates), resulting in a total of 54 transect runs for the year, during early morning (around 6:00) and late afternoon (around 16:30). Our total annual sampling effort across the three seasons in 2016 to 2021 was a distance of 1 786.2 km.

While driving the transects, the driver maintained a low speed (~10 km h^{-1}), while 2–4 observers searched for potential prey species of cheetahs *Acinonyx jubatus* and leopards *Panthera pardus*, including ungulates and large birds. We recorded the number of conspecific individual animals observed at each sighting. Whenever possible, age and sex of the animals were also recorded, but these data can have potential observer bias, and were therefore

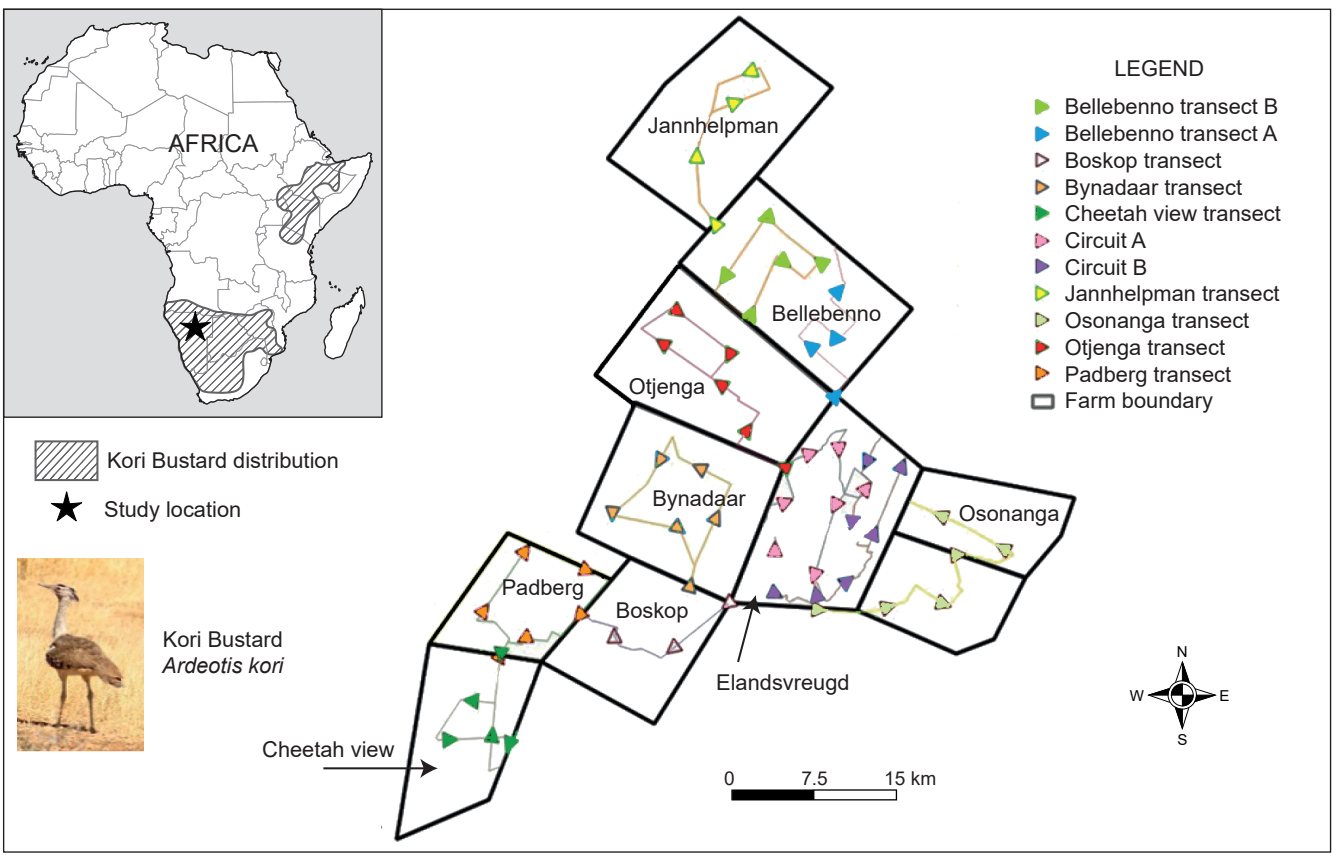

Figure 1: Spatial distribution of the driven transects for biodiversity surveys on Cheetah Conservation Fund property in north-central Namibia. Individual transects are illustrated with distinct colours; arrows indicate the route of the vehicle. Inset shows the current geographic distribution of the Kori Bustard *Ardeotis kori* (BirdLife International 2023); the star indicates the study area location in Namibia. Photograph: Kathan Bandyopadhyay

not included in our analysis. After spotting an animal, we recorded the perpendicular distance to it from the transect using a Bushnell rangefinder (Bushnell Golf Tour V5 Patriot, Kansas, USA). Transects were separated by 2–5 km to maintain independence of observations.

We used the conventional distance-sampling approach (CDS) in the program Distance version 7.4 (Thomas et al. 2010) to estimate the annual density of Kori Bustards for the most-recent calendar year (2021–2022) based on data pooled across the three seasons. In addition, we assessed seasonal variation in Kori Bustard density based on long-term transect dataset (2016–2021) wherein we pooled the data of these multiple years into the corresponding seasons.

We fit four detection functions: (i) half-normal, (ii) uniform, (iii) hazard rate, and (iv) negative exponential, with cosine, simple polynomial and Hermite polynomial series expansion. We fit these expansions to examine and explain the fitted graph between the detection function and perpendicular distance, and truncated the outliers to improve goodness of fit. We truncated distance beyond 150 m to improve the goodness of fit of the best model. Akaike's Information Criterion (AIC) values were used to select the best model, and Kolmogorov–Smirnov statistics to examine each model's goodness of fit (Buckland et al. 2004). Finally, the population size of Kori Bustards was estimated by multiplying bustard density by the total area of the wildlife reserve and farms.

We surveyed 48.7 km^2, which constitutes 8.4% of the total CCF property. Seasonal estimates were conducted by cumulatively sampling 28.1%, 38.5% and 28.5% of the entire property in the cold-dry, hot-dry and hot-wet seasons, respectively (Supplementary Tables S1 and S2). We recorded 33 sightings of Kori Bustards, with an encounter rate of 2 birds in 100 km in the 2021–2022 calendar year, which yielded an estimated density of 0.34 birds km^{-2} (± 0.1 SE [95% CI: 0.18–0.63]). Our data from north-central Namibia return a population projection of 196 Kori Bustards on the CCF property during 2021–2022. The uniform cosine model was selected as the base model based on the AIC value (AIC = 291.04), with a detection probability of 0.21 and effective strip width of 40.97 m (Supplementary Figure S2). The mean cluster size of observed bustards was 1.13 ± 0.064 birds. However, owing to insufficient observations, we were unable to project the growth rate of the Kori Bustard population in our study area to investigate the trend for this population.

We recorded 53, 101 and 58 independent observations of Kori Bustards in the cold-dry, hot-dry and hot-wet seasons, respectively, across the period 2016–2021. We found no statistically significant seasonal variation in the density estimates, although the mean density in the hot-dry season (0.52 ± 0.17) appeared slightly higher than in the hot-wet (0.44 ± 0.14) and cold-dry (0.44 ± 0.12) seasons (Figure 2). Details on mean cluster size, seasonal detection probability, and the goodness of fit of the best models are reported in Tables 1 and 2.

The largest populations of Kori Bustards reside in Namibia and Botswana (Herremans 1998; Allan and Osborne 2005). Although the total population size of this species in its native resident habitat (Namibia, Botswana and South Africa) is unknown, the population trend is decreasing (Birdlife International 2023). In the rest of Africa, estimates range between 5 000–10 000 individuals, with an area of occupancy of 721 000 km^2 (Osborne and Osborne 1998). To our knowledge, only the study of Osborne and Osborne (1998) has addressed the ecology and conservation management of the Kori Bustard in Namibia. The detection probability of the bird was higher during the cold-dry and hot-dry seasons (0.34 and 0.33, respectively) than in the hot-wet season (0.26), likely due to the growth of graminoid and of forb foliage in the savanna landscape. Still, the detection probability had a contrasting effect on the density estimates. This might be explained by observer bias and observer-favoured sampling sites with variable vegetation types, road networks and accessibility, with under-reporting of more difficult to reach areas.

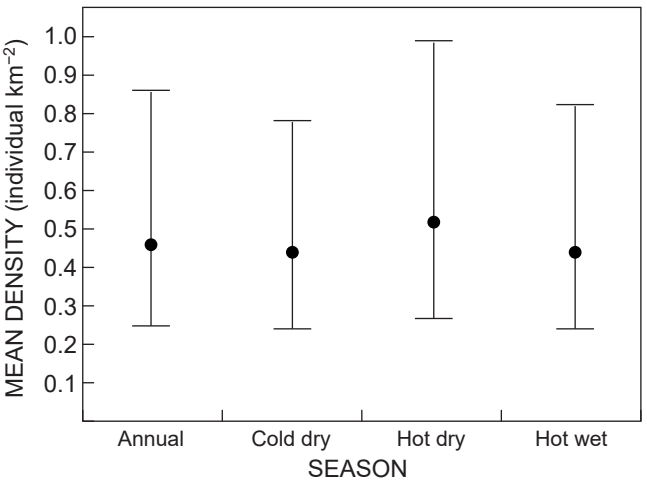

Figure 2: Annual and seasonal density estimates (individual km^{-2}) of Kori Bustards *Ardeotis kori* on Cheetah Conservation Fund property in Namibia for 2016–2021; error bars are 95% confidence intervals

Instead of driven transects as used in our study, random transects distributed across the area that are sampled by walking might provide more-accurate density estimates (Smithsonian National Zoological Park 2014), allow nest monitoring (Mmassy et al. 2018), computing of the sex ratio, and inferring movements (Mmassy et al. 2019). However, walked transects are substantially more labour-intensive than driven transects, take longer to execute, and are unsuited for areas with dangerous wildlife. Nonetheless, in the absence of marked birds in our study area, we cannot conclude the underlying reason for any potential seasonal variation of the density estimates. A recent study in the Serengeti ecosystem highlighted variation in the seasonality and sex-specific movement attributes of Kori Bustards (Mmassy et al. 2019). Breeding females confined their movements to a small area to participate in parental duties, whereas males used large open grasslands to elicit courtship displays to conspicuous females (Mmassy et al. 2018). Previously, it was reported that Kori Bustards are nomadic in Namibia and resident in countries in other parts of their range, such as in Zimbabwe and Botswana (Shaw 2013). In our study area, permanent and predictable water was available year-round at natural and artificial

Table 1: Estimated density (birds km^{-2} [standard error]) of Kori Bustards *Ardeotis kori* in the study area of Namibian woodland savannah during 2021–2022, based on distance sampling using Distance version 7.4. A single global detection function was modelled from the entire study area. AICc values are reported instead of AIC values owing to a small sample size. Cos = uniform cosine model; UN = uniform model

Year	Number of observations	Model	Adjustment	Density [SE]	AICc	Delta AICc	Mean cluster size	Effective strip width (m)
2021–2022	33	UN	Cos	0.34 [0.1]	293.35	0	1.13	40.97
2021–2022	33	null			336.61	43.26		

Table 2: Seasonal variation in the population size of Kori Bustards *Ardeotis kori* in the study area of Namibian woodland savannah from 2016–2021. A single global detection function was modelled by pooling multiple-year data (2016–2021) of corresponding seasons from the entire study area. At the same time, the density (birds km^{-2} [standard error]) across pooled years for each season was subsequently estimated in Distance version 7.4. AICc values are reported instead of AIC values owing to a small sample size. Models: HN = half-normal; HZ = hazard rate; UN = uniform. Adjustments: Cos = uniform cosine model; Pol = simple polynomial model

	Number of observations	Model	Adjustment	Density [SE]	AICc	Delta AICc	Mean cluster size	Effective strip width (m)
Cold-dry, best model	53	UN	Cos	0.44 [0.12]	533.28	0	1.4	68.11
Cold-dry, null model	53	null			537.99	4.71		
Hot-dry, best model	101	HZ	Pol	0.52 [0.17]	1 035.24	0	1.24	93.25
Hot-dry, null model	101	null			1 044.50	9.26		
Hot-wet, best model	58	HN	Cos	0.44 [0.14]	569.45	0	1.37	69.21
Hot-wet, null model	58	null			580.83	11.35		

waterpoints, which might have precluded the need for the local Kori Bustard population to migrate seasonally to access water.

Kori Bustard populations are thought to be declining throughout the species' entire range, a trend justifying its classification as Near Threatened. To our knowledge, reliable estimates of population size are not available for any country where the species occurs. Nonetheless, widespread population declines are conceivable and could be related to hunting and persecution (Astley-Maberly 1937; Porter 1949; Herremans 1998), bush encroachment driven by overgrazing (Collar 1996; Senyatso 2011; Nghikembua et al. 2021) and infrastructural development, especially powerline-caused mortality (Collar et al. 2017).

Owing to data deficiency and challenges to their conservation as exemplified above, the status and viability of Kori Bustards across Namibia and throughout their range are largely unknown. Localised populations likely persist in some areas, such as in open grasslands protected as wildlife reserves and in remote areas with a minimal human footprint. We suggest that investigating the distribution and density of component populations, as well as connectivity between them, should be prioritised for conservation research. Information on survival of various age classes, disease risk and direct anthropogenic impacts, such as hunting, mortalities from powerlines and road kills, also need to be evaluated.

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Data availability statement — The data associated with this article is available in the Zenodo online repository (10.5281/zenodo.7903107).

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