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Norwegian University of Science and Technology

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Preamble

Over the years, I have passed through the Naabi hill plains in the south east area of Serengeti National Park several times on my way from Arusha to Seronera. Quite frequently, I have observed large numbers of Kori bustards on these trips, and this was the beginning of my interest in the Kori bustard. I was inspired to develop a study to understand more about the occurrences of such a large Kori population. I therefore contacted Professor Eivin Røskaft, who was also excited about my idea of developing and testing hypotheses about Kori bustard observations in the Southeast Serengeti National Park. I thank him for his positive response towards this unique study. I express my deepest respects and appreciation to my mentor and PhD supervisors Professor Eivin Røskaft and Dr. Kjetil Bevanger, who supervised and challenged my research work and supported my career in the field of conservation biology. Without their knowledge and support, this research would have been impossible. Specifically, I would like to convey my special gratitude to Professor Eivin Røskaft, who always encouraged me with a spirit of hard work as the only path to academic success. I extend my thanks to the Department of Biology at NTNU for hosting me as a PhD student and its staff for the cooperation showed to me during the entire PhD study period. I am very grateful to my lecturers, Professor Eivin Røskaft, Professor Gunilla Rosenqvist, Professor Vidar Grøtan, and Professor Martin Frank Hohmann-Marriott, others and my fellow students, Katharina Bading, Eivind Drejer, Elise Skottene, Signe Løvmo and Semona Issa who engaged in many interesting discussions that broadened my understanding of conservation biology and philosophy of science. I am sincerely grateful to Dr. Roel May and Eivin Røskaft for advice on scientific writing and data analysis, Dr. Oddmund Kleven for DNA analysis and Dr. Frode Fossøy and Dr. Craig Jackson for contributing ideas on data analysis. I emphasize my thanks to the Director General TAWIRI Dr. Simon Mduma for granting study permission and his good advice and wishes on the achievement of my PhD career, without forgetting to mention his advice: “Time management is a critical discipline towards achievement”.

I specifically thank Kjetil Bevanger and Torgeir Nygård for providing some of their project GPS collars to track Kori bustard in the Serengeti. Thanks to the Norwegian Institute for Nature Research (NINA), The American Species Survival Plan (SSP), the Jacksonville Zoo in the USA, European Union’s Horizon 2020 research and innovation programme under grant agreement No. 641918 (AfricanBioServices), and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBS) for funding this research, as well as the Tanzania National Parks (TANAPA) and Tanzania Commission for Science and

Technology (COSTECH) for granting research permits. I thank Mama Berit Røskaft for taking care of me while in Norway and understanding of her husband Professor Eivin's responsibilities in developing my career, as well as for regularly hosting me in her home for meals. Thanks to Dr. Craig Jackson for invaluable assistance in mapping the study area and comments during manuscript writing. I thank those people who contributed their constructive ideas towards the success of my work without forgetting Dr. Wilfred Njama Marealle for his great help not only in this work but also during my early days at NTNU and in Trondheim. I thank the Serengeti Wildlife Research Centre (SWRC) for logistical support and the entire community of SWRC for their hospitality during field work. I am indebted to Dr. Robert Fyumagwa, Eirik Skjetne, Juma Mkwizu, Jackson Lyimo, Jackson Ngatauti, Noel Massawe and others whose names I cannot recall but who volunteered to assist me during field work. I thank Sara Hallager, Katie Bagley and other staff of the Smithsonian National Zoological Park and Zoo Atlanta of USA for facilitating the availability of funds through SSP.

My heartfelt thanks should go to my late mother Anna Joseph who tirelessly cared me from childhood and built in me a spirit of hard work for the success of my future life, which has brought me to where I am today. May God rest her soul in the eternal life, Amen. Finally, I am also indebted to my beloved wife Hilda, who had to perform my duties to take care of our children Jackson, Glory and Kelvin, who were lonely for a long time during my absence in the course of my studies. I acknowledge their patience during the entire period of my absence and also their endless prayers to God for me to be in good health and successful in my examinations. My brothers, sisters and friends also supported me through prayers, and I thank them.

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List of Papers

Paper I

Mmassy, EC & Røskaft, E. (2014) Factors affecting local ecological knowledge and perceived threats to the Kori bustard *(Ardeotis kori struthiunculus)* in the Serengeti Ecosystem, Northern Tanzania. International Journal of Biodiversity and Conservation 6, 459–467.

Paper II

Mmassy, EC, Fyumagwa RD, Jackson CR, Bevanger K, & Røskaft E. (2016) Kori bustard *(Ardeotis kori struthiunculus)* occurrence in the Serengeti grass plains, northern Tanzania. African Journal of Ecology. DOI: 10.1111/aje.12351.

Paper III

Mmassy EC, Fyumagwa RD, Bevanger K, & Røskaft E. (submitted) Breeding ecology of Kori bustards (*Ardeotis kori strunthiunculus)* in the Serengeti National Park.

Paper IV

Mmassy EC, May R, Jackson CR, Kleven O, Nygård T, Bevanger K, & Røskaft E. (submitted) Seasonal migration and resource selection in the Kori bustard in the Serengeti ecosystem.

Declaration of Contribution

I declare that this thesis is my original research work and all co-authors contributed their ideas during manuscript preparation. Philosophies and research design, data analysis and manuscript preparation were conducted with help from my supervisors, Professor Eivin Røskaft and Dr. Kjetil Bevanger. Manuscript writing and data analysis (paper IV) were performed with help from Dr. Roel May and Dr. Oddmund Kleven. Dr. Craig Jackson contributed ideas in manuscript writing and Arc GIS maps drawings. Dr. Robert Fyumagwa and Dr. Torgeir Nygård contributed their comments in Papers II and III and Paper IV, respectively.

Summary

The decline of wildlife habitats in savannah grasslands and its effect on birds' biodiversity has become a common phenomenon. Land use changes due to human populations and increasing poverty are among the most important drivers of this development. Through habitat encroachments, livestock rearing, conversion of natural land into settlements, economic activities and agricultural production, humans have occupied wild animal habitats. Habitat fragmentation and loss has caused the displacement and extinction of several bird species in various ecosystems. The establishment of protected areas (PAs) has been the main solution to rescue wildlife survival, including non-threatened, threatened and endangered species. Wildlife offtake also significantly contributes to the decline of wildlife species. In addition to the importance of establishing PAs, it is equally important to understand the factors affecting the species, species population status, breeding ecology, movement range and resource selection. These factors are of particular focus in this thesis, which examines the ecology and conservation challenges of the Kori bustard *Ardeotis kori struthiunculus* in the Serengeti ecosystem. The main objectives emphasize the factors that affect local ecological knowledge and perceived threats, density and occurrence, breeding ecology, seasonal migration and resource selection of the Kori bustard. I hypothesized that local people adjacent to the Serengeti National Park have good knowledge of ecology and the threats facing the Kori bustard (Paper I); the Kori bustard population density in the grass plain varies with season and with different habitats (Paper II); the breeding of the Kori bustard is influenced by the habitat and season and lasts for some time (Paper III); and 1) the home ranges of male Kori bustards are larger than the home ranges of females during the breeding season due to displaying behaviour; 2) the home ranges of male Kori bustards are smaller than the home ranges of females during the non-breeding season because they have less movements after the breeding season; 3) Kori bustards migrate seasonally between breeding and non-breeding periods, with males migrating over longer distances than females; and 4) the habitat preferences of the Kori bustard are gender specific and differ across seasons in response to temporal resource requirements (Paper IV).

It has been claimed that the Kori bustard, is declining throughout its range, including in Eastern Africa, due to reasons such as habitat loss and illegal offtake. To extend the knowledge of the importance of these factors, a study was carried out by interviewing local people adjacent to the Serengeti National Park. Overall, local people close to the park, including the Maasai tribe, had good knowledge regarding the identification of the Kori bustard. Generally more males from all surveyed tribes showed better ability of identifying the species than females. Varying

among age groups while educated and non-educated people showed similar levels of species identification. The results indicated that the Kori bustard population is smaller than before and observation frequency was declining. Illegal offtake is indicated as the main threat to the species in the study villages.

These results inspired further research to understand population density and revealed that the density of Kori bustard in the study area is approximately 1.3 birds per km^2 and is highest in the green grass habitat and during the short dry season. As no similar study has been conducted previously on the species in the Serengeti ecosystem, it is difficult to be decisive regarding the population status.

Further studies were carried out to determine the Kori bustard breeding ecology in relation to habitat and season. The findings revealed that the breeding season starts with a courtship display that peaks during the short dry and short rain seasons, whereas nests and chicks peak during long rain season. The adult sex ratio was skewed in different seasons, with male biases during the long and short rain seasons and female skewed during long and short dry seasons Over two years of field work, 1157 individuals and 14 nests were recorded, of which 36% of the nests were predated. The mean clutch size was 1.4 eggs per nest. This research highlights that the peak frequency of courtship displays occur during the early stages of the breeding season. Sex ratio skewness may be caused by the post-breeding migration of males and the breeding season lasts for some time as it covers three seasons (but not the long dry season).

To better understand the species' habitat requirements and seasonal variations, satellite GPS units were fixed on the back of Kori bustards to determine seasonal migration, ranging behaviour and habitat utilization. The results revealed that Kori bustards have distinct movement patterns related to the breeding (December-June) and non-breeding periods (July-November). Some Kori bustards contract their home ranges within a common breeding area; however, several individuals migrated away from the breeding area during the non-breeding period. The bird revealed sexual differentiation in the seasonal responses to habitat preference. Males showed a preference for open grassland, alternating with shrublands during the breeding and non-breeding seasons, whereas females preferred to use more closed grassland vegetation, especially treed grassland. Different seasonal movement patterns of males and females can be explained by differences in sexual activity.

Introduction

Conservation Challenges

Globally and particularly in the tropics, there are significant conservation challenges and rapid biodiversity loss mostly induced by anthropogenic pressure (Sala et al. 2000, Millennium-Ecosystem-Assessment 2005, Vié et al. 2009, Souza et al. 2015). The savannah ecosystem occupies 20 percent of the world's land surface area (Van Wilgen 2009), whereas in Africa, the savannah ecosystem covers 50 percent of the land surface area (Du Toit and Cumming 1999). Africa is rich in biodiversity, accounting for approximately a quarter of the global biodiversity including the largest assemblage of large mammals roaming freely in many countries (UNEP-WCMC 2016). The human population growth rate on the continent, however, is the main driver of the unsustainable use of wildlife resources and loss of biodiversity (Kramer et al. 2009, UNEP-WCMC 2016). The human impact on the savannah's biodiversity is particularly connected to land use changes because of the need for more agricultural land and livestock keeping (Du Toit and Cumming 1999), as well as unregulated wildlife hunting for domestic and commercial purpose both inside and outside protected areas (PAs) (Child 1996, Milner-Gulland and Bennett 2003). The geographical ranges of approximately 173 mammal species in the world have decreased by 50 percent and over the past 25 years, African birds have shown a decline (UNEP-WCMC 2016). Approximately 10 percent of African bird species are considered to be threatened with extinction (BirdLife-International 2013).

PAs are excluding humans from traditional land area (Wittemyer et al. 2014) and force people to settle at the PAs' edges (Luck 2007). Human communities at a PA border increase wildlife threats by blocking migratory corridors and increase habitat fragmentation (Mwalyosi 1991, Ottichilo et al. 2001). Thus, the protection of large landscapes may shelter biodiversity and encourage the free range movement of species (Moritz et al. 2008) compared to small PAs. Climate change and erratic rainfall have caused major pressures on global biodiversity (Rinawati et al. 2013). Diseases are documented to cause local to global extinction of species, such as the extinction of the golden toad *Incilius periglenes* of Costa Rica due to chytridiomycosis disease. The eruption of rinderpest that hit East Africa in 1890 killed 95 percent of the wildebeest and buffalo *Connochaetes taurinus* populations (Sinclair and Arcese 1995).

Biodiversity Conservation Approach

To date, PAs have been considered as a primary conservation approach to protect biodiversity (Prato and Fagre 2005, Gaston et al. 2008, Rands et al. 2010). PAs for biodiversity conservation vary from nature reserves, which are strictly for biological reserves, and national parks, to habitat or species management areas. Conservation areas involve both traditional reserves, private owned protected areas and community based conservation areas (Mittermeier et al. 2011). PAs are used as ecological baselines for the long term monitoring and conservation of nature and a tool for the conservation of biodiversity and sustainable economic development (Sinclair and Arcese 1995). PAs are a shelter for world biodiversity from human associated factors, provide a living space for wild communities and potentially offering plans for the restoration of natural habitats in the future. PAs are a sanctuary for wildlife species biodiversity and provide intact habitats for scientists, educators and conservationists to study and monitor biodiversity loss.

Wildlife conservation has adapted the Yellowstone conventional and exclusionary principle of a top down approach, which was used during the formation of the oldest national park in the world in 1872 (Pretty and Smith 2004). The formation of Yellowstone evicted and displaced local communities (Myers 1972) and subsequently restricted the exploitation of previously accessible wildlife and other natural resources. The combination of the exclusion principle, rapid human population growth, poverty, global demand for natural resources and political instability have triggered extensive loss of natural land cover and ecosystem functioning, giving way to threats to biodiversity (Damania et al. 2005, Ehrlich and Pringle 2008, Vedeld et al. 2012). An example is the Everglades National Park of the United States, where rapid human population growth and economic development in south Florida has reduced the population of wading birds nesting in the Everglades by more than 90% in spite of extensive protection efforts (Ogden 1994).

The effective conservation of species involves information about dispersal and ecological factors influencing quality of habitat (Rushton et al. 2004). Most of the world's leading habitats in biodiversity loss can be poor in species or ecosystem data. Data deficiency can be resolved by incorporating local ecological knowledge (LEK) or indigenous knowledge (IK) to complement scientific information and as a tool to provide biological information for the long term monitoring of population trends (Huntington 2000, Anadón et al. 2009) and the ecosystem (Gilchrist et al. 2005). LEK can be a valuable tool that provides important baseline information when managing wildlife populations that occur in remote areas inhabited by indigenous people (Kramer et al. 2009, Geldmann et al. 2013, Ziembicki et al. 2013).

Behavioural studies of animals are important for making substantial contributions in the conservation of species in different habitats. PAs must cohere with the ranging behaviour of animals, as some animals require a large range while others require small ranges based on seasonal resource selection (Gauthreaux 1982, Holbrook et al. 2002, Jahn et al. 2010, Chapman et al. 2011). Ranging behaviour will help to design the size of an area for the protection of species generally or a particular species. Understanding the breeding behaviour of an animal, especially endangered species, can help recover its conservation through habitat management and refining breeding systems.

Although the Serengeti ecosystem is considered as a potential birds' area and is endowed with a variety of bird species ranging from resident to wintering species (Fishpool and Evans 2001), there are no published ecological studies on local ecological knowledge, breeding, population density, movement and resource selection of the Kori bustard. This work is based on the results obtained from projected hypotheses on the ecology of Kori bustard in the Serengeti ecosystem. The main focus was local ecological knowledge and threats to the species, seasonal occurrence and density, the breeding season and associated predictors, and the movement and resource selection of the Kori bustard.

Threats to Kori bustard

Kori bustard is categorized by IUCN as near threatened over its entire African range (IUCN 2016) and is facing conservation challenges all over its geographical distribution. Human induced activities have changed the African savannah ecosystems and reduced wildlife animal ranges (Ramankutty and Foley 1999, Ogutu et al. 2005). Vegetation cover change may influence climate and hydrology changes that can affect wildlife species over a wide range (Galvin et al. 2001, Root et al. 2003). Increase in human population size and illegal off-take of game birds and low density wildlife species, such as the Kori bustard, is a main cause of the decline of some bird species in parts of Africa (Ash and Miskell 1998, Collar 1996). The disappearance of species such as the Ostrich (*Struthio camelus*) in North and West Africa (Thiollay 2006) and the northern Sahara (Bertram 2014) was caused by illegal offtake. Findings in Botswana suggest that unregulated hunting is a threat to bustards (Senyatso et al. 2013). In Kenya, for instance, in the nearby Loita plains where Kori bustards are known to be numerous, wheat production farms continues to expand (Ottichilo et al. 2001). In South Africa, collisions with powerlines are another cause of mortality for bustards, although the population impact is not clear (Bevanger 1998). Together with low reproductive rates, predation pressure and human induced mortality factors, the Kori bustard is showing signs of chronic decline over its entire range (Senyatso et al. 2013).

Ecology and Breeding of the Kori bustard

The Kori bustard occurs at low-densities and is wide spread in Africa. In southern and eastern Africa, the species is found in the savannah and open bushlands areas and rarely observed in the woodland (Collar 1996). Breeding habitats outside PAs are difficult to find because of rapid population growth and suitable Kori bustard habitats being changed for agricultural purposes. In the Serengeti, the species is mostly seen in the short grass plain (grass length ranges 15 cm to 1 metre) of the south eastern parts of the ecosystem (Sinclair 1975).

The breeding season of Kori bustards varies with locality. Generally, in the Eastern African region, *A. k. struthiunculus* breeds from January to June and from August to November, while *A. k. kori* breeds from September to April (Johnsgard 1991). Bustards are K-selected species - slow to mature, long-lived and with a low reproductive output (Del Hoyo et al. 1996). Breeding success is heavily rainfall dependent, and during drought periods breeding is reduced significantly. The breeding of the Kori bustard is clearly communicated with the courtship display (Fig. 1) but not well documented (Osborne and Osborne 1998). Kori bustards, like other bustards, exhibit a lekking (assemblage during breeding) system with no cooperative breeding system for incubation and care of young (Morales et al. 2001, Alonso et al. 2012, Riou and Combreau 2014). During the breeding season, male bustards gather singly or in loose lek-like formations to display (Hallager and Boylan 2004). Females lay their eggs in a shallow scrape (Fig. 2) on the ground and nests are usually partially hidden by tall grasses, small trees or bushes (Mwangi 1988, Maozeka 1993). Details on egg laying and incubation are partly unknown in the wild nesting birds (Osborne and Osborne 1998). Although variation in mean clutch size has been observed in different bustard species, the Kori bustard has been shown to have small clutch sizes ranging from 1 to 2 eggs (Osborne and Osborne 2001). The Asian Houbara bustard (*Chlamydotis undulata undulata*) has 3.2 (Koshkin et al. 2016) and the Great bustard (*Otis tarda*) has 2.12 (Rocha et al. 2013). There is no clear explanation for why such clutch variations occur.

Figure 1: Kori bustard courtship display in the Serengeti short grass plain

Distribution and rainfall variation may be important factors affecting Kori bustard breeding. It has been claimed that the Kori bustard in the Serengeti only has one breeding season, occurring in April (Sinclair 1978). The individual Kori bustard breeding corresponds to seasonal physical and biological variables and may be affected by bush fire regimes. Like most ground nesting birds, Kori bustards lay pigmented eggs (Fig. 2) to conceal them from predators (Lack 1958). In areas with regular fire management, however, egg pigmentations can be less important. In the savannah ecosystem, fire is used as an important agent to stimulate biodiversity during which many mobile species such as birds are killed (Bendell 1974, Mills 2004). During the dry season, approximately 62% of the grass in the Serengeti National Park is burnt off by wild fires (Sinclair 1975), which affects ground nesting species.

Figure 2: Eggs of the Kori bustard in shallow nest scrapes and with different pigmentations based on the background colour of the habitat.

Home range, movement and resource selection

A home range is an area being utilized by an animal during its regular activities of mating, eating and caring for young (Burt 1943). These three factors have been shown to influence and describe the home range and habitat use by different animals during their normal activities. Food availability and distribution are the main contributing factors to home range size and habitat preferences (Holbrook et al. 2002, Rolando 2002, DeVault et al. 2004, Niedzielski and Bowman 2016). Knowledge on movement behaviour and habitat use is important in understanding animal ecological requirements and making management plans (Willems and Hill 2009). Movement and home range varies with species, sex and spatial resource selection (Ostfeld 1990). For many tropical birds, the knowledge of home range and resource selection as bases for conservation actions and management is lacking. The basic information on many bustards in Africa is missing compared to the bustard in Eurasia and Australia. Although the genus *Ardeotis* is the heaviest flying and largest bird among the bustard genus, it still remains understudied. Studies of large bodied bustards such as the Great bustard, Australian bustards (*Ardeotis australis, Ardeotis nigriceps,* Arabian bustards (*A. arabs)* and *A. kori kori* have shown that those birds exhibit migration movement during breeding and non-breeding seasons (Nikolaus 1987, Streich et al. 2006, Ziembicki and Woinarski 2007, Dutta et al. 2011, Senyatso 2011). In Eastern Africa, the movement patterns, home range and habitat utilization of Kori bustard (*A. k. struthiunculus)* have not been assessed.

Thesis Aims

The main objective of this study has been to learn about the overall ecology of Kori bustard, with four sub aims;

1) Study factors affecting local ecological knowledge and perceived threats to the Kori bustard in the northern Serengeti communities (Paper I)
2) Study Kori bustard densities in the Serengeti grass plains (Paper II)
3) Study breeding ecology of Kori bustards in the Serengeti National Park (Paper III)
4) Study seasonal migration and resource selection of the Kori bustard in the Serengeti ecosystem (Paper IV).

Methods

Study Area

The study was carried out in the Serengeti National Park (SNP) and Western Ngorongoro Conservation Area, both being one of the two main components of the Serengeti-Mara ecosystem (SME), located between latitudes 1^0 28’ and 3^0 17’ S and longitudes 33^0 50’ and 35^0 20’ E and extending from northern Tanzania to south-western Kenya. The SME covers a total land area of approximately 25,000 km^2, of which 14,763 km^2 lie within the SNP and 8094 km^2 in the Ngorongoro Conservation Area, Open Areas and three Game Reserves; Ikorongo (563 km^2), Grumeti (416 km^2), Maswa (2200 km^2), the Ikona Wildlife Management Area (600 km^2), the Loliondo Game Controlled Area (4000 km^2) and the Maasai Mara Natural Reserve (1368

km^2) to the north in Kenya (Fig. 3).The ecosystem currently suffers due to conflict between conservationists and local communities (Hofer et al. 1996). The conflicts in the western Serengeti result from the fact that local people are prohibited from accessing the reserved area to meet their demand for natural resources, such as pasture and water for livestock to sustain their livelihoods (Kideghesho et al. 2007).

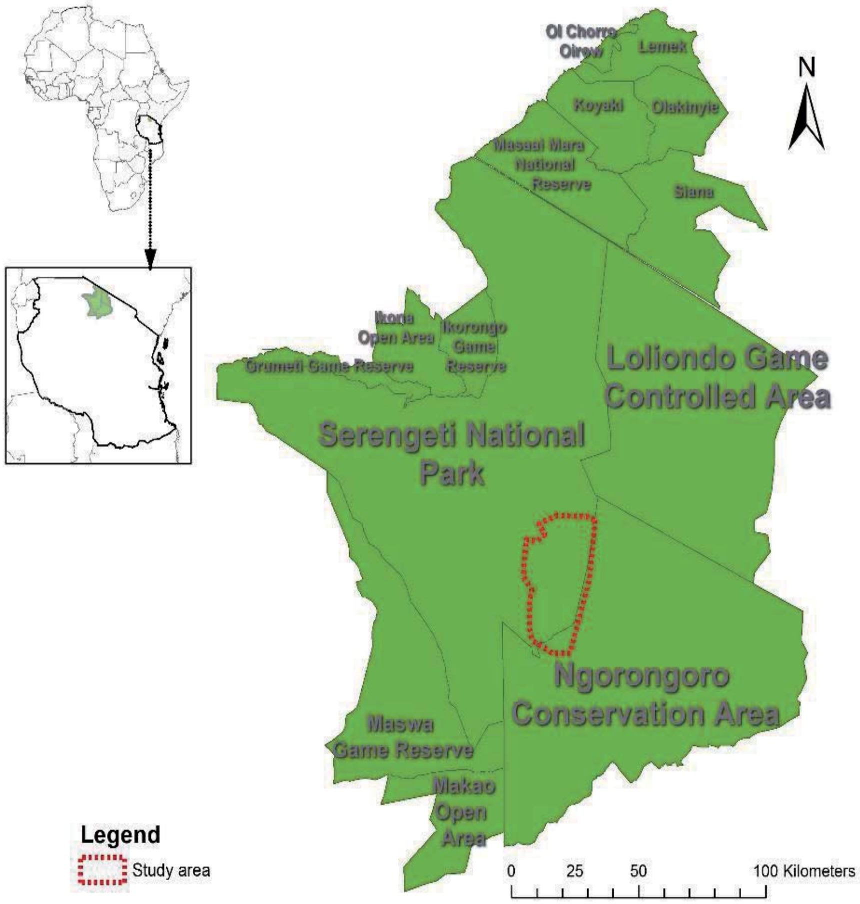

Figure 3: Map of the Serengeti Ecosystem showing the study site and different protected areas

A major part of the SNP is dominated by Acacia savannah woodlands and riverine forests, particularly in the western and northern parts (Herlocker 1976, Senzota 1982). The study sites in the eastern Serengeti and western Ngorongoro plains, however, are dominated by grasslands. There are two major seasons in the ecosystem: a wet season and dry season (Norton-Griffiths et al. 1975). The dry season occurs from July to October, while short rains start in November and continue for almost two months to December. A short dry period is experienced between January and March, and the long rain season generally lasts from March to June. (Sinclair 1978). The average annual rainfall varies from 600 mm in the south-east plains to 1100 mm in the north (Pennycuick 1975). The mean temperature in the study area ranges between 15^0C and 27^0C and is usually higher in the western parts compared with the eastern parts; it can rise to more than 36^0C in the dry period (Sinclair et al. 2000). The research focused on the southern SNP, an area dominated by short grass plains with grass ranging in height from approximately 15 cm to 1 metre (Sinclair 1978) and where large numbers of Kori bustards are frequently observed.

Study Species

The Kori bustard is the heaviest flying bird known in the world. It is native to Africa and belongs to the family Otididae. It has a long neck, a long feet each with three fingers, and light brown or grey plumage (http://www.krugerpark.co.za/africa_kori_bustard.html). Due to taxonomic differences, there are two subspecies of Kori bustard, *Ardeotis kori struthiunculus* occurring in Eastern Africa and *Ardeotis kori kori* occurring in southern Africa (Fig. 4a). The range size of both sub species has contracted by 21 percent in East Africa and 8 percent in southern Africa. The population size declined considerably after 1970 in its entire range except for Zambia, which shows a slightly increase, and Angola, where there is no clear trend (Fig. 4b) (Senyatso et al. 2013). The body weight is approximately 7-15 kg for males and 5.5-7 kg for females during the non-breeding season (Johnsgard 1991, Bailey and Hallager 2003). The male differs from the female by having a larger body size with a thick neck and/or a darkened throat (during the breeding season) (Fig. 5). The female is smaller in body size than the male and is black on the crown (Bailey and Hallager 2003). Subadult males are similar to adult males but have a thinner neck and are larger than subadult females. Subadult females have thinner legs than adult females and a brown-black back (Osborne and Osborne 2001). The Kori bustard is listed in CITES Appendix II and as Near Threatened by IUCN criteria (BirdLife-International 2013). The southern sub-species *A. k. kori* is listed as vulnerable in the South African Red Data Book (Brooke 1984) and the Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland (Barnes 2000).

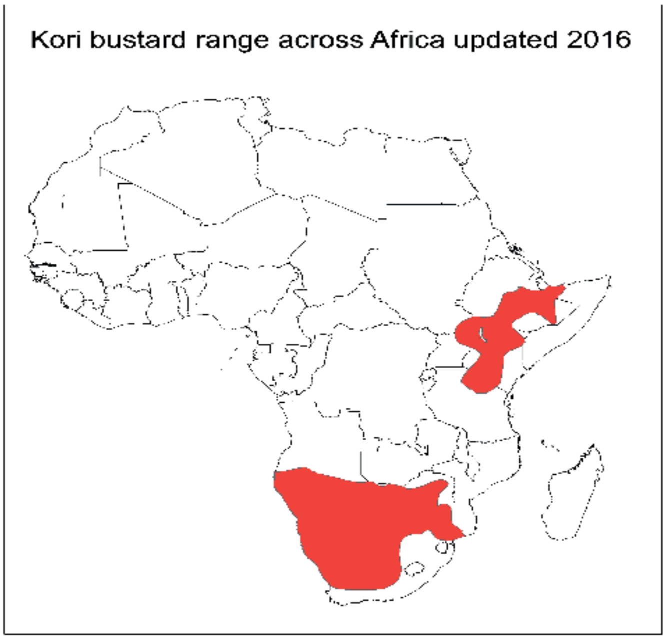

Figure 4a**:** Kori bustard range in Africa (Source: BirdLife International)

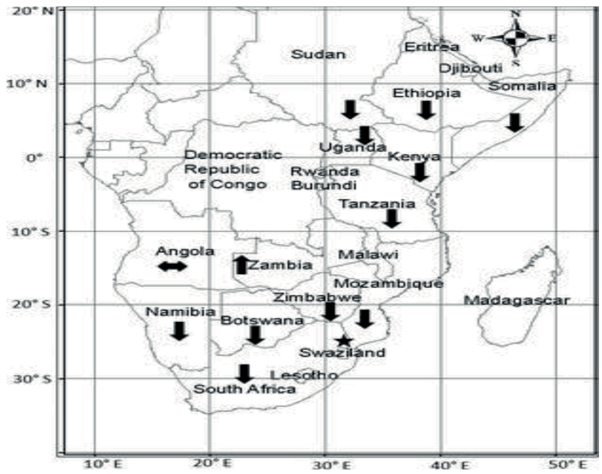

Figure 4b: Kori Bustard *Ardeotis kori struthiunculus* population trends in each range state from 1970–2009 based on published sources and in-country expert opinion. ★ Strong evidence for possible local extinction; ⬇ strong qualitative evidence for population decline; ⬌ population trend unclear; ⬆ strong qualitative evidence for population increase. None of the range states have quantitative estimates of population decline (Senyatso et al. 2013).

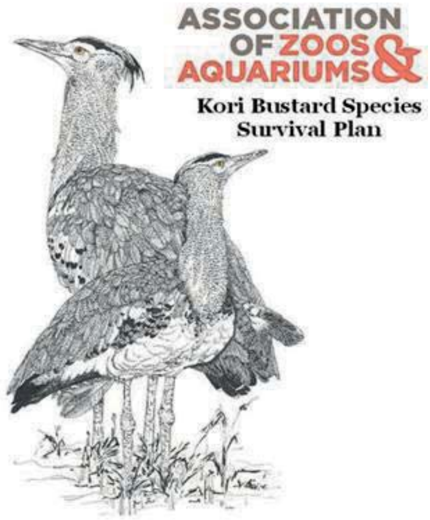

Figure 5: Pictures showing morphological differences of the two sexes of Kori bustard.

Data Collection

The entire study was conducted between 2013 and 2015 in SNP and adjacent communities in the northern part of the Serengeti ecosystem. The study in the northern Serengeti communities aimed to understand local knowledge of the ecology of and threats to the species prior to embarking on the ecological study.

Local Ecological Knowledge and Threat

Thirteen villages were selected based on their proximity to the Serengeti National Park, Loliondo Game Controlled Area, Ikorongo Game Reserve and Ikona Open Area, where the Kori bustard could be frequently observed. Households interviewed were randomly selected within each village. A picture of the Kori bustard was presented to survey participants for identification. Individuals who correctly identified the species were further interviewed to understand their knowledge in relation to the species. Closed ended questionnaires were administered to collect data on the local understanding of ecology and perceived threats to the Kori bustard in the northern Serengeti communities on 2013 (Paper I).

Occurrence in the Grass Plains

Data estimating Kori bustard density, occurrence, breeding and behaviour were collected through transect counts from 2014 to 2015. Transect counts for the Kori bustard were conducted for four days at the start of every month for the entire study period. Kori bustards within 100 m on each side of the transect vehicle were counted and recorded after every 1-km long transect, including those that ran away, provided they were within the transect during counting. When a 1-km transect was completed another 1 km was driven without making any recordings (Paper II).

Breeding Ecology

The breeding ecology of Kori bustard was investigated between 2014 and 2015. To search for and record the nests, chicks and subadults, random 1 km transects were surveyed from a vehicle followed by breeding habitat such as grass height and grass colours. Courtship displays were recorded when the male Kori bustard showed a full neck and white tail feather display (Fig. 1). Females hiding in the grass were treated as an indication of nesting females, and the search for nests was intensified. Female and male Kori bustards that were not in display were also recorded for adult male-female sex ratio (Paper III).

Migration and Resource Selection

The Kori bustard was approached by driving slowly and following it for approximately five minutes until it was unwilling to run fast. Then, the vehicle stopped close to the bird, and a person jumped out and captured it by hand. GPS satellite collar (AWT 210 grams and ARGOS 105 grams) were fitted to the back of 14 kori bustards (Fig. 6) to track seasonal migration and resource selection between 2013 and 2014 (Paper IV).

Figure 6: Kori bustards fitted with GPS collar backpacks.

Major Findings

Paper I emphases the ability to identify Kori bustards and understand the local ecological knowledge and factors leading to the decline of the species among local people close to Serengeti National Park. Paper II focuses on the density and occurrence of the species in relation to the season, area, grass height and colour. Paper III gives highlights on the breeding signs, season, area, habitat and number of nests and eggs. Paper IV focuses on movement of the species during different seasons and types of habitat utilized by the species in different seasons.

Paper I: Local Ecological Knowledge and Perceived Threats

We assessed local knowledge of the Kori bustard in the 13 villages around the northern and eastern part of the Serengeti ecosystem. The results of this study indicated that gender and tribe are important factors in explaining variation in the knowledge of Kori bustard ecology.

Our results show that 59.7 % (N = 330) of interviewed individuals identified the picture of Kori bustard correctly. Of the interviewed tribes, the Maasai tribe show the highest knowledge of identification of the species at 97 % (N = 107. Approximately 66 % (N = 107) of the interviewed individuals from the Ikoma tribe could identify the species, whereas 18 % (N = 103) of interviewed individuals from the Kurya tribe were able to identify the species from the picture. Only 44 % (N = 25) of the remaining interviewed tribes could identify the Kori bustard correctly. The difference among tribes in identifying the Kori bustard through its picture was statistically significant.

Our results further revealed that gender knowledge of identifying the species was statistically significant, whereby males were able to correctly identify the Kori bustard more often than females. In total there was a high level of knowledge regarding the habitat of the species, frequency of observation, population size, group size, nesting habitat, food used by the species and factors that threaten the survival of the Kori bustard among the interviewees. The results indicated that 80.6% of respondents claim that the species is rarely seen, 91.0% claimed the population is small, 90.5% indicated that the species nests in open grasslands, 90% claimed that it feeds on a variety of food and 77.6% claimed that illegal harvest is the biggest threat to the species.

Generally, the best understanding of the biology of Kori bustard was shown by the Maasai tribe (64.5 %), which had the highest level of knowledge varying from good to very good knowledge. The Ikoma tribe ranked second at 54.8 % by having varied knowledge of the biology of the species. Kori bustard knowledge variation on the biology of the species was significantly explained by gender, with males having more knowledge than females. There was no difference in knowledge variation with regard to education level and different age groups, and it is not clear why such education and age variation occurred.

Paper II: Density and Occurrence

The overall results of this study showed that the density of Kori bustard in the short grass plain was determined by season and area rather than grass colour and grass height.

The results from this study indicated that 70.2 % of observed Kori bustards were observed as a single individual. Although Kori bustards were mostly observed as a single individual, the mean density of the species in the grass plain where this study was conducted was 1.3 per km^2 (N = 1897) individuals. Different selected sites in the study area differed in the density of the Kori bustard. Although it was not statistically significant, the density of the Kori bustard was highest in the north west and south east areas. The results also showed significant differences between the density of the Kori bustard and different grass heights within different transects. In this study, the short grass with height ranging from 11-30 cm accommodated a high density of Kori bustards compared to other grass heights. Likewise, the results showed that population density was highest in the green grass habitat, although the green colour was most common when it was longer than 10 cm and there were significant differences in the frequencies of green colour in different grass height groups. Our results indicated that the density of the Kori bustard in the study area was determined by four major different seasons and differed significantly. The density of the Kori bustard was highest during the long rain season that runs from April to June and during the short dry season that runs from January to March. It was also observed that the density of the Kori bustard was lowest during the long dry season from July to September. Consequently, the density of the species was also the lowest during short rain season that runs from October to December.

Paper III: Breeding Ecology

The study revealed that the breeding of Kori bustard starts with courtship behaviour, which peaks during the short dry and short rain season before the peak in nest and chicks during the long rain season. Frequent courtship displays were observed during the noon time and in the short grass habitat, although it was not statistically significant ($\chi^2 = 5.26$, df = 2, p = 0.072 and $\chi^2 = 4.32$, df = 2, p = 0.116, respectively). The courtship display was mostly observed in the north east of the study site, whereas the courtship display in the south west, south east and north west sites were very similar. From this study, the high frequency of courtship displays was observed during the short dry seasons and short rain season and there were no differences in courtship displays in different grass heights and colours. The site were generally found to be the main predictor of the courtship displays.

The results showed that there was both adult male and female skewed sex ratios in different seasons and grass colours. A female skewed sex ratio was observed during the short dry and long dry seasons. A male skewed sex ratio was observed during the long rainy and short rainy seasons. With respect to grass colour, the sex ratio was female skewed in the green habitats and male skewed in greenish and brownish habitats; however, there was no skewed sex ratio in relation to grass height. The season and site were generally found to be the main predictor of the adult male and female sex ratio.

Although there was high courtship display frequencies in the north east, the highest number of nests (64.3 % of the total observations) was found in the NW site, while nests were absent in the south east and south west sites of the study area. The study showed that Kori bustards nest most during the short dry season (71.4 %), with few nests during the long rain season (28.6 %), and most nests were found in the brownish grass habitat. The results generally showed that the brownish grass colour and short grass were most preferable variables for the nesting of the Kori bustard.

The results further indicated that although there were more nests with two eggs, there is a probability of only one chick to be raised according to Fisher's exact probability test (P = 0.004). It was observed that female Kori bustards undergo several breeding attempts within a single breeding season if the nest is predated; however, this was single observation.

Paper IV: Seasonal Migration and Resource Selection

The results from sex identification using DNA analysis indicated that of the 14 individual Kori bustards fixed with satellite GPS collars, 9 were females and 5 were males. Our research findings showed that male and female Kori bustards had different home range use that further differed by month and season. Female Kori bustards were more clustered from February to May, which is the period of long rainfall, and the clustering was reduced during the other months, signifying that the female Kori bustard utilize bordering areas of their utilized core area or move and utilize other habitats. Unlike females, males' home ranges were clustered year round with the exception of January and February.

The migration movements were clearly indicated by males as they moved far away from the areas of capture, especially during the dry season from July to November, although their movement was restricted to within the Serengeti ecosystem. This movement fluctuation was minimal in females, however, especially during the short dry season from January to April. The results revealed the presence of distinct movement in the Kori bustard during the breeding season (December-June) and non-breeding season (July–November). Moreover, the male Kori bustards showed a high average home range size (589.5±2 SD) compared to the female home range size (376.5±2.1 SD) during the breeding season and a home range size of 405.0±3.8 SD during non-breeding season, whereas females had a home range size of (363.3±1.5 SD). The average annual home range size was also higher in males (501.9±2.7 SD) than the annual range size of females (370.9±1.8 SD).

As for the parsimonious model, the results show that both sexes of Kori bustard indicated noticeable differences in habitat preferences. Male Kori bustards showed a preference for open grassland and shrubbed grassland, whereas females preferred treed grassland. Further, the results highlighted that the habitat preference in male Kori bustards alternates between the breeding (shrubbed grasslands) and non-breeding season (open grasslands).

Discussion

This thesis provides basic information and findings about the Kori bustard regarding local ecological knowledge, occurrence and density, breeding ecology, seasonal migration and resource selection. My results and findings provide new information about the Kori bustard in Tanzania.

Local Ecological Knowledge and Perceived Threats

The results indicated that the majority of local people in the northern Serengeti had good knowledge of the Kori bustard's ecology and threats faced by it. The nomadic nature of activities and long lives among the Maasai (pastoralists) and Ikoma (hunters) people contributed to the understanding of the habitat of and threats to the Kori bustard (Paper I). It has been described that the cultural sharing of traditional activities and ancestral knowledge with subsequent generations over a long period of time builds on the experience of the past and present generations (McGregor 2000, Papworth et al. 2009). Thus, it is clear that wildlife hunting tribes, such as the Ikoma people, will acquire knowledge of the species (Barnett 2000, Magige et al. 2009). As a result of the division of house hold activities, males exhibited a better understanding of the biology of the Kori bustard as they graze and water cattle across large geographical areas while females are confined to indoor activities (Paper I) (Pfeiffer and Butz 2005, Mmassy and Røskaft 2013). Previous studies have shown that females had more negative attitudes towards wildlife conservation (Kideghesho et al. 2007, Røskaft et al. 2007), which probably demoralizes knowledge of understanding of birds. The study also found that education level and age does not necessitate knowledge of understanding birds as the ability of respondents to identify the Kori bustard was not significant, indicating that local indigenous people share the knowledge among themselves regardless of age and education level. The hunting of the Kori bustard as a source of meat for households among northern Serengeti tribes (Magige et al. 2009) suggests the possibility that every individual could know the biology of and threats to the species. Respondents presented correct knowledge about the feeding, nesting habitat and rare observation of the species in the ecosystem and surroundings villages as they experienced before. This was due to habitat loss in adjacent areas to the ecosystem through conversion to subsistence farming and hunting for food. This knowledge corresponded to the literature review on the cause of scarcity of the species across its range (Stevenson and Fanshawe 2002, Magige et al. 2009, Senyatso et al. 2013). A similar study examining the local ecological knowledge of Ivory gull revealed the decline of the species in Arctic Canada (Mallory et al. 2003). This local ecological knowledge is important as it can provide inputs for further actions and management implementation for the conservation of the species. The knowledge of the species presented by the northern Serengeti people is actual information that is known in the literature on the Kori bustard. This knowledge can be linked directly to the ecological preferences and threats faced by the species. It is clear that ecosystems are undergoing rapid changes and should be mirrored in human ecological knowledge of the ecosystem change and species disappearances. The knowledge and practices of local and indigenous people can increase awareness of changes occurring in various ecosystems and offer insight into strengthening and managing ecological systems and species loss (Garibaldi and Turner 2004). The attitudes of local communities adjacent to the ecosystem towards species conservation must be assessed for proper conservation measures, including the participatory community-management approach.

Density and Occurrence

The density of the Kori bustard was found to be 1.3 birds per km^2, although there has been no study conducted on the same species in any part of Tanzania for comparison to know the current density status of the species and it was not significantly different among the study sites. Although the short grass plain of Serengeti ecosystem covers approximately 10,000 km^2 (Sinclair 1978), the Kori bustard occurs only in areas where the grass is less than 1 metre tall (Paper II & III), which makes it difficult to estimate the total population of the species as it is seldom found in tall grass (Paper II & III). The intensive land use, population increase and hunting practices in communities adjacent to the Serengeti National Park contributed to the low number of species (Paper I). The density of the Kori bustard was high in green grass habitat and medium grass height of 11-30 cm, demonstrating a good habitat structure important for food accessibility and vigilance opportunity against predators (Block and Brennan 1993). Kori bustards associate with wild ungulates in green grass habitat that provide protection from predators and food by flushing out insects in animal trampling (Fernández-Juricic et al. 2004, McCollum 2015). Fresh droppings from wild ungulates attract beetles and other invertebrates, which are one of the Kori bustard's food components. High density was observed during the short dry season and long rain season, which was linked to breeding season preparation as courtship displays occurred earlier in the short rain season and continue towards the long rain season (Paper III). The species density declined after the breeding season, which describes species migration to other habitats possibly due to food, courtship or predator avoidance (Paper IV).

Breeding Ecology

As revealed by the study, courtship behaviour is critical during the short dry and short rain seasons. This is evident in the previous study that the density of the species was found to be higher during short dry season than any other season in the study area (Paper II), which expounds similar concerns to the Australian bustard *Eupodotis australis* (Ziembicki 2010). This behaviour tends to reflect the breeding season preparation of the species. Prior establishment is generally a reproductive strategy for birds to hatch their young in nests when food is abundant (Perrins 1970, Drent 2006). Courtship display frequency was observed in short grass, although it was statistically insignificant. This suggests that habitat selection may be based on abundant food resource availability during reproduction (Moreira et al. 2004, Traba et al. 2008, Tarjuelo et al. 2013). The highest courtship display frequency was observed during the noon time 11.00 am to 2.00 pm, although it is statistically insignificant. Courtship display time has been observed to differ from displays reported from captivity (Mwangi 1988, Hallager and Boylan 2004, Gompu 2012). Variations in environmental conditions between wild and captive breeding may influence courtship display time, although more study is needed. The Kori bustard sex ratio was male skewed during nesting season. The skewness tendency proposes that male Kori bustards engage in post mating migration during nesting (Paper II & IV) as they play a main role in provisioning of gametes and none in the parental care of young (Jiguet and Bretagnolle 2001, Moreira et al. 2004). Most nests were observed during short dry season in short and brownish grasses reflecting the preparation of breeding season for young to coincide with abundant food supply during long rain season (Paper II) and that Kori bustard nest in habitats with good visibility to detect and camouflage eggs against predators (Magaña et al. 2010, Zadeh et al. 2010). Female Kori bustards undergo several breeding attempts within a single breeding season after former nests' predation; however, single observed females could not validate statistical tests. Nest predation accounted for 36 % of observed nests in SNP. This predation phenomenon exists among Kori bustard families (Magana 2007). The mean clutch size of the Kori bustard was 1.4 eggs, which is small compared to the mean clutch size of more than 2.1 eggs for other bustards (Rocha et al. 2013, Koshkin et al. 2016). The average brood size was 1.0 chick per brood; this varies from the southern African sub-species *A. k. kori*, which was found to have an average of 1.52 chicks (Osborne and Osborne 1998).

Seasonal Migration and Resource Selection

The study found sex differences in the seasonal movement behaviour of the Kori bustard with clustered home ranges for females from February to May, signifying a critical breeding period (Paper III) and resource availability (Senyatso 2011). Female breeding bustards have a smaller home range as they take part in incubation and take care of young (Jiguet et al. 2000). Clustering was reduced in the remaining months, indicating low or no breeding and dispersal movement (Alonso et al. 2000) away from the natal nesting area for food and predator avoidance. Males showed clustered home ranges during breeding and non-breeding seasons except January and February, demonstrating courtship display movement to the open habitat and thereafter returning to their area of preferences (Takahashi et al. 2015). The presence of different home range sizes during the non-breeding season is reflected in the tendencies of some individuals to have longer migration movement while being absent in other individual; however, the seasonal home range size of males and females did not differ despite clear migration.

The migration movement of the Kori bustard is influenced by breeding and non-breeding seasons. Males indicated a clear migration movement away from the area of capture during the dry season from July to November just inside the Serengeti ecosystem; however, there is no clear reason for long migration in males only and not for both sexes as females exhibit no clear migration.

Migration may relate, however, to distinctions in the spatial-temporal distribution of resources and courtship, as for other bustards (Alonso et al. 2000, Morales et al. 2000).

Females did not show movement in the ecosystem except small fluctuations from January to April which is perhaps driven by seeking displaying males for copulation, resource availability or camouflage from predation. Searching for a new breeding habitat or additional mating after the previous clutch loss can also be a major reason (Tarjuelo et al. 2013).

The habitat preferences of male and female Kori bustards differed from each other and in different seasons. Males preferred open grassland and shrubbed grassland, whereas females preferred treed grassland, which indicates that the species breeding system requires different habitats for different activities. Males require open grassland habitats that accelerate displays to females, while females require habitats with vegetation that warrant concealment and feasible nourishment of young (Paper III), (Morales et al. 2008, Lapiedra et al. 2011, Traba et al. 2015). In this study, females preferred only treed grasslands during both breeding and non-breeding seasons as males were alternating their preferences in open grassland and shrubbed grassland during breeding and non-breeding seasons. Two different habitat preferences due to periodical movement in males may play different roles for food in shrubbed grasslands and courtship display in open grassland. Species that use most of their time dwelling on the ground are found to depend most on vegetation linked to the factors that facilitate individual life and reproduction (Delgado and Moreira 2000, Morales et al. 2008).

Prospect for Future Studies

The Kori bustard is listed in appendix II of CITES and on the IUCN red list as near threatened species. This study is unique in disclosing basic information on the LEK, occurrence and density, breeding ecology, and seasonal movement including resource selection of the Kori bustard in the Serengeti ecosystem. To conserve *A. kori struthiunculus* for future generations, additional studies on the species are needed, especially ecological requirements, as the species utilizes different habitats in different seasons. The management authority must conduct a recruitment assessment of Kori bustards in the Serengeti ecosystem to develop future strategies for the conservation of the species, especially outside of the PAs and buffer zones. The species is confirmed to utilize hunting blocks in the ecosystem, a situation that will clearly hasten illegal offtake of the species for meat and trade. Because density data for the species is lacking and no records are available as the species has never been researched in Serengeti ecosystem, the recorded density in this study cannot be considered as high or low; hence, the study on the density and habitat requirements of the species must be repeated at least after five years. The increasing illegal exploitation of natural resources by local people from communities alongside the Serengeti National Park makes community participation in the conservation and management of the species important. Public education by protection managers on threats and how to conserve the species would help to minimize illegal offtake and further species decline.

Because this study was the first conducted on this species in the Serengeti National Park, the mapping of the species over the entire ecosystem, additional collaring of male and female Kori bustards and additional breeding information is necessary for understanding their habitat requirements.

Conclusions

Birds' conservation is strongly dependent on available local information to assist in developing conservation priorities, strategies and implementation of conservation programmes. Local ecological knowledge of the Kori bustard and threats to it in the northern Serengeti is well acknowledged and transferred among local residents with regard to gender, age, tribe, and education. Locals' understanding of the Kori bustard's ecology and its threatened status can assist the management authorities to increase their efforts and further conservation strategies of the species outside protected areas.

The density of Kori bustard is high during the long rain and short dry seasons and its distribution is influenced by grass height (11-30 cm) and season. Courtship displays are initiated during the short rain season (October-December) and peak during the short dry season (January-March). The preferred nesting habitat is grassland and the Kori bustard can undergo several breeding attempts within a single breeding season due to nest predation. Predation of the species is possibly high as few nests, chicks and subadults were observed during the transect counts however this should be interpreted with caution as nests and chick may be hidden in tall grass and difficult to detected. The sex ratio is male-skewed during the breeding period and after the mating period, indicating a post-breeding migration of males. The breeding season in the Serengeti plain is relatively long as chicks were seen in different seasons except for the long dry season. The study highlights how available seasonal resources and habitat preferences are forming the movement patterns of the Kori bustard in the Serengeti ecosystem. The movement patterns among individual Kori bustards during the breeding and non-breeding periods indicate partial movements among females, whereas males migrate between different habitats of open grasslands and shrublands. The Kori bustard's habitat preferences in the Serengeti ecosystem are sex-specific and differ throughout the year with males utilizing mostly shrubbed and open grassland and females utilizing mostly treed grassland.

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Factors affecting local ecological knowledge and perceived threat to the kori bustard (*Ardeotis kori struthiunculus*) in the Serengeti Ecosystem, Northern Tanzania

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This study examines local tribal knowledge regarding the ecology of the kori bustard (*Ardeotis kori struthiunculus*) and assessed threats to this species in Northern Serengeti communities. A picture of an indigenous kori bustard was presented to survey participants in villages in the study area. General knowledge on the kori bustard was tested in relation to the bird's general habitat, nesting habitat, food and number of individuals in groups. Of the survey respondents, 56.7% knew the name of the kori bustard and were therefore included in further analyses. The Maasai tribe showed the greatest knowledge of the species, with 98% of individuals identifying the species correctly. Additionally, male survey participants were generally more knowledgeable than females. No differences among age groups or individuals with different education levels were found, suggesting that there is a local knowledge transfer of the species to all age groups regardless of educational level of respondents and that education is not an obstacle to the local knowledge. The study concludes that nature of activities e.g. nomadic and social life, gender and tribes were contributing factors to the knowledge of the kori bustard in the northern Serengeti.

Key words: Local knowledge, kori bustards, Serengeti ecosystem.

INTRODUCTION

The study of local ecological knowledge (LEK) has been growing as a scientific field in recent years, partly due to the recognition that such knowledge can contribute to the management of various ecosystems and ecological processes, the conservation of biodiversity and rare and threatened species, and the sustainable use of natural resources (Berkes, 1999; Colding, 1998; Johannes, 1998). LEK is the informal, often explicit knowledge held by a specific group of people about their local ecosystems and includes the interplay between organisms and their environment (Olsson and Folke, 2001). LEK differs from 'traditional' ecological knowledge

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(TEK) in the sense that the former has been derived from more recent human-environment interactions (e.g. those occurring within a few generations) rather than being embedded in deeper cultural practices (Ohmagari and Berkes, 1997).

Analyses of many LEK systems have identified various components of LEK, including a component related to local observational knowledge of species and other environmental phenomena, a practical component related to resource use activities, and a belief component related to how people fit into or relate to ecosystems (Berkes et al., 2000). The understanding of LEK plays a major role in aiding and promoting the improvement of scientific research and the management of ecosystems (Berkes et al., 2000).

The study of LEK began with species identification and classification (ethnobiology) and evolved to include the study of people's understanding of ecological processes and their relationships with the environment (Berkes, 1999; Williams and Baines, 1993). Not all traditional practices and belief systems are ecologically adaptive, and they can change with time. Acknowledging the importance of LEK is commonly assumed, incorrectly, that indigenous peoples sustainably conserve natural resources (Redford and Sanderson, 2000). Local traditional knowledge has showed an intergenerational decline and may vary with age and gender (Gómez-Baggethun et al., 2010; Law et al., 2010; Quinlan and Quinlan, 2007).

Local ecological knowledge about medicinal plants and the identification of traditional foods appears to decrease with increasing formal education (Giovannini et al., 2011; Wester and Youngvanit, 1995). Thus, formal education may contribute to the loss of local traditional knowledge because it reduces the time and number of opportunities that children have to attain local traditional knowledge and skills from their elders (Heckler, 2002; Luoga et al., 2000).

Local knowledge and its applications seem to be declining owing to a combination of factors, including loss of local language, land use change, inaccessibility to traditional resources due to conservation programmes, industrialization and globalization, and the transition to market economies (Benz et al., 2000; Kingsbury, 2001; Turner and Turner, 2008). Because this loss of knowledge affects local communities in developing countries, the remaining local ecological knowledge must be safeguarded through a number of methods, including environmental policies designed to protect its pools (Montes, 2010).

Local ecological knowledge can be maintained in traditional communities by controlling and monitoring access to certain sites and resource use. This may result in improvements of the knowledge base, which can then be used to respond adaptively to change in certain environments. Through the use of particular local knowledge, a community may benefit by securing employment and education through conservation experiments and/or natural resource management in a specific project area that is related to local ecosystem conservation (Drew and Henne, 2006). Indigenous people are frequently experts on their local ecosystems and can have a broad spectrum of indigenous knowledge. Rapid local language shift to the global language might however, make them lose this intellectual knowledge. Many cultures have disappeared as a result of indigenous people exhausting the environment's ability to sustain their population (Mazzocchi, 2006). Further-more, such disappearance of indigenous culture has been exacerbated by European colonization, which has eroded and destroyed much traditional knowledge by replacing it with Western educational and cultural systems (Mazzocchi, 2006); economic development and the transition to market economies (Godoy et al., 2005); loss of access to traditional resources due to conservation policies; and more generally, the forces of industrialization and globalization (Turner and Turner, 2008). Local and traditional ecological knowledge is increasingly recognized as an important component of scientific research, conservation, and resource management, especially where LEK and TEK fill gaps in the scientific literature or offer a critical source of basic environmental data (Thornton and Scheer, 2012).

Gathering scientific information regarding local ecological knowledge of kori bustard has never been carried out in the Serengeti ecosystem. In this study we found that 1) illegal hunting among local people for food exists, 2) kori bustards are rarely observed indicating a low population size, and 3) that their nesting habitat outside the national park has been turned into agricultural land and human settlements. Thus it is obvious that the species is in unimaginable threat. The outcome of our study has provided us an image that the species needs to be closely monitored and that local communities/tribes who are more knowledgeable on kori bustards are to be fully involved in conservation of the species to provide their ideas to the management authority on how to conserve this species in the future.

Study species

Although kori bustards are used by tribes in the Serengeti ecosystem as a source of food in household diets (Magige et al., 2009), there is no clear evidence that the species is used in other social cultural, or economic contexts. In Tanzania, the current range of the kori bustard is restricted to the northern plains of the Serengeti and the Tarangire-Manyara ecosystems. The range of this sub-species where it was historically found (in parts of East Africa, Somalia, Sudan and Ethiopia) has been shrinking, such that its current range is much smaller than its historical range (Hallager and Boylan, 2004).

The kori bustard is listed by CITES (Appendix II) as near threatened (Birdlife-International, 2009; 2013) and faces many threats. The main threats to the kori bustard are human-induced, including habitat destruction through agricultural development, as well as shrub encroachment caused by overgrazing and subsistence hunting (Magige et al., 2009; Senyatso et al., 2013). The poison used to control locusts is toxic to birds and may also be affecting the kori bustard populations (Barnes, 2000). The kori bustard is an omnivorous species, and its food sources are expected to be quite diverse. However, according to Arlott (1996), kori bustards consume mostly insects and plant material in their grassland habitat. The population status of this species and its population trends remain unknown, both in Tanzania and the entire East Africa. Thus, local understanding of ecology and threat of the kori bustard may provide inputs that management authorities can apply for sustainable management of areas where the small range of species occurs.

Since people in the northern Serengeti live a traditional life style that includes hunting wildlife for food and as a source of income, we hypothesised that people in our study area might have LEK of the kori bustard *(Ardeotis kori struthiunculus)*. We also hypothesised that there would be differences in local knowledge of this species' ecology among different tribes. We further hypothesised that the threats faced by the kori bustard are well understood by the people of the northern Serengeti because they live in the villages adjacent to the Serengeti National Park where the species is found. Scientific information about this species' ecology and the factors influencing the major threats to the species is limited. The goal of our study was to provide information on whether the species needs to be monitored, which includes the possibility of local community-based monitoring because the species utilizes habitat found on communal lands. The outcomes of the study could also help management authorities consider impacts to this species when developing various conservation programs in the communities surrounding protected areas. Local knowledge could provide broad insights into kori bustard conservation that could be used by management authorities when developing management plans.

METHODOLOGY

Study area

The mean temperatures in the study area range between 15 and 27°C, while the mean annual seasonal rainfall varies from 1,050 to 1200 mm (Sinclair et al., 2000). According to United Republic of Tanzania (URT) (2003, 2013), the study area has a total population of approximately 40,000 people.

The Serengeti ecosystem covers an area of 25,000 km^2 and straddles the border of northern Tanzania and southern Kenya. The ecosystem comprises several different conservation areas (Figure 1) that harbour a variety of animals such as wildebeests (*Connochaetes taurinus*), antelopes, carnivores and birds. A yearly migration of animals including wildebeests occurs in the area (Maddock, 1979) of which during the northern migration, the wildebeests often travel out of the protected area and enter unprotected areas with comparatively high human population densities. During the migration season, kori bustards are associated with the migrating animals and may be vulnerable to snares used by poachers to catch large animals. The villages found along the Serengeti ecosystem are fairly typical of the region, in that, hunting of wildlife for food is still a common practice (Holmern et al., 2007).

Study communities

The Northern Serengeti is highly diverse in terms of ethnicity. Over 20 tribes live in the area. We were able to interview individuals from the major and the largest tribes, including migrants. Individuals from the Meru, Chaga, Iraq, Mbulu and Sonjo tribes are immigrants to the northern Serengeti. Agro-pastoralism plays a major role in the livelihoods of these tribes. Although we interviewed people from 18 tribes in the selected villages, we used only the data from the three largest tribes (Maasai, Kurya and Ikoma) in our analyses because these tribes had sufficient number of survey respondents. There are no inter-tribal conflicts among the interviewed tribes; however, the health of the ecosystem suffers due to conflicts between conservationists and local communities. The conflict stems from the conservation and management authority prohibition of access to natural resources for many tribes living in the area (Kideghesho et al., 2007). The Maasai are nomadic, herding their livestock to green pastures and water. The Ikoma have traditionally hunted wild animals as a source of income and food, while the Kurya have traditionally been primarily farmers, but practice hunting activities to some degree.

Generally, the people in the region are poor (US $150-200 per annum). Their annual incomes, which are generally earned through agro-pastoralism, are far lower than Tanzania's average per capita income of US $280 (WB, 2003). To compensate for the hardship of earning a low income, many communities in the area engage in illegal hunting and charcoal burning (Kideghesho, 2010). With the increasing rates of human and livestock population growth in the region, these activities have caused ecosystem fragmentation, natural resource depletion and habitat destruction (Kideghesho, 2010), including the extinction of bird species of conservation concern.

Data collection using questionnaires

The study site was selected as an example of the type of socio-ecological context that occurs where communal areas are adjacent to protected areas. However, the site was also selected because of the conflict between local communities and management authorities towards access to wildlife resources.

Fieldwork was conducted in 13 villages of the northern Serengeti that were selected prior to beginning of the survey in October, 2011. The villages were selected based on their proximity to protected areas (Loliondo Game Controlled Area, Ikorongo Game Reserve, Ikona Open Area, and Serengeti National Park), where we expected the kori bustard to be frequently observed.

The closed-ended question interviews (Newell, 1993) were conducted in Kiswahili with the aid of well-trained local translators who translated Kiswahili into the local tribal languages because most elders knew only their tribal language. The use of local translators increased the number of people who could be interviewed, because the translators could communicate with respondents in their local language. Furthermore, because the respondents live adjacent to the protected areas and illegal subsistence hunting of wildlife still occurs, they were initially concerned about talking with us because they thought we were

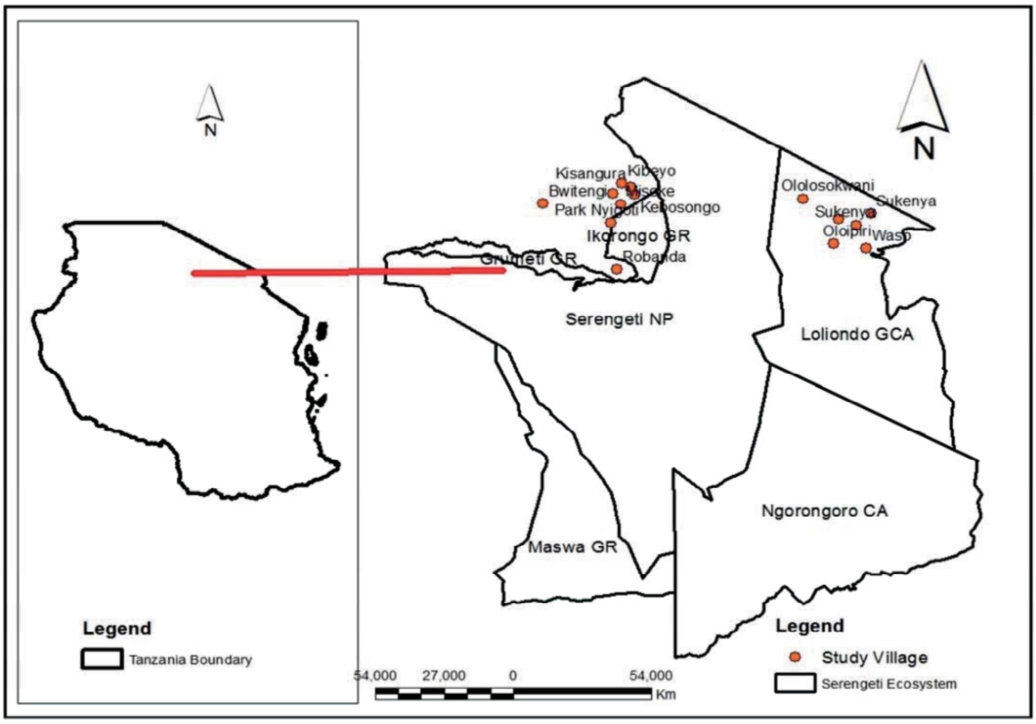

Figure 1. Map of the Serengeti ecosystem showing the locations of surveyed villages in the northern Serengeti.

Figure 2. Kori bustard on the Serengeti plains (photo: E. Røskaft).

wildlife officers who wanted to investigate poaching including the kori bustard. The current proposed road construction from Mto wa Mbu to Musoma town (Fyumagwa et al., 2013) was another barrier to recruiting survey participants, as some people thought we were environmentalists or conservationists who wanted to convince the local people to oppose the proposed road construction. This problem was resolved by the village leaders who convened a village meeting where he expressed our aim to interview people in the area.

During the survey, a picture of the indigenous kori bustard (Figure 2) was shown to the participants. All respondents were between 18 and 85 years of age and were able to recognise the picture as a bird. However, not all respondents were able to identify the species. Face-to-face interviews were conducted in which the respondents were asked different questions after identifying the picture of the bird as kori bustard (Mmassy and Røskaft, 2013). A total of 330 individuals were randomly picked from households in the selected villages, of which 197 individuals (Table 1) were able to identify the kori bustard by looking at the picture. We stratified our sample of interview respondents based on tribe, gender, age and education level to test for species knowledge.

In our analyses, we included only the three most common tribes (Maasai, Ikoma and Kurya) and 25 individuals from a combination of other smaller tribes (Luo, Chaga, Jita, Iraq, Mbulu, Meru, Natta, Maragoti, Mungurumi, Zanaki, Ikizu, Mwira, Sukuma, Isenye, Sonjo) who identified the kori bustard correctly.

Table 1. Knowledge variables related to kori bustard biology derived from the responses of interview participants and the validation of their knowledge using literature.

Variable	Correct knowledge	Incorrect knowledge	No. of respondents
How often do you see the species	Rarely: 80.6%	Frequently: 19.4%	191
Population size	Small: 91.0%	Large: 9.0%	162
Group size	1-2 individuals: 66.8%	>3 individuals: 33.2%	129
Nesting habitat	Open grasslands 90.5%	Mixed woodlands 9.5%	137
Food	insects, reptiles, small mammals, seeds, and roots 90%	insects, reptiles, small mammals, seeds, and roots 10%	190
Threats	Illegal hunting 77.6%	Other, such as accidents, 22.4%	98

Sources: Birdlife-International, 2008; Hallager, 2012; Harrison et al., 1997. Respondents who provided a correct answer were designated as having correct knowledge.

Table 2. Analysis of the general knowledge of the kori bustard among people of the northern Serengeti in relation to gender, tribe, educational level and age groups.

Constant/independent		Dependent variable/general knowledge (%)						
		Poor	Week	Average	Good	Very good	Total	χ^2 =; *p* =
Gender	Male	35.7	7.1	22.0	24.7	10.6	255	19.17; 0.002
	Female	62.7	4.0	14.7	14.7	4.0	75	
Tribe	Kurya	83.5	5.8	4.9	4.9	1.0	103	184.1; 0.000
	Maasai	2.8	5.6	27.1	38.3	26.2	107	
	Ikoma	36.8	8.4	31.6	23.2	0.0	95	
	Others	56.0	4.0	12.0	24.0	4.0	25	
Education	No or primary education	40.7	7.0	20.5	22.3	9.5	273	2.298; 0.807
	Secondary education	47.4	3.5	19.3	22.8	7.0	57	
Age	14-45 years	42.9	5.1	19.8	23.0	9.2	217	6.118; 0.295
	Above 45 years	39.8	8.8	21.2	21.2	8.8	113	

The respondents were asked various questions about the species, such as how often the bird was observed, the habitats in which it was most frequently observed, the species' population size, why the bird preferred to live in the habitat where it is observed, how many individuals were observed at a time per group, where it placed its nests, why it uses a particular breeding habitat, the food source of the species, and threats to the species.

Local people in the Serengeti ecosystem could identify the species to the genus level (bustard). The identification to the genus level, that is, bustard, was done following Balmford et al. (2002), since mammals and birds need genus level identification (e.g., 'rabbit'). We grouped some items of knowledge that varied among only a small number of respondents. For example, rodents and other small mammals listed as food sources were recorded as mammals, while all types of reptiles (snakes and lizards) were recorded as reptiles. Seeds, flowers, leaves, fruits and roots were recorded in a single category as plant materials. All woodland, forest and shrub land habitats were combined and designated as mixed woodlands, while open grassland was retained as a separate category. Frequency of observation of the species was recorded as two categories: observed daily (at least once per week or more) and observed rarely (less than once per week). Information on food availability, safety from predators and the use of different habitats was separated into two categories: food availability and safety from non-human predators and hunters. Species occurrence was categorised as a single individual, two individuals, or greater than two (3-20) individuals.

The information provided by the respondents was assessed/analyzed and compared to information from various literature sources (Table 1) to validate the respondents' knowledge as correct or incorrect (Table 1). Respondents who provided correct answers were designated having correct knowledge and those who could not provide correct answer were designated providing incorrect knowledge (Table 1). The six knowledge variables were thereafter pooled and varied between 0 and 6. Individuals with knowledge for 0 or 1 of the variables were given a value of 1 (poor), followed by those who had knowledge of 2 variables (weak), those who had knowledge of 3 (average), those who had knowledge of 4 (good), and those who had knowledge of 5-6 variables (very good) (Table 2).

Statistical analysis

The information included in the analyses was collected through questionnaire surveys that were coded and entered into a computer. Statistical Package for the Social Sciences (SPSS), version 16, manufactured by SPSS Inc., was used for the analyses. Chi square analyses were primarily used to calculate the percentages of respondents at a significance level of $p = 0.05$.

RESULTS

Of the individuals interviewed, 59.7% (N = 330) correctly identified the picture as a kori bustard, while 40.3% (N = 133) were unable to identify the species. The Maasai tribe was the tribe with the highest level of knowledge of the species, with 97% of individuals identifying the species correctly (N = 107). However, only 66% of the interviewed individuals from the Ikoma tribe (N = 95) and 18% from the Kurya tribe (N = 103) were able to identify the kori bustard from the picture. Among the other surveyed tribes, 44% of the individuals surveyed were able to identify the kori bustard correctly (N = 25). The difference among tribes in identifying the kori bustard was highly significant ($\chi^2 = 139.7$, df = 3, P< 0.001). There was a highly significant difference between the genders, with males correctly identifying the bird more often than females ($\chi^2 = 17.88$, df = 1, P< 0.000). In contrast, there were no significant differences in ability to identify the bird among age groups or individuals with different education levels ($\chi^2 = .848$, df= 1, P = .357; $\chi^2 = .477$, df = 1, P = .490, respectively).

Generally, most of the interviewed individuals knew the kori bustard well, and they displayed a high level of knowledge of the species with regards to frequency of observation, population size, group size, nesting habitat, food sources and threats to the species (Table 1). The Maasai tribe showed a high level of knowledge of the biology of the kori bustard overall, with 74.5% of the respondents showing good to very good knowledge of the bird. The second most knowledgeable tribe was the Ikoma, where 54.8% of individuals exhibited good to very good knowledge. The Kurya tribe was the least knowledgeable, with only 5.9% of the respondents having good to very good knowledge (Table 2; $\chi^2 = 46.8$, df = 12, P< 0.000). Men had significantly more knowledge than women (Table 2), but there were no detected differences in knowledge with regards to the age or education level of the respondent (Table 2).

A linear regression analysis with general knowledge as the dependent variable and gender and tribe (the two variables that were significant in the analyses described above) as independent variables explained 8.8% of the variation in knowledge ($r^2 = 0.088$). The results showed that, in general, tribe (Beta = 0.194, T = 3.611, P< 0.0001) and gender (Beta = 0.191, t = -3.558, P <.0001) independently explained some of the variation in knowledge of kori bustard ecology (ANOVA; F = 15.685, P< 0.000).

DISCUSSION

The majority of the interview participants from tribes in the northern Serengeti knew the kori bustard and showed good knowledge of the bird's general ecology. The overall good knowledge of members of the Maasai and Ikoma tribes on the biology of and threats to the kori bustard may be due to the nature of the activities (hunting and nomadic migration) that have been practiced by these tribes since historical times. Given that the Maasai tribe is pastoralist and nomadic in nature, its members are likely to encounter this species frequently (Mmassy and Røskaft, 2013). The knowledge and understanding of kori bustard ecology within the Ikoma tribe may be due to their hunting practices and the inheritance of hunting knowledge from their ancestors, because hunting has been an integral part of life in Serengeti for thousands of years (Holmern, 2010). The Ikoma have traditionally been a hunting tribe that collects eggs from game birds (Magige et al., 2009) and hunts wild animals for food and income (Barnett, 2000). This type of practice could have increased their knowledge of a species like the kori bustard.

Male respondents generally showed better knowledge of kori bustard biology and were better able to identify the bird from a picture. This result may reflect the division of household tasks in the villages in this study. Males conduct outdoor activities, while females practice more indoor activities (Mmassy and Røskaft, 2013; Røskaft et al., 2004). According to Pfeiffer and Butz (2005), Maasai women are responsible for taking care of domestic animals in small confined areas around their homes, while males graze herds of cattle across large geographical areas.

Females are frequently less knowledgeable about wildlife, including birds around the world (Kideghesho et al., 2007; Mmassy and Røskaft, 2013; Røskaft et al., 2007). However, ethnobiological research suggests that women are more knowledgeable about medicinal plants and small mammals because they are more engaged in healing practices and the collection of food (Letsela et al., 2003). This type of knowledge can, on the other hand, vary with geographical location, social status, ethnicity, occupation and experience (Heckler, 2002). Therefore, we suggest that the different societal roles of the two genders in our study may have resulted in greater knowledge of birds among men (Røskaft et al., 2004).

Formal education is not necessarily a prerequisite for having local knowledge of a certain place. In fact, research in the fields of ethnobiology, natural food identification and ornithology has revealed variation in local knowledge between people with a formal education and those without education. In this respect, educated people might be less knowledgeable than uneducated ones (Giovannini et al., 2011; Mmassy and Røskaft, 2013). In our study, we found that the ability of respondents to identify the kori bustard was similar without considering the level of education. This suggests that LEK of kori bustard has been shared among the indigenous people of all age groups and education levels in the study area. Again if the kori bustard has been used as food source in the study area it is possible for almost every individual to acquire some knowledge of the species. The yearly association of the kori bustard with the animal migration (wildebeest) may also have contributed to the increased identification knowledge of the inhabitants.

Most respondents displayed correct knowledge (according to our comparison with literature sources) of the kori bustard by stating that it was rarely observed in the Serengeti ecosystem. These infrequent observations of the species may indicate a declining population or low population density or both. According to respondents, the rarity of this species might be due to habitat loss as also stated by Hallanger and Boylan (2004) and/or being hunted for food (Magige et al., 2009). According to Hallager and Boylan (2004), both subspecies of kori bustards are facing an uncertain future and birds are absent in areas where they were previously found. However, a population trend for this species was not available at the time of this study because the species' population has not yet monitored in the study area. The range of the kori bustard is much smaller than it was a few years ago due to the fact that the kori bustard is presently declining throughout its range (Hallager and Boylan, 2004). This trend is occurring in the northern Serengeti, where people reported that the species is rarely observed, as there is an increase in human population and the demand of resources in the area. As has been reported in other parts of southern Africa (Hallager, 2012), the rarity of the species in the study area may probably be due to rapid human population growth and activities associated with development.

Given that the gathering of eggs from most large grassland birds, including kori bustards, is tradition among tribes living close to Serengeti National Park (Magige et al., 2009), it would be possible for the tribes to develop accurate knowledge of the decline of the species, even though there are no existing data for the Serengeti population.

In our study area, there was a high level of knowledge on the nesting and feeding habitats of the kori bustard. Local knowledge was consistent with the literature, which shows that the kori bustard nests in grasslands (Harrison et al., 1997). It is clear that LEK can strengthen conservation programs by providing information on a given species (Drew, 2005). Some studies have suggested that local people's knowledge have been used as input for designing and applying management plans for sustainable development, especially in protected areas (Agrawal, 2000; Papageorgiou and Vogiatzakis, 2006). In the case of the kori bustard in the Serengeti, management authorities must work with local people in order to achieve successful conservation of the kori bustard (Ghimire and Pimbert, 1997).

The most serious threat to the kori bustard in the northern Serengeti, according to the respondents in this study, is illegal hunting. This result may act as a challenge to management authorities to take appropriate action because the management authority has never been informed about the presence of illegal hunting of kori bustards. The threats to the kori bustard may be more serious than previously thought, given that its population size is not known and, according to this study, the bird is now rarely seen in the Serengeti ecosystem. The respondents claimed that the greatest threats to the kori bustard are from the hunting of these birds for food.

Bird conservation has been strongly dependent on the available biological information (Filion, 1987). The LEK presented by respondents will largely help in the development of conservation priority strategies and implementation of the species conservation program. The outcome of a study of the species will give information whether the species needs to be monitored, including local community-based monitoring as the species utilize communal lands. It might also help the management authority to take into account this important species when developing various conservation programs on communities surrounding protected areas. Such local knowledge might provide broad insight into management authorities when developing aspects of the species management plan. LEK of a species matters as different local knowledge can be shared between stakeholders which might lead to an extensive knowledge of a species in its surroundings

Conclusion

Local ecological knowledge can help traditional community-based systems control and monitor access to sites and resources, thereby protecting natural resources. To conserve *A. kori struthiunculus* for future generations, we recommend additional research on this species. In particular, information is needed on population status, threats (apart from hunting for food) and ecological requirements. Additionally, public education would help prevent degradation of this species' habitat and minimize illegal hunting, and could be effective measures for preventing further population declines.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Paper II

African Journal of Ecology

Kori bustard (*Ardeotis kori struthiunculus*) occurrence in the Serengeti grass plains, northern Tanzania

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Abstract

The kori bustard (*Ardeotis kori struthiunculus*) is indigenous to grasslands and lightly wooded savannahs of southern and eastern Africa. The species is categorized as near threatened in its entire range due to anthropogenic factors and low reproductive rates. The aim of this study was to analyse the impact of grass colour, grass height, season and location on the density/occurrence of this bird species in the Serengeti grass plains, Tanzania. Data were collected from January 2014 to June 2015 using transect counts in four seasons: (i) short dry, (ii) long rain, (iii) long dry and (iv) short rain seasons, respectively. The mean density of kori bustard in the grass plains was 0.25 ± 1.01 per 0.2 km^2 with near-significant differences among the study sites. The occurrence of kori bustard was high in the medium height (11–30 cm) during the long rain and short dry seasons. The kori bustard density is relatively low, and the distribution varies with grass height and season. We suggest that conservation efforts should be directed at preventing its local extinction by protecting the habitat from excessive human activities, such as livestock grazing and illegal offtake.

Key words: Kori bustard, northern Tanzania, occurrence, season, Serengeti plains

Résumé

L'outarde kori (*Ardeotis kori struthiunculus*) fréquente les prairies et les savanes peu boisées d'Afrique de l'Est et du Sud. L'espèce est classée « quasi menacée » dans la totalité de son aire de répartition à cause de facteurs anthropiques et d'un faible taux de reproduction. Le but de cette étude était d'analyser l'impact de la couleur et de la hauteur de l'herbe, de la saison et de la localisation sur la densité/la présence de cette espèce dans les plaines herbeuses du Serengeti, en Tanzanie. Nous avons collecté des données entre janvier 2014 et juin 2015 en faisant des comptages sur transects pendant quatre saisons : (i) petite saison sèche, (ii) grande saison des pluies, (iii) grande saison sèche et (iv) petite saison des pluies. La densité moyenne d'outardes kori dans les plaines herbeuses était de $0.25 \pm 1.01/0.2$ km² avec des différences quasi significatives entre les sites étudiés. La fréquence des outardes kori était élevée dans les herbes de hauteur moyenne (11–30 cm) pendant la longue saison des pluies et la petite saison sèche. La densité d'outardes kori est relative faible, et leur distribution varie avec la hauteur de l'herbe et les saisons. Nous suggérons d'orienter les efforts de recherche vers la prévention de leur extinction locale, en protégeant l'habitat contre l'excès d'activités humaines, tels le pâturage du bétail et les prélèvements illégaux.

Introduction

The future survival of wildlife is threatened by increasing human pressure due to high human population increases in many countries in sub-Saharan Africa (Abbitt, Scott & Wilcove, 2000; Ceballos & Ehrlich, 2002; Balmford, Green & Jenkins, 2003; Gaston, Blackburn & Goldewijk, 2003; Harcourt & Park, 2003). For a significant period of time, habitat fragmentation and loss has caused displacement and extinction of threatened bird species in various ecosystems (Alroy, 2001; McKee *et al.*, 2004; Senyatso, Collar & Dolman, 2013).

The largest kori subspecies (*Ardeotis kori*) is indigenous to the grasslands and lightly wooded savannahs of

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southern and eastern Africa. The nominate subspecies *Ardeotis kori kori* occurs in Botswana, Zimbabwe, Namibia, southern Angola, South Africa and Mozambique (Johnsgard, 1991), while *Ardeotis kori struthiunculus* occurs in Ethiopia, Kenya and Tanzania. Seemingly, the species has undergone considerable population decline in all its range states, except in Zambia and Angola. In East Africa, the population of *Ardeotis kori struthiunculus* had declined by 21% by the late 19th century (Senyatso, Collar & Dolman, 2013). The species is listed in Appendix II of CITES and categorized as near threatened by the IUCN (BirdLife-International, 2013).

Kori bustard (*Ardeotis kori* spp.) populations are dramatically declining in both open and protected areas that are close to human settlements due to illegal hunting, habitat loss, low reproductive rates, the disappearance of large mammals and collision with power lines (Dale, 1990; Collar, 1996; Lawes, Fly & Piper, 2006; Thiollay, 2006; Manu, Peach & Cresswell, 2007; Magige *et al.*, 2009). Fifteen years ago, the kori bustard population in South Africa was estimated to number 2000–5000 birds (Anderson, 2000), although the numbers are thought to be decreasing throughout southern Africa (Senyatso, Collar & Dolman, 2013). Shaw (2013) found that the annual mortality of kori bustard in the Nama Karoo district alone, due to collision with power lines, was approximately one-seventh of the South African population, that is 720 individuals. In the early 1970s, the kori bustards in Africa were one of the most characteristic elements of the northern Sahelian avifauna, except in the heart of Tenere; however, by 2004, no single bustard was observed (Thiollay, 2006). Increased human population adjacent to protected areas has shown to cause pressure on wildlife through illegal hunting (Herremanns, 1998; Loibooki *et al.*, 2002; Kideghesho, 2006). In Burkina Faso, studies have revealed that the main factors correlated with large bird extinction or decline in protected areas were hunting, habitat degradation and fragmentation due to intensive cattle grazing, wood cutting and farming (Thiollay, 2006). A similar situation was observed in the Serengeti ecosystem where the kori bustard population is declining due to habitat degradation and hunting (Mmassy & Røskaft, 2014).

Behaviour and density are basic aspects of a species' ecology, but remain poorly known for the free-ranging kori bustard and little data exist on wild birds (Mwangi, 1988; Osborne & Osborne, 1998; Hallager & Boylan, 2004; Hallager & Lichtenberg, 2007; Lichtenberg & Hallager, 2008).

Birds' density is often positively correlated with habitat suitability and a sign of minimum anthropogenic disturbance (Huhta, Mappes & Jokimaki, 1996; Martin, 1998; Clark & Shutler, 1999; Robertson & Hutto, 2006). Serengeti National Park holds the largest natural grasslands in the world and is famous for its large aggregates of mammals and birds. However, the bird community structure of these grasslands has been poorly studied (Gottschalk, Ekschmitt & Bairlein, 2007). Maintaining the Serengeti National Park grasslands will provide critical refuges for grassland birds, including kori bustards, Karamoja apalis (*Apalis karamojae*), Francolins, secretary bird (*Sagittarius serpentarius*) and all vulture species, all of which have shown disturbing declines in recent decades (Herremanns, 1998; Sinclair, Mduma & Arcese, 2002).

Therefore, for effective management and conservation action of free-ranging kori bustard in the Serengeti plains, a reliable population estimate is required (Braun, 2005; Marques *et al.*, 2013). The aim of this study was to identify vital environmental factors that influence the occurrence and density of kori bustard within four study sites in the Serengeti grass plains.

In this study, we predicted that (i) because we performed our fieldwork in similar habitats, the density of kori bustard will be similar within the four study areas with no seasonal differences, and (ii) kori bustard will be equally distributed, regardless of differences in grass height and colour.

Materials and methods

Study area

This study was conducted in the Serengeti grass plains in an area located on the eastern Serengeti National Park and western Ngorongoro Conservation Area grass plains, Tanzania, between 1° and 3°30' S and 34° and 36° E (Figure 1). Serengeti National Park (14,763 km^2) is characterized by highland savannahs dominated by thorny woodland trees (*Acacia, Commiphora, Ficus, Combretum* and *Podocarpus*) and extensive grass plains (Herlocker, 1976). However, the study sites in the eastern Serengeti and western Ngorongoro plains are dominated by grasslands. The climate is warm and dry with mean annual temperatures between 15°C and 27°C (Sinclair, 1995).

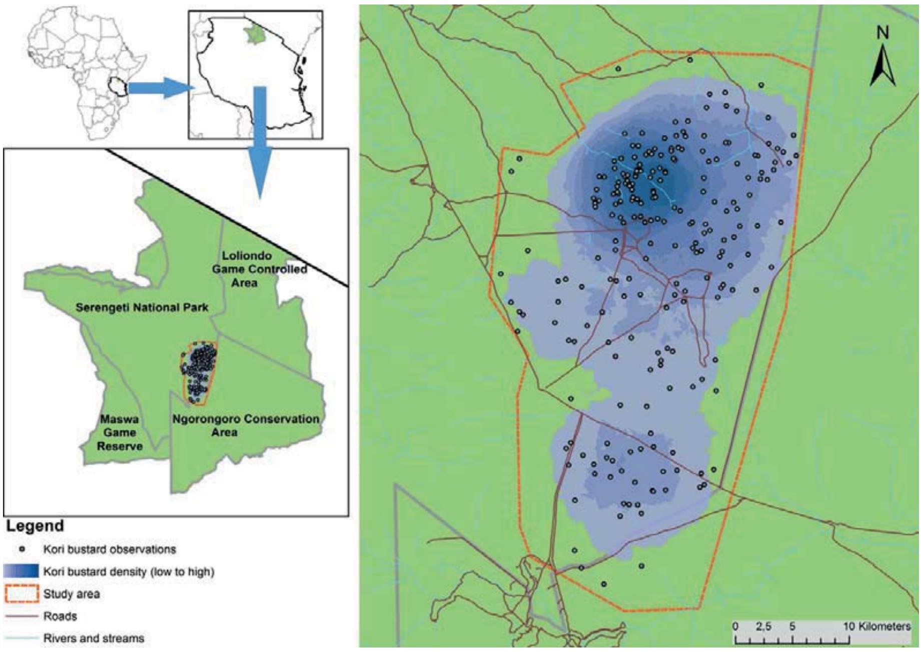

Fig 1 Map of Serengeti National Park showing the Kori bustard study area (indicated in red)

Rainfall on the Serengeti plains is bimodal, and the long rain season occurs between March and May and the short rain season between November and January (Norton-Griffiths, Herlocker & Pennycuick, 1975). Rainfall is generally lower in the south and east (500 mm year^{-1}) of the ecosystem than in the north and west (950–1150 mm year^{-1}). Vegetation cover in Serengeti National Park is influenced mainly by soil type and rainfall and can be broadly classed into eastern grass plains, central acacia woodlands and northern broadleaf forests (Sinclair, 1995).

The Ngorongoro Conservation Area (8094 km^2) spans vast expanses of highland plains, savannah, savannah woodlands and forests, from the plains of the Serengeti National Park in the north-west, to the eastern arm of the Great Rift Valley. The southern and eastern slopes of the highlands receive high rainfall, but the western plains lie in the mountains' rains shadow and receive less precipitation.

In the Serengeti National Park, human activities are prohibited and contrast that of Ngorongoro Conservation Area in which human activities and settlements are allowed. The Ikoma Open Area allows human settlement and some human activities, including livestock keeping, hunting by residents, farming and firewood collection. The neighbouring Ikorongo and Grumeti Game Reserves are partially protected and only allow trophy hunting.

Data collection

The data were collected at four sites including Naabi–Ngorongoro–Ndutu South (south-west, SW), Naabi–Ngorongoro–Ndutu North (north-west, NW), Maasai–Barafu–Golkopjes North (north-east, NE) and Maasai–Barafu–Golkopjes South (south-east, SE) (Figure 1). The study areas are predominantly treeless and dominated by short grass with a maximum height of 30 cm, along with some small trees and shrubs in a few kopje areas. Kori bustard observations were recorded on a monthly basis from January 2014 to June 2015. The study was divided into four seasons: (i) short dry season (January – March), (ii) long rain season (April – June), (iii) long dry period (July – September) and 4) short rain season (October – December). The study sites were selected because of previous anecdotal observations of large numbers of kori bustards during specific periods.

We collected data by driving a vehicle slowly (20 km per h) in randomly selected 1-km-long transects (n = 1897). All birds within 100 m of each side of the observation vehicle were counted; thus, each transect covered 0.2 km². When a 1-km transect was completed, another 1 km was driven without making any recordings. All kori bustards observed within each transect line were recorded, including those that flew away but were within transects at the start of the observation. Kori observations within transects were performed by visual scanning of the immediate surroundings, and Zeiss binoculars (10x40, field 7.1$^{0)}$ when required, while a Leica CRF 900 (200 m) rangefinder was used to determine the distance from the vehicle. The censuses were conducted in all four study sections (NW, SW, NE and SE). A minimum of 25 transects were conducted daily for four days, starting at the beginning of every month and including a minimum of 100 transects per month. Kori bustards were also recorded outside the transects, but these observations were not included in the analysis. Grass height was initially measured by tape measure (100 cm) followed by visual estimates of grass height over the entire area of observation.

Data analyses

Because kori bustard density data were not normally distributed, we log-transformed the data to make them normally distributed. Before log transformation, we added the integer 1 to all observations to avoid transformation of zeros. Therefore, all statistical tests are conducted with log-transformed data.

We determined the density of kori bustards in relation to the following variables: grass colour (green = 100% green, greenish >50% green, brown = 0% green); height of grass was described as very short (less than 10 cm), medium height (11–30 cm) and tall (>30 cm); season and study site (SW, SE, NW and NE). These four areas were the result of dividing the study area of Figure 1 into four equal sites.

We calculated the total density of kori bustard per 0.2 km² (i.e. all koris observed on both sides of the vehicle during the 1-km transect) and compared the mean density among the study sites. Furthermore, an analysis of variance was used to compare the mean kori bustard density in relation to grass colour, grass height and season in the four study areas. Chi square (χ^2) tests were used to compare variations of kori bustard observation with season and habitat, that is grass height and colour. Linear regression analyses were used to relate the density of kori bustard to the four study sites, grass height and colour at different seasons.

Results

The kori bustards were regularly seen in the same area, and most observations were of single birds (70.2%). The mean density of kori bustard in the Serengeti grass plains was 0.25 individuals per 0.2 km² (±1.01, SD, n = 1897, not log-transformed data). The density was 0.12 individual/0.2 km² (±0.48, SD, n = 314) in the NE area, 0.24 individual/0.2 km² (±0.86 SD, n = 264) in the SW area, 0.28 individual/0.2 km² (±1.28 SD, n = 514) in the SE area and 0.28 individual/0.2 km² (±1.01 SD, n = 805) in the NW area. There was no statistically significant difference in kori bustard densities among the four study areas (log-transformed data: ANOVA; F = 2.423, df = 3 and 1893, P = 0.064).

Although the most common colour of the grass was green when it was longer than 10 cm, a significant difference in the frequencies of green colour existed in different grass height groups (χ^2 = 165.5, df = 4, P < 0.001; Table 1). A significant difference in kori bustard density existed in transects with different grass heights (log-transformed data: ANOVA; F = 7.527, df = 2 and 1894, P < 0.001), with the highest densities in short grass habitats ranging from 11 to 30 cm. Statistically significant variations in densities also occurred with grass colour (log-transformed data: ANOVA; F = 5.319, df = 2 and 1896, P = 0.005).

Table 1 Relation between grass colour and height where kori bustards were observed

Grass colour	Grass height 0-10 cm	11-30 cm	>30 cm	Number of observations
Green	238	346	4	588
Greenish	244	158	11	413
Brown	649	242	5	896
N total	1131	746	20	1897

Kori bustard densities differed highly significantly among the four different seasons (log-transformed data: ANOVA; $F = 12.382$, df = 3 and 1893, $P < 0.001$). The density was highest during the long rain season (April–June: 0.33 individual/0.2 km² ±1.40 SD, $n = 610$) and the short dry season (January–March: 0.30 individual/0.2 km² ±0.92 SD, $n = 677$), while the density was the lowest during the long dry season (July–September: 0.01 individual/0.2 km² ±0.12 SD, $n = 208$) and the short rain season (October–December: 0.14 individual/0.2 km², ±0.58, SD, $n = 402$).

A linear regression analysis with kori bustard density (log-transformed) as the dependent variable and area, season, grass height and grass colour as independent variables was significant ($r^2 = 0.017$; ANOVA $F = 7.989$, df = 4 and 1892, $P < 0.001$). However, only season ($B = -0.013$, $t = -3.645$, $P < 0.001$) and area ($B = 0.006$, $t = 1.961$, $P = 0.050$) were significant contributors in explaining the density variation. Grass length ($P = 0.409$) and grass colour ($P = 0.220$) did not contribute significantly in explaining this variation.

Discussion

The results indicate that kori bustard density in the Serengeti grass plains is approximately 0.25 individual per 0.2 km^2, or approximately 1.3 individuals per km^2. The mean density did not differ among the four different study sites. According to studies by Frith (1973) and Isakov (1974) in Australia and India, intensive land-use practices have been part of *Ardeotis australis'* decline in parts of Australia, as well as the decline of *Otis tarda* in Europe. The few individuals observed in the Serengeti grass plains may be connected to intensive land-use practices in adjacent communities, as well as hunting (Mmassy & Røskaft, 2014). We must emphasize, however, that there is no previous information available about kori bustard densities in the Serengeti grass plains or other areas in Tanzania with which to compare. Thus, repeating this study will be necessary after a period of 5–10 years.

Kori bustard density was highest in green grass habitats with medium height (11–30 cm), probably because of food availability and topographic advantages for vigilance against predators. Habitat structure is considered to be important in determining habitat use by birds (Block & Brennan, 1993). Given that different habitat types vary with respect to composition and spatial distribution of food resources, it could be expected that the habitats used by kori bustards have sufficient species-specific resources. A high kori bustard density in green habitats might be influenced by an abundant food supply, such as insects. The presence of large herds of wild animals in green habitats may be attractive to kori bustards because they may offer protection from predators, ultimately increasing the time available to individual birds for finding and consuming food (Roberts, 1996; Fernández-Juricic, Siller & Kacelnik, 2004). Thus, the combination of food and offer of protection might influence kori bustard to congregate in these green habitats. The presence of fresh animal droppings may also attract beetles and other invertebrates, which are a source of food for the bustard.

Kori bustard density was high during the short dry season (January–March) and the long rain season (April–June). These high densities may be related to breeding season preparations as the male kori bustard courtship display was observed from late October throughout the breeding season during field data collection. The declining number of kori bustards at the study site after the breeding season indicated that the species migrate to more favourable habitats, for example with respect to food availability, during the long dry season (June–September) and migrate back to the plains before the rainy season.

Although not significantly different, the greater number of kori bustard observations in NW and SE, as well as in high grass habitats, that is medium height (11–30 cm), could be related to the kori bustard predator avoidance behaviour from sites with grass that is too long or too short. Given that a different habitat type varies strongly with respect to composition and spatial distribution of food resources, the habitats used by kori bustards are expected to have sufficient resources for the individual's daily demands.

Conclusions and recommendations

In conclusion, kori bustard density varied between the four study sites, but was statistically insignificant; however, seasonal variations in density were significantly different. The density was high during the long rain and short dry seasons. The study also confirmed that the distribution of kori bustard in the study sites was influenced more by grass height (11–30 cm) than by grass colour. Our predictions corresponded better with the season representing the main contributing factor for kori bustard density.

Due to a lack of data and research, kori bustard density recorded in our study in the Serengeti grass plains cannot be categorized as low or high. The species is listed as near threatened by the IUCN, and it is consequently important that the management authorities take appropriate actions to ensure the survival of the species. Protection of suitable habitats of the species within the Serengeti Ecosystem together with public education is imperative. The increasing illegal exploitation of natural resources by local people from communities alongside the Serengeti National Park makes community participation in the conservation and management of the species important. The large seasonal variations in density indicate that the population may utilize large parts of the ecosystem, thereby increasing the likelihood of encountering detrimental anthropogenic activities. Based on an earlier study of illegal offtake of grassland birds and eggs for home consumption (Magige *et al.*, 2009), we advise protected area managers to address such threats posed by illegal offtake.

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Paper III

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