**Breeding ecology of Kori Bustard *Ardeotis kori strunthiunculus* in the Serengeti National Park**

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**The breeding ecology of the Kori Bustard was studied in the plains of the Serengeti National Park, Tanzania in 2014 and 2015. Random transects were used to search for male courtship displays, nests, chicks and subadults. GPS satellite collars were used to locate nesting females. Linear regressions analyses and post hoc were used to determine the predictors that contributed most to the variation of the dependent variables (courtship display, nest, chicks, subadults). The results indicate that courtship behaviour peaks during the short dry and short rainy season before the peaks in nests and chicks. The highest nest frequency was found in short grass habitats. Female Kori Bustard may undergo repeated nestings within a single breeding season. The adult sex ratio was female skewed during breeding season. The Kori Bustard-breeding season in the Serengeti plains is relatively long, lasting almost for nine months, and taking place during all seasons except for the long dry season. We recommend that management authorities conduct assessments of Kori Bustard recruitment as well as habitat suitability in the Serengeti ecosystem to develop future conservation strategies.**

**Écologie de reproduction de l’Outarde Kori *Ardeotis kori strunthiunculus* dans le Parc National de Serengeti**

L'écologie de reproduction de l’Outarde Kori a été étudiée dans les plaines du Parc National du Serengeti, en Tanzanie en 2014 et 2015. Des transects aléatoires ont été utilisés pour rechercher les parades nuptiales des mâles, les nids, les poussins et les subadultes. Les colliers satellites GPS ont été utilisés pour localiser les femelles nicheuses. Les analyses de régressions linéaires et post hoc ont été utilisées pour déterminer les prédicteurs qui ont le plus contribué à la variation des variables dépendantes (parade nuptiale, nid, poussins, subadultes). Les résultats indiquent que le comportement de la parade culmine pendant les courtes saisons de sècheresse et de pluie précédant les pics des nids et des poussins. La fréquence de nidification maximale a été observée dans les habitats à haute herbe. La femelle Outarde Kori peut faire des nichées répétées au cours d'une seule saison de reproduction. Le sexe ratio des adultes était déséquilibré chez les femelles pendant la saison de reproduction. La saison de reproduction de l’Outarde Kori dans les plaines du Serengeti est relativement longue, s’étalant sur presque neuf mois et se déroulant pendant toutes les saisons, à l’exception de la longue saison sèche. Nous recommandons aux autorités de gestion de mener des évaluations du recrutement de l’Outarde Kori ainsi que de ses habitats dans l'écosystème du Serengeti pour développer des stratégies de conservation futures.

**Keywords:** breeding, season, habitat, sex ratio, Serengeti plain**s**

**Introduction**

Different birds exhibit a variety of breeding systems (Davies 1985) including a polygamy mating system in bustards. The most extreme and specialised example of breeding system is polygamy in birds and involve lekking where males display in congregation. Females visit such leks solely to assess a potential mate to copulate (Höglund and Alatalo 1995). Leks are described as “exploded” when males within a display aggregation are separated by considerable distance and aggregation cannot be detectable until displaying males are mapped over large areas. Exploded lekking occupies a position between classical and resource-based leks and appear to be particularly widespread among the Otididae family (Morales, et al. 2001). The study of a species’ breeding system and factors influencing breeding habitat selection is most important in considering conservation approaches for the species (Höglund 1996, Morales, et al. 2001).

The Kori Bustard*Ardeotis kori strunthiunculus* is the largest flying bird belonging to the bustard family (Otididae). The species is indigenous to the grasslands and lightly wooded savannah of southern and eastern Africa (Lichtenberg and Hallager 2008). The population of the species is declining over its entire range due to low reproductive rates (Lichtenberg and Hallager 2008), reduced breeding (Lichtenberg and Hallager 2008), shrub encroachment, unregulated and illegal hunting and degradation of habitat range. Currently the species is considered as near threatened (BirdLife-International 2016).

Kori Bustard is a polygynous species (one male mate with multiple females) which tend to be gregarious outside the breeding season, (Osborne and Osborne 2001). During the breeding season, the Kori Bustard males occur either singly or gather in loose lek-like formations and perform “balloon” displays to attract females. This behaviour is most intense in the early morning and evening (Hallager and Boylan 2004, Lichtenberg and Hallager 2008).

As in other bustard species, the female Kori Bustard makes no real nest, rather a shallow scrape on the ground, which is usually near a small clump of grass allowing the nesting female to hide. Kori Bustard clutch sizes range from one to two eggs while three eggs are rare (Osborne and Osborne 2001).

Although the Kori Bustard occurs in northern Tanzania, there is no published data on its breeding ecology in the Serengeti ecosystem. In this paper, we present data on Kori Bustard breeding ecology including the occurrence of courtship displays, nest site (four different areas) and habitat (grass colour and height) selection, clutch size, breeding season and male-female sex ratio in the grass plains of the Serengeti National Park (SNP). The aim of this study was to determine the timing and location of the Kori Bustard breeding activity in the Serengeti study area. We tested the hypotheses that Kori Bustard prefer short grass and green grass habitat and that the peak of the breeding season occurs during the long rainy season (March to May). In addition, we describe temporal distribution of male courtship behaviour, nest detection, and chick observations. We hypothesised that the Kori Bustard courtship displays occur before the peak of breeding season and during the colder parts of the day. The breeding season would be quite long and nest and chick predation are possible causes of this long breeding season.

**Methods**

***Study area***

The Serengeti National Park is one of the two main components of the Serengeti-Mara ecosystem (SME), located between latitudes 1° 28’-3° 17’ S and longitudes 33° 50’- 35° 20’ E and extending from northern Tanzania to south-western Kenya. The SME covers a total land area of approximately 25 000 km2, of which 14 763 km2 lies within the SNP and 8 094 km2 in the Ngorongoro Conservation Area. The average annual rainfall varies from 600 mm in the south-east plains to 1 100 mm in the north (Pennycuick 1975). The mean temperature ranges between 15 OC to 27 OC. The temperature is usually higher in the western parts compared with the eastern parts and may rise to more than 36 OC during the dry period. Our research focused on the southern SNP, an area dominated by short grass plains and where Kori bustards (study species) are frequently observed.

A major part of the SNP is dominated by Acacia savannah woodlands and riverine forests, particularly in the western and northern parts (Senzota 1982). However, grasslands dominate in the southeast.

There are two major seasons in the ecosystem: a wet season extending from November to May and a dry season extending from June to October. These seasons are further subdivided into short dry (January to March) and long dry (July to September), as well as long rain (April to June) and short rain (October to December) seasons (Norton‐Griffiths, et al. 1975). Although exact start and end times for dry and rain seasons vary annually, we used Norton-Griffiths four-season designation for our analyses.

***Field data sampling***

Data were collected over two breeding seasons between January 2014 and August 2015. During the study period we surveyed 1 878 random 1 km transects over the entire study area without transect overlap. Transects were surveyed from a vehicle, driving at a speed of approximately 20 km per hour. Transect surveys were conducted from 07:00-18:00 during the first week of every month for four days with a maximum of 25 transects per day and a minimum of 100 transects per month.  
The variables observed included; 1) grass colour (green = 80-100% green, greenish 10-80% green, and brown = 0% green); 2) grass height (short < 10 cm, medium = 11-30 cm and tall ≥ 30 cm), which, together, defined six different habitat types; 3) season (short dry (January-March), long rainy (April-June), long dry (July-September) and short rainy (October-December) and 4) time of day (morning = 07:00-10:00, midday = 11:00-14:00 and evening = 15:00-18:00). Grass colour was categorized as green when completely green, greenish when ranging from nearly dry to yellowish, and brown when completely dry. Grass height was measured by tape measure (100 cm) followed by visual estimates of grass. Measurements were taken where Kori Bustard, nests, chicks subadults and courtship display were seen and estimated with the surrounding grass height when more than one Kori Bustard are observed within the same transect. The study area in the southern SNP Plain was categorised into four sites (southwest SW, southeast SE, northwest NW and northeast NE) (Figure 1).

The sex of adults was determined as male when individuals were larger in body size with thick necks and/or a darkened throat (during the breeding season) and as female when individuals were smaller in body size than males and had black on the crown (Bailey and Hallager 2003). Subadult individuals were differentiated from adults when they were observed to have different features from adult birds. Subadult males are larger resembling adult males but with a thinner neck and are larger than subadult females. Subadult females have thinner legs than adult female and a brown-black back (Osborne and Osborne 2001). The adult male and female Kori Bustard were counted during transects surveys and counts were used for determining the sex ratio in relation to the study area, seasons, sites and habitats.

Courtship display was recorded when the male Kori Bustard was displaying with a full neck and tail white plumage/feather display as described by Lichtenberg and Hallager (2008). Females hiding in the grass were treated as indication of nesting females, and the search for nests was intensified. Observed nests, chicks and subadults in different habitats, sites and seasons were recorded. Egg number was recorded together with egg width and length (in mm) using a Vernier calliper.

We expressed the adult sex ratio as tertiary sex ratio (the ratio at sexual adulthood) and quaternary male/female ratio in adults past the age of sexual reproduction (Mayr 1939), as the total number of adult males divided by the sum of adult males and females observed during the fieldwork. Thus, sex ratio is expressed as a number around 0.5.

Chicks and subadults were photographed using a digital camera, and body size of subadults was estimated in relation to the size of adult birds. Kori Bustard chicks were easily identified as their mother accompanied them. The chicks studied ranged in age from one to 24 weeks. Their age was estimated based on the 2014 international studbook for the Kori Bustard (SNZP 2014) by comparing individual chicks with pictures in the book.

In addition to random transects, nests were also located using GPS satellite collars attached to nine female Kori bustards (Mmassy, et al. 2016). GPS was used to map areas used by nesting females and to locate nests. Consequently, abundance data of all variables were recorded as presence (1) or absence (0; viz. missing observations were recorded as 0) of nests, chicks or subadults respectively.

***Data analysis***

To examine the relation of environmental factors (site, season, grass height, grass colour, and time of day) to the frequency of courtship display, nest, chick, subadult, and adult sightings, we first performed chi-square tests for each pair of variables. Next, we constructed logistic regression models to examine the association of all environmental variables taken together and our outcomes of interest. The mean sex ratio of adults males and females in different environmental factors was determined by the analysis of variance (ANOVA). Fisher’s exact probability test was used to determine the probability that two eggs will results into two chicks. The significance level of all statistical tests was set at alpha (*P* ≤ 0.05).

**Results**

***Courtship behaviour***

In total, 1 878 transects were conducted for nineteen months in which 1 157 adults Kori bustards were recorded including 94 displaying individual males. The rate of courtship display differed statistically significantly between the four sites (χ² = 29.29, df = 3, *P* < 0.001). The highest rate of courtship display was observed in NE (Figure 2A). The observed courtship rate in NE was significantly higher than in SE (χ² = 43.9, df = 1, *P* < 0.001), as well as that of NW (χ² = 6.33, df = 1, *P* =0.012), but not in SW (NS), (χ² = 2.13, df = 1, *P* = 0.145). However the rate of courtship display differed also significantly between SE and SW (χ² = 25.1, df = 1, *P* < 0.001), as well as between SE and NW (χ² = 40.0, df = 1, *P* < 0.001), but not between SW and NW (NS) (Figure 2A). The courtship displays were highest in the short dry season (Figure 2B) and no courtship display was found in the long dry season (χ² = 11.25, df = 3, *P* < 0.010, Figure 2B). The courtship displays furthermore, differed statistically significantly between the short dry and the long rain seasons (χ² = 25.2, df = 1, *P* < 0.001), as well as between the short dry and the short rain seasons (χ² = 5.84, df = 1, *P* = 0.016). No significant difference in courtship behaviour was found between different habitats (grass length (χ² = 4.32, df = 2, *P* = 0.116) and grass colour (χ² = 5.69, df = 2, *P* = 0.056) or at different times of the day (χ² = 5.26, df = 2, *P* = 0.072) (Figure C D & E)

A logistic regression analysis with behaviour (courtship, no courtship) as the dependent variable and site, season, time of day, grass height and grass colour as the independent variables indicated that only site was a significant contributor to the variation in courtship displays (Table 1).

***Sex ratio***

The adult male to female sex ratio differed statistically significantly between different seasons (F =13.58, df = 3 and 655, *P* < 0.001; Table 2). The adult male to female sex ratio was female skewed during the short rain and long rain seasons, whereas a male skewed sex ratio occurred during the long dry and short dry seasons. A Tukey post hoc test revealed that the highest ratio of males to females encountered was highest in short dry season (equal ratio) than the long rain season (female skewed) (*P* < 0.001), and long rain season (female skewed) differed significantly from the short rain season (less female skewed) (*P* = 0.008).

The adult male to female sex ratio differed statistically significantly between different sites (F = 6.58, df = 3, and 654, *P* < 0.001; Table 2). The adult male to female sex ratio was male skewed in the SE and SW sites while in the NE and NW sites it was female skewed. A Tukey post hoc test revealed that SE site (male skewed) differed significantly from NW site (female skewed) (*P* < 0.001), and SE site differed significantly from NE (female skewed) site (*P* = 0.009), while SW (equal ratio) site differed significantly from NW site (female skewed) (*P* = 0.039).

The adult male to female sex ratio differed statistically significantly between different grass colours (F =5.86, df = 2 and 655, *P* *=* 0.003; Table 2). Finally, the sex ratio was equal skewed in the green grass habitats and female skewed in greenish and brownish habitats. A Tukey post hoc test revealed that the male to female ratio in green colour differed statistically significantly from brownish colour (*P* = 0.003).

No differences in sex ratio were found between different grass lengths (NS).

***Nests and clutch size***

Totally, 14 nests with a total of 20 eggs were recorded. Among the recorded nests, five were observed in 2014 and nine in 2015. However, 36% of the nests were predated. The clutch size varied between one and two eggs. The mean clutch size was 1.4 eggs (± 0.5 SD, N = 14), while the mean egg length and width were 85.2 ± 4.2 cm and 58.7 ± 1.6 cm respectively (N = 19).

Based on data obtained from a bird with a GPS satellite collar we observed a female undertaking repeated nesting attempts during the study period. This female nested three times in different locations in the NW site during a single breeding season in March and May 2014 and again in January 2015. The nesting distance between two nests in 2014 was 2.6 km. The distance between the second nest in 2014 and the nest in 2015 was 9.3 km. Observed number of nests was not statistically different between sites (χ² = 11.70, df = 3, *P* = 0.008, Figure 2A), however the highest number of nests (64.3 % of the total observations) was found in the NW site. Most nests were observed during the short dry season (71.4% of the total observations); however, a few nests were also recorded during the long rain season (28.6% of the total observations, Figure 2B). No significant difference in observed nests between seasons (χ² = 2.363, df = 3, *P* = 0.501) and grass height (χ² = 0.159, df = 2, *P* = 0.923) was found, probably due to our low sample size (Figure 2C). Furthermore, most nests were found in the brownish grass habitat (χ² = 10.70, df = 2, *P* = 0.005, N = 9, Figure 2D). The observed nests between green and greenish grass were statistically significant (χ² = 7.733, df = 1, *P* = 0.005). A logistic regression analysis with the frequency of nests (presence and absence) as the dependent variable and site, season, grass height and grass colour as the independent variables indicated that grass colour and height of the grass were the most significant factors contributed to the variation in nest distribution, with birds preferring brownish and short grass (Table 1, Figure 2C & 2D).

***Chicks and subadults***

Females with chicks were observed 25 times, among these observations each female had a single chick and only one female was observed with two chicks making a total of 26 chicks, with an average brood size of 1.0 chicks per brood. Again, 23 subadult Kori bustards were recorded, 69.2% during long rain and 30.8% during short dry (χ² = 19.82, df = 3, *P* ˂ 0.001, Figure 2B). A Fisher’s exact probability test (*P* = 0.004) indicated that there were significantly more two-egg nests (8/14) than two chick broods (1/26) indicating that many two-egg nests do not result in two chicks. There was slightly significant difference in the observed chicks were found between sites (χ² = 8.73, df = 3, *P* = 0.033), with (69.2%, N=18) of chicks found in NE (Figure 2A). The majority of the 26 chicks of different ages ranging from one day to two months were recorded during the long rainy season (65.4%, N=17) followed by the short dry seasons (26.9% N=7) and short rainy season (χ² = 34.13, df = 3, *P* < 0.001, Figure 2B). The observed chicks in short dry season and long rain season was significantly higher (χ² = 32.054, df = 1, *P* < 0.001), as well as between long rain season and short rain season (χ² = 6.265, df = 1, *P* = 0.012). No significant difference in observed chicks were found between different habitats (grass height (χ² = 5.50, df = 2, *P* = 0.064 though (61.5% N=16) were found in medium height and grass colour (χ² = 6.47, df = 2, *P* = 0.039) although (42.3%, N=11) of chicks were found in green grasses (Figure 2C & 2D).

A logistic regression analysis with presence of chicks or no chicks indicated that grass height and season were almost significant contributors to the variation in the distribution of chicks, with chicks observed more frequently when grass was low/high (Table 1).

Finally, a logistic regression analysis with subadult, no subadult as the dependent variable and sites, season, habitat and grass colour as the independent variables indicated that only season was a predictor for the variation in observed subadult encounter rates (Table 1).

**Discussion**

The aim of this study was to determine the timing and location of the Kori Bustard breeding activity in the Serengeti study area. We tested the hypotheses that Kori bustards prefer short grass and green grass habitat and that the peak of the breeding season occurs during the long rainy season (March to May). In addition, we describe temporal distribution of male courtship behaviour, nest detection, and chick observations. We hypothesised that the Kori Bustard courtship displays occur earlier before the peak of breeding season and during the colder parts of the day and that breeding season would be quite long and examined nest and chick predation as a possible causes of this long breeding season.

Important findings in this study is that courtship behaviour is influenced by season and site. Breeding occurs almost throughout the year as chicks were observed in all seasons except long dry season. Females undergo several breeding attempts in a single season if the previous nest is predated. Sex ratio is male skewed during long dry season and during short dry season.

The results indicate that the courtship behaviour of the Kori Bustard in the Serengeti plain peaks during the short dry and short rainy seasons, and before the peak of nests and chicks. As birds normally have their young in the nest when food is abundant, they must lay eggs sometime earlier (Perrins 1970). Previously published data on the density of Kori Bustard in the Serengeti plains indicated that during the short dry season individual Kori bustards become more abundant in the study area than in other seasons (Mmassy, et al. 2016). The appearance of a high number of individual Kori bustards during that season may reflect the onset of the breeding season. Our hypothesis that breeding season starts earlier before long rain season also corresponds with a study on Australian Bustard *Eupodotis australis* (Ziembicki 2010). We also postulated that courtship display would occur in the short grass habitat, as this would allow females to see displaying males easily. This postulate was supported, as it was not statistically significant although the highest rate of courtship displays were observed in the short grass habitat (Figure 2C). Other studies on the Little Bustard *Tetrax tetrax* conducted in central Spain have found that males and females occupied areas with abundant food resources during breeding season as reproductive territories (Traba, et al. 2008, Tarjuelo, et al. 2013). However, this does not apply to all bustard species. A recent study in Spain on the Great Bustard found the short grass habitat to be important during courtship as it increased the visibility of displaying males to females (Alonso, et al. 2012), although the study did not control for the grass length.

The courtship displays occurred with highest frequency during the noon hours. This finding differs slightly from our prediction that courtship display occur during the morning and late afternoon. The result correspond to the Kori Bustard observations in captivity (i.e. in zoos), where they have been found to display during noon (Gompu 2012) as well as during the morning, afternoon and evening hours (Hallager and Boylan 2004). It is however, not known if it was statistically tested and how often it was observed. These differences in the time of courtship displays between Kori bustards in captivity and natural habitats may as well be due to variations in environmental conditions such as temperature, although more research is needed to explore whether this is the case.

The sex ratio of the Kori Bustard in the Serengeti National Park tended to be female skewed, and in most cases significantly so. During the long rainy (late breeding) season, the sex ratio was extremely female-skewed. This may be due to the role of the male Kori Bustard during breeding and nesting periods, as his presence is most important at early stages of the breeding season. Research on Little Bustard has shown that courting is the main duty of males during the breeding season (Jiguet and Bretagnolle 2001) and that male Little Bustards do not seem to participate in the parental investment beyond the provision of gametes during mating (Jiguet, et al. 2000, Moreira, et al. 2004). Our research suggests that since male Kori Bustards do not participate in incubation or take care of the offspring, they may migrate to other areas. Post-mating migration has been reported in Great Bustard males in summer regions. Environmental factors such as searching for feeding ground and conducive ambient temperature have been explained as the cause of post-mating migration in Little Bustard (Morales, et al. 2000, Alonso, et al. 2009). However, more research is needed to test whether partial migration of male Kori Bustard after mating occurs in the Serengeti plains, and where do they go and how far, as there are indications that bustard density drops dramatically in the study area after the breeding season terminates (Mmassy, et al. 2016).

High percentage of nests were observed in short grasses and most chicks were sighted in sites with medium height grasses. Results from Great Bustard studies on nest-site selection have suggested that females look for habitats with good visibility while incubating (Magaña, et al. 2010). Similarly, research on the breeding habitat of the Houbara Bustard *Chlamydotis macqueenii* in the Central Steppe of Iran indicates that the Houbara Bustard nests in short grass habitats to spot approaching predators (Zadeh, et al. 2010). What is more, research on the Asian Houbara Bustard *Chlamydotis (undulata) macqueenii* in Mori Xinjiang-China and on the Asian Houbara Bustard in Central Saudi Arabia have found that these species breed in habitats with significantly lower grass height (Combreau and Smith 1997, Yang, et al. 2003). The camouflage and spotting of enemies due to predation might lead Kori bustards to nest in short grass and hide chicks in the medium grass height.

The highest frequency of subadults appeared during the long rainfall season and after the peak of nests and chicks. The latter was observed to take place during the short dry, short rainy and long rainy seasons. Observations of chicks during the short dry, the short rainy as well as the long rainy seasons seems to imply that the Kori Bustard breeding season may last for almost nine months (from October to June), covering all seasons except the long dry season.

We were unable to acquire enough samples to test if female Kori bustards undergo several breeding attempts within a single breeding season if the nest is predated. Although we observed one female Kori Bustard that nested twice within a single season this is not enough to justify the case statistically. Observations of few nests, chicks and subadults may indicate a predation loss of nests and chicks or it is because of few observations due to low detectability of chicks and nests because they may be hidden in the tall grass to protect themselves from being detected by predators. The nest predation in our study accounted for 36% loss of the observed nests. We found evidence of predation through GPS-monitored nests. Crushed eggs and presence of teeth marks like that of mongooses or jackals remained on egg shells. Again, research on other bustard species seems to support this finding. For example, a study in central Spain showed that up to 39% of Great Bustard clutches are lost due to egg predation (Magana 2007). Similarly research was observed in Asian Houbara Bustard in which 85% of nests were lost because of predation (Koshkin, et al. 2016) . Nest predation is the primary source of nest loss across a wide diversity of species (Ricklefs 1969, Martin 1993). In Great Bustard nest losses and chick mortality are largely attributed to predation and starvation (Magana 2007, Abdulkarimi, et al. 2010). This may apply to the Kori Bustard, being a grasslands ground-nesting bird.

The mean clutch size of Kori Bustard found in this study might be small compared with the mean clutch size of other bustard species (Osborne and Osborne 1998, Rocha, et al. 2013, Koshkin, et al. 2016). The Great Bustards in Spain and Hungary has shown to have even smaller clutch size (Morales, et al. 2002, Watzke 2007). As for the number of chicks per brood, we observed an average brood size of 1.0 chicks per brood, which indicates that at least one chick can be raised by a single female and raising of two chicks can be rare.

We conclude that the peak frequency of courtship displays occurs during the early stages of the breeding season. The Kori Bustard nests in tall and medium grass habitats and it can undergo several breeding attempts within a single breeding season due to nest predation. Few observations of nests, chicks and subadults may support the prediction that the nest predation may be high. Other reasons, which may contribute to nesting failure and which need to be studied, includes predation of nesting females, climate change and fire regime management. Male-skewed sex ratio after the mating period may indicate a post-breeding migration of males. Finally, we conclude that the breeding season of Kori Bustards in the Serengeti plain is relatively long because of observed chicks for several months, with the exception of the long dry season. A study of Kori Bustard breeding ecology is of great importance as it is a near threatened species, listed in appendix II of CITES. It is therefore crucial to understand its breeding ecology for further action towards conservation of the species. We recommend that management authorities conduct a recruitment assessment of Kori Bustards in the Serengeti ecosystem to develop future strategies for the conservation of the species. This should include studies on habitat preferences by the species inside and outside the protected areas, the buffer zones, and seasonal migration grounds.

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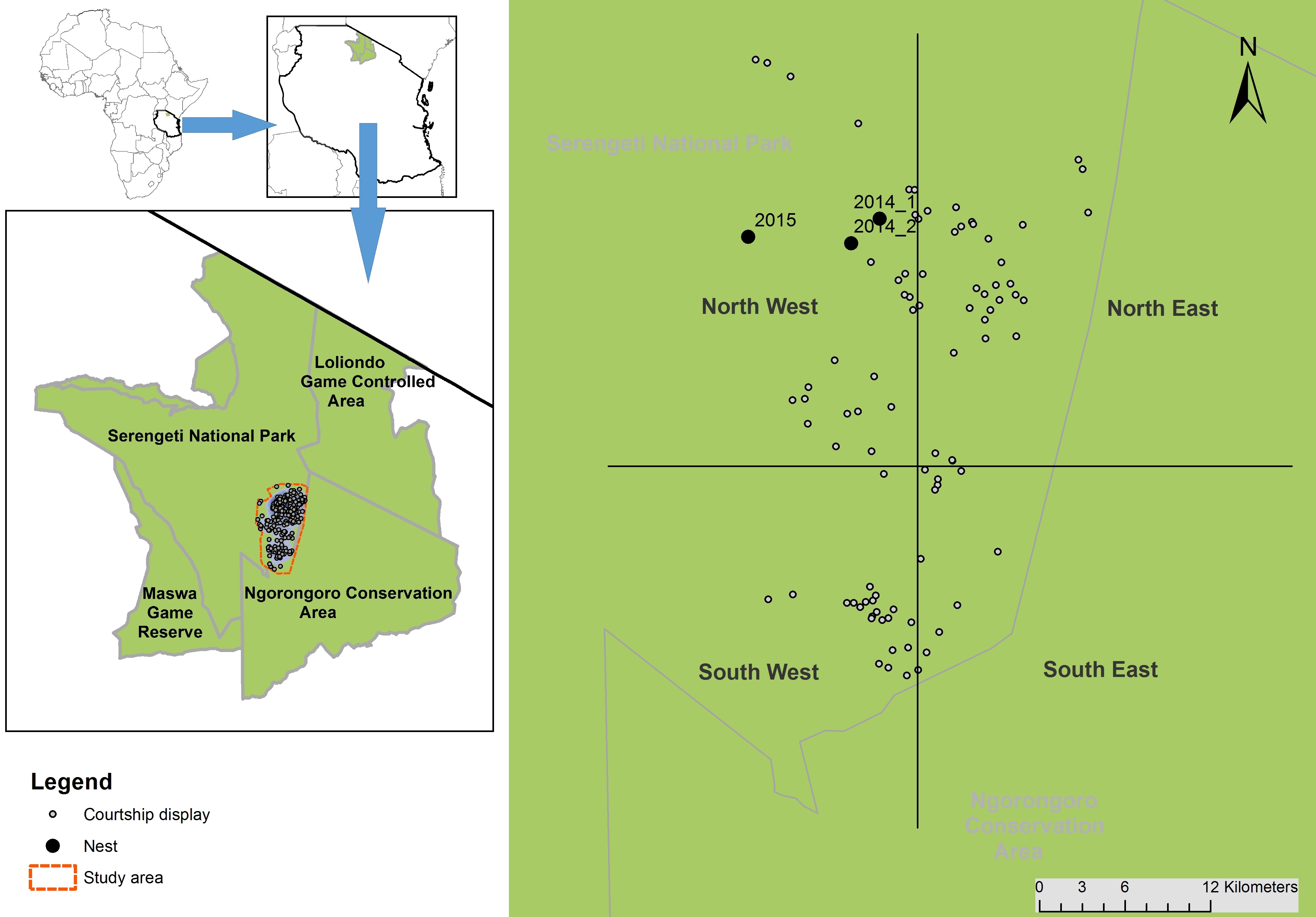
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**Table 1:** Logistic regression analyses with dependent values (horizontally) and independent values (vertically). All independent variables were used in all tests except for time of the day, which is used only for courtship display. N = 655 for all except subadult (n = 654)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Courtship behaviour | | Nests | | Chicks | | Subadult | |
|  | ***Wald*** | ***P*** | ***Wald*** | ***P*** | ***Wald*** | ***P*** | ***Wald*** | ***P*** |
| Site  Season  Grass height  Grass colour  Time of day | 9.869  0.920  0.396  0.694  1.222 | 0.002  0.338  0.529  0.405  0.269 | 1.797  0.946  5.520  4.786 | 0.179  0.322  0.019  0.027 | 0.369  3.199  3.363  0.174 | 0.544  0.074  0.067  0.676 | 0.555  0.137  0.503  1.086 | 0.459  0.725  0.297  0.485 |
| Adjusted R2 |  | 0.056 |  | 0.209 |  | 0.053 |  | 0.031 |
| Wald χ2 |  | 258.2 |  | 200.3 |  | 253.4 |  | 193.6 |
| Wald p |  | <0.001 |  | <0.001 |  | <0.001 |  | <0.001 |

**Table 2:** Distribution of Kori Bustard sex ratio (number of males/number of males + number of females; values > 0.5 indicate skewed female ratio while number < 0.5 indicate more males), in relation to site, season, habitat, grass colour and time during breeding season (N = 1157 observations of adult Kori Bustards).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable categories | | Sex ratio ± SD | No. of Kori Bustard observations | No of transects |
| Site | SE | 0.62± 0.46 | 66 | 317 |
| SW | 0.51 ± 0.46 | 95 | 263 |
| NE | 0.43 ± 0.45 | 294 | 510 |
| NW | 0.36 ± 0.45 | 203 | 807 |
| Season | Short dry | 0.51 ± 0.46 | 441 | 781 |
| Long rain | 0.22 ± 0.36 | 134 | 610 |
| Long dry | 0.58 ± 0.49 | 6 | 208 |
| Short rain | 0.43 ± 0.46 | 78 | 298 |
| Grass height | Short | 0.46 ± 0.46 | 323 | 1131 |
| Medium | 0.41 ± 0.45 | 260 | 746 |
| Tall | 0.49 ± 0.46 | 9 | 20 |
| Grass colour | Green | 0.51 ± 0.45 | 299 | 588 |
| Greenish | 0.41 ± 0.45 | 151 | 413 |
| Brownish | 0.37 ± 0.47 | 208 | 896 |



**Figure 1**: Map of the Serengeti National Park showing the Kori Bustard study area. Open dots indicate male Kori Bustard courtship displays, while dark closed dots indicate different nests of one GPS satellite collared female in 2014 and 2015.

**Figure 2 A - DE:** Observations (percentage) of courtship displays, nests, chicks, subadults and time in the Serengeti grass plains in relation to site, season, habitat and grass colour.