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Caption: *Cyrtodactylus myintkyawthurai*, endemic to Myanmar. Medium: Water colours on watercolor sheet. © Aakanksha Komanduri

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COMMUNICATION

Nesting success of Sharpe's Longclaw (*Macronyx sharpei* Jackson, 1904) around the grasslands of lake Ol'bolossat Nyandarua, Kenya

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Abstract: Sharpe's Longclaw *Macronyx sharpei* is an endangered Kenyan endemic bird restricted to high-altitude grasslands with long tussocks. The species occurs on the grasslands surrounding Lake Ol'Bolossat in Nyandarua, Kenya, an area that is globally recognized as an Important Bird and Biodiversity Area. The grasslands receive little conservation measures, which have led to the decline in the population density of Sharpe's Longclaw. Nesting success in birds is crucial for their population growth. The daily survival rate for natural nests of Sharpe's Longclaw in the grasslands of Lake Ol'Bolossat had not been systematically assessed prior to this study. Natural nests were actively searched during the breeding seasons of March–May 2016, while artificial nests were constructed using dry grass containing artificial eggs made of cream modeling clay. Natural nests had a higher daily nest survival percentage than artificial nests. The highest daily nest survival rate was 40% and the lowest 0.01%. Predators, livestock grazing and fires greatly reduced the survival of nestlings. We recommend intensive ecological management of the high-altitude grasslands of Lake Ol'Bolossat.

Keywords: Daily survival rate, Endangered, endemic, Lake Ol'Bolossat, nest, nestling, Sharpe's Longclaw.

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Author contributions: HAR—conceived and designed experiment of the study, collected field data, analyzed data, interpreted data, discussed data, wrote the manuscript. CMW—designed study, analyzed, interpreted and discussed data, wrote the manuscript. PN—designed study, analyzed and interpreted data, wrote the manuscript.

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INTRODUCTION

Approximately, 350 bird species are grassland dwellers in Kenya (Morris et al. 2009). Sharpe's Longclaw *Macronyx sharpei* (Jackson 1904) is among these grassland birds. It is 16 to 17 cm long, with upper parts heavily marked with buff and rufous streaks, yellow underparts, and white outer tail feathers in flight (BirdLife International 2016). Sharpe's Longclaw is endemic to Kenya and it is listed as globally endangered in the International Union for Conservation of Nature (IUCN) Red List of threatened species (BirdLife International 2016). The preferred habitat for Sharpe's Longclaw is the high-altitude grasslands of the central Kenyan highlands. The population of Sharpe's Longclaw in the grasslands of Ol'Bolossat has been on the decline due to the loss of feeding and nesting habitats caused by the conversion of grasslands into crop fields, afforestation, uncontrolled bird shooting, mining activities and constant use of insecticides (Monadjem & Virani 2016).

For birds that lay eggs in nests and incubate them until they hatch, many eggs are lost due to predation, which varies with the quality and site of nests (Martin & Clobert 1996). Nests located in hidden places (for example, cavities) have a higher probability of survival than those located in open ground (Walk et al. 2010). During the breeding season, the selection of good nest sites is important because it affects nesting success and the survival of the nestlings (Lima 2009). Other factors that affect nesting success of grassland birds include wind and sunlight direction, which influence the microclimate of the nest (Wiebe et al. 2001; Tieleman et al. 2008).

Sharpe's Longclaw constructs its nest in long grass tussocks (Dominic et al. 2020), which provide both nest material (Collias & Collias 2014) and cover from predators (Muchai & Plessis 2005). However, tussocks can be destroyed by various human activities such as farming, fires and overgrazing (Wamiti et al. 2008) which alter the quality of bird nesting habitats and reduce nesting areas. Nests in inferior quality habitats will expose eggs and nestlings to predators such as snakes, predatory birds and moles, leading to decreased nest success (Pace et al. 1999; Polis et al. 2000). Adverse weather conditions have also contributed to the decline in nesting success of Sharpe's Longclaw (Stephenson et al. 2011; Shiao et al. 2015). During heavy rains, runoff water destroys nests reducing nesting success and survival rates (Rodriguez & Barba 2016).

Nesting success is mainly influenced by changes in habitat structures through management practices. These changes reduce nesting substrates which hide the nest from their predators (Ammon & Stacey 1997). Nesting success is also related to the structure of the habitat (Bowman & Harris 1980), nest site features (Norment 1993), nesting bird behavior (Cresswell 1997) and parental activity (Martin et al. 2000). The nests located in hidden places such as cavities, shrubs, and tussocks have a higher probability of survival than nests located in open spaces (Walk et al. 2010). Food availability is also an important factor determining nestlings' growth and survival (Roff 1992).

Increased parental activity escalates the risk of nest predation (Martin et al. 2000). The birds with minimal parental activities, therefore, reduce nest predation. Habitats may indirectly influence predation risks, food availability for nesting birds, and time and energy available for nest defense (Martin 1995). When a predator visits a particular nest and takes some of its contents but not all (i.e., partial depredation), the behavior may lead to selective pressure, which is not enforced by complete nest predation (Lariviere & Messier 1997; Amundsen 2000).

To properly manage the declining populations of grassland dwelling birds, habitat protection is important because it directly influences their nesting success (Winter & Faaborg 1999). Determining the nesting success of Sharpe's Longclaw is therefore, important when developing species-specific conservation measures. This study was designed to determine the nest success of Sharpe's Longclaw in the grasslands around Lake Ol'Bolossat in Nyandarua , Kenya.

STUDY AREA AND RESEARCH METHODS

Study area

Lake Ol'Bolossat is located in Kenya, Nyandarua County, Ol-joro-orok Sub-County. It lies between latitudes 0.1640 90' 00" South and longitudes 36.4450 26' 00" East (Figure 1). It is positioned in Ongata Pusi valley and is adjacent to the Rift valley with an elevation of 2,340 m above sea level. It is a natural wetland covering an area of approximately 43.3 km^2 and its open waters cover 4 km^2. It has a rich biodiversity zone with many species of water birds and other threatened species. The riparian land around Lake Ol'Bolossat is covered by grasslands inhabited by birds (Wamiti et al. 2008). It was internationally recognized as the sixty-first Important Bird and Biodiversity Area (IBA) in Kenya in March 2008 by BirdLife International (Mwangi et al. 2010) and protected officially from February 2018

Figure 1. Lake Ol'Bolossat basin showing the main geographical features in the study area (Google 2018).

(Nature Kenya 2018).

The climate is sub-humid throughout the year and is mainly influenced by the surrounding highlands. Lake Ol'Bolossat has a rainfall pattern between 700 and 1,000 ml with long rains from April to July, and short rains in November (Wamiti et al. 2008). Temperatures are cold because of the wind blowing from the Aberdare ranges, which can bring frost that can destroy grass, including the tussocks favored by Sharpe's Longclaw (Wamiti et al. 2008).

Methods

Determination of natural nest success

Nests were searched during the breeding seasons of March to May (2016) by fortuitous encounters, or by following adults carrying nesting material during incubation and feeding of the young, or by dragging a 50m rope between two people and flushing birds from nests (Bibby et al. 2000). Once the nests were located, global positioning system (GPS) coordinates were taken for future geo-location. They were checked after three days to determine their status.

Care was taken during nest searches to avoid disturbance to the nests and surrounding vegetation. A stick was used to hold the vegetation aside to prevent contact with human clothing/skin that would leave behind scents that attract predators. Mayfield nesting success formula was used to estimate the probability of successful nesting (Mayfield 1975).

$$\text{Daily survival probability} = \frac{\text{Exposure days - Failed nests}}{\text{Exposure days}}$$

Daily survival probability refers to the probability of the nestling to survive from one day to the next in the nest. In contrast, exposure days refer to the total number of days a nest will be observed active and susceptible to failure.

Nest survival refers to the probability that a nest fledges at least one chick using a nesting period of 26 days (4 laying, 12 incubating, and 10 nestling).

Nest survival= daily survival probability $^{\text{nesting period}}$

Predation rate for artificial nets

Artificial nests were used to assess the effect of different variables on the rate and trend of nest predation (Major & Kendall 1996). They allow researchers to manipulate the number of nests in the study area, and take less time to place and locate than natural nests (Yahner & Delong 1992). However, the lack of an incubating adult may affect the ability of predators to locate them (Martin 1987).

The artificial nest experiment in the grasslands of Lake Ol'Bolossat was conducted between March and July 2016. Experimental nests were constructed 10 cm wide and 5 cm deep using dry grass interwoven to mirror Sharpe's Longclaw nests as much as possible. Cream non-toxic modeling clay was used to make artificial eggs. The plasticine eggs were similar in size, shape and color to Sharpe's Longclaw eggs. After shaping the egg, a marker was used to make irregular spots. Edge effects were considered near forests, roads, and hedgerows (Keyel et al. 2013) and extended between 50–100 m into the nesting habitat (Bollinger & Gavin 2004).

The grassland habitat was divided into several portions measuring 1,000 x 850 m. Three line transects were laid in each habitat 200 m apart. Samples of 30 nests were laid out. These included three nests in two transects and four in one transect, repeated two more times in habitats with tussocks. Each nest had three white plasticine eggs, which were left for a minimum of 21 days, a duration that resembles Sharpe's Longclaw incubation period.

The average distance between nests was 250 m. Artificial nests were randomly placed together with Sharpe's Longclaw nests but at a specified distance of 250 m away. GPS coordinates were taken for the future location. The eggs were examined for bites or teeth impressions and the appropriate records made, ensuring a proper differentiation between avian and rodent predators (Dion et al. 2000). Nests were considered depredated when the plasticine eggs were destroyed or showed bite marks.

Data analysis

Raw data were recorded and then tabulated in Microsoft Excel for cleaning and storage. Quantitative data was exported to SPSS (Statistical Package for Social Sciences) software version 25.0 (IBM corporation, Armonk, New York, United States of America) for analysis. An unpaired t-test was used to test for the statistical difference between the daily survival percentage of natural and artificial nests. The null hypothesis was rejected when $p \leq 0.05$.

RESULTS

Sharpe's Longclaw nesting success

A total of seven natural nests were identified in seven locations between April and July 2016, and observed during the nesting period. Nests were discovered on 12 May, 26 May, 10 June, 02 July, and 06 July around the grasslands of Lake Ol'Bolossat. At the beginning of the study, nests were in various stages of development: two nests had eggs, two nests had nestlings, and three nests were in the construction stage. One of the seven natural nests located in Nduthi was abandoned during the construction stage, possibly due to flooding caused by heavy rains. Three eggs were recorded in each nest, although nests located in Rurii and Nduthi had none (Table 1). All eggs hatched to chicks in Mukindu, Kirima, Munyeki, and Makereka nest locations, indicating a 100% hatching rate. However, the eggs in Kanguo did not hatch (Table 1). Tussock height ranged between 25.0 m in Makindu to 21.5 m in Rurii (Table 1).

Daily survival of natural and plasticine eggs

The highest daily nesting survival among the natural nests of 96% was recorded in Kirima, while the least daily survival of 75% was recorded in Rurii, as shown in Table 2. The least daily survival rate of natural nests of 0.01% was observed in Rurii, while the highest daily survival rate of natural nests of 40% was reported in Kirima (Table 2; Figure 2). The survival of chicks in some of the nests was greatly reduced. For example, one of the nests was found with healthy chicks during the interval check, but a chunk of round feaces was found in the nest on the next checking date. This was an indication that the chicks had been predated by an unknown animal (Image 1).

The artificial nests recorded the highest nest daily survival of 90% in Rurii, Nduthi and Kanguo, while the least daily survival of 67% was recorded in Munyeki and Makereka (Table 2). The least daily survival rate for plasticine egg of 0.003% was recorded in Munyeki and Makereka, while the highest daily survival rate of 6.0% was reported in Rurii, Nduthi, and Kanguo (Table 2; Figure 2). A large portion of the tussocks that contained a total of 10 artificial nests was consumed by fire. Of the remaining ten nests, two experimental nests were attacked by unknown predators, leaving bite marks on the eggs (Image 2). Other factors that strongly

Table 1. Sharpe's Longclaw nesting success.

No. of nest	Nest Location	Status at Discovery	Tussock size	No. of nest	No. of eggs	No. of chicks	Status
1	Makindu	Construction	25.0	1	3	3	Chick fledged
2	Rurii	Laying	21.5	1	0	0	Faeces found
3	Nduthi	Construction	24	1	0	0	Nest abandoned
4	Kirima	Fledging	23	1	3	3	
5	Kanguo	Laying	27	1	3	0	
6	Munyeki	Laying	25	1	3	3	
7	Makereka	Fledging	24	1	3	3	

Image 1. Picture showing fresh faeces from unknown predictor (sourced from this study).

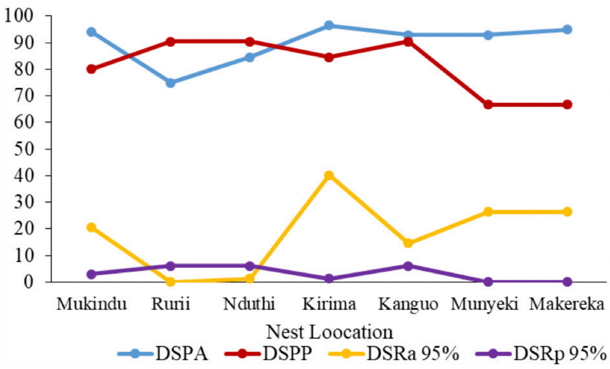

Figure 2. Daily survival percentage and daily survival rate for both natural and artificial nests. DSPA—Daily survival percentage for natural nest | DSPP—Daily survival percentage for artificial nest | DSRa—Daily survival rate for natural nest | DSRp—Daily survival rate for artificial nest.

Table 2. Daily nest survival for natural and artificial nests.

Study site	DSP_A	DSP_P	DSR_a 95%	DSRp 95%
Mukindu	94.12	80.00	20.67	3.00
Rurii	75.00	90.47	0.01	6.0
Nduthi	84.61	90.47	1.30	6.0
Kirima	96.50	84.61	40.14	1.30
Kanguo	92.86	90.47	14.56	6.0
Munyeki	92.86	66.70	26.35	0.003
Makereka	95.00	66.70	26.35	0.003

Key: DSP_A—Daily survival percentage for natural nest | DSP_p—Daily survival percentage for artificial nest | DSRa—Daily survival rate for natural nest | DSRp—Daily survival rate for artificial nest.

contributed to the low survival of plasticine eggs were human disturbance, livestock grazing, and trampling on the eggs.

In comparison, there was no significant difference between daily survival of natural (90.14±2.19) and artificial (81.35±4.06) nests (unpaired t-test; df= 12; t= 1.29; p= 0.11).

DISCUSSION

Sharpe's Longclaw is a threatened bird due to the rapid encroachment of its habitat. This endemic and endangered species is restricted to highland grasslands in Kenya (Dominic et al. 2020). This study has revealed a higher hatching success of Sharpe's Longclaw in some areas around the grasslands of Lake Ol'Bolossat, such as Makindu, Kirima, Munyeki, and Makereka. The higher nesting hatching success could be attributed to dense, long tussocks, which helped conceal the nests from predation. However, in some nests, the hatching success of chicks was greatly reduced due to predation. This was revealed by the presence of a chunk of round faeces in the nest. Predation is the main cause of nest failure in grassland nesting birds and many populations living in fragmented habitats experience low reproductive success worldwide (Chalfoun et al. 2002; Klug & Jackrel 2010). Human disturbance, fires, and livestock grazing leading to trampling on the eggs are other factors that strongly contributed to reduced hatching success.

Image 2. Photos of some damaged experimental eggs (sourced from this study).

The study has also found that daily natural nest survival of Sharpe's Longclaw is higher in grasslands around Lake Ol'Bolossat, especially in areas such as Kirima, Makereka, Mukindu, Munyekia, and Kanguo. The higher daily survival can be attributed to dense, tussocks, which help protect the nests from predators. The nests located in dense long tussocks have a higher probability of survival than those located in open fields (Walk et al. 2010). Also, the lowest and highest daily survival rate of the natural nests were observed in Rurii and Kirima, respectively. It was noted that the survival of the chicks was greatly reduced in some of the nests due to predation. This is consistent with a study carried out by (Leonard et al. 2017), which has reported that the predators significantly reduce the nest survival rate. Besides, flooding also destroyed the nests resulting in reduced nest success and survival rates. This finding is also reported by Rodriguez & Barba (2016) on the growth and survival of Great Tit *Parus major* nestlings.

Parental activity and nest-site characteristics strongly impact the predation of eggs and nestlings (Martin et al. 2000). Parental activity such as loud calls and beggings can act as a signal for the nestlings and attract predators (Martin et al. 2000; Muchai & Plessis 2005), hence increasing the probability of predation. This is because parents always visit nests more frequently to feed the young. Birds with low predation rates have developed short to long on and off bouts to reduce activities that would attract predators (Conway & Martin 2000). Nests likely to be attacked by predators are always located early in their nestling cycle (Skutch 1985). Nests that are not well concealed have a high predation rate in the incubation stage than during the nestling stage (Liebezeit & George 2002).

It is also observed that the daily survival of natural and artificial nests is not significantly different in the grasslands of Lake Ol'Bolossat. This can be attributed to the fact that the plasticine eggs resembled almost natural eggs and the predators could not differentiate them (Estrada et al. 2002).

Approaches to conserve threatened birds

Increased agricultural activities diminish and fragment suitable breeding habitats for Sharpe`s Longclaw (Wamiti et al. 2008). This reduces the habitat for breeding birds leading to the formation of patches. Therefore, the predators may specialize on the patches in search of rewarding prey, decreasing Sharpe`s Longclaw population. Increased vegetation heterogeneity would significantly reduce the risk of nest predation (Davis 2015). This is because shrubs would grow together with grassland, reducing the nest's visibility to their potential predators.

Mowing of the vegetation should not occur frequently, and if it does it should only happen after nestlings have left their nests around mid-July. When delayed nesting occurs, mowing should be delayed to guard the nests together with their fledglings (Gruebler et al. 2012). In addition, dry vegetation should be left on the habitat because it will provide cover and offer the birds with nest construction materials in the next breeding season (Shaffer et al. 2019).

Overgrazing should be discouraged, but instead, moderate grazing should be enhanced because it is beneficial. This is because moderate grazing prevents the growth of foreign grass and improves the nesting habitat for Sharpe`s Longclaw (Bock et al. 1993; Sutter 2006; Wersher et al. 2011). Large grassland fields should be identified, preserved and protected as they reduce the rate of nest destruction and brood parasitism (Davis & Sealy 2000). Burning of the grasslands should also be discouraged since it destroys the eggs leading to reduced population growth of Sharpe's Longclaw during its breeding time.

The recovery of grassland can be achieved through the seeding of native grasses in both private and public lands through Conservation Reserve Program (CRP); (Best et al. 1998; Riffell et al. 2008); and the formation of buffers around agricultural fields (Adams et al. 2013). This aids in designing a suitable habitat for the birds during nesting.

In conclusion, some areas of Lake Ol'Bolossat had higher survival rates of the eggs and nestling. In contrast, others had low survival rates due to predators, human activities, livestock grazing and fire. This is due to the low survival rate caused by increased habitat loss through human activities, thereby exposing eggs and nestlings to predictors. Therefore, measures to protect and conserve grasslands inhabited by Sharpe's Longclaw around Lake Ol'Bolossat should be enforced to prevent their extinction in the near future.

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