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Diurnal time-activity budget and habitat use of Wattled Crane *Bugeranus carunculatus* in Boyo Wetland and Bale Mountains National Park, Ethiopia

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Summary

The diurnal time-activity budget and habitat use of the Wattled Crane *Bugeranus carunculatus* were studied at Boyo Wetland and Bale Mountains National Park. The study was carried out in four habitats (agricultural land, grassy field, mudflat, and shallow wetland) at Boyo Wetland and two habitats (grassland and swampy habitat) in the Bale Mountains. Instantaneous scan sampling was used to collect the daily activity time budget, scanning each individual in turn and categorizing its behaviour in six behavioural states. We made observations from 06:00 to 18:00 from October through June 2014/2016 and 2016/2017. We performed ANOVA and T-test to look at how diurnal activity pattern differed among habitat types and time periods of the day. Foraging was most prevalent, accounting for 39% of the time budget followed by locomotion (20%) and vigilance (16%) and social behaviour (2%). The time spent on various activity patterns across habitats and between seasons were significantly different ($p < 0.05$). Across habitats, the daily pattern for foraging and locomotion showed two peaks, in the agricultural habitat and grassland habitats, whereas percent time devoted to vigilance, resting and comfort movement followed an inverse pattern, peaking at mudflats and shallow wetland. The Wattled Crane spends more time feeding on farmland than in the wetland. This could create conflict with farmers and threaten the Wattled Crane. Therefore, urgent actions are needed to restore the degraded wetlands.

Keywords: Bale Mountains, Boyo Wetland, time-activity budget, foraging, Wattled Crane

Introduction

The Wattled Crane *Bugeranus carunculatus* is the largest and rarest of the six African crane species and is one of the most wetland-dependent species of all African cranes (Meine & Archibald 1996). It is classified as Vulnerable in the revised IUCN Red List of threatened species with a decreasing population (IUCN 2019). Historically it was more numerous, with an estimated population of 13 000–15 000 in 1985 (Beilfuss *et al.* 2007; Bento *et al.* 2007), distributed across eleven African countries (Johnsgard 1983). However, records from the 1970s to the 1990s show that the species experienced a significant decline across its range (Meine & Archibald 1996), largely due to loss and degradation of wetland habitat (Konrad 1981). Currently, there are isolated

populations in South Africa and Ethiopia, and a larger, widespread, floodplain population in south-central Africa, cumulatively amounting to fewer than 9600 (Morrison 2019).

Due to their morphological appearance, behaviour, and their cultural significance, cranes in general have been intensively studied for many years throughout the world from their ecology to their movements using satellite tracking (Harris 1994, Harris & Mirande 2013), especially in North America, Europe and Asia (Takekawa and Orthmayer 2001). However, there is only limited information about the ecology of Wattled Cranes in Ethiopia. Past studies on their distribution include those by Konrad (1981), Urban & Walkinshaw (1967), Beilfuss *et al.* (2000) and Bento *et al.* (2007), with a population survey by Motsumi *et al.* (2007). Meanwhile, Davenport and Urban (2010) reported on the activity patterns of captive individuals, and Jones *et al.* (2006) carried out molecular studies in southern and south-central Africa. In addition, studies on time budgets have been published for cranes in North America (Tacha 1988) and Europe (Alonso & Alonso 1993); however, there remains very limited past information on the activity pattern of wild populations of Wattled Cranes in Africa. Such information has immense importance for quantifying how Wattled Cranes apportion their time to cope with varying energy demands, how they cope with various environmental changes on a daily, seasonal, and a year-to-year basis, and how these birds use different habitat types (Maxson & Pace, 2016).

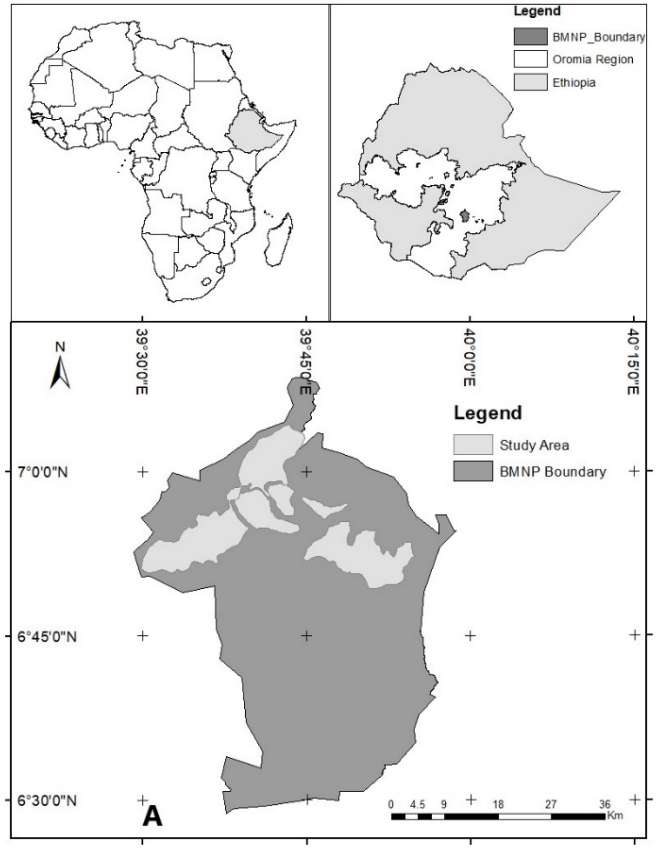
The application and implementation of conservation measures towards a species or the habitat on which it depends, requires a detailed understanding of that species ecology and life history strategies, including how the species interacts with its environment (Liu *et al.* 2010). In addition to the importance of the ecological studies for species-level conservation planning, the availability of such information on Wattled Cranes will have other benefits such as serving as baseline data for subsequent biological and ecological studies on the species. Therefore, this study is aimed at determining the time budget and diurnal rhythm of behaviour of Wattled Cranes both seasonally and across different habitats of the Boyo Wetland and Bale Mountains National Park.

Materials and methods

Study sites

This study was carried out in Boyo Wetland (BW) and Bale Mountains National Park (BMNP), which support the Ethiopian Wattled Crane population's main wintering and breeding habitats in Ethiopia, respectively. BW is situated in the central Rift Valley area of Ethiopia, located between 7°29′ N and 38°03′ E (Fig. 1a) in the South Nations Nationalities and Peoples Region, 300 km southwest of Addis Ababa. The altitude ranges from 1850 to 1900 m asl. The wetland is a freshwater lake and swamp (Delelegn 1998). During the peak wet season of August and September, the water level rises and the whole area of the wetland becomes flooded, whilst during the dry season the water level recedes and changes to a vast area of grassland, which local communities use for uncontrolled/unregulated grazing. The wetland is part of the Bilate River basin that drains from the Gurage Highlands south into Lake Abaya (EWNHS 1996). The wetland has two main inflows or tributaries: the Weira River from southern highland areas, and the Guder River from the Western mountains. Near the regional capital, Hosaena, the two merges to form BW before draining to join the Bilate River in the eastern part of the wetland.

The BMNP, which is located in the southeastern part of the Ethiopian plateau, is part of Conservation International's Eastern Afromontane Biodiversity Hotspot Area (Williams *et al.* 2004). It is also Conservation International's 34th Biodiversity hotspot (Williams *et al.* 2005) and may also be nominated for World Heritage Site listing for its rich biodiversity and the wide ecological services it provides, both nationally and regionally (OARDB 2007). It is located 400 km southeast of Addis Ababa and 245 km east of BW. The Park belongs to the Bale-Arsi massif, which forms the western section of the southeastern Ethiopian highlands (OARDB 2007). It encompasses 2150 km^2 of mountains and forest and lies between the geographical coordinates of 6°29′ to 7°10′ N and 39°28′ to 39°57′ E (Fig. 1b). It is one of the most intact remnants of Ethiopia's indigenous forests (Marino 2003). It covers an altitudinal range of 1500 to 4377 m at Tullu Deemtu, which is the second highest peak in Ethiopia (Hillman 1986, EWNHS 1996, Fishpool & Evans 2001). The Park possesses the largest extent of Afroalpine habitats (above 3000 m asl) in Africa, which is where Wattled Cranes breed (Marino 2003, Ash & Atkins 2009). In the Afroalpine habitat of the National Park, Wattled Cranes favour areas with extensive wetlands and lakes with islands, located at an altitude of 3502 to 4034 m (Tadele 2018).



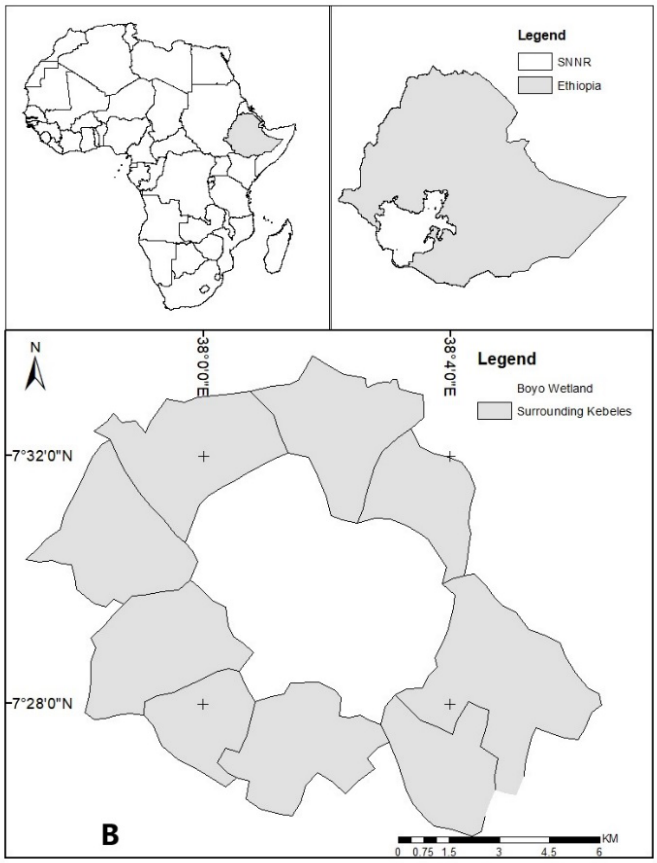


Figure 1. Map of the study areas (a) Bale Mountains National Park and (b) Boyo Wetland.

Methods

To determine the diurnal time-activity budget of Wattled Cranes at BW, four habitat types were recognized: 1) agricultural land (farmland for subsistence crops), 2) grassy field, 3) mudflat, and 4) shallow wetland. In the breeding habitat at BMNP, two different habitat types were identified based on the availability of vegetation and water, and using cues such as the level of small mammal activity in the surrounding areas. Based on this, habitats were classified as grasslands when the availability of grassy area was high (>50 % grass cover) and as swampy area (alpine wetland dominated by emergent grasses and other herbaceous plants), following a methodology similar to Aborn (2010). Behavioural observations and habitat use data were collected from October to June 2015/2016 and 2016/2017 in BW and from June to November 2014/2017 in the Afroalpine habitats of BMNP. Observations were made between 06:00 and 18:00. To assess the influence of the time of the day on behavioural activities, days were divided into three 4-h blocks from sunrise to sunset: morning (06:00–10:00), midday (10:01–14:00) and afternoon (14:01–18:00) following Aborn (2010). Similarly, to assess habitat preferences for Wattled Cranes, we recorded habitat type for each flock seen, and number of individuals in the flock. Observations were reasonably well balanced across time periods, among habitats and between

seasons, enabling variations in activities and their relationship to variables to be assessed. A flock was considered as those consisting of more than two individuals occurring within 10 m from one another (Wang *et al.* 2011).

During data collection, once flocks were found, instantaneous scan sampling was carried out (Altmann 1974, Sutherland 2004), to record the daily activity time budget of the species through scanning each individual in turn and categorizing its behaviour into different behavioural states. Individuals from a flock in visible fields were scanned for five minutes, during which instantaneous behaviour was recorded at 15-second intervals (20 observations per focal bird) (Weins *et al*. 1970, Zhou *et al.* 2010). Focal individuals flying outside the observation area were assumed to be in flight for the balance of the 5-minute period and observations were resumed at the start of the next period from the location where the bird took flight. Similar methods have been used for different crane species including Siberian Crane *Leucogeranus leucogeranus* (Jia *et al.* 2013), Sandhill Crane *Grus canadensis* (Tacha 1988), Common Crane *Grus grus* (Alonso & Alonso 1993, Avilés & Bednekoff 2007), Black-necked Crane *Grus nigricollis* (Kong *et al.* 2008), as well as captive Wattled Cranes (Davenport & Urban, 2010). However, birds were not sexed due to their similar morphology, and observations were restricted to adult birds because the number of juveniles in the wintering habitat at BW was too low to collect a sufficient amount of data for analysis. In this study, six behavioural states were distinguished.

1. Foraging (a crane picking, digging, or drinking (Wang *et al.* 2011) and searching for food while walking with lowered head (Zhou *et al.* 2010)).
2. Resting (a crane pausing or sleeping),
3. Comfort movement (cleaning or preening as well as muscle stretching comfort movement, locomotion, vigilance and social interaction).
4. Vigilance or alert (scanning its area by erecting its head upward (Tacha 1988).
5. Locomotion (walking while raising the head, running, flight and flapping).
6. Social interaction (behaviours of intraspecific interactions such as dancing and agonistic behaviours).

Data analysis

The behavioural data were initially checked with the Shapiro-Wilk test, to test if the data fitted a normal distribution or not. If the data fitted normal distribution, a parametric tests such as a one-way ANOVA (e.g., activity among habitats, flock size among habitats) was used for the time budget and the variation across different habitats and between seasons. On the contrary, if data were not normally distributed, log transformation (log 10) was applied to the raw data to comply with normality. If this yielded similar results, we reported the results based on raw data then applied only non-parametric tests such as the Mann-Whitney U test (e.g., activity between seasons and flock between seasons).

For the statistical analysis of focal observations, the percentage of occurrences among different behaviours, as well as time periods, was reported. The frequency of the different behaviours was also tallied, and a Student's T-test and ANOVA were used to determine any statistical variation in the frequency of behaviours in relation to habitat types, time periods of a day and seasonal variations. Chi-square test and

Pearson correlation analyses were conducted to examine associations and relationships between behaviours and flock size. All the above analyses were undertaken using SPSS version 20.

Results

During the whole study period both in BW and BMNP a total of 452 focal observations representing 2260 min or 37.7 hrs were gathered. A total of 134 (29.6 %) focal observations were conducted in agricultural fields whereas 102 (22.6 %), 105 (23.2) and 111 (24.6) focal observations were made on the mudflat, grassland, and shallow wetland habitats respectively.

Compared to other activities, Wattled Cranes spent more time (39.3 %) foraging with a mean frequency of 7.74 (± 0.59) per 5 min. While on locomotion, they spent 20 % of their time either looking for food or making other types of movements. The least amount of time was spent on social behaviour, which accounted for 2 %, while the rest of their time was allocated for resting and comfort movement (Table 1).

Table 1. Activity-time budget of Wattled Cranes over 37.7 hours of observation time across all habitat types.

Activity	Total activities recorded	Percentage (%)	Mean/5 min ± SE
Foraging	3,500	39.3	7.74 ± 0.59
Locomotion	1,775	20	3.93 ± 0.04
Vigilance	1,378	16	3.05 ± 0.35
Comfort movement	1,289	15	2.85 ± 0.49
Resting	824	9.3	1.82 ± 0.40
Social behaviour	134	2	0.3 ± 0.11

In the agricultural and grassland habitats, more of the daily activity budget was made up of foraging or locomotion compared to foraging in the mudflat and shallow wetland habitats where they devoted more time to vigilance, resting and comfort movement, as they gathered to drink or roost (Table 2). When considering each activity in relation to the four different habitat types, there was a significant variation in frequency of foraging activity ($\chi^2_{(3)} = 35.728$, $p < 0.05$), resting ($\chi^2_{(3)} = 39.682$, $p < 0.05$), comfort movement ($\chi^2_{(3)} = 56.287$, $p < 0.05$), vigilance ($\chi^2_{(3)} = 12.108$, $p < 0.05$) and locomotion ($\chi^2_{(3)} = 43.400$, $p < 0.05$), of Wattled Cranes among the four habitat types. However, there was no significant variation in the activity level of social behaviour ($\chi^2_{(3)} = 6.157$, $p > 0.05$), across the different habitat types.

Table 2. Activity-time budget of Wattled Cranes across four habitat types expressed as the mean number of activities per 5 min ± SE.

Activity	Habitat type			
	Agricultural area (n= 134)	Shallow wetland (n=105)	Grassland (n= 111)	Mudflat (n= 102)
Foraging	9.97 ± 0.86	5.40 ± 1.16	8.44 ± 1.26	6.66 ± 1.34
Locomotion	5.51 ± 0.76	2.65 ± 0.77	4.10 ± 0.89	3.05 ± 0.77
Vigilance	3.14 ± 0.76	3.76 ± 0.95	2.03 ± 0.48	3.21 ± 0.82
Comfort movement	0.49 ± 0.52	4.83 ± 1.09	2.75 ± 1.02	3.90 ± 1.23
Resting	0.69 ± 1.23	2.72 ± 0.77	2.21 ± 1.00	1.94 ± 0.91
Social behaviour	0.13 ± 0.13	0.53 ± 0.28	0.34 ± 0.30	0.21 ± 0.19

Time spent for foraging ($\chi^2_{(2)} = 40.037$, $p < 0.05$), resting ($\chi^2_{(2)} = 52.483$, $p < 0.05$), comfort movement ($\chi^2_{(2)} = 30.866$, $p < 0.05$), vigilance ($\chi^2_{(2)} = 23.180$, $p < 0.05$) and locomotion activity ($\chi^2_{(2)} = 24.489$, $p < 0.05$) varied significantly across the time of the day or showed a pattern within a day. Foraging activity most often peaked in the morning and least often during the afternoon. In comparison, resting and comfort behaviours were more frequent during the afternoon than the morning and midday. Vigilance behaviour peaked in the morning then decreased in the midday and finally reached its lowest level in the afternoon. However, movement activity was significantly higher in the morning than during midday and afternoon. The time spent preening increased as birds come to roost and aggregate together for overnight roosting and also during midday when they returned for drinking and midday roosting (taking some time to rest during the midday; Fig. 2).

With regard to time spent on social behaviour, the variation was not significant across daily time periods ($\chi^2_{(2)} = 4.778$, $p = 0.092$), where the frequency of time spent on social behaviour was higher during the afternoon than during morning or midday.

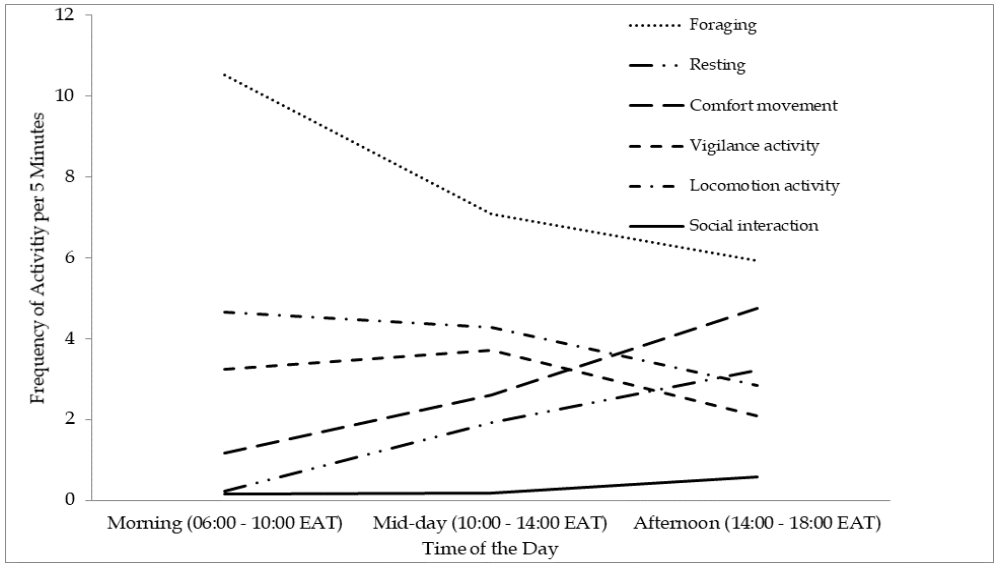


Figure 2. Frequency of different behaviour types per 5-minute intervals across three time periods.

Seasonally, foraging behaviour varied significantly ($U = 22{,}325$, $p < 0.05$), being more prevalent during the wet season (mean 8.42 ± 0.83) than the dry season (mean 7.16 ± 0.83) per five-minute focal observation. In addition, the observed frequency of vigilance behaviour was significantly greater in the wet season (3.83 ± 0.58) than the dry season (2.38 ± 0.40, $U = 19{,}797$, $p < 0.05$) and the same is true for comfort movement ($U = 22{,}702$, $p < 0.05$) and resting ($U = 22{,}857$, $p < 0.05$), where the percentage of time spent moving and resting was higher during the dry season than during the wet season (Fig. 3).

A total of 452 flocks were observed during the study period and the mean flock size was 4.67 (±0.44 SE) with range 2 to 29. A significant difference in flock size was observed among the habitat types at BW ($\chi^2_{(3)} = 13.1$, $p < 0.05$), where flock size in the shallow water or wetland habitat was larger (6.49 ± 0.41) than in the other habitat types.

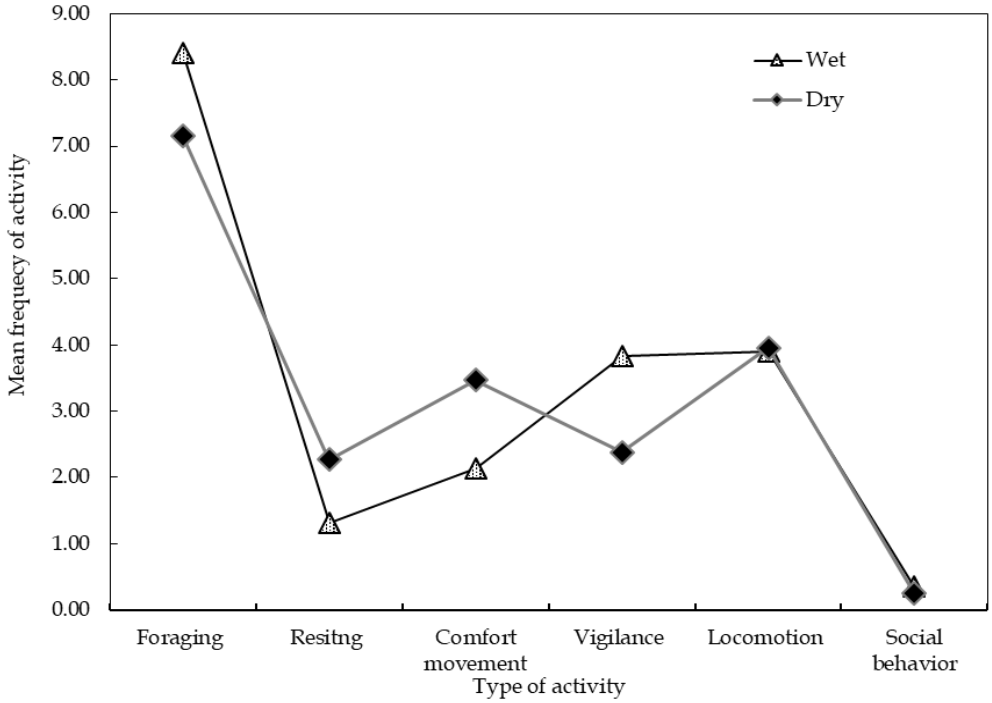


Figure 3. Mean frequency of different activity types of Wattled Cranes during different seasons.

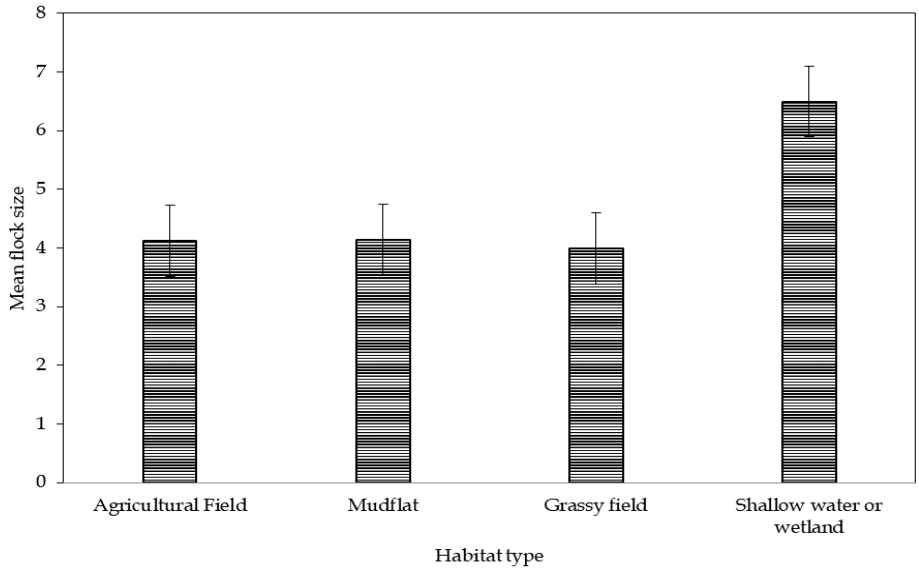


Figure 4. Variation in flock size of Wattled Cranes across the four Boyo habitat types.

In addition, flock size was also significantly different ($\chi^2_{(2)} = 6.55$, $p < 0.05$), across the three-time categories of the day, where the mean flock size in the afternoon (6.44 ± 1.15), range 2 to 29 was much greater than the midday (3.42 ± 1.22), range 2 to 24 and the morning (2.04 ± 0.343), range 2 to 11.

There was also significant variation in flock size between the dry and wet seasons ($U = 32{,}377$, $p < 0.05$), whereby the mean flock size during the dry season was larger (5.67 ± 0.713) than the wet season (3.14 ± 0.425). As flock size increased time spent on vigilance decreased ($r^2 = -0.145$, $p < 0.05$). In addition, flock size was negatively correlated with foraging, ($r^2 = -0.232$, $p < 0.05$) as well as locomotion ($r^2 = -0.147$, $p < 0.05$). However, flock size was positively correlated with comfort movement ($r^2 = 0.223$, $p < 0.05$) and social behaviour ($r^2 = 0.295$, $p < 0.05$).

Discussion and conclusions

Birds diurnal time activity budget may vary significantly between breeding and wintering seasons (Turner 1982), as a strategy to cope with environmental factors such as differing habitat types, food abundance and climate (Yang *et al.* 2007). During the study period, Wattled Cranes spent more time foraging (39.3 %) and this was significantly affected by habitat type, time of the day, and season. Similarly, Konrad (1981) reported that procurement of food takes up the greater part of the day for wild Wattled Cranes in Africa. By contrast, Wattled Cranes in captivity spent only 25 % of their time budget on foraging compared with wild birds (Davenport & Urban 2010). In captivity, animals are provided with food resulting in decreased time spent on searching for food. Similar to Wattled Cranes, other wetland birds such as Siberian Crane (Jia *et al.* 2013), Hooded Cranes (Zhou *et al.* 2010) and Canvasback *Aythya valisineria* (Hohman & Rave 1990) spend more energy searching for food or foraging than on other activity types.

Wattled Cranes spent more time feeding in agricultural habitat than in the other three habitat types in BW, even though this species is considered as the most wetland-dependent of Africa's cranes (Konrad 1981). This might be due to the abundant food resources or waste grains in maize and wheat fields combined with the scarcity of food in wetlands due to habitat degradation caused by heavy siltation from the surrounding watershed (Deboch, 2018). Similarly, Black-necked Cranes have been forced to choose new habitats of traditionally cultivated fields with abundant potato residues compared to wetland habitats, which were degraded due to increased human disturbance in Huize Nature Reserve, Yunnan, China (Wu *et al.* 2013).

The activity budgets of Wattled Cranes differed significantly between diurnal time periods, where locomotion and foraging were more frequent in the morning than during midday and afternoon. Since feeding is directly related to energy procurement, diurnal distribution should reflect patterns of an individual's diurnal energy demands, given constant food availability. Therefore, the morning feeding peak probably occurred because Wattled Cranes had not fed for 11–12 h and they had to feed in the early morning to make up the energy debt incurred during the night, similar to wintering Common Cranes in Gallocanta, Spain (Alonso & Alonso 1992). Time spent being vigilant was higher during the breeding season than the dry season, due to their occurrence in pairs/small flocks during the breeding season compared to large flocks during the dry season. The reason behind the negative correlation between flock size and vigilance might be that as the number of individuals in a group

increased, the time allocated to scanning for danger decreased as this responsibility is shared among more individuals; this is termed a 'many eye hypothesis' (Roberts, 1996). Similar results were also observed in Black-necked Cranes (Yang *et al.* 2007), Common Cranes (Avilés & Bednekoff 2007), Red-crowned Cranes *Grus japonensi*s (Wang *et al.* 2011) and other vertebrate animals like Columbian Ground Squirrels *Urocitellus columbianus* (Fairbanks & Dobson 2007). Contrary to this, when group size increases, the level of foraging competition also increases (Roberts 1996).

Time spent being vigilant by Wattled Cranes (15.5 %) was much less pronounced than in Red Crowned Crane*s* (23.6 %) in Shengjin Lake (Wang *et al.* 2011) and Hooded Cranes *Grus monacha* (24.8 %) in Yancheng Biosphere Reserve, China (Li *et al.* 2015). This might be due to the fact that Wattled Cranes in BW are well adapted to human disturbance as there is no culture of killing or shooting by the local people.

Wattled Cranes spent more time foraging during the wet season in BMNP than in the dry season in BW. This is likely due to the high energy demand during the breeding season or the scarcity of available food in the Afroalpine habitat, forcing cranes to search for food for a longer time. Similar results were obtained by Hohman & Rave (1990), where the difference in time allocation for foraging between sites was due to characteristics of the food, mode of foraging, disturbance level and characteristics of the habitat for Canvasbacks. In addition, energy demands of birds at high altitude such as BMNP is high compared to those in lowland areas because of the high basal metabolism rate due to lower temperatures leading to elevated thermoregulatory costs (Londoño *et al.* 2015). Another theory is that foraging time differs because foraging strategies differ between areas and between seasons. During the breeding season or at the breeding area, Wattled Cranes feed mostly on tubers or soft roots of grasses, which they dig up and it is time consuming elevating the foraging time. Whereas, during the dry season, Wattled Cranes mostly feed on farmlands, gleaning waste grains from the fields.

Flock size showed significant variation both among the habitat types and across the three daily time periods, where larger flock size was observed in the shallow wetland habitat and during the afternoon. This might be due to large flock formation at the shallow wetland during the midday for roosting and drinking as well as during the afternoon for night roosting. Cranes typically roost on the ground or while standing in shallow water to protect themselves from danger (Johnsgard 1983).

Data analysis was restricted to adult birds because the number of juveniles at BW or the wintering habitat was low and it was not possible to collect enough data on juveniles. However, juvenile cranes tend to be less vigilant, as in Sandhill Cranes (Tacha 1988) and Common Cranes (Alonso & Alonso 1993, Avilés & Bednekoff 2007), and are known to devote more time to feeding than to vigilance. Adult Common Cranes with juveniles seem to scan their area more frequently (Avilés 2003).

Overall, the results of this study show that wintering Wattled Cranes in BW exhibit different behavioural patterns in different habitat types, seasons, and times of day. This allows them to adapt to the changing environment and other biotic and abiotic factors. Contrary to Wattled Cranes' known behaviour as one of the most wetland-dependent species of all African cranes (Meine and Archibald, 1996), the results show that they spend more time in farmland than in wetland habitats, especially for foraging. This suggests that the natural foods of this vulnerable species, predominantly *Eriocholoa fatmensis* and *Eriocholoa meyeriana* grasses, are decreasing due the degradation of the size of the wetland (Tadele 2018). However, spending

more time in farmland may create a conflict with farmers around the wetland, which could expose them to more threats. Urgent measures should therefore be undertaken to restore wetland habitats and enhance the growth of natural food sources for the Wattled Crane.

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