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Plant Diet Selectivity and Some Environmental Parameters at Foraging Sites of Wattled Crane (*Bugeranus carunculatus)* in Malagarasi Wetlands, Tanzania

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Abstract

Wattled Crane *Bugeranus carunculatus* is a threatened wetland-dependent bird species of sub-Saharan Africa with a declining population throughout its range due to habitat degradation. Ecological studies on this species have come from large populations in Botswana and Zambia. Little is known of the isolated small populations, especially those in Tanzania where about 200 individuals survive. This study reports observations made on vegetation height, water depth and consumption of plant tubers at foraging locations of the Wattled Crane in Malagarasi-Muyovozi Ramsar Site. Foraging birds preferred wet habitats with short vegetation. Birds fed mainly on *Pycreus nitidus* and *Cyperus articulatus* plant tubers but not those of *Eleocharis*, a chief food plant in southern Africa, which in this study was restricted to deep water levels along lakeshores. As water gradually recedes, the swamp provides good foraging environment for the Wattled Crane. Moreover, it is during the same period when human activities especially livestock grazing and burning increase in the swamp. These human activities are likely to interfere with water level balance and change wetland vegetation structure. Furthermore, if such activities are not controlled could affect productivity, availability and accessibility of the plant tubers, the predominant food of the globally threatened Wattled Crane.

Keywords: *Eleocharis*, *Pycreus nitidus*, tuber selectivity, wetland-dependent birds.

Introduction

The Wattled Crane *Bugeranus carunculatus* [Gmelin 1789] is an endemic bird species to wetlands in sub-Saharan Africa with a global population of about 8,000 individuals, which is declining in many of its range states due to habitat degradation as a result of burning, grazing and conversion of swamps for agriculture (Beilfuss et al. 2007, BirdLife International 2018). Illegal trapping for international animal live trade is also among the major threats to the Wattled Crane in southern Africa (Morrison and van der Spuy 2006, John 2015). The species is listed as 'Vulnerable' by the IUCN and on CITES-Appendix II (BirdLife International 2018).

Wattled Cranes are abundant in Botswana and Zambia where about 80% of the global population survives, and there are two smaller isolated populations in South Africa and Ethiopia (Beilfuss et al. 2007). Other small populations (< 500 birds) are found in Angola, Malawi, Mozambique, Zimbabwe, Democratic Republic of Congo and Tanzania (BirdLife International 2018). In Tanzania, the species has been nearly extirpated from its historic range (Elliott 1983), and the only viable population (c. 200 birds) is found in Malagarasi-Muyovozi Ramsar Site (Beilfuss et al. 2007). Previous aerial surveys have indicated that the lake swamps and adjacent grasslands host a significant portion of this population at one particular season (Parker 1984, Kaaya et al. 2007). Seasonal fluctuation in the Wattled Crane numbers has also been reported in the floodplain of Malagarasi (John 2013) suggesting seasonal use within the Ramsar Site. However, there is still limited information on the possible factors that determine the Wattled Crane's habitat use.

Although the Wattled Crane use upland habitats and sometimes agricultural land, e.g., in Ethiopia (Abebe 1998), it remains the most wetland-dependent of the six species of crane in Africa (Beilfuss et al. 2007). Other species are Black Crowned Crane *Balearica pavonina*, Grey Crowned Crane *B. regalorum*, Blue Crane *Anthropoides paradiseus*, Demoiselle Crane *A. virgo* and the migratory Eurasian Crane *Grus grus.* Wattled Cranes are highly dependent on wetlands for foraging, roosting and nesting (Meine and Archibald 1996, John et al. 2012) making them more susceptible to degradation and major hydrological deteriorations, both of which have increased in recent decades due to pressures for developments (Mumba and Thompson 2005, Wetlands International 2010).

Like many non-diver waterbirds, Wattled Cranes have to wade through shallow water for foraging. Few large waterbirds can forage in water deeper than the lengths of their legs and/or beak (Ntiamoa-Baidu et al. 1998). Wattled Cranes predominantly feed on sedge roots, rhizomes and bulbs in shallow and soft ground (Douthwaite 1974); however, they will also take grass sward and seed, and animals including small aquatic snails, fish and frogs (Hockey et al. 2005). Accessibility of plant tubers and other food resources may depend on water depths and other habitat configurations such as vegetation height (Bayliss and Yeomans 1990, Whittingham and Evans 2004, Traill and Brook 2011). The present study reports foraging observations of a small population of the Wattled Crane in western Tanzania. In addition to vegetation height and water depth at foraging locations, the study investigated the plant tuber selection because in other countries (e.g., Zambia), the Wattled Crane feeding activity is highly correlated with the presence of plant tubers especially that of *Eleocharis* (Douthwaite 1974, Ndirima 2007).

Materials and Methods

Study area

The Malagarasi wetlands (3–6°S, 30–32°E) were designated as the first Ramsar site for Tanzania in 2000 (Nkotagu and Ndaro 2004). Located in the northwestern Tanzania, it remains the largest (approximately 3.25 million ha) Ramsar Site in the country. The core area or central drainage of the Ramsar Site comprises shallow lakes with the major being Nyamagoma (53 km^2) and Sagara (328 km^2). Additionally, there is open water in the dry season covering about 250,000 ha together with a permanent papyrus swamp of about 200,000 ha with large peripheral floodplains that fluctuate widely on a yearly basis depending on the amount of rainfall but cover up to 1.5 million ha (Kashaigili and Majaliwa 2010). The wetland habitats are surrounded by very extensive miombo woodlands and wooded grasslands. The Malagarasi wetland habitats could be grouped into several types (Kashaigili and Majaliwa 2010): floodplain grassland, floodplain woodlands, permanent swamps, open water bodies, riverine, and ground forest. The floodplains, in the peripheral of permanent swamps, and those associated with the rivers are inundated by floods, which vary in level as much as 6 m over a series of dry or wet years in the more southerly regions of the wetland. These floodplains have saline alkaline soils of a mineral hydromorphic nature (Nkotagu and Ndaro 2004).

The present study focused on the central drainage (Figure 1) of the Ramsar Site due to the presence of representative habitats, more important is the presence of a large area of marshes and floodplains (Hughes and Hughes 1992, Kashaigili and Majaliwa 2010). Aerial counts during the dry season have suggested that the Ramsar Site central drainage basin could host *c.* 50% of the estimated Tanzanian population of the Wattled Crane (Parker 1984, Kaaya et al. 2007). Moreover, the southern part of the Kigosi-Muyovozi Game Reserve around the Lake Nyamagoma is known to be an important site for the Wattled Crane (Parker 1984). Specific study sites included the Lumbe swamp south of Lake Sagara and areas surrounding the Lake Nyamagoma (within < 35 km perimeter from open water). At Lake Nyamagoma, south-west (Kasisi) and north-east swamps (Chagu) of the lake were treated as different sites. Most of Lumbe Plain is covered with perennial grass swamp, which collapses as the flood recedes. The fieldwork took place between April 2010 and December 2011.

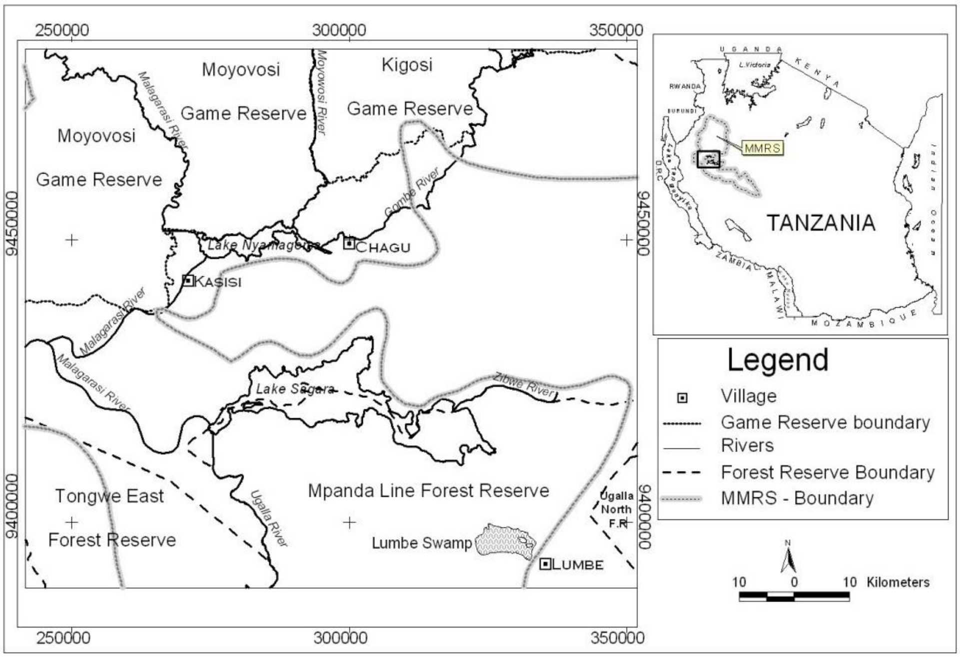

Figure 1: Map of the study sites within the core wetland area of Malagarasi-Muyovozi Ramsar Site (MMRS); the present study concentrated in the swamps near the three villages; Lumbe, Kasisi and Chagu.

Methods

Vegetation

Vegetation sampling was conducted in August 2010, which is a transition from high to low floods. At this time it was neither too dry (which is usually followed by burning and grazing) to complicate identification nor too wet to limit navigation. Ten locations were selected; four from inland swamp and six from lake swamps. At each location, between 17 and 23 quadrats (1 m x 1 m) were sampled at 50 m apart along a transect emanating from four cardinal directions from the centre of the station (modified from Coppedge et al. 2008). Within a 1 m^2 wooded frame, vegetation was surveyed to establish a species list, and assess the relative frequency and species percentage cover. Species accumulation curves were used to determine the minimum quadrats in each vegetation sampling location. At all the study sites, the curves flattened at 12-15 quadrats indicating adequate sampling.

Birds, vegetation height, and water depth

A telescope (Bushnell: 20 x 40 x 60) and binoculars (8 x 42 FOV430') were used to scan the wetlands (at the three sites) for birds from April 2010 to September 2011. Focal observations (Altmann 1974) were conducted for 30 min for each of 222 birds to confirm the foraging activity before approaching to record vegetation height and water depth at foraging locations. After each observation, the survey team moved to other locations to search for birds. Taking into consideration of the Wattled Crane beak and leg lengths [exposed culmen 124-185 mm; tarsus 232-342 mm (Johnsgard 1983)], water depths at 123 foraging locations were measured by a graduated rod and later in the analysis were categorised in three groups: dry; absence of surface water, shallow; < 35 cm, deep; ≥ 35 cm. In setting limit between shallow and deep, it was assumed that water depth past bird's tibio-tarsal joint would cause difficulties for wading and may interfere with the Wattled Crane foraging.

Selection of tubers by the Wattled Crane

From focal observations on the wattled crane, the field team identified selected tuber plant species fed on by this bird. Following observations of beak digging by cranes in completely grazed, burnt or dried areas, tubers were dug for identification. Sometimes, broken stolon fragments were easily found on probe-holes or floating in shallow waters. Plants, which could not be identified in the field were collected, labelled, and pressed or preserved in Nalgene bottles with 80% alcohol for laboratory/herbarium identification at the University of Dar es Salaam.

Data analyses

Data were analysed using the SPSS for Windows Release 16.0 (SPSS Inc., Chicago, Illinois) and BioDiversity Professional software (McAleece et al. 1997). Several statistical analyses were performed and normality and homoscedasticity of the data were tested by examining the residuals and calculating Levene tests, respectively. When data did not meet the requirements (e.g., non-normal distribution), non-parametric statistics were used otherwise parametric tests were preferred. Kruskal-Wallis and analysis of variance (ANOVA) was used for testing differences in water depth and vegetation height selection for foraging birds, respectively, whereas *t*-test was used for testing selection of tubers. Results were considered significant at $P < 0.05$. BioDiversity Professional software was used to determine plant species diversity, similarities, and distribution or aggregation using χ^2 test. Because of the unequal vegetation quadrat numbers for all the three study sites, frequency proportions were used to run the BioDiversity Professional software. Bray-Curtis Cluster Analysis (single link) was employed for vegetation similarities and Shannon's index for plant diversity.

To determine tuber preference, a linear food selection index (Strauss 1979) was used; ($L = r - p$; where r and p are proportions of selection of plant species and of their respective relative abundances in the habitat, respectively). However, for *Eleocharis*, a known chief feed tuber for the Wattled Crane elsewhere (Doathwaite 1974), but was completely avoided in this study, the Jacobs (1974) index of food selection was employed; ($D = \frac{r-p}{r+p-2rp}$, where $r = 0$, when food item is present in the environment but not selected).

Results

Plant species composition

Thirty-four plant species were recorded from 210 quadrats (1 m x 1 m) at 10 stations distributed as follows: Chagu; 20 species in 64 quadrats, Kasisi; 19 species in 62 quadrats, and Lumbe; 17 species in 84 quadrats. Plant species diversity index (Shannon-Wiener) in the 10 surveyed stations ranged from 1.99 to 2.0. Plant species similarities ranged from 36% to 88% and stations from the same sites were more similar than between sites (Figure 2).

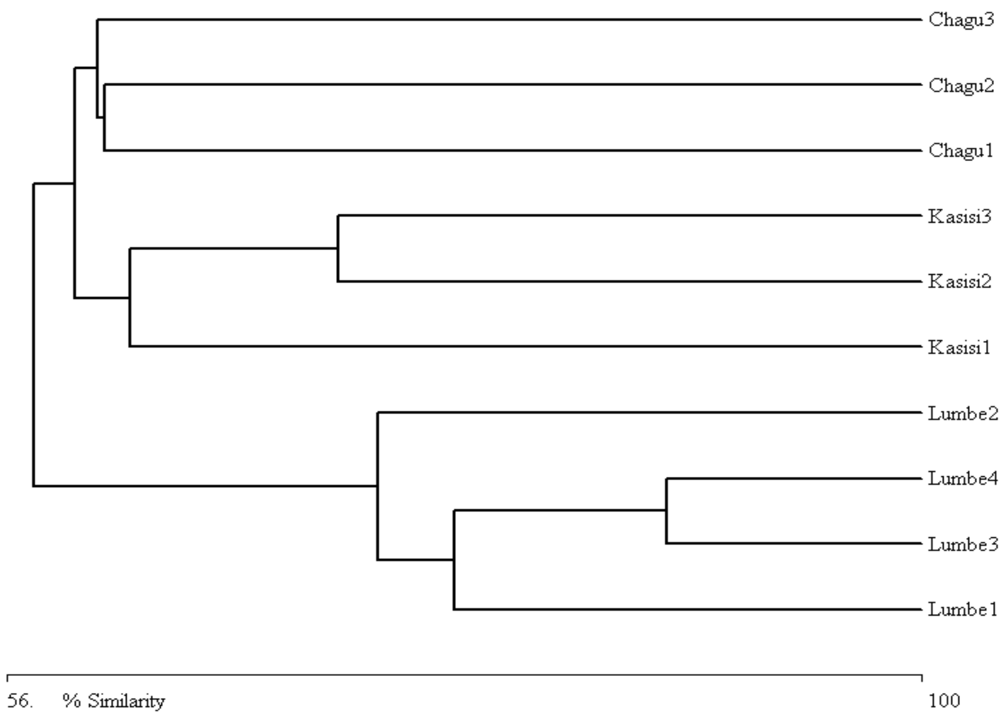

Figure 2: Neighbour-Joining dendrogram showing the vegetation relationship among the three study sites and within the sampling locations in the central drainage area of the Malagarasi wetlands. Plant composition was more similar in stations surveyed from the same study sites than between sites as indicated by three distinct clusters (Lumbe, Kasisi and Chagu). The inland swamp (Lumbe) is more distinct from the two lake swamps.

Foraging water depth and vegetation heights

The selection of two environmental parameters, water depth and vegetation height, for foraging of the Wattled Cranes were not significantly correlated (r_s = 0.161, P = 0.76, n = 123). Birds foraged in shorter vegetation (mean ± *SD*; 45.42 ± 28.83 cm). No statistical difference was found for vegetation height selection during foraging among sites ($F_{(2, 120)} = 0.132$, P = 0.877). Birds were observed foraging in dry/wet soil, shallow and few (15%) in water ≥ 35 cm (Table 1). Generally, birds foraged in water < 35 cm (14.12 ± 16.59 cm, n = 123). Those that waded in deep water were on few occasions seen to stripe seed heads off tall grass of the genus

Echinochloa. Two species of *Echinochloa* were recorded at the study sites; *E. haploclatum* and *E. pyramidalis*. Despite the variation presented in Table 1, which shows significant difference in water depth within the inland swamp, Lumbe, pooled data showed no significant difference in foraging-water depth selection for the Wattled Cranes (Kruskal-Wallis: H = 1.092, df = 2, P = 0.579).

Feed plant tubers preference

The Wattled Crane foraged on tubers of the following plants: *Cyperus articulatus, C. denudatus*, *Nymphea capensis*, *Pycreus nitidus* and *Scirpus brachyceras* (Figure 3). Preferences varied from one site to the other. *Pycreus nitidus* and *C. articulatus* were selected in much greater proportions than their natural occurrence at inland and lake swamps. For example, the selection of *P. nitidus* and *C. articulatus* did not differ significantly ($t_{19,60}$ = 1.359, P > 0.05) at Kasisi, a lake swamp site. The Wattled crane did not forage on *Eleocharis dulcis* tubers, although it was relatively common (χ^2 = 1.937, df = 9, P = 0.992, Table 2). *Cyperus denudatus* was selected in much less proportion than its availability at inland swamp, while selection of the rest of the species across all the three sites was proportionate to their natural availability (i.e., linear food selection indices close to zero; Figure 3).

The Wattled Crane's diet species were either randomly distributed (*C. denudatus;* χ^2 = 4.067, df = 9, P = 0.907, *C. articulatus;* χ^2 = 4.278, df = 9, P = 0.892, *S. brachyceras;* χ^2 = 3.349, df = 9, P = 0.948) or in regular distribution patterns (*P. nitidus;* χ^2 = 0.352, P = 0.999, *N. capensis;* χ^2 = 1.202, df = 9, P = 0.998, Table 2).

Table 1: Water depth selected by the wattled crane *Bugeranus carunculatus* during foraging among three study sites in Malagarasi wetlands in 2010 and 2011

Sites	Dry (%)	Shallow (%)	Deep (%)	Totals (n)	P-value	Statistical test
Lumbe	36^a	53^a	11^b	73	0.001	ANOVA (F = 7.244)
Kasisi	20	40	40	15	0.380	Kruskal-Wallis (H = 1.934)
Chagu	57	34	9	35	0.281	Kruskal-Wallis (H = 2.536)

Different superscript letters show statistically different water depth means at P < 0.05 (Bonferroni Post Hoc Test of multiple comparisons).

Table 2: Distribution status of plant species foraged by Wattled Crane in Malagarasi wetlands

Species	Authority	Family	σ^2	M	χ^2	Df	$P(A)$	*Aggregation
Cyperus articulatus	L.	Cyperaceae	0.048	0.101	4.278	9	0.893	Random
Cyperus denudantis	L.f.	Cyperaceae	0.191	0.423	4.067	9	0.907	Random
Eleocharis dulcis	(Burm. f.).	Cyperaceae	0.045	0.211	1.937	9	0.992	Regular
Nymphaea capensis	Thunb.	Nymphaeaceae	0.011	0.087	1.202	9	0.998	Regular
Pycreus nitidus	Lam.	Cyperaceae	0.030	0.778	0.352	9	0.999	Regular
Scirpus branchyceras	Hosch. ex A. Rich.	Cyperaceae	0.030	0.083	3.349	9	0.948	Random

**The BioDiversity Professional software categorizes species in aggregates depending on the probability of occurrence (using proportions of each plant species in a community), P(A), in the study plots with regular having the highest probability followed by random.*

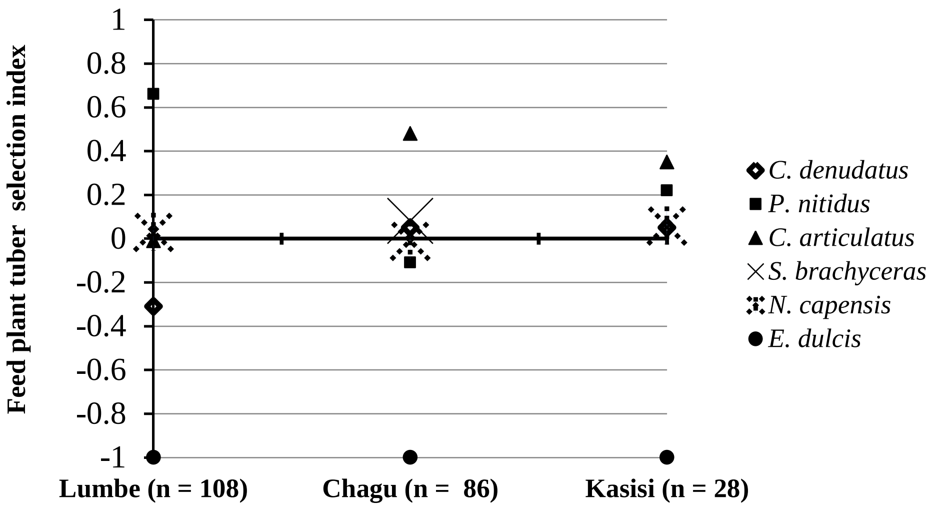

Figure 3: Selection of feed plant tuber by the Wattled Cranes *Bugeranus carunculatus* at three different localities (Lumbe is an inland swamp whereas the rest are lake swamps); *n* = number of individual observations at each site. The index ranges from –1 to +1, with positive values indicating preference and negative values indicating avoidance.

Discussion

Vegetation composition

This study shows similarly low vegetation species richness and diversity indices to other studies from Malagarasi (Ndangalasi et al. 2004). The lower species richness and diversity are in agreement with the general hypothesis that few plant species are adapted to waterlogged habitats due poor aeration. Organisms including plants that live in wetlands must have anatomical, morphological, physiological, or behavioural adaptations to enable them to acquire, conserve, store, or find oxygen (van der Valk 2012).

Foraging water depth and vegetation height

The Wattled Crane foraged in dry and shallow waters not beyond its beak length, which is consistent with other studies on water levels and foraging birds (Ntiamoa-Baidu et al. 1998, Colwell and Taft 2000). For waterbirds that feed in water without diving, the neck and leg length (Ntiamoa-Baidu et al. 1998, Colwell and Taft 2000, Hattori and Mae 2001, Traill and Brook 2011) usually determines the maximum depth of feeding sites. In China, Siberian Cranes *Grus leucogeranus* relocate to other places when water levels are > 50 cm due to difficulties in accessing tubers (Jia et al. 2013). As for the Wattled Crane, water level > 35 cm would be difficult to wade and dig tubers because of the length of leg and neck (Johnsgard 1983). This study suggests that the Wattled Cranes prefer shallow and dry grassland especially those with soft ground because they contain easily accessible tubers. From a few samples of tubers dug for identification, it was noted that birds were digging tubers in soft ground. At Kafue Flats in Zambia, Douthwaite (1974) noted that the diets of Wattled Cranes were largely of rhizomes dug from soft mud.

The Wattled Cranes foraged in a variety of vegetation heights with preference for short vegetation (about one third of their body heights). The Wattled Cranes locate food by mostly visual, feeding in shorter vegetation would facilitate their foraging success. Other studies on birds have suggested that the selection of lower vegetation height allows more visual cues to detect prey items (Eiserer 1980, Berchard 1982) and respond to disturbance from predators (Whittingham and Evans 2004). Until further studies prove the effect of predation in Malagarasi, it may not be a major factor driving the Wattled Cranes to forage in shorter vegetation (John 2015).

Plant tuber selection by the Wattled Crane

Although no attempt was made to measure nutritional content of the tubers, it may play a determining role in selection (Owen 1972, Doerr et al. 1974, Remington and Braun 1985, Balasubramanian et al. 2004, Hongfei et al. 2012). For example, in China, Red Crowned Cranes *Grus japonensis* were found to select plants containing a high proportion of crude protein and low crude fibres (Hongfei et al. 2012).

Nonetheless, in this study, the following physical environmental attributes could have led to the higher selection of *P. nitidus* than its natural occurrence:

(a) *P. nitidus* grows well in wet swamps and swamp-edges, sometimes gregarious in disturbed swamps and then often recognisable by its robust stolons (Haines and Lye 1983),

(b) *P. nitidus* occurred in several sizeable patches or single species clump more greener than surrounding vegetation stands, which can easily be located by flying birds unlike other *Cyperus* species, which were intermixed or scattered thinly,

(c) *P. nitidus* patches were of short vegetation (preferred by foraging Wattled Cranes), and

(d) *P. nitidus* stolons were either on the surface of very wet soil or floating in shallow waters, and could easily be extracted by the Wattled Cranes.

It was however noted that *P. nitidus* stolons wither very easily in the absence of moisture which, could restrict its availability for cranes during the dry season or at dry grasslands. Moreover, *C. articulatus* was also selected at lake swamps most probably because of its abundance as it prefers lake shores and standing water (Haines and Lye 1983) while *P. nitidus* was rare at the lake swamps, especially at Kasisi, which is waterlogged throughout the year. Few observations were made at this site (Table 1, Figure 3) as the Wattled Cranes were few.

The Wattled Crane did not forage on *Eleocharis* although it is known to be its main food in other southern Africa countries specifically in Zambia and Botswana (Douthwaite 1974, Beilfuss et al. 2007). Actually, it has been claimed that the availability of *Eleocharis* feed source is the main factor behind its distribution pattern in Zambia, Mozambique and Botswana (Bento et al. 2007, Ndirima 2007). *Eleocharis* tubers in this study were not accessible as the plant was restricted along deep-water shorelines and in permanent lake swamps. Moreover, *Eleocharis dulcis* is sensitive to saline environment (Eliot et al. 1999) which could limit its spatial and temporal distribution. This plant prefers water-prone areas and performs poorly above waterline although growing under constantly flooding conditions leads to sexual reproduction, which lowers tuber formation (Beilfuss 2000, Finlayson 2005), consequently limiting feed source for Wattled Crane. Other plant species such as water lilies *N. capensis*, which become the Wattled Crane food in Zambia during the dry season (Douthwaite 1974) although abundant in Malagarasi were inaccessible to the Wattled Cranes during the dry season due to animal disturbances such as increased human activities (fishing, excavation of lungfish and cattle grazing), and congregation of other waterbirds.

Conclusion

This study provides some environmental parameters (e.g., optimal foraging vegetation height and water depth, food selection), which are important for identifying suitable foraging sites for the Wattled Cranes. This in turn could help in designing a conservation strategy for the Wattled Crane, which could include zoning, and restricting human activities, such as farming and livestock grazing in areas close to foraging sites. The Wattled Crane preferred short grassland floodplains; these habitats are prone to invasion of papyrus if farming is not controlled. Papyrus, aggregated in Malagarasi Swamp, is an opportunistic invasive macrophyte following eutrophication (Kipkemboi et al. 2002, Brooks et al. 2011). It is an emergent macrophyte forming extensive dense floating rafts of vegetation (Denny 1984), which the Wattled Crane is not able to penetrate. Already rice paddies have been reported in the Malagarasi wetlands and there is a continued expansion of tobacco farming in woodlands adjacent the swamps (Dinesen and Baker 2006).

Increased agricultural activities will likely affect the water level balance, and release of fertilisers and pesticides in the aquatic ecosystem resulting into eutrophication, which will favour the expansion of papyrus. Furthermore, livestock grazing and burning were common throughout the study sites. Although their impacts on wetland birds in Malagarasi are still undocumented, increased livestock grazing and frequent burning may result into change of vegetation composition, structure and soil compaction, thereby affecting flooding periods, which is likely to affect availability and accessibility of feed resources for many wetland-dependent birds particularly the Wattled Cranes.

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