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SHORT COMMUNICATION

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Bird community structure across habitats in a protected area of South Sudan

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1 | INTRODUCTION

Birds are the best-known components of the Earth's biodiversity (Bibby, Jones, & Marsden, 1998; Pomeroy, 1992) and realise many ecological functions in their habitats (Gatesire, Nsabimana, Nyiramana, Seburanga, & Mirville, 2014; Judd, Campbell, Kellogg, Stevens, & Donoghue, 2008; Stevenson & Fanshawe, 2002; Di Vittorio et al., 2018), being also bioindicators of healthy ecosystems and human perturbances (Mistry, Berardi, & Simpson, 2008; Slabbekoorn & Ripmeester, 2008) as their abundance is well known to change considerably due to anthropogenic activities (Askins, Lynch, & Greenburg, 1990; Bock, Bock, & Bennett, 2001).

Although there are a number of descriptive field studies and field guides on the birds of East Africa (Cave & McDonald, 1955), lesser studies have investigated the community structure of bird assemblages in that part of the world, and particularly in South Sudan (Nikolaus, 1989) where the socio-political instability has heavily constrained the scientific research in the area (Balmford et al., 2001). Systematic surveys of birds were poor, perhaps even non-existent, in South Sudan for the past 25 years due to civil unrest in the country (De Waal, 2014). Consequently, our knowledge of birds in the country is still extremely poor, even in the Key Biodiversity Areas (KBAs). Bandingilo National Park is one of KBAs in South Sudan, which includes internationally recognised sites that are important for the conservation of birds and are also sites of global significance for the conservation of biodiversity (Lever, 1984).

Here, we analyse the community assemblage of birds in the Bandingilo National Park, with emphasis on the guilds inhabiting the various habitat types, and the variation in abundance in relation to seasonality and trophic characteristics.

2 | STUDY AREA AND METHODS

The field study was carried out in Bandingilo National Park, South Sudan (Figure 1). This protected area was established in 1992 and is located in a wooded area near the White Nile River in South Sudan's Equatoria region, within the states of Jubek and Imatong (5°25′58″N 32°16′39″E). This park also contains large marshlands stretching up into Jonglei State. More recently, the National Park has absorbed Mongalla Game Reserve and the park now comprises roughly 10,100 km^2 area. The study area is characterised by tropical wet and dry climate (average annual temperature = 27.7°C) with average rainfall being 903 mm. The dry season occurred from November to March (mean temperature = 29.9°C; mean precipitation = 141mm), and the wet season from April to October (mean temperature = 25.7°C; mean rainfall = 950 mm).

In the study area, the following habitat types were surveyed: (a) riverine, (b) woody savannah, (c) shrubland, (d) grassland, (e) riverbanks and openwater, and (f) water flooded area. The characteristics of the various habitat types were as follows:

Riverine: This is the habitat strip extending along the river course, from 0.5 to 1.0 km from the riverbanks. It consisted of a mixture of grass and woody plants dominated by *Acacia siberiana* and *Acacia nilotica*.

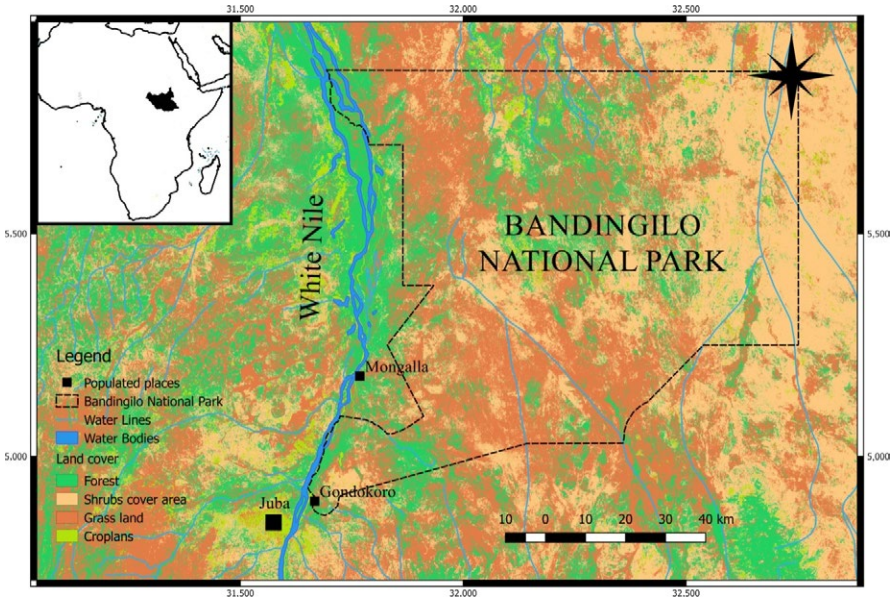

FIGURE 1 Map of the study area showing the position of Bandingilo National Park including the absorbed Mongalla Game Reserves

Woody savannah: These are undisturbed thicket areas mainly comprised of *Acacia* and *Combretum* woodlands interspersed by evergreen trees *Ficus* spp., and other common species like *Ziziphus spinachristi*, *Lannea sinensis*, *Grewia tembensis*, *Grewia bicolor* and *Lonchocarpus laxiflorus*.

Shrublands: This habitat, dominant in the highest well-drained ground like Mogiri, Jabur and Kuda, consisted of a strong presence of *Combretum* sp., interspersed by grasses (*Hyperrhenia rufa* and *Hyperrhenia filibendula*).

Riverbanks and openwater: This occurs mostly in the main River Nile, with the main vegetation type being floating, with *Eichhornia crassipes*, *Cyperus papyrus*, *Coccinia grandis*, *Cayratia ibuenis*, *Luffa clyindrica* and ferns (e.g. *Cyclosorus interruptus*). This habitat covers most of the study area from Gondokoro to Mongalla.

Water Flooded Areas: These are small to big shallow depression mostly filled with grasses. These depressions, that are numerous in the Kuda area, are fed by rains and runoff with no connections flowing to river channels or other water bodies.

The field study was conducted between June 2016 and January 2018, in both dry and wet seasons. Overall, the survey lasted two weeks every month (for 18 months). The survey was done every day (08:00–12:00, 15:00–17:00), at 360 randomly selected sampling stations for birds that were situated along different habitat types of Mongalla, Kuda, Jabur, Mugiri, Gondokoro and in the centre of Bandingilo National Park. In each of the above-mentioned six study sites, 60 randomly fixed 500-metre-radius points were selected, and each point was visited three times by the observers (once every six months). In each site, a team of five field ornithologists with standardised knowledge of bird identification recorded the data. Each habitat type was monitored for almost identical research time (9 hr per person per site). Any bird species opportunistically seen or heard during the entire period of field work was also recorded but not used for our statistical analyses. The identification of the recorded birds was performed visually and by photographic record. All individuals were identified to species level with binocular and using Van Perlo (2002). The risk of a multiple encounter with same individuals was minimised by walking along different routes of a same sampling station and by spacing the various sampling stations by at least 300 m each another. Nonetheless, as it is typical of bird census studies, it cannot be excluded that some individuals were observed multiple times along our field study.

In order to compare the diversity metrics of the bird assemblages among habitats, we calculated various distinct univariate measures of community diversity for each habitat type (Magurran, 1988):

1. Species richness, that is the total number of species recorded into each habitat type;
2. Dominance: $D = 1 - \text{Simpson index}$;
3. Simpson index: $S = 1 - D$.
4. Shannon–Wiener index (Shannon & Weaver, 1963):

$$H' = -\Sigma \left[n/N \log \left(n/N \right) \right]$$

where n is the number of individuals of each species in each habitat type and N is the total number of birds that were recorded in each habitat type.

5. Evenness, calculated by Pielou's formula:

$$e = H' / \log S$$

with H′ representing Shannon's index, and S the total number of bird species observed in each habitat type (Magurran, 1988).

Bootstrap analysis was applied to generate upper and lower confidence intervals of all indices, with 9,999 random samples, each with the same total number of individuals as in each original sample, being generated (Harper, 1999). Generalized linear models (GLM) were used to model the survey results and to quantify their

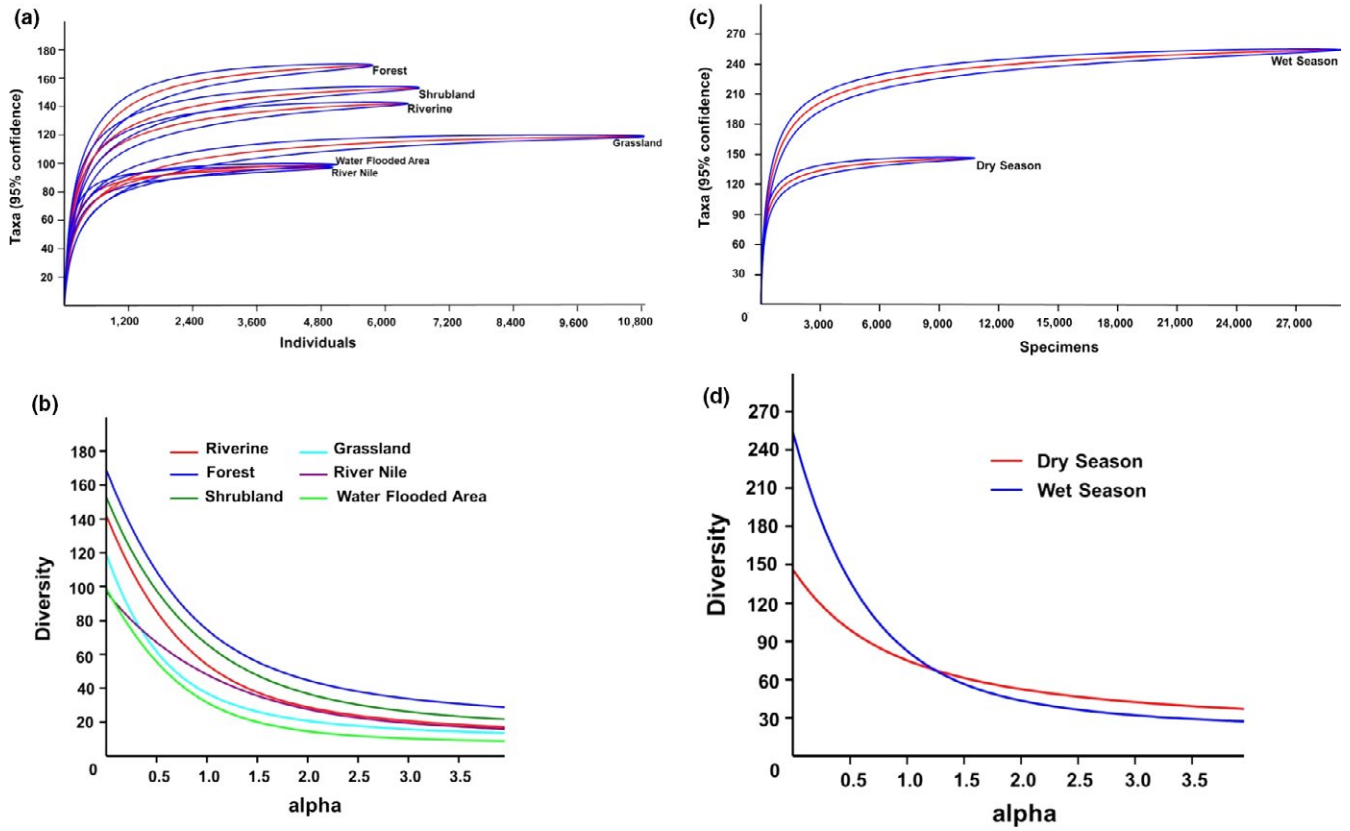

FIGURE 2 (a) Saturation curves (with 95% confidence intervals after 9,999 bootstraps) and (b) diversity profiles for the community diversity of birds in the various habitat types of Bandingilo National Park, South Sudan; (c) Saturation curves (95% confidence, after 9,999 bootstraps), and (d) diversity profiles for the community diversity of birds in wet versus dry season in Bandingilo National Park, South Sudan

TABLE 1 Variation of community diversity indices for the bird assemblages in the six habitat types at the study area in South Sudan

	Riverine	Woody savannah	Shrubland	Grassland	Riverbanks and openwater	Water flooded area
Species richness	142	169	153	119	97	99
Individuals	6,434	5,777	6,649	10,856	5,024	5,107
Dominance	0.03468	0.02228	0.02721	0.04812	0.03629	0.06858
Simpson	0.9653	0.9777	0.9728	0.9519	0.9637	0.9314
Shannon	3.989	4.314	4.19	3.613	3.872	3.453
Evenness	0.3802	0.4421	0.4315	0.3116	0.4955	0.3192

relationship with habitat preference, number of species, diversity, seasonality and trophic level (Hosmer & Lemeshow, 2000). In the model, the number of individuals and species was used as dependent variable, and the identity link function and a normal distribution of error were used (McCullagh & Nelder, 1989). In order to compare frequencies of observed individuals among the trophic categories, a contingency table chi-squared test was used. GLM analyses were performed with Statistica version 5.0 computer software, and all other statistical tests with Past 3.0 software. Alpha was set at 5%.

3 | RESULTS AND DISCUSSION

A total of 39,992 bird individuals, belonging to 264 different species, were observed (Supporting Information Table S1). Summarised information on each species is given in Supporting Information Table S2. Individual rarefaction curve revealed that community diversity was sampled adequately in all habitat types, given that the plateau phase between number of individuals and number of detected taxa was clearly reached in all cases (Figure 2a). Community diversity

TABLE 2 GLM estimates and significance (Wald test) showing the probability of abundance of counted species in the study area by habitat type

	Estimate	Standard	Wald	*p*
Intercept	233.592	5.075	2118.638	0.000
Riverine	−0.182	0.081	5.056	0.024
Woody savannah	−0.389	0.125	9.644	0.001
Shrubland	0.305	0.101	8.993	0.002
Grassland	0.041	0.039	1.071	0.300
Riverbanks and openwater	0.216	0.105	4.233	0.039
Water flooded area	−0.08289	0.072	1.318	0.250
Explained deviance	89.43%			

was much higher in woody savannah than in the other habitat types, followed by shrublands and riverine habitats (Figure 2a; Table 1). Diversity profiles confirmed a considerable heterogeneity among the various habitat types, with woody savannah being clearly separated from the other habitat types (Figure 2b). Our GLM analysis revealed that the number of individuals (of all different species) decreased with the increase of vegetational cover (from grassland to woody savannah, estimate = −39.486; Wald = 15.394; $p = 0.000087$), while no effect was detected considering the number of species (estimate = −1.714; Wald = 0.158; $p = 0.690$) and the relationship between diversity (Shannon–Wiener index) and preferred habitats (GLM, estimate = −0.040; Wald = 0.156; $p = 0.692$).

In terms of trophic category, granivore and insectivores were significantly more abundant (in terms of frequency of observed individuals, with all habitats pooled) than other trophic groups ($p < 0.0001$ at chi-squard test). The number of counted individuals decreased with the increase of trophic level (from herbivorous to carnivore) (GLM, estimate = 13.72; Wald = 10.048; $p = 0.015$).

In terms of seasonality, individual rarefaction curve revealed that community diversity was much higher during the wet season (Figure 2c), and diversity profiles confirmed a considerable heterogeneity between wet and dry seasons (Figure 2d). However, a GLM model revealed no differences in the number of observed individuals between the wet and dry season ($p > 0.05$), while the number of observed species increased with the increase of shrubland areas and River Nile areas and decreased with increasing of woody savannah and riverine areas (Table 2).

In the present study, we found considerable differences in species diversity between habitats (with the woody savannah being by far the most speciose type of habitat in the area) and in terms of seasonality (with much more species detected by wet season), with also a considerable effect of the trophic category, as the granivore and insectivores were significantly more abundant than other trophic groups.

The difference of species diversity between seasons in our study could likely be referred to the effect of Palearctic-African migration patterns (migration season in autumn; Sulieman, Pengsakul, Afifi, & Zakaria, 2016), but also to the different vegetation condition in the wet season compared to the dry season. Indeed, it is well known that vegetation cover has a strong influence on the avifauna in either temperate or tropical regions (Scott-Mills, Dunning, & Bates, 1989), and the vegetation cover is dramatically different between seasons at the study area (our unpublished observations).

Our study also revealed that the bird assemblages of woody savannah sites are more diverse and with an higher evenness than those from other habitats. Higher species diversity and evenness in woody savannah habitat is well established, and riverine habitats in particular share many similarities with true forest (this latter pattern clearly emerged in our study). This evidence highlights the importance of wooded environments for maintaining the diversity of birds, but also the importance of open areas and environmental mosaics characterised by the presence of shrubland areas and the banks of the River Nile, which contains a wide range of different types of vegetation providing a wide range of microhabitats for different species of birds (Sulieman et al., 2016). Although wooded areas are massively fragmented in our study area, recent research in Uganda has suggested that forest birds are able to move among forest fragments to a greater extent than was previously thought (Dranzoa, Williams, & Pomeroy, 2011). So, also the isolated small forests could still keep a considerable conservation value.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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