Influences of Vegetation Structure on Birds Species Numbers and Diversity in Nimule National Park, South Sudan

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ABSTRACT

A study of the relationships between bird community and vegetation was conducted in Nimule National Park, during January and March 2019. The objective of the study was to determine how bird species numbers and diversity were influenced by habitat variables and vegetation attributes. Point-count sampling method was applied to determine species numbers; simultaneously, the vegetation variables were sampled in three habitats using the quadrat method in a (20m x20m) plots Centered on the bird-count points. Results revealed a strong correlation between bird community and physiognomic variables of the tree layer, in particular, canopy closure and tree basal area were the key factors that influenced bird species numbers and diversity. Shrub layer characteristics and floristics, expressed as tree species richness and tree species diversity, were less correlated to bird species numbers and diversity.

Keywords: Species Richness, Vegetation, Physiognomic Variables.

INTRODUCTION

Many developing countries are experiencing rapid population growth, consequently enormous pressure is exerted on the natural habitats and their associated flora and fauna (Sodersrom *et al.*, 2003). Vegetation has long been thought to be a major factor in determining bird community composition (Terborgh *et al.*, 1990; Wiens, 1992; Javed and Kaul, 2002; Lancia *et al.*, 2005; Rajpar and Zakaria, 2011; UNEP, 2018). Many studies have found physiognomic attributes of vegetation such as foliage height diversity, foliage volume, and percent vegetation cover to be correlated with bird species richness and diversity (MacArthur and MacArthur, 1961; Balda, 1969; Karr and Roth, 1971; Karr and Freedmark, 1983; Jimenez, 2000; Rajpar and Zakaria, 2010). However, our understanding of how vegetation determines bird community composition in tropical regions, especially in South Sudan, is still limited.

Seymour and Simmons (2008) reported that birds often have correlation with their habitats. This method or approach could be used at times as surrogates for assessing the impact of habitat change (Veraat *et al.*, 2004; Ma *et al.*, 2009). Monitoring correlation between species abundance, diversity and habitat provides basic information for determining the causative factors of population fluctuation of bird species (Norwell *et al.*, 2003). Similarly, the assessment of vegetation composition and structure is a useful tool to examine and understand the habitat characteristics and impacts of disturbance or alteration of habitats on the bird species (Rajpar and Zakaria, 2011).

Given its diverse topography and climate, South Sudan is endowed with a rich and abundant biodiversity (Kano, 2004; UNEP, 2018). Over 790 species of birds, representing about 8% of the world birds, were recorded in South Sudan (Nikolaus, 1989) and about 184 (24%) species of the above number are migrants (Niclaus, 1989).

Geographically, South Sudan lies in the centre of migration routes between three continents and Nimule, by the virtue of its location along the River Nile, lies on the route of migration of palaearctic migrants wintering in Africa south of the Sahara. Biodiversity in South Sudan has been declining at a rapid rate due primarily to habitat degradation, especially in natural forests (Sommerlatte and Sommerlatte, 1990; UNEP, 2018). The vegetation cover in Nimule National Park is considered representative of changes to natural forests in South Sudan in recent decades (AWF, 2014). Past anthropogenic activities have created uniform vegetation in Nimule National Park (UNEP, 2018). Studies of species richness and diversity of bird communities in Nimule National Park are urgently required. The goal of this study was to examine the avian community in Nimule National Park in relation to vegetation characteristics.

MATERIALS AND METHODS

Study area

The study was conducted in Nimule National Park, which is located in Torit State closed to the Ugandan

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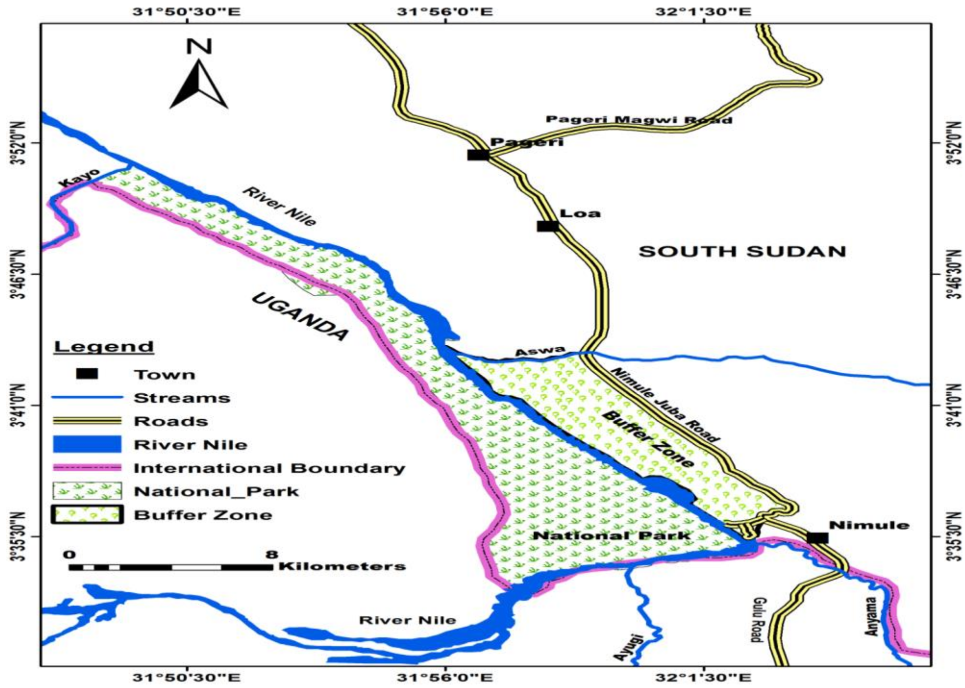

Fig. 1: Map showing location of Nimule National Park (© Evuk 2016).

border between latitudes 3^0 35'– 3^0 52'N and longitudes 31^0 45' - 32^0 30'E. It covers an area of 256 km^2, and is about 190 km south of Juba, the capital city of South Sudan. This park was established first as a Game Reserve in 1935 and later gazetted as a park in 1954 (UNEP, 2018). It is adjacent to Mount Kei Forest Reserve and Mount Otzi Forest Reserve, which are two important bird areas in Uganda (UNEP, 2018).

The topography of the Nimule area in general is that of the late pre-Cambrian period characterized by a mix of hills and low lying areas criss-crossed by many seasonal and perennial rivers; its elevation is between 500 – 800 m above sea level (AWF, 2014). The park is drained mainly by the River Nile, which constitutes one of the major physical features of the park and borders it from the east; and the other is River Keyu which flows through the park from Uganda (Fig. 1). The climate of Nimule National Park and the surrounding area is essentially of continental type experiencing orographic and conventional rainfall characterized by thunderstorms (AWF, 2014). The mean annual rainfall varies from 1000 – 1200 mm; with two distinct wet and dry seasons. Normally the wet season begins from April to November and the dry season from December to March.

Data collection design

Fifty study points were selected out of sixty two by means of random numbers and, were established in a succession from shrub to old riverine forests inside the park proper; and additional ten points established in the buffer zone for purpose of comparison and check-listing the bird species of Nimule National Park and its environs. In order to reduce the impact of edge effect and maintain independence among points, the points were located at least 100 m from the edge of major habitat types and 200 m between points.

Bird counts

Avian communities were surveyed using the point-count method, which is well designed for surveying birds in structurally complex vegetation within the tropics, such as the forests in NNP (Bibby *et al*, 2000). This technique is more efficient than transect methods in estimating the relationship between bird species richness and habitat, because the survey points were located to correspond exactly with a vegetation survey.

The counts were conducted under favourable weather conditions during the dry season, January and March 2019. Points were visited twice each. The first survey was conducted early in the morning after sunrise 7:30 am to 11:00 am, and the second from 15:00 pm to 6:00 pm just before sunset when birds were most active. To avoid disturbances caused by the observer's arrival, counts were begun one minute after reaching the survey point. Birds were counted for a duration of 10 minutes following Lee and Marsden (2008), and Zakaria *et al* (2009). During each count, the number of individuals of each species heard or seen in a circle with a radius of 15 m around each point was recorded. Flushed individuals were also recorded, and their known original positions were included in the analysis. However, birds flying above the plots were not recorded due to unknown original position. The methodology was used as described by Bibby *et al* (2000), Aborn (2007) and Nadeau *et al* (2008). Bird counts throughout the surveys were done by one observer so as to avoid inter-observer bias.

Vegetation measurements

Vegetation measurements were also conducted by a team of 15 observers in January and March 2019. The vegetation variables were sampled in three habitats using the quadrat method in a (20m x 20m) plots simultaneously and were centred on the bird-count points. This method is one of the most commonly used and accepted methods to survey vegetation in a variety of habitats (Fernandez-Alaez *et al*, 2002; Bibby *et al*, 2000; Mumby *et al*, 1997; Hudon, 1997). A total of 50 quadrat plots were sampled for vegetation structure within the consistency of the point count stations. In each plot, the following vegetation variables were estimated: (1) mean tree diameter at breast height (DBH, cm), (2) tree basal area (BA, m^2/ha), (3) tree density (TD, trees/ha), (4) canopy closure (CC, %), (5) canopy height (CH, m), (6) tree species richness (TSR), (7) tree species diversity (TSD), (8) shrub cover (SC, %), (9) shrub height (SH, m), (10) heterogeneity of shrub height (HSH) (Kent and Coker, 1992; Bibby *et al*, 2000). Canopy closure (CC) and shrub cover (SC) were estimated by using a sighting tube (2 cm diameter). For each variable, the sighting tube was used 20 times at each vegetation survey plot. To investigate shrub cover, five quadrats of (1x1) m were established in the plot (four at the corners and one at the centre). In each quadrat, the height of the shrub layer was measured at five random points.

HSH is the coefficient of variation in SH. Individual tree basal area was calculated based on diameter at breast height, and basal area (BA) was obtained by summing the basal area of individual trees and dividing it by the vegetation plot area (0.04 ha).

Data analysis

SPSS (version 21.0) software packages were used for statistical analysis. The total number of all bird species for each site was calculated as: the number of birds seen + the number of birds heard. The relative abundance (%) of avian species was estimated using the expression: n/N x 100 following (Zakaria *et al*, 2009), where n is the number of a particular bird species and N is the total observations detected for all species. Bird species richness (BSR) and tree species richness (TSR) were calculated for each plot by determining the total number of species observed at each point. Bird species diversity (BSD) and tree species diversity (TSD) were obtained by the Shannon-Wiener index (H'). And was calculated for each site as: H' = -(Total bird species/ (total birds) * [I_n (total bird species/ (total birds)]; which indicates the higher the index the higher the diversity (Magurran, 2004).

Canopy closure and shrub cover square-root transformation was done to strengthen the normality of the variables. Other variables were analyzed using the original data, because the statistical assumptions were met. BSR and BSD were correlated with vegetation variables. Multiple regressions analyses were examined by SAS. In order to select vegetation variables that can accurately predict bird species richness and diversity, the stepwise model selection method was used. A 0.05 significance level was used as a criterion for the selection of variables. Outliers were checked by Studentized residuals.

RESULTS

A total of 6395 individual birds, comprising 138 species belonging to 41 families, and sixteen orders were recorded during the survey period (Tables 1 and 2). The orders include: Anseriformes, Apoliformes, Caprimulgiformes, Charadriiformes, Ciconiformes, Colliiformes, Columbiformes, Coraciiformes, Cuculiformes, Falconiformes, Galliformes, Gruiformes, Passeriformes, Pelicaniformes, Piciformes and Strigiformes. Of these, 42 species were in the order Passeriformes (accounting for 30% of the total number of species) and 18 (13%) were in the order Ciconiformes, 17 (12%) were in the order Coraciformes and 17 (12%) in the order Falconiformes. Among the Passeriformes, species belonging to 12 families were recorded, of which Ploceidae (Weavers, Whydahs and Sparrows), Sturnidae (Starlings and Oxpeckers), Columbidae (Doves and Pigeons), Laniidae (Shrikes and allies), Motacillidae (Wagtails) and Bucerotidae (Hornbills) were most frequently observed. Eleven species were abundant and widely distributed in the park: Village Weaver (*Ploceus cucullatus*) 29.86% of all detections, Ruppell's long-tail Starling (*Lamprotonis purpuropterus) 16.20*%, African Firefinch (*Lagonostista rubricate)* and allies 35.60%, Blue-eared Glossy Starling *(Lamprotornis chalybaeus)* 8.50%, Northern Red Bishop (*Euplectes fransciscaus*) 5.37%.

Table 1: Relative abundance of bird species within Nimule National Park, January-March, 2019, South Sudan.

Family name	Scientific name	Common name	Observations	% of all detection
Anatidae	*Aythya erythrophthalma*	African Pochard	80	2.90
	Plectopterus gambensis	Spur-winged goose	4	0.14
	Alopochen aegyptiaca	Egyptian goose	13	0.47
	Sarkidiornis melanotos	Knob-billed duck	11	0.40
	Dendrocygna viduata	White-faced duck	6	0.22
Apodidae	*Apus affinis*	Little swift	28	1.02
	Cypsiurus parvus	Palm swift	35	1.27
Caprimulgidae	*Macrodipteryx longipennis*	Standard winged nightjar	2	0.07

(Table 1 continue)

Family name	Scientific name	Common name	Observations	% of all detection
Jacanidae	*Actephilornis africanus*	African jacana	18	0.65
Charadriidae	*Himantopus himantopus*	Black-winged stilt	11	0.40
	Gallinago nigripennis	African snipe	2	0.07
	Vanellus spinosus	Spur-winged plover	44	1.60
	Charadrius pecuarius	Kittlitz's plover	1	0.04
	Vanellus melanocephallus	Black-winged plover	4	0.14
Ardeidae	*Ardea melanocephala*	Black-headed heron	6	0.22
	Ardeola ralloides	Squacco heron	14	0.51
	Ardea cinera	Grey heron	32	1.16
	Nysticorax nycticora	Night heron	4	0.14
	Egretta intermedia	Yellow-billed egret	2	0.07
	Egretta gavzetla	Little egret	12	0.43
	Ardea purpurea	Purple heron	2	0.07
Threskiornithidae	*Hagedashia hagedash*	Hadada ibis	67	2.43
	Plegadis falcinellus	Glossy ibis	40	1.45
	Threskiornis aethiopicus	Sacred ibis	24	0.87
Ciconidae	*Ciconia episcopus*	Woolly-necked stork	26	0.94
	Leptoptilos crumeniferus	Marabou stork	15	0.54
	Ephippiorhynchus senegalensis	Saddle-billed stork	4	0.14
Ciconidae	*Anostomus lamelligerus*	Open-billed stork	53	1.92
	Ibis ibis	Yellow-billed stork	21	0.76
	Ciconia abdimii	Abdim's stork	94	3.41
Scopidae	*Scopus umbretta*	Hamerkop	8	0.29
Upupidae	*Upupa epops africanaa*	African hoopoe	88	3.20
Coraciidae	*Coracias abyssinica*	Abyssinian roller	14	0.51
Colliidae	*Colius striatus*	Speckled mouse bird	33	1.20
	Colius macrourus	Blue-naped mouse bird	14	0.51
Columbidae	*Oena capensis*	African namaqua dove	126	4.58
	Streptopelia semitorquata	Red-eyed dove	213	7.74
	Streptopelia capicola	Ring-necked dove	46	1.67
	Streptopelia dicipiens	Mourning dove	1	0.4
Bucerotidae	*Bucorvus leadbeateri*	Ground hornbill	2	0.07
	Tochus flavirostris	Yellow-billed hornbill	14	0.51
	Tockus nasutus	Grey hornbill	263	9.55
	Tockus flavirostris	Red-billed hornbill	9	0.33
Alcedinidae	*Ceryle rudis*	Pied kingfisher	1	0.04
	Megaceryle maxima	Giant Kingfisher	1	0.04
	Alcedo cristana	Malachite kingfisher	9	0.33
	Haleyon leucocephala	Grey-headed kingfisher	2	0.07
	Halcyon albiventris	Brown-hooded kingfisher	1	0.04
	Halcyon senegalensis	Woodland kingfisher	7	0.25
	Ceyx pictus	African pygmy Kingfisher	4	0.14
Meropidae	*Merops pusillus*	Little bee-eater	6	0.22
	Eurystromus glaucurus	Broad-billed Roller	7	0.25
	Merops bulocki	Red-throated bee-eater	8	0.29
Phoeniculidae	*Phoeniculus purpureus*	Green (Red-billed) wood hoopoe	2	0.07
Cuculidae	*Centrophus senegalensis*	Senegal coucal	245	8.90
	Cuculus solitaris	Red-chested cuckoo	1	0.04
	Cuculus gularis	African cuckoo	42	1.52
Accipitridae	*Haliaeetus vocifer*	African fish eagle	38	1.38
	Milvus migrans	Black kite	17	0.62

(Table 1 continue)

Family name	Scientific name	Common name	Observations	% of all detection
	Chelictinia riocourii	Swallow-tailed kite	11	0.40
	Melierax metabates	Dark-chanting goshawk	4	0.14
	Necrosyrtes monachus	Hooded vulture	2	0.07
	Gyps ruppellii	Ruppell's vulture	6	0.22
	Accipiter tachiro	African goshawk	1	0.04
	Lophaetus aocipitalis	Long-crested eagle	3	0.11
	Aquila verreauxii	Verreaux's eagle	1	0.04
	Kaupifalco monogrammicus	Lizard buzzard	14	0.51
	Aquilla rapax	Tawny eagle	43	1.56
Falconidae	*Falco tinunculus*	(Common) Kestrel	3	0.11
	Falco cuvierii	African Hobby	1	0.04
	Falco ardosiaceus	Grey Kestrel	1	0.04
	Falco biarmicus	Lanner Falcom	4	0.14
Phasianidae	*Francolinus clappertoni*	Clapperton's francolin	68	2.47
Numididae	*Numida meleagris*	Helmeted guinea fowl	9	0.33
Balearicidae	*Balearica regulorum*	Crowned crane	2	0.07
Corvidae	*Corvus albus*	Pied crow	20	0.73
Pycnonotidae	*Pycnonotus barbatus*	White-vented bulbul (common)	46	1.67
Motacillidae	*Motacilla flava*	Yellow wagtail	3	0.11
	Motacilla aguimp	African pied wagtail	12	0.43
	Tmetothylacu tenellus	Golden pipit	4	0.14
	Anthus similis	Long-billed Pipit	2	0.07
Laniidae	*Laniarius crythrogaster*	Black-headed gonolek	3	0.11
	Nilaus afer	Northern brubru	2	0.07
	Lanius collaris	Fiscal shrike	10	0.36
	Malaconotus blanchoti	Grey-headed bush shrike	16	0.58
	Lanariarius ferrugneus	Tropical boubou	188	6.83
Estrildidae	*Lagonostista rubricata*	African fire finch	198	7.19
	Lonchura malabarica	Silverbill	15	0.54
	Urageginthus bengalus	Red-cheeked cordon blue	88	3.20
	Amadina faciata	Cut throat	16	0.58
	Estrilda melpoda	Orange-cheek waxbill	36	1.31
	Estrilda troglodytes	Black-rumped waxbill	2	0.07
Muscicapidae	*Batis molitor*	Chin-spot flycatcher	10	0.36
Nectariniidae	*Nectarinia johnstoni*	Scarlet-tufted malachite sunbird	6	0.22
Sturnidae	*Lamprotonis purpuropterus*	Ruppell's long-tail starling	446	16.20
	Buphagus africanus	Yellow-billed oxpecker	38	1.38
Ploceidae	*Ploceus luteolus*	Little weaver	18	0.65
	Ploceus cucullatus	Village weaver	822	29.86
	Ploceus vitellinus	Vitalline weaver	26	0.94
	Ploceus nigricollis	Black-headed weaver	5	0.18
	Ploceus heuglini	Heuglin's masked weaver	3	0.11
	Ploceus taeniopterus	Northern-masked weaver	164	5.96
	Euplectes franciscanus	Northern red bishop	148	5.37
	Ploceus badius	Cinamon weaver	127	4.61
	Quelea quelea	Red-billed quelea	83	3.01
	Polceus inteolus	Little weaver	66	2.40
	Quelea erythrops	Red-headed quelea	14	0.51
	Vidua macroura	Pin-tailed whydah	21	0.76

(Table 1 continue)

Family name	Scientific name	Common name	Observations	% of all detection
	Steganura paradiseae	Paradise whydah	9	0.33
Fringillidae	*Serinus spp*	Finches?	980	35.60
Phalacrocoracidae	*Phalacrocorus africanus*	Long-tailed cormorant	18	0.06
Pelecanidae	*Pelecanus onocrotalus*	White pelican	32	1.16
Picidae	*Campethera nubica*	Nubian wood pecker	8	0.29
	Mesopicos goertae	Grey wood pecker	2	0.07
Sagittariidae	*Sagittarius serpentarius*	Secretary bird	2	0.07
Strigidae	*Bubo africanus*	Spotted eagle owl	1	0.04
	Tyto alba	Barn owl	1	0.04
	Total		5777	

Table 2: Bird species identified during the study within the buffer zone of Nimule National Park, January - March, 2019

Family name	***Scientific name***	**Common name**	**Observations**	**% of all detection**
Estrildidae	*Hyporchera chalybeata*	Indigo bird	44	1.60
Sturnidae	*Lamprotornis chalybaeus*	Blue-eared glossy starling	234	8.50
Ploceidae	*Bubalornis albirostris*	Buffalo weaver	77	2.80
	Anaplectes rubriceps	Red-headed weaver	132	4.79
Dicruridae	*Discrurus adsimilis*	Drongo	12	0.43
Falconidae	*Falco naumanni*	Lesser kestrel	3	0.11
Accipitridae	*Terathophius ecaudatus*	Bateleur eagle	1	0.04
Meropidae	*Merops nubicus*	Carmine bee-eater	11	0.40
Ardeidae	*Ardeola ibis*	Cattle egret	104	3.78
Total			618	

After William and Arnold (1980) and Sinclair and Ryan (2003)

Cinamon Weaver (*Pleceus badius*) 5.0%, Northern Masked Weaver (*Ploceus taeniopterus*) 6.0%, Red-eyed Dove (*Strptopelia semitorquata*) 8.0%, Grey Hornbill (*Tockus nasutus*) 9.55%, Senegal Coucal (*Centrophus senegalensis*) 9.0%, and Tropical Boubou (*Lanariarius ferrugneus*) 7.0%. There were equally a huge assortment of finches (*Serinus* spp) which were not positively identified. One hundred and twenty nine of the 138 (93%) birds' species were recorded in the park proper, though they were present also in the buffer zone; while nine of the 138 species (7%) were exclusively observed in the buffer zone. They included: the Drongo (*Discrurus adsimili*), Red-headed Weaver (*Anaplectes rubriceps*), Buffalo Weaver (*Bubalornis albirostris*), Carmine Bee-eater (*Merops nubicus*), Cattle Egret (*Ardeola ibis*), Indigo Bird (*Hyporchera chalybeata*), Blue-eared Glossy Starling (*Lamprotornis chalybaeus*), Lesser Kestrel (*Falco naumanni*), Bateleur Eagle (*Terathophius ecaudatus*).

Mean number of birds were higher in the buffer zone 74.50 (± 23.98) compared to that inside the park proper 49.09 (± 11.93) (Table 3). Results showed that in terms of species richness, there was higher diversity index inside the park proper than there was in Buffer zone **(**Table 3), though this only indicated that the Park had more species than the Buffer zone.

Most of the tree layer structures were closely correlated with bird species richness and bird species diversity (Table 4); the coefficients ranged from about 0.5 to >0.7 suggesting, according to Fowler *et al* (2009), a moderate to strong correlation; whereas the floristic attributes, expressed as tree species richness and tree species density, were weakly correlated with bird species richness and bird species diversity.

The shrub layer was found to have little influence on birds (Table 4). Shrub height and heterogeneity of shrub height were very weakly correlated with bird species richness and bird species diversity. Only shrub cover had a moderately negative correlation probably reflecting the effect of canopy closure.

Table 3: Mean number of bird species, total number and diversity of birds species records in Nimule National Park and the Buffer zone, (January - March, 2019)

No.	Study sites	Mean number of bird species	Total number of birds observed	Diversity index
1	Inside the park	49.09 (± 11.93)	5793	3.6
2	Buffer zone	74.50 (± 23.98)	745	1.7

Table 4: Pearson coefficients of correlations between avian variables and tree vegetation variables

Variable	BSR	BSD
DBH	0.56***	0.59***
BA	0.61***	0.70***
CH	0.50***	0.49***
CC	0.63***	0.66***
TD	0.56***	0.64***
TSR	0.43**	0.45**
TSD	0.36*	0.36*
SC	-0.37*	-0.41**
SH	0.15	0.15
HSH	0.18	0.16

*P<0.05, **P<0.01, ***P<0.001

The relationship between bird species richness and bird species density and physiognomic variables of the tree layer are presented in (Figures: 1 and 2).

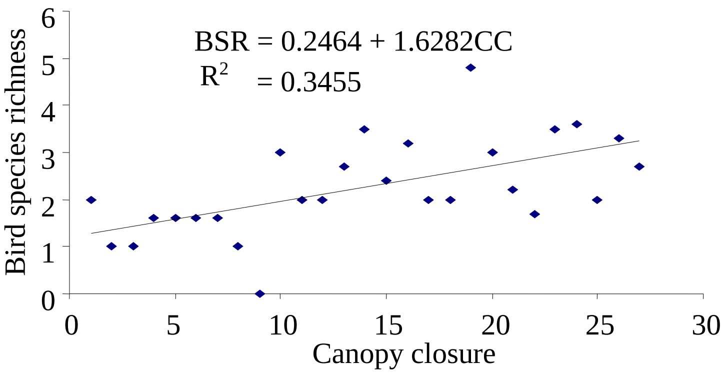

Figure1. Relationship of bird species richness to canopy closure

The stepwise model selection procedure selected the model with bird species richness as the dependent variable and canopy closure as the single independent variable. The equation for the regression line was as shown in (Figure: 1). Fifty nine percent of the variation in bird species richness was explained by variation in canopy closure.

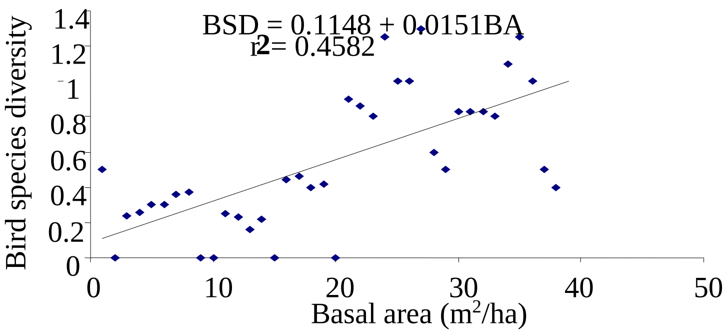

Figure 2. Relationship of bird species diversity to tree basal area

The stepwise model selection procedure selected the model with bird species density as the dependent variable and basal area as the single independent variable. The prediction equation was as shown in (Figure: 2). Variation in basal area accounted for sixty eight percent of variation in bird species density.

DISCUSSION

Bird species abundance

Several studies have revealed that anthropogenic activities result in enhancing the distribution and dispersal of avian species, as many bird species have expanded their home ranges because of their ability to utilize landscapes transformed by humans, hence, have become more abundant in number and widespread in distribution (Magnall and Crowe, 2003; Naidoo, 2004). This pattern of bird community distribution was observed in this study by the difference in species abundance between the areas inside the park proper and the buffer zone. The buffer zone was characterized by human activities such as intensive grazing by cattle, cultivation and other anthropogenic activities. This explains the high numbers of bird species that are generalist in habit, which are known to thrive well in most human disturbed landscapes but not of any particular conservation concern (Soderstrom *et al*, 2003).

Bird species diversity

This study showed that the value of Shannon-Weaner diversity indices were higher inside the Park than in the Buffer zone. This disparity may be attributed to the intensive presence of humans and their associated activities in the Buffer zone. Continued extractive activities through clearance of vegetation for cultivation, collection of firewood and building materials as well as livestock grazing may lead to loss of biodiversity. This agrees with findings of Fishpool and Evans, (2001), who noted that agricultural encroachment or habitat clearance is the major threat to important bird areas (IBA).

Influences of vegetation structure on bird abundance and diversity

This study showed that the number and diversity of bird species were strongly positively correlated with aspects of vegetation structure. The results of this study agree with other researchers such as MacArthur and MacArthur (1961); Karr (1971); Rice, 1983; Douglas *et al*, 1992; Bolck and Brenan, 1999; Champlin *et al*, 2009; and Zakaria *et al* (2009) who reported that vegetation structure and floristic composition, expressed as species diversity and abundance, may be useful in explaining the distribution, abundance and diversity of the bird guilds.

Most tropical forest birds are dependent on forest canopy for nesting or foraging. Therefore, canopy volume may be a good predictor of avian community indices. However, due to lack of accurate methods for measuring canopy volume, the relationship between canopy volume and avian community indices was not analyzed. Though canopy closure is not as good as canopy volume, it can be used to reflect the extent of forest canopy. In this present study, canopy closure was one of the variables most strongly correlated with bird species richness and diversity. Other structural variables, though they do not directly influence most birds' lives, were correlated with avian community indices because these variables are strongly associated with canopy volume and canopy closure.

Of these variables, basal area of the tree was more closely associated with bird species richness and bird species density than diameter at breast height, canopy height and tree density. This may be because basal area is most closely associated with canopy volume and can reflect the forest structure better. It was not always the case that plots with high diameter at breast height and canopy height values were in old forest (some plots in shrub land have a few huge trees). And, it was not always the case that plots with high tree density values were in riverine forests (some plots in regrowth forest have many small trees). Basal area incorporates both tree density and diameter at breast height in one variable, making it better able to reflect the forest canopy volume and forest structure.

These results showed that the shrub layer had little influence on bird species richness or bird species density, as has also been found by others (Szaro and Balda, 1986). The shrub layer provides some bird species with breeding or feeding sites, although Bibby *et al.*, (2000) pointed out that fewer than 15% of bird species intensively use the low shrub layer in tropical forests. This was also true in this sub-Saharan study site in South Sudan.

The stepwise model selection procedure selected canopy closure as the single vegetation variable predicting bird species richness and basal area of tree as the single independent variable predicting bird species density. All other variables related to tree layer structure were not included in the equations although they were correlated with bird species richness and bird species density, possibly due to their correlations with canopy closure and basal area. Floristic variables and shrub layer variables did not appear in the final regression equations because they were intrinsically weakly or not correlated with avian community indices.

CONCLUSIONS AND RECOMMENDATION

Vegetation composition and vegetation structure are key factors that influenced the bird species abundance, distribution and diversity. Diversity index of bird species within Nimule National Park was higher than in the Buffer zone. Difference of vegetation characteristics within and without the park was responsible for the observed pattern. Habitat clearance due to the on-going anthropogenic activities had influence on vegetation structure which in turn influenced bird species abundance and diversity.

The richness and diversity estimates in this study did not account for detection probability; however, because we used a small bird count area, the assumption of a complete count could be met. To improve further investigations, one would recommend using variable-circle in this case; detection probability should be taken into account because each species in a given habitat has its own probability of being detected, which is usually smaller than 100%.

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