HABITAT USE AND IMPLICATIONS FOR AVIAN SPECIES IN SAMBISA GAME RESERVE, BORNO STATE, NIGERIA

Iorember, A.

Department of Ecology, Cross River National Park Akamkpa, P. M. B. 1028 Calabar, Nigeria.

Correspondence Email: *Alhajiiorember@yahoo.com;* **Phone:** +2348063239264

ABSTRACT

The study determined the effect of vegetation physical structure on avian species diversity and abundance in Sambisa Game Reserve in Borno State, Sudano-Sahelian vegetation. Bird species were observed, identified, counted and the associated vegetation variables were estimated in a 64 1000-m-long transects, 3 surveys per transect, from 2011 to 2012. The vegetation variables were lumped into various principal components (PCs) with principal component analysis (PCA), but only the first principal component (PC1) with the highest variance (25.15 %) and characteristics of complex vegetation, named vegetation physical structure complexity, was used in the regression analysis. A positive linear relationship existed between PC1 and bird species diversity indices ($F_{1, 165} = 51.54$, $P < 0.001$ for Shannon Wiener bird species index and $F_{7, 187} = 59.69$, $P < 0.001$ for bird species richness). Feeding guild abundances (Insectivores, Frugivores, Raptors and Nectarivores) showed positive relationship with the PC1 but granivore abundance showed a negative relationship with PC1. The PC1 probably played the most important role in the pattern of bird diversity and abundance in the Reserve. Increasing bird diversity and abundance across the complexity gradient was probably accommodated by increasing potential food and protection resources. If the logging activities in the Reserve are not properly checked, there will be serious threats of bird population decline and bird species loss, especially, insectivores, due to their high dependence on high trees with dense undergrowth. However, granivore population will build up and pose threats to the Reserve host communities' farmed cereal crops.

Key words: Bird diversity; habitat loss, vegetation, Sambisa Game Reserve.

INTRODUCTION

An established knowledge about factors responsible for the spatial and temporal distribution of faunal species is a litmus paper for indicating any change in the ecosystems (O'Connell, *et al*., 2007). In most terrestrial ecosystems, plant communities determine the physical structure of the environment, and therefore, have a considerable influence on the distribution and interaction of animal species (Lawton, 1983; McCoy & Bell, 1991). For bird species, Macthur, and Macthur, (1961), MacArthur, *et al., (*1962), MacArthur, (1964) and Joshi, *et al.,* (2012) reported that vertical diversity of foliage may be more important than the actual composition of plant species in determining bird species distribution. While Emien, (1977), Verner *et al.,* (1986) and Jones *et al*., (1996) stated that vegetation physical structural variables such as percentage litter cover, canopy cover, numbers, sizes and height of trees, number of saplings, bushes and shrubs may determine bird and habitat relationships. For this work, the size or number of these variables, except bushes, added up together is called vegetation physical structural complexity (Smith *et al*., 2008; Tews *et al*., 2004).

Furthermore, Wiens and Rotenberry, (1981) stated that areas of higher habitat diversity (more complex in physical structure and composition) tend to support most bird species, as diverse habitat structure offer a variety of ecological niches occupied by different bird species. Bird species changes in their species composition and populations of their communities when their associated ecological niches are changed (MacArthur & MacArthur, 1961; Shamkar Raman *et al*., 1998; Chettri, *et al*., 2001; Shankar Raman, 2001).

Therefore, understanding and predicting the likely consequences of changes in bird natural habitat (vegetation physical structural complexity) by natural factors or anthropogenic disturbances (e.g. logging) on species distribution is a major prerequisite for achieving the conservation of biodiversity (Bibby, *et al*., 2000; O'Connell, *et al*., 2007). For such changes to be detected, conservationists need to monitor the population abundance, diversity and the associated habitat use over time.

This study was conducted in Sambisa Game Reserve because the reserve is experiencing habitat (vegetation) loss due to heavy grazing, slashing and felling trees by graziers and commercial fuel wood collectors for livestock and source of supporting income respectively (Ezealor, 2002). But habitat loss is negatively correlated with avian diversity and abundance because it affects occupancy and resource use patterns of birds (Block and Brennan, 1993; Chettri, *et al.*, 2001) and some bird species or guilds are linked to some specific vegetation physical structure (Cody, 1983). Besides, no such study had been done in the tropical sudano-sahelian vegetation at local scale and considering all the vegetation variables in lump up.

The objectives of the study were to determine: (1) the effects of vegetation physical structure of the Reserve (Sudano-Sahelian vegetation) on avifauna in view of emphasizing the importance of vegetation cover on wild birds to the Reserve managers and conservationists in the tropical acacia woodland, (2) based on the birds' associated habitat, to identify the areas in the Reserve that are most important for birds, and (3) not only in terms of number of birds, or number of species, but also – if possible to detect − for certain species, or guilds that, due to their specialized way of living, are more vulnerable, should the Reserve habitat or the Sudano-Sahelian vegetation habitat lost continues.

MATERIALS AND METHODS

Study area

Sambisa Game Reserve is a game reserve amid farmlands, located in the southern part of Borno State, Nigeria between latitudes at 11°15 -11°30N and Longitudes 13°22 -'13°37E with a total land area cover of 68,600ha (520 sq. Km) at altitude c. 35-100m (Bawden, 1972). The Reserve experiences distinct wet (May to October) and dry (November to April) seasons. The Reserve annual mean rainfall is 250-500mm (MNR, 1974).The Reserve has extreme hot period (March-April), extreme dry cold season (November-February) and a mixture of moderate hot and cold season (May-October) temperature regimes. At the time of this survey, the monthly mean sunshine hour was twelve hours. The Reserve lies within the catchment area of the Yedseram and Ngadda Rivers. Therefore, there are lots of flood plains (fadamas), the rivers' tributaries and depressions (lowland areas) divided by relatively drier areas that collect water during the rainy season (Bawden, 1972). The general Reserve vegetation is Sudano-Sahelian (acacia woodland).

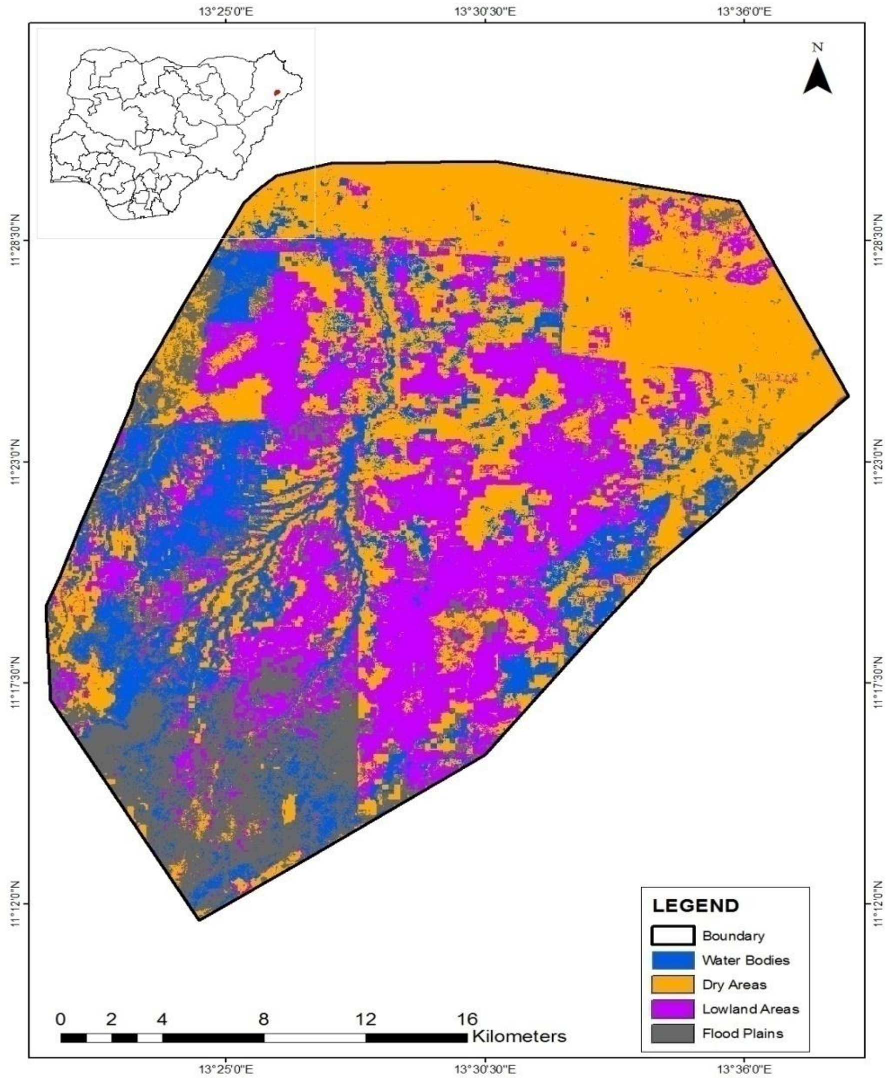


Figure 1: Map of study area

Experimental design

The Reserve was subjectively classified into four categories - drier areas, floodplains, lowland areas (depressions) and rivers. Sixty four 1km-line transects which were sub-divided into 100m-sections, were systematically sampled with the aid of Global Positioning System (GPS) in a stratified random fashion across the categories.

Bird survey method

Each transect was walked slowly while bird species and numbers per species in their associated habitat, were recorded by sight and sound in a 50 m wide strip on each side of the transect (Joshi, *et al.*, 2012). The surveys were carried out during morning hours, from 06:00 to 10:00am, and in the evenings, from 03:00pm to 06:00pm, in the cold dry season of the Reserve (i.e. between

November and February) in 2011 and 2012. A pair of binoculars and field guide was used to confirm identification of birds. The total number of surveys made was 192 (63 on drier areas, 24 in the floodplains, 66 in the lowland areas and 39 along the river's sides).

Vegetation measurements

A 10m x10m quadrat was sampled both at the beginning and the end, in opposite direction of each transect's sections to count and find mean number of trees (tno) (trees with >13.4cm diameter trunk dbh above 1m in height), two hands (h2) (trees with 5.7cm <≥ 13.4cm diameter dbh), one hand(h1) tree with 5.7cm diameter trunk dbh, saplings(finger) (trees with > 5.7cm trunk diameter dbh), and shrubs (sn) and visually estimated mean percentage of tree canopy cover(tcp), percentage shrubs cover (scp) (2, 1–2 and <1 m), average trees height (th), shrubs (sh) and grass height (gh). Within each 10m x10m quadrat, four 1m x1m quadrats were taken to visually estimate mean percentage grass cover (gcv) and litter cover (lcv) following Catling & Burt, (1995), Jones, *et al.* (1996) and Manu, (2002). All the vegetation measurements were taken by the same observer in the cold dry seasons (between November and February) of the Reserve. The mean vegetation variables per section and transect were employed to bring out a true vegetation variables' representatives of a transect since there was no homogeneity in vegetation variables distribution on the same transect due to grazing activities and burnt spots (Ricketts & Imholf, 2003; Smith, *et al.*, 2008).

Statistical analyses

Two bird diversity indices (Margalef's index for species richness and Shannon Wiener diversity index (H)) and feeding guild abundances (granivores, insectivores, frugivores, raptors and nectarivores) were calculated on each transect. The bird species feeding guilds were categorized based on their major food habits and field observations following Chettri, (2005). Principal component analysis (PCA) was used to group the vegetation variables into Principal components (PCs) (August, 1983). But only the first principal component (PC1) with the highest variance (25.15 %) and characteristics of complex vegetation (Fig. 2 and Table 1), named vegetation physical structure complexity, was used as predictor (continuous independent variable) following Chettri, (2005) and Crawley, (2007). The bird diversity indices and the feeding guild abundances were used as response variables while the Reserve categories were used as categorical explanatory variables in a stepwise linear regression analyses. One-way analyses of variance (ANOVA) were performed to assess differences in the bird diversity indices and the feeding guild abundances among the Reserve categories. Non parametric test (Kruskal-Wallis ANOVA test) was also performed to be rest assured that the different in the bird diversity indices and guild abundances among the Reserve categories did not come from statistical error. Tukey-HSD post hoc test were later used to establish significance difference of pairwise comparisons between the Reserve categories (Grafen & Hails., 2002). Kruskal-Wallis ANOVA test was also performed to assess differences in vegetation physical structure complexity (PC1) among the Reserve categories because PC1 data were not normally distributed (Fligner-Killeen test of homogeneity of variances, chi-squared = 29.26, df = 3, P < 0.001). Box plots with notches were used to display significance difference of pairwise comparisons of PC1 between the Reserve categories. All statistical analyses done were simplified and checked with the Akaike Information Criterion (AIC) in 2.12.0 R-version.

Sampling consideration

The bias that could have confounded the results with the different landscape structure, soil texture and structure, plant species and terrain among the Reserve categories was checked by statistically eliminating the categories. The bias that could have also confounded the results due to the effect of time of day was controlled by starting count of birds on all the transect lines at the same start time and by taking a start point of all transect lines to be an end point in subsequent visits because some species are more active later in the day(Shields, 1977) and Manu, (2002). Due to the effect of time of day on bird activities, no transect was observed in the afternoon because birds are less active in the afternoon (Shields, 1977) and Manu, (2002). The effects of season were also controlled by conducting the research only in the dry cold season of the Reserve (Kimball 1949). Another bias that could have come from double count and misidentification of habitat use by some birds was checked by not taking count of other birds in flight above 5m but raptors, and only birds that took off in the front of the observer (adopted from Callard & Burt., 2009).

RESULTS

Bird diversity ─ vegetation physical structure complexity (PC1) relationship

Analysis shows that there was a significantly and positively relationship between Shannon Wiener bird species diversity index and PC1 on the drier areas 'low-lying areas' and 'rivers' ($F_{1,\ 165}$ = 51.54, P < 0.001 and R^2= 0.23; Fig.3) but there was a zero relationship between PCI and Shannon Wiener bird species index in 'flood plains' ($F_{1,\ 21}$ = 0.0007, P = 1 and R^2= -0.05; Fig. 3). There was also a significantly and positively relationship between Margalef's bird species richness index and PC1 ($F_{7,\ 187}$ = 59.69, P < 0.001, and R^2= 0.24; Fig. 4) on all the Reserve categories ('drier areas', 'lowland areas' 'floodplains' and 'rivers').

Bird feeding guild abundance ─ vegetation physical structure complexity (PC1) relationship

Analysis shows that granivore abundance significantly and positively related with PC1 in 'floodplains' ($F_{1,19}$ = 36.58, P < 0.001 and R^2 = 0.64), but significantly and negatively related with PCI on the rest of the Reserve categories ($F_{1,163}$ = 18.39, P < 0.001 and R^2= 0.1). Insectivore abundance significantly and positively related with PC1 in the same manner in each of the Reserve category ($F_{4,184}$ = 26.33, P < 0.001 and R^2= 0.35). Frugivore abundance was significantly and negatively related with PC1 along the 'rivers' ($F_{1,\ 34}$ = 4.65, P = 0.04 and R^2= 0.09), but significantly and positively related with PC1 on the rest of the Reserve categories ($F_{1,163}$ = 22.9, P < 0.001 and R^2= 0.12). Raptor abundance significantly and positively related with PC1 ($F_{1,187}$ = 13.79, P< 0.001 and R^2= 0.06) in the same manner on all the Reserve categories. Nectarivore abundance significantly and positively related with PC1 on 'drier areas' ($F_{1,58}$ = 31.2, P < 0.001 and R^2= 0.34) but showed no relationships with PC1 in the 'low-lying areas' ($F_{1,\ 61}$ = 3.39, P = 0.07 and R^2= 0.04), along the 'river's sides' ($F_{1,\ 37}$ = 0.02, P = 0.9 and R^2= -0.03) and 'floodplains' ($F_{1,\ 22}$ = 2.06, P = 0.2 and R^2= -0.04).

Vegetation physical structure complexity (PC1) ─ the Reserve categories relationship

The vegetation physical structure complexity (PC1) differed significantly across the Reserve categories (chi-squared = 63.69, df = 3, P < 0.001). Box plots with notches (Fig. 5) showed that 'rivers' were significantly higher in PC1 than 'low-lying areas' and 'drier areas' but 'floodplains'.

Bird diversity ─ the Reserve categories relationship

A one-way ANOVA tests show there was a significant difference in bird species richness and Shannon Wiener diversity index among the Reserve categories ($F_{3,188}$ = 9.89, P < 0.001) and ($F_{3,185}$= 7.29 and P < 0.001) respectively and the Kruskal-Wallis tests also show similar result (P < 0.001) and (P < 0.001) respectively. Tukey-HSD post hoc tests show that 'rivers' had significantly more bird species and higher Shannon Wiener diversity index than 'drier areas' and 'low-lying areas' but floodplains (Table 2).

Feeding guild abundance ─ the Reserve categories relationship

The granivore abundance did not differ significantly between Reserve categories ($F_{3, 188}$ = 1.04 and P = 0.4) and Kruskal-Wallis test also showed similar results (P = 0.6). A one-way ANOVA tests showed that the insectivore, frugivore and raptor abundance differed significantly among the Reserve categories ($F_{3.185}$ = 29.39 and P < 0.001), ($F_{3,185}$ = 19.7 and P < 0.001) and ($F_{3,59}$ = 4.304 and P = 0.001) respectively and the Kruskal-Wallis tests also showed similar results (P < 0.001), (P < 0.001) and (P = 0.04) respectively. Tukey-HSD post hoc tests showed that 'rivers' had significantly higher insectivore abundance than 'drier areas', 'low-lying areas' and 'floodplains' (Table 2) while 'floodplains' and 'rivers' were significantly higher in frugivore abundance than 'drier areas' and 'low-lying areas', (Table 2). 'Floodplains' had significantly higher raptor abundance than 'drier areas' and 'low-lying areas' while rivers had more raptor abundance than low-lying areas (Table 2). A one-way ANOVA test showed that nectarivore abundance differed insignificantly across the Reserve categories ($F_{3,188}$ = 1.95 and P = 0.1) and the Kruskal-Wallis test (P = 0.2)

DISCUSSION

Bird diversity, abundance and vegetation physical structure complexity (PC1)

The increasing bird diversity indices and abundances with PC1 gradient results increase the body of evidence to support 1960s' hypothesis (Macthur, R. H., & Macthur, J. W., (1961), that vegetation physical structure predicts bird diversity and abundance. These results empirically illustrate what Begon, *et al.*, (2008) stated that the increase in vegetation physical structure complexity increases potential foods, shelters, protections and nesting resources for avian species. As the increased PC1 in the Reserve could as well mean an increase in number of *Balanites spp*., *Diospyros spp*., *Ziziphus spp*. and *Detarium spp*. which were obvious fruiting tree crops for birds in the Reserve which in turn mean increase in food potential while that of *Acacia spp*. could mean increase in protection cover. Therefore, bird species Red-cheeked Cordon-bleu (*Uraeginthus bengalus*) and Green-Winged Pytilia (*Pytilia melba)* which seems to be easy prey for raptors were commonly sighted in dense acacia stands. The zero relationships between PC1 and Shannon Wiener bird diversity index while bird species richness increased with PC1 in floodplains could be caused by the domination in individuals of one or two species in the floodplain avian community. As explained by Pielou, (1969), when one or two species dominated a community, Shannon Wiener diversity index formula tends to return lower value even when species richness is high. It could be that the domination (as a result of relatively high abundance) of a bird species was high with respect to PC1 because higher PC1 could provide more protective cover for more individuals of the bird species birds against the high abundance of raptors in the floodplains. This could also be the reason for the granivore abundance to increase with PC1 only in the floodplains. The weak negative linear relationship between granivore abundance and PC1 could be due to the decline in seed banks with an increase in PC1 (Diaz & Telleria, 1995; Chettri, *et al.,* 2005). This relationship implies that if the felling of trees continues, the Reserve will become an open habitat and the granivores' population might take over the Reserve, and due to their numbers, becoming more harmful to the host communities' farm crops.

The feeding guild that is most vulnerable to local extinction

Specifically, In Sambisa Game Reserve, insectivorous birds show the strongest affinity to PC1 (R^2=35%) in each of the Reserve category. Therefore, they are the most vulnerable to population decline and local extinction than other feeding guilds against the habitat degradation. This is because Small fragments are impoverished in insectivorous prey as leaf-litter and soil-dwelling invertebrates decline as a result of desiccation in less forested areas. This change can diminish the birds' prey base and reduce insectivorous birds (Sekercioglu, *et al*., 2001). Therefore, the strongest affinity could be the abundance of insects, which is usually associated with high trees with dense canopy (Zanette, *et al.,* 2000; Chettri, *et al.,* 2005), due to the moist conditions and dense foliage always associated with higher trees with dense undergrowth (Erwin, 1982).

Overall bird preferred habitats

Floodplains and rivers were the most important avian habitats in the Reserve because they were the richest in bird diversity and the most valued habitats for frugivores, insectivores and raptors (Table 1). The fringe forests, highest in PC1, river banks and the highest moisture condition (Bawden, 1972; Erwin, 1982) along the rivers and floodplains which made them more diversed habitats, could be the reason for their most valued avian habitats (Rotenberry,1985; Diaz, 2006; Khanaposhtani, *et al*., 2012). Besides, more older trees could be often found in the fringe forests of the rivers and floodplains and older trees provide more food availability for foliage-and-gleaners than younger trees, as well as more breeding site for birds nesting in tree holes (Thompson, *et al.,*1999; Hobson and Byne, 2000b; Laiolo, 2002; Keller, *et al.*, 2003), which in turn could be prey for the raptors (Chettri, *et al.,* 2005). Therefore, Bearded Barbets (*Lybius dubius)* feeding on *Detarium macrocarpium*, Bruce's Green Pigeons (*Treron waalia)* feeding on *Diospyros mespiliformis*, Great Spotted Cukoo (*Clamator glandarius)*, Red-Shouldered Cukoo Shrike (*Campephaga phoenicea)* European Turtle Dove (*Streptopelia turtur) (*migrant) and levvaillant's cukoo (*Oxylophus levaillantii)* were sighted only in floodplains and along the riversides. Red Throated Bee-eaters (*Meropsbulocki)* were breeding on the river banks

Fig.2 Alignment of the variables to their pcs

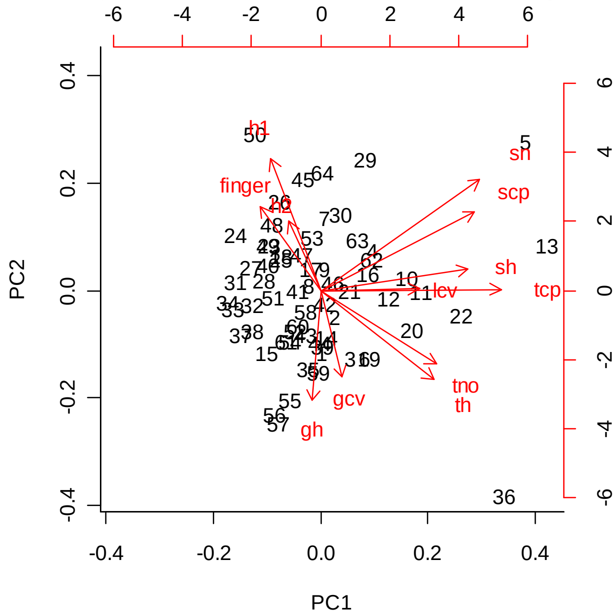


Fig.3 Fitted bird diversity index regression lines

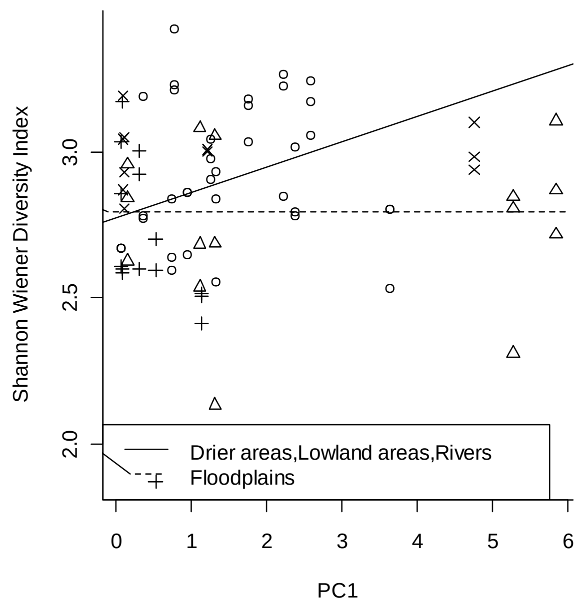


Fig.4 Fitted bird species richness regression line

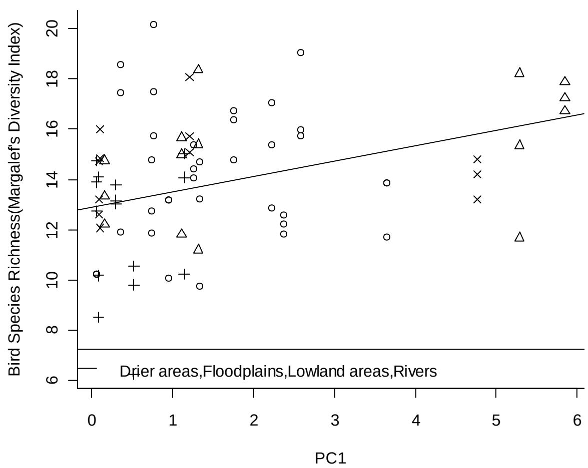
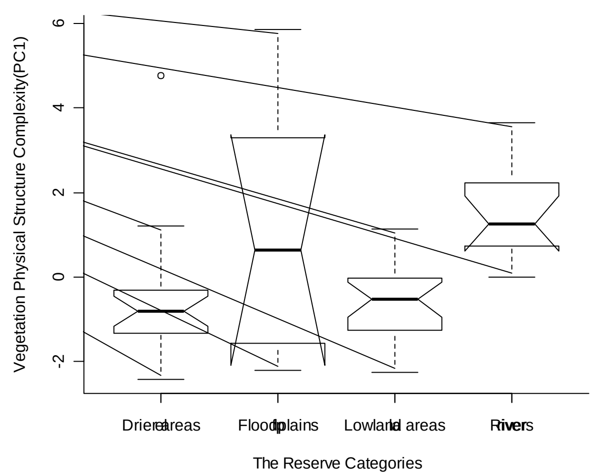


Fig.5 Comparisons of the Mean PC1



Conservation implications

The anthropogenic activities such as heavy grazing, heavy trampling due to settlements and collection of fuel wood in the Reserve then Sudano-Sahelian vegetation bring about subtle changes in habitats available to faunal species (avian). Such changes benefit some species or guilds at the expense of others. As generally depicted by the results, if the on-going habitat degradation in the Reserve is not properly checked, there would be decline in population of bird species, individuals and eventual loss in some bird species. Specifically, insectivores are more vulnerable to the local extinction because of their heaviest dependence on high trees with dense undergrowth. However, granivores would explode in populations and not migrate as the cutting of trees or trampling on dense undergrowth (shrubs) encourages recruitment of more grass plants which provide large seed bank for sustaining population of granivores in dry season.

Table 1: Principal components' explained variation

Principal component	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**C6**	**PC7**	**PC8**	**C9**	**PC10**	**PC11**	**PC12**
Standard deviation	1.74	1.29	1.15	1.07	1.01	0.93	0.87	0.84	0.79	0.63	0.55	0.42
Proportion of variance	0.25	0.14	0.11	0.09	0.08	0.07	0.06	0.06	0.05	0.03	0.03	0.01
Cumulative proportion	0.25	0.39	0.50	0.60	0.68	0.75	0.081	0.87	0.093	0.96	0.99	1.00

Table 2: multiple comparisons of Shannon Wiener diversity index, bird species richness and abundance between the Reserve categories (Tukey-HSD post hoc test)

Response variable	**The Reserve Category**	**Mean Diff.**	**lwr**	**upr**	**p**
Bird species richness	River-Lowland areas	1.95	0.82	3.08	<0.001
	River - Drier areas	1.91	0.78	3.05	<0.001
	River - Floodplains	0.37	-1.08	1.8	1
	Floodplains-Drier areas	1.54	0.20	2.88	0.02
	Floodplains- lowland areas	1.58	2.91	0.05	0.01
	Lowland areas- Drier areas	-0.04	-1.02	0.95	1
Shannon Wiener diversity index	River-Lowland areas	0.19	0.07	0.31	<0.001
	River-Drier areas	0.21	0.08	0.33	<0.001
	River-Floodplains	0.12	-0.04	0.28	0.2
	Floodplains-Drier areas	0.08	-0.06	0.23	0.5
	Floodplains- lowland areas	0.07	0.21	0.06	0.7
	Lowland areas- Drier areas	0.02	-0.09	0.13	1
Log Frugivore abundance	River-Lowland areas	0.80	0.35	1.24	<0.001
	River-Drier areas	0.91	0.46	1.37	<0.001
	River-Floodplains	-0.35	-0.92	0.23	0.4
	Floodplains –Drier areas	1.26	0.73	1.80	<0.001
	Lowland areas - Drier areas	0.12	-0.28	0.57	0.9
	Lowland areas- Floodplains	-1.14	-1.62	-0.62	<0.001
Log Raptor abundance	River-Lowland areas	0.32	0.01	0.63	0.04
	River-Drier areas	023	-0.08	0.54	0.2
	River-Floodplains	-0.18	-0.57	0.22	0.7
	Lowland area – Drier areas	-0.09	-0.36	0.18	0.8
	Lowland areas- Floodplains	-0.50	-0.86	-0.14	0.01
	Floodplains – Drier areas	0.41	0.04	0.77	0.02
Log Granivore abundance	River-Lowland areas	-0.07	-0.38	0.23	0.9
	River-Drier areas	0.20	-0.50	0.11	0.3
	River-Floodplains	-0.10	-0.47	0.31	1
	Floodplains-Lowland areas	-0.12	-0.48	0.24	0.1
	Lowland areas - Drier areas	-0.12	0.39	0.14	0.6
	Lowland areas- Floodplains	-0.01	-0.36	0.35	1
LogNectarivore abundance	River-Lowland areas	-0.35	-0.90	0.20	0.4
	River-Drier areas	-0.24	-0.80	0.32	0.7
	River-Floodplains	0.18	-0.53	0.9	0.9
	Floodplains – Drier areas	0.42	-1.08	0.24	0.4
	Lowland areas–Drier areas	0.11	-0.37	0.6	0.9
	Lowland areas- Floodplains	0.53	-0.12	1.18	0.2

And due to their numbers, they could be harmful to the Reserve host community farmers' cultivated cereal crops in wet season. This could reduce the crops yield and the farmers' income, compelling them to collect fuel wood in the Reserve for sale as supporting income. We recommended that the Management of the Reserve should put more efforts at law enforcement to check the habitat-degrading activities in the Reserve. Non-governmental organizations (NGOs) and conscientious conservation persons should support the Reserve management with programmes that help in checking the conservation crises mentioned in this work. A programme that could bring conservation education to the doorsteps of the host communities and improve the efficiency and effectiveness of the law enforcement outfit of the Reserve will be helpful.

CONCLUSION

The results of this research have highlighted the importance of high trees with dense undergrowth to some bird communities in Sambisa Game Reserve, Sudan-Sahelian vegetation zone .The results have also showed that increase in number of high trees with density of undergrowth was at the expense of granivores. Therefore, the study provides the predictive power for determining the likely fate of certain avian species or feeding guilds should the Reserve, Sudan-Sahelian habitat continue to lose due to the anthropogenic activities. The results further showed that trends in bird species' abundance were not only determined by the quantitative vegetation physical structure complexity but also the qualitative perspective. The results of this research have also pointed out the importance of riversides and floodplains to birds in sudano-sahelian vegetation zone. However, the results of this study are limited because there are still many factors that are responsible for the birds' distribution in the study as the R^2 values of the results were all very small.

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