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Effect of habitat structure on avian diversity and distribution: the case of main camp, Hwange National Park, Zimbabwe

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Abstract

Bird species distribution is due to preference of certain types of habitats and many birds may disappear if their habitat is destroyed. The vegetation in Hwange National Park has been modified by elephant activity due to their high and growing numbers. An investigation into the influence of habitat structure on bird species distribution was carried out during the month of October 2012 in Main Camp, Hwange National Park. Birds were surveyed using the point count technique and various vegetation variables, that included height, stem diameter, canopy volume, were measured in six homogenous vegetation types. Visual assessments of elephant damage on the vegetation were also carried out. A total of 41 bird species and 311 individuals were found in the area sampled. The most speciose and abundant bird order found were the Passeriformes (24 species and 175 individuals respectively) and its members are found occurring in all the vegetation types. Grasslands provided the most favoured habitat for the birds. Elephant damage in the study area was moderate to high and had an insignificant influence on the bird species diversity. Regression analysis showed a relationship between bird species diversity and stem diameter as well as canopy volume (R^2=0.835, p=0.007; R^2=0.827, p=0.008 respectively), but no relationship was found between bird species diversity and plant species diversity as well as height and elephant damage levels (R^2=0.417, p=0.099; R^2=0.169, p=0.228; R^2=-0.0004, p=0.970 respectively). The results therefore imply that habitat structure has an influence on the distribution of bird species in the park.

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Introduction

The physical structure of habitat provides different niches that can be exploited by different organisms. In general, the greater the diversity in physical structure of a particular habitat the greater the biodiversity of organisms found in that area (Wallace and Mahan, 1975). This has been known for nearly a century for birds, but it is probably true for most plants and animals. Distribution of birds, particularly with respect to its geographical and spatial arrangements, has long engaged the attention of ornithologists (Newman, 1983). When we ask why birds are where they are today, how they got there or why some birds are restricted to single island or particular habitat while others are worldwide, we do not always have the answer. It is almost inconceivable to think of a bird without calling to mind the type of habitat where it lives as well as the niche it occupies in its habitat (Telleria, 1992).

The habitat structure consists of both biotic and abiotic components. The abiotic component consists of sunlight, water and soil, which in turn make possible growth of green plants, which birds use either directly or indirectly for food and cover or as a source of nesting materials. The growth habit of plants (size, density and species composition) found in a particular habitat helps determine that habitat's avifauna (Moreau, 1966). Habitat structure has at least three major elements: structural complexity, heterogeneity and scale. The structural complexity represents variation in habitat structure attributable to the abundance of individual structural components, which are the physical elements of the habitat (McCoy and Bell, 1991).

The vegetation in Hwange National Park has suffered from some negative effects from frequent uncontrolled fires and elephant damage which have modified the vegetation. This in turn has affected other animal species, including birds, which have declined in numbers and some have even disappeared from the ecosystem. This clearly shows the deterioration of the health of the ecosystem and it can no longer support life of these disappearing species.

Research is of fundamental importance because continuous scientific investigations are needed for the maintenance of National Parks and Reserves. It is on research results that policy, long-term planning, management, assessment of vulnerability of the area, limitation of visitors and so forth, must be based. Birds are relatively easy to study and often open a doorway for further nature and scientific studies. They engage in fascinating behaviours and play important roles in the ecosystems that sustain life. Birds show close affinities to particular habitats and may respond to subtle variations in habitat, subtle detail that are easy to escape the eye. For instance differences in vertical structure of a forest might influence the species that utilize that forest. Due to their ability to respond to subtle changes in habitat, birds are excellent indicators of local ecological condition and overall health of the environment, often alerting environmentalists to potential problems. Their distribution and also changing populations provide clues to overall health of their habitat (Sutherland *et al*, 2004).

Birds also, are generally colourful, charismatic, easily identified, and popular with the public. For these reasons, birds, especially songbirds, are a major focus of monitoring efforts. Research and study of birds is vital to learn more about them and develop ways to ensure that they are conserved and they do not become extinct for the enjoyment of present and future generations. Distribution of bird species is due to the preference of certain habitats with usually a specialized niche within that habitat. Many birds will disappear entirely if their habitat is destroyed or degraded because they are unable to adapt to different living conditions.

Nationally, Hwange is considered to be of conservation importance for 24 species, including *Ciconia episcopus, Oxyura maccoa, Gallinula angulata* and *Chlidonias hybridus*. It also contains

possibly the largest protected populations of *Tockus bradfieldi* and *Buphagus africanus* in the Southern African subregion. Other nationally uncommon or threatened species that breed in the Park are *Ephippiorhynchus senegalensis, Ardeotis kori* and *Bucorvus cafer*.

Although birds are such important fauna and Hwange National Park is home to many bird species of conservation importance, no study has been carried out on how habitat structure influences bird species distribution in this park. In view of the changes which are occurring in Hwange National Park it is important that a study of bird species distribution and habitat structure be carried out. The major objective of the study was to determine whether there is a relationship between bird species distribution and the habitat structure in Main Camp, Hwange National Park, Zimbabwe. The study also aimed at identify bird species found in different homogenous vegetation types, inventorying of the species and numbers of birds of conservation status and assessing how birds respond to changes in the habitat structure brought about by elephant activity in Main Camp, Hwange National Park, Zimbabwe

The study was undertaken in light of the importance of habitat structure as a vital determinant of the avifauna in a locality. The study thus sought to unveil the relationship between habitat attributes and bird species composition. The study also aimed at gaining some insight into the numbers and proportions of bird species of conservation status in the park. Some parts of Hwange National Park were currently going through major changes attributed to the high elephant numbers during the time of study. A study to document how these changes affect other species including the avifauna comes in handy. This study assessed bird populations in areas with different levels of elephant damage to see how the birds are responding to the elephant activity and hence the suitability of birds as indicators of the general health status of the park. In addition to that, information from such studies comes in handy in helping to update the bird distribution map for the park.

Materials and methods

The study was carried out in the areas around Main Camp, Hwange National Park, Zimbabwe, during the month of October 2012 in the late dry season.

Study area

Hwange National Park (18°44°06°S, 26°57°18°E) is the largest national park in Zimbabwe and the third largest in Africa after Serengeti in Tanzania and Kruger National Park in South Africa. It is situated in the North-West of the country and covers an area of 14,651km² with an average altitude of 1,000m above sea level. It is bounded by Botswana to the West, Tsholotsho Communal Land to the South-East, Forestry Commission land to the East and Matetsi Safari area to the North (Fig. 1). The park is divided into a Northern Wild Area, Central Wild Area and Southern Wilderness Area for management purposes. It comprises of three major camps; Hwange Main Camp, Sinamatella Camp and Robins Camp all located in the Northern part of the Park. The study was carried out in areas around Main Camp.

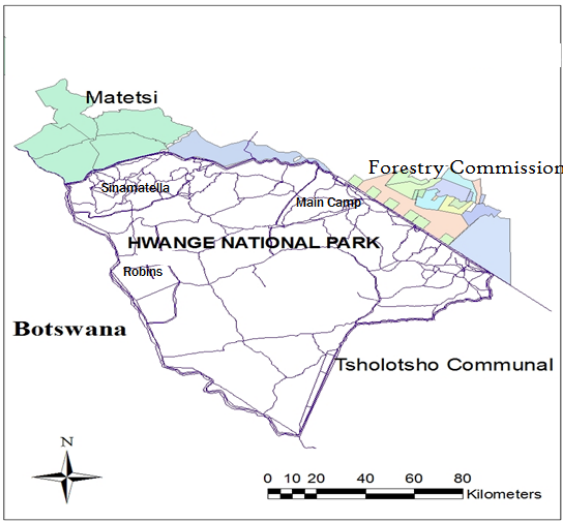

Fig. 1. Hwange National Park and its neighbouring areas.

Climate

Water is a key limiting resource in Hwange National Park; hence there are three "seasons" that are defined by the abundance of water. These are a wet season, an early dry season and a late dry season.

The early dry season spans from April-June. From May to June it is warm to hot (25°C) during the day but temperatures can drop to below freezing on particularly cold winter nights. The late dry season is from July-October. September and October are the hottest months. During these dry seasons the animals are concentrated around the man-made waterholes. The rainy season stretches from November-March. Summer rains arrive mainly in the form of afternoon thunderstorms and the vegetation bursts into life. The area has relatively low average rainfall of between 570-650mm per annum. Temperatures can reach over 38°C, while on average they range from 18-28°C. Birdlife is most spectacular at this time.

Topology

Hwange is essentially flat, becoming more broken in the North. The most significant topographical feature is unquestionably the watershed, which stretches across the Park from Ngamo and Kennedy towards Main Camp and northwest to Shumba and lies between the main Makgadikgadi (Botswana)/Zambezi valley watershed (Wilson, 1975). The north and north-west of the park are drained by the Deka and Lukosi rivers and their tributaries, and the far south of the park is drained by the Gwabadzabuya River, a tributary of the Nata River (Loveridge *et al.*, 2006). There are no rivers in the rest of the park, although there are fossil drainage channels in the Main Camp and in the Linkwasha areas, which form seasonal wetlands. In these areas without rivers, grassy pan depressions and pans have formed. Some of these pans, such as many of the pans in the Shumba area, fill with rainwater, while others, such as Shokwanki and Nehimba, are fed by natural groundwater seeps (Dudley *et al.*, 2001). Many of the pans are additionally supplied by water pumped from underground by park authorities and stake holders within the park (Davison, 1967).

Geology and Soils

Most of the Park is underlain by Kalahari Sands, which cover two-thirds of the park (Ferguson, 1938). In the North-West there are basalt lava flows of the Batoka Formation, stretching from south of Bumbusi to Botswana border (Watson, 1960). In the North-Central area, from Sinamatella going eastwards, there are granites and gneisses of Kamativi-Dete Inlier and smaller inliers of these rocks are found within the basalts in the north-west (Lockett, 1979). Karoo sediments and the Pre Cambrian rocks are also some types of geology that can be found in the Park (Love, 1999).

Flora

The park is close to the edge of the Kalahari Desert, a region with very little water and very sparse, xerophile vegetation. The Kalahari woodland is dominated by Zambezi teak, Sand Camwood (Baphia) and Kalahari bauhinia (Hyde *et al.*, 2010). Seasonal wetlands form grasslands in this area. The north and north-west of the park are dominated by Mopani woodland. The distribution of the main vegetation types in the Hwange National Park is dependent on the type of soil. There are over 1,070 plant species in the park which include about 255 trees and shrubs and over 202 grasses, (Hwange Management Plan, 2000). The vegetation of Hwange is primarily woodland 64%, scrubland 32%, with only grasslands and savanna 4% (Hwange Management Plan, 2003). Small areas of grasslands are in drainage lines and in upland situations in the North-West of the park.

Fauna

The park hosts over 100 mammal and 400 bird species, including 19 large herbivores and 8 large carnivores. All Zimbabwe's specially protected animals are found in Hwange and it is the only protected area where gemsbok and brown hyena occur in reasonable numbers. Grazing herbivores are more common in the Main Camp Wild Area and Linkwasha Concession Area, with mixed feeders more common in the Robins and Sinamatella Wild

Areas, which are more heavily wooded (Chamaille-Jammes *et al.*, 2009). Distribution fluctuates seasonally, with large herbivores concentrating in areas where extensive water pumping is maintained during the dry season. Major predators include the lions, whose distribution and hunting is strongly related to the water pans and waterholes, leopards, spotted hyenas, cheetahs and the African wild dogs (painted dogs) whose population is thought to be one of the larger surviving groups in Africa today, along with that of Kruger National Park and Selous Game Reserve (Girman *et al.*, 2001).

Data collection

Selecting sampling plots for the study

A digital map for the area was used to identify areas with homogenous vegetation types and a total of 6 such areas were identified. In each respective homogenous vegetation type, 3 random points were selected for sampling using the random point tool of QGIS. All points were in the form of circular plots with 50m radii which were separated by distances of 500m from each other. In these homogenous vegetation types, bird counts and vegetation surveys were carried out.

Bird point counts

In each homogenous vegetation type, bird counts were carried out in the three randomly selected points on two occasions in the breeding season. The point count technique (Ralph *et al.*, 1993) was used. This method involves remaining at a point for a fixed period and counting birds heard and seen. The point counts were conducted during the breeding season to take advantage of the singing behaviour of birds as they vocalize in charming mates and defending territories.

The point counts were done within 5 hours of dawn (generally 05:30 to 10:30 a.m.) when birds are most actively singing. At each sampling point, an allowance of 2 minutes was given to let the birds settle after having been disturbed by the arrival of people and a fixed period (5 minutes to 10 minutes) was spent conducting the bird counts. All birds seen and heard within the 50m radius and beyond were noted and identified with the aid of the expertise of game rangers. Bird identification was based on morphological features or nature of vocalisation. Separate recordings of birds seen flying over sampling sites were made. The total number of bird species and abundances were recorded for each sampling site and totals for each homogenous vegetation type calculated.

For each habitat type the Shannon Wiener diversity index (H') to determine species richness and diversity were calculated using the formula below:

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

Where p_i is the proportion of individuals belonging to the *i*th species in the data set.

The Simpson diversity (λ) and Soerensen similarity (QS) indices for each homogenous vegetation type were also calculated using the following formulae:

$$\lambda = \sum_{i=1}^{R} p_i^2$$

Where p_i is the proportion of individuals belonging to the *i*th species in the data set

$$QS = \frac{2C}{A+B}$$

Where QS is the quotient of similarity;

A and B are the number of species in samples A and B; and

C is the number of species shared by the two samples.

Vegetation survey

Vegetation surveys to determine the habitat structure was carried out in each of the 3 randomly selected sampling sites within the 6 homogenous vegetation types. This was carried out by measuring a number of parameters in belt transect of 1m width

and 50m length made from the centre of the sampling site to the edge in four directions (north, east, south and west). The parameters measured included: canopy volumes, tree heights, stem diameters and damage percentages for plant species occurring within the belt transects. These were recorded on the data together with the plant species names using prepared data sheets. Identification of the tree species was done with the aid of game rangers and reference textbooks (Field guide to trees of Southern Africa by Van Wyk and Van Wyk, 1997). Tree species richness and diversity for each homogenous vegetation type was calculated using the Shannon Wiener diversity index.

Height

The height for trees in each sampling point within a homogenous vegetation type was measured using a three metre (3m) rod. The rod was placed so as to lean vertically to the tree. If the tree was shorter than the rod then the height was read directly from the rod. In cases where the tree was longer than the rod, estimates were made as to how many times the tree was longer than the rod and then the tree height was obtained by simply multiplying this by the rod length. The mean height for each sampling point was calculated and the overall mean height for the homogenous vegetation types also calculated. Categorisation of plants into height classes was done to obtain the vertical distribution of canopy cover for the different homogenous vegetation types.

Canopy volume

In each sampling site within a homogenous vegetation area tree canopy volume was determined. In determining the canopy volume for each tree the greatest canopy diameters taken at right angles to each other were measured using a 20m flexible measuring tape and denoted D1 and D2. Canopy depth was also measured using the 3m rod and denoted CD. Canopy volume was then calculated from the canopy diameters and canopy depth using the following formula:

$$\text{Canopy volume} = \frac{\pi}{4} * D1 * D2 * CD$$

Mean canopy volumes for each random sampling point and consequentially for each homogenous vegetation type were calculated.

Stem diameter

Tree stem diameters were measured at breast height using a tape measure for all straight trees. For multi-stemmed trees stem diameters were taken just above the buttress swelling. Where multi-stemmed trees occurred before the above ground, the stem diameter was measured separately unless the stems were distinctly joined at the base and one diameter was measured. The tape measure was used to measure the stem circumference for each tree and the following formula was used to calculate the diameter:

$$\text{Diameter} = \frac{\text{Circumference}}{\pi}$$

The mean stem diameter for each random sampling site and for the homogenous vegetation types were calculated and recorded.

Damage level assessment

The damage level assessments were done through visual inspection of each tree measured in the random sampling sites using the scale given in Table 1. below. The overall damage level for the homogenous vegetation areas was then concluded from the information obtained from each random sampling site within the respective homogenous vegetation area.

Table 1. Scale for tree damage level.

Level	Class	Description
No damage	0	no damage at all
Low	1	slight damage
Moderate-light	2	branches broken but tree retains growth form
Moderate-high	3	branches broken and tree growth form altered
High	4	dead trees

Data analysis

The data obtained from the study was tabulated and represented graphically. Regression analysis was used to test whether various factors such as plant

species diversity, height, stem diameter, canopy volume and elephant damage levels can be used to predict the bird species diversity in the different homogenous vegetation types.

Results

Overall bird species richness and diversity

A total of 6 homogenous vegetation types were sampled for bird distribution. These included; *Acacia* shrubland/thicket, *Dichrostachys* shrubland/thicket, Mixed open woodland, Grassland, *Terminalia* shrubland and *Baikiaea* open woodland.

A total of 41 bird species were observed at the various sites that were sampled during the study. All the birds were positively identified to species level and were distributed across 9 orders and 26 families (Table 1., Appendix A). The most species rich and diverse Order was Passeriformes which had a total of 24 species (H'=2.63) and 175 individuals (Table 2.). Orders Apodiformes, Charadriiformes, Cuculiformes and Psittaciformes were the least speciose (one) and had the lowest diversity (H'=0) with each having only one bird species belonging to it.

Table 2. Bird order diversity.

Order	Number of families	Number of species	Shannon diversity index
Apodiformes	1	1	0
Charadriiformes	1	1	0
Columbiformes	1	3	0.65
Coraciiformes	3	5	1.20
Cuculiformes	1	1	0
Falconiformes	1	3	0.93
Galliformes	2	2	0.58
Passeriformes	15	24	2.63
Psittaciformes	1	1	0

A total of 311 bird individuals were encountered in the study area with the Passeriformes also maintaining a pole position (175) followed by the Columbiformes (39) and the least was the Charadriiformes (2) (Fig.2.).

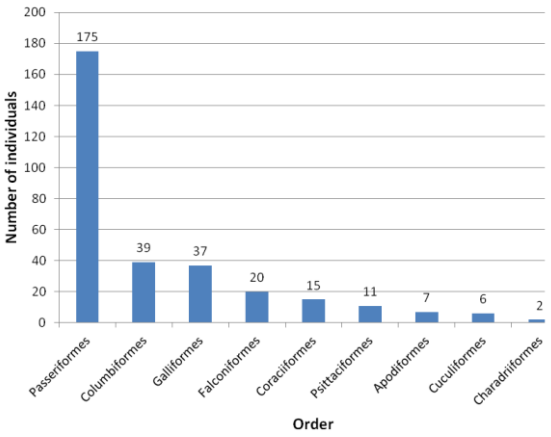

Fig. 2. Rank-abundance graph of bird orders according to number of individuals in Main Camp, Hwange National Park, Zimbabwe.

Distribution and abundances of bird species around Main Camp, Hwange National Park

The distribution of the 311 bird species encountered in the six homogenous vegetation types is given in Appendix B (Table 2.). The most speciose habitat was the Grassland with 20 species in total (49%) and the least rich habitat type was the *Baikiaea* open woodland, which had 9 species (22%) (Table 3.).

Table 3. Distribution and abundances of bird species around Main Camp.

Vegetation type	Number of bird species	Overall abundance
Acacia shrubland/thicket	16	52
Baikiaea open woodland	9	25
Dichrostachys shrubland/thicket	13	40
Grassland	20	132
Mixed open woodland	10	17
Terminalia shrubland	12	45
Total		**311**

In terms of abundances the Grassland also took a pole position with a total of 132 birds and the Mixed open woodland had the least number of birds with 17 birds. Some species were found in more than one vegetation type, most being found in two or more, with the Laughing dove occuring in all the sampled sites, the Yellowbilled kite in all except the *Baikiaea*

open woodland, the Forktailed drongo, Whitebrowed sparrow-weaver and Yellowbilled hornbill in 4 vegetation types, and the Blue waxbill, Neddicky and Whitecrowned shrike in 3 vegetation types. There are also some bird species that were observed in only one vegetation type, such as the Arrowmarked babbler, Barn swallow, Groundscrapper thrush and Masked weaver found only in the *Acacia* shrubland/thicket, the Grey hornbill only in the *Baikiaea* open woodland and the Blackcheeked waxbill, Blacksmith plover, Goldenbreasted bunting, Greyheaded sparrow, Plumcoloured starling and Violeteared waxbill in the Grassland among others. The Bradfield's hornbill is the only bird of conservation status that was observed during the study and it was found in only one vegetation type, the Mixed open woodland.

Table 4. Bird species diversity and evenness.

Vegetation type	Shannon Bird species diversity (H′)	Shannon Bird species evenness (E_H)	Bird species Simpson diversity (λ)
Acacia shrubland/ticket	2.58	0.93	0.087
Baikiaea open woodland	2.05	0.93	0.15
Dichrostachys shrubland/thicket	2.36	0.92	0.11
Grassland	2.59	0.86	0.10
Mixed open woodland	2.15	0.93	0.13
Terminalia shrubland	2.03	0.82	0.19

Bird species diversity, evenness, similarity and dominance

The overall bird species Shannon diversities for all the homogenous vegetation areas are relatively high, greater than 2.0 as shown in Table 4., indicating diverse and equally distributed bird communities. The evenness of the communities is also relatively high (ranging from 0.82-0.93), almost reaching complete evenness. The Simpson diversities are relatively low in all the homogenous vegetation areas and this shows that the observed bird communities were of high diversity.

The values for the evaluations of similarity in bird species within the sampled homogenous vegetation areas are low indicating dissimilarity as the areas have few bird species in common (Table 5.). Only one comparison, *Dichrostachys* vs. *Terminalia,* show a considerable similarity (QS = 0.56).

Table 5. Soerensen's quotient of similarity.

Vegetation type	Similarity index
Acacia vs. *Baikiaea*	0.32
Acacia vs. *Dichrostachys*	0.41
Acacia vs. Grassland	0.33
Acacia vs. Mixed	0.23
Acacia vs. *Terminalia*	0.36
Baikiaea vs. *Dichrostachys*	0.36
Baikiaea vs. Grassland	0.21
Baikiaea vs. Mixed	0.32
Baikiaea vs. *Terminalia*	0.29
Dichrostachys vs. Grassland	0.30
Dichrostachys vs. Mixed	0.35
Dichrostachys vs. *Terminalia*	0.56
Grassland vs. Mixed	0.20
Grassland vs. *Terminalia*	0.44
Mixed vs. *Terminalia*	0.45

Table 6. Vegetation survey variables as observed in the different vegetation types.

Vegetation type	Mean height (cm)	Mean stem diameter (cm)	Mean canopy volume (m^3)
Acacia shrubland/ticket	375.70	21.06	217.89
Baikiaea open woodland	312.84	7.25	10.69
Dichrostachys shrubland/thicket	352.88	10.51	37.89
Grassland	301.95	19.61	192.82
Mixed open woodland	324.66	12.14	16.51
Terminalia shrubland	160.61	6.11	1.73

Vegetation survey variables in the different habitats

The mean heights stem diameters and mean canopy volumes of the six homogenous vegetation types are shown in Table 6. The greatest mean height was

observed in the *Acacia* shrubland/ticket (375.7cm) and the lowest in the *Terminalia* shrubland (160.61cm). The *Acacia* shrubland/ticket also had the highest average stem diameter (21.06cm) and mean canopy volume (217.89m^3) (Table 6.).

Shannon Wiener Diversities for Vegetation Attributes

The overall plant species and height diversity indices for all the homogenous vegetation areas are shown in Table 7 .below. Plant species diversities are relatively high, ranging from 0.82 to 1.87, with the grassland having the least diversity. There is also less diversity in plant height in all the homogenous vegetation areas, especially in the *Terminalia* shrubland whose overall diversity is low (0.61).

Table 7. Shannon Diversity indices for bird species, plant species and plant height in the 6 homogenous vegetation areas.

Vegetation type	Plant species diversity (H′)	Plant height diversity (H′)
Acacia shrubland/ticket	1.20	1.14
Baikiaea open woodland	1.86	1.30
Dichrostachys shrubland/thicket	1.69	0.83
Grassland	0.82	1.19
Mixed open woodland	1.13	1.00
Terminalia shrubland	1.87	0.61

Elephant damage levels in different vegetation types

Elephant damage in the sampled areas was moderate to light for most of the homogenous vegetation areas sampled except for the *Baikiaea* open woodland where most trees had slight damage and the *Terminalia* shrubland which had moderate to high damage (Table 8.) with most of the tree canopies absent.

Table 8. Elephant damage levels.

Vegetation type	Overall damage level
Acacia shrubland/ticket	Moderate-light
Baikiaea open woodland	Low
Dichrostachys shrubland/thicket	Moderate-light
Grassland	Moderate-light
Mixed open woodland	Moderate-light
Terminalia shrubland	Moderate-high

Influence of vegetation parameters on bird species diversity

The regression analysis showed that bird species diversity was significantly influenced mostly by stem diameter (R^2 = 0.84, p = 0.007) and canopy volume (R^2 = 0.83, p = 0.008). On the other hand, bird species diversity was not affected by plant species diversity (R^2 = 0.42, p = 0.099), plant mean height (R^2 = 0.17, p = 0.228) and elephant damage levels (R^2 = -0.25, p = 0.97) (Table 9.).

Table 9. R^2 and P-values for different relationships tested,

Relationship	R^2-value	Adjusted R^2-value	P-value
Bird species diversity-Plant species diversity	0.534	0.417	0.099
Bird species diversity-Plant mean height	0.336	0.169	0.228
Bird species diversity-Mean stem diameter	0.868	0.835	0.007
Bird species diversity-Mean canopy volume	0.861	0.827	0.008
Bird species diversity-Elephant damage level	0.000404	-0.249	0.970

Discussion

Bird species richness and diversity

The Main Camp is one of the two main birding areas in Hwange National Park and the study saw a total of 41 species being observed. The birds were distributed across 9 orders and 26 families in the 6 different homogenous vegetation areas that were sampled. The different vegetation types account for the

diversity of bird species that were observed since the different bird species have preferences when it comes to habitats, food sources or nesting materials. The occurrence of certain species in a given vegetation type does not mean that the birds use it solely as a habitat. Most of the birds were seen perching on trees or flying about as they moved from one tree to another. Some birds were seen feeding on the ground below trees that produce seeds such as *Acacia tortilis* and *A. erioloba*.

The most abundant birds observed belong to the order Passeriformes. The Passeriformes form one of the most diverse terrestrial vertebrate orders and includes more than half of all bird species. They occupy a wide range of habitats from grasslands, woodlands, scrublands, forests, deserts, mountains and urban environments. They mostly prefer areas with trees since most are arboreal and live primarily on trees. This is the reason why the bird species from these order were observed the most during the study. The least diverse orders included Apodiformes, Charadriiformes, Cuculiformes and Psittaciformes, each having one species representing them in the study area. This may be due to the fact that they do not prefer the various types of habitats provided by the different vegetation types in the area. Another reason could be due to competition for food and nesting areas with other species which are found in large numbers in the area, such as the abundant passerines.

Distribution and abundances of bird species in the different vegetation types

In the 6 homogenous vegetation types sampled during the study it was seen that most species were found in the Grassland with 49% of the sampled birds occurring there. This could be attributed to the presence of a water bath in the area that the birds visit for water. The grassland also had a few trees that were used for nesting purposes by some of the birds, especially the Whitebrowed sparrow-weaver (*Eurocephalus anguitimens*) that had nests in the *Acacia tortilis* trees. The least diversified vegetation type was the *Baikiaea* open woodland which had 22% of the bird species observed in the study. The area is dominated by the Zambezian teak (*Baikiaea plurijuga*), and other plant species, such as *Acacia fleckii, Baphia massaiensis, Ochna pulchra* and *Guibourtia coleosperma* are evenly distributed within the woodlands but the tree species richness is very low. This means that less bird species will choose such an area as a habitat.

Most bird species especially the passerines were found to be occuring in more than one vegetation type. This is because they are not confined to only one type of habitat since the members of this order occupy a wide range of habitat as they try to meet their individual needs, in terms of food and shelter. There are however some birds that were seen in only one vegetation type which included the Bradfield's hornbill (*Tockus bradfieldi*) and Emerald spotted dove (*Turtur chalcospilos*), both found in the mixed open woodland and Blackcheeked waxbill (*Estrilda erythronotos*), Blacksmith plover (*Vanellus armatus*), Goldenbreasted bunting (*Embrezia flaviventris*), Greyheaded sparrow (*Passer griseus*), Pied babbler (*Turdoides*), Pied crow (*Corvus albus*), and Plumcoloured starling (*Cinnyricinclus leucogaster*) which were all seen in the grassland only. The reason for this may be the presence of the water bath as earlier mentioned, as most birds visit the bath in the morning then go back to their respective habitats. The presence of insects may be another reason as the birds could be seen foraging for food on the ground.

The Bradfield's hornbill (*Tockus bradfieldi*) was the only species of conservation that was observed in the study and it only occurred in the Mixed open woodland which covers less than 10% of the study area. This observation could imply that the birds of conservation status are becoming less in the park but since the study was only done in a small portion of the whole park the conclusion of the implication may be false.

Vegetation survey variables and elephant damage levels

The *Acacia* shrubland/thicket had the highest mean height, stem diameter and canopy volume of all the homogenous vegetation types. This is due to the big sizes of the trees found in this vegetation type (very tall trees with large trunks and canopies). These include the *Acacia erioloba* and *Dichrostachys cinerea* which were the most abundant in the area. These have large canopy sizes which are used by many birds as nesting sites, especially the *Acacia erioloba* where nests belonging to the Grey lourie (*Corythaixoides concolor*) were observed. The *Dichrostachys* shrubland/thicket also had relatively high mean height but lower stem diameters and canopy volume. The *Dichrostachys cinerea* trees which dominate the area had low canopy volume as it had been altered by the elephant due to foraging. Both the *Acacia* shrubland/thicket and *Dichrostachys* shrubland/thicket had moderate-light elephant damage with trees having broken branches but still retaining their growth form.

The Grassland had relatively high mean height, stem diameter and canopy volume because only a few tall trees and fewer shrubs were found scattered within the sampled plots. The tree branches were also broken due the damage by elephants as they move through the grasslands in search for food or water. The lowest means for height, stem diameter and canopy volume were observed in the *Terminalia* shrub land. The main reason for the observation was that most of the trees, especially *Terminalia sericea* and *Ochna pulchra* had been destroyed by elephants, altering the height and consuming most of the canopies. The damage level for the area was moderate-high. Cumming *et al* (1997) argue that elephant populations cause change in vegetation structure due to large population increases recorded in the park. The *Baikiaea* open woodland had the lowest elephant damage with most trees having slight damage and means for height, stem diameter and canopy volume were reasonably high. Elephant damage in this woodland is small because of the low palatability of the *Baikiaea plurijuga* hence they are less favoured to be included in the elephant diet (Childes and Walker, 1987).

The results for the relationships between bird species diversity and various factors tested showed that the relationships that exist are with stem diameter and canopy volume. The other relationship models could not account fully for the variation that is experienced in the sampled area of Main Camp.

The relationship model for bird species diversity-plant species diversity could only explain 42% of the variation (R^2=0.417, p=0.099). The same was observed for bird species diversity-mean plant height model (R^2=0.169, p=0.228) and bird species diversity-elephant damage levels (R^2=-0.0004, p=0.970). For the bird species diversity-mean stem diameter and bird species diversity-mean canopy volume relationship models the variation that could be explained was 84% and 83% respectively and the p-values were 0.007 and 0.008 respectively suggesting significant slopes and y-intercepts. The models were hence useful in the prediction of bird species diversity in the different homogenous vegetation areas.

Bird species richness diversity and elephant damage levels

The results show no relationship between bird species richness and elephant damage levels in all 6 homogenous vegetation types sampled during the study. Bird species diversity is relatively high in all the vegetation types despite the differences in elephant damage levels. Elephant damage in the least bird species rich vegetation type, the *Terminalia* shrubland (2.03), is moderate to high but the bird species diversity is not much different from the least damaged vegetation type, the *Baikiaea* open woodland (2.05).

Diversity indices

The Shannon-Wiener bird diversity indices for all the homogenous vegetation types sampled during the

study have high values ranging from 2.03-2.58. These values indicate bird species richness and evenness in the different vegetation types meaning an effective number of bird species are represented in the observed data. Plant species diversity indices range from 0.82-1.87, which are lower than the bird species diversities but still show relatively high diversity in the plant species occurring in the homogenous vegetation types. The lowest value of 0.82 was found on the Grassland where only 4 plant species were observed in small numbers. The values for diversity index also approach zero in cases where there is either a concentration of one species and the others are rare, or there is unequal abundances of different species (Shannon, 1948).

There is lower diversification in plant height in the sampled homogenous vegetation types. The *Acacia* shrubland/thicket, *Dichrostachys* shrubland/thicket and Grassland have index values that are slightly higher than 1, and the rest are lower than 1 with the lowest observed in the *Terminalia* shrubland (0.61). This is because the vegetation is concentrated in one height class, in the case of *Terminalia* shrubland the vegetation is mainly shrubs of 1-2m in height.

Conclusion and recommendations

The results of the study show that Main Camp has diverse birdlife rich in the passerines that are the most abundant group. Enthusiast birdwatchers or regular tourists can find the area to be interesting since there is diversity in vegetation types that provide different habitat for the various bird species found. A wide range of species can also be seen at water baths that are set at various locations. The area sampled for the study shows low levels of elephant damage. The only area with moderate-high levels of elephant damage showed an alteration in vegetation structure and it had the lowest bird diversity, meaning elephant activity affects bird species distribution though in somewhat insignificant measures.

The vegetation survey showed that plant species diversity and height do not have much influence on the diversity of bird species, and stem diameter and canopy volume do. This shows that birds are much concerned with cover when choosing the location of their habitats and so the habitat structure has an effect on bird species distribution. Several limitations were experienced in the study, such as the sampling of only some of the homogenous vegetation types found in the area and it was done during one season. The study period was short and could not include every bird species that inhabit the study area and also the resources, such as the availability of a vehicle to reach some parts of the study area, were limiting. This means the results could not give a full overview of the state of birdlife in the area, some of the birds that are found could not be included in the study. The results can therefore be assumed to be true for the area in the vicinity of the heart of Main Camp.

There is need for regular bird studies to be carried out to monitor and assess the birds that are found around the park. The studies will have to include all the seasons to accommodate the migratory birds that include that include inter-African and also Palearctic migrants. Seasonal counts are also important for the estimation of periodic variation of the bird communities. The most part of Main Camp was not sampled as the means to reach other areas was not available, so the studies to follow should cover other areas that were not sampled. This will aid in coming up with a full inventory of the bird community around Main Camp. The studies should also consider the temporal variation in bird activity as this study only focused on the birds that are active in the early hours of the day.

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Appendices

Appendix A

Table 1. List of bird species observed in the study.

Order	Family	Common name	Scientific name
Apodiformes	Apodidae	Africa Palm-swift	*Cypsiurus parvus*
Charadriiformes	Charadriidae	Blacksmith plover	*Vanellus armatus*
Columbiformes	Columbidae	Cape turtle dove	*Streptopelia capicola*
Columbiformes	Columbidae	Emerald-spotted dove	*Turtur chalcospilos*
Columbiformes	Columbidae	Laughing dove	*Streptopelia senegalensis*
Coraciiformes	Bucerotidae	African Grey hornbill	*Tockus nasutus*
Coraciiformes	Bucerotidae	Bradfield's hornbill	*Tockus bradfieldi*
Coraciiformes	Bucerotidae	Yellowbilled hornbill	*Tockus flavirostris*
Coraciiformes	Coraciidae	Lilacbreasted roller	*Coracias caudatus*
Coraciiformes	Phoeniculidae	Redbilled woodhoopoe	*Phoeniculus purpureus*
Cuculiformes	Musopheagidae	Grey lourie	*Corythaixoides concolor*
Falconiformes	Accipitridae	Bateleur	*Terathopius ecaudatus*
Falconiformes	Accipitridae	Whitebacked vulture	*Gyps africanus*
Falconiformes	Accipitridae	Yellowbilled kite	*Milvus migrans parasitus*
Galliformes	Numididae	Helmeted guinea fowl	*Numida meleagris*
Galliformes	Phasianidae	Redbilled francolin	*Francolinus adspersus*
Passeriformes	Cisticolidae	Neddicky (Piping	*Cisticola fulvicapilla*

		cisticola)	
Passeriformes	Corvidae	Pied crow	*Corvus albus*
Passeriformes	Dicuridae	Forktailed drongo	*Dicrurus adsimilis*
Passeriformes	Emberizidae	Goldenbreasted bunting	*Emberiza flaviventris*
Passeriformes	Estrildidae	Blackcheeked waxbill	*Estrilda erythronotos*
Passeriformes	Estrildidae	Blue waxbill	*Uraeginthus angolensis*
Passeriformes	Estrildidae	Violeteared waxbill	*Uraeginthus granatinus*
Passeriformes	Hirundinidae	Barn swallow	*Hirundo rustica*
Passeriformes	Laniidae	Longtailed shrike	*Corvinella melanoleuca*
Passeriformes	Laniidae	Whitecrowned shrike	*Eurocephalus anguitimens*
Passeriformes	Malaconotidae	Tropical Boubou shrike	*Laniarius aethiopicus*
Passeriformes	Passeridae	Greyheaded sparrow	*Passer griseus*
Passeriformes	Ploceidae	Masked weaver	*Ploceus velatus*
Passeriformes	Ploceidae	Redheaded weaver	*Anaplectes rubriceps*
Passeriformes	Ploceidae	Whitebrowed sparrow-weaver	*Plocepasser mahali*
Passeriformes	Prionopidae	White helmetshrike	*Prionops plumatus*
Passeriformes	Pycnonotidae	Blackeyed bulbul	*Pycnonotus barbatus*
Passeriformes	Sturnidae	Cape glossy starling	*Lamprotornis nitens*
Passeriformes	Sturnidae	Greater blue-eared glossy starling	*Lamprotornis chalybaeus*
Passeriformes	Sturnidae	Plumcoloured starling	*Cinnyricinclus leucogaster*
Passeriformes	Timaliidae	Arrowmarked babbler	*Turdoides jardineii*
Passeriformes	Timaliidae	Pied babbler	*Turdoides bicolor*
Passeriformes	Timaliidae	Titbabbler	*Macronous bornensis*
Passeriformes	Turdidae	Groundscrapper thrush	*(Psophocichla)Turdus litsitsirupa*
Psittaciformes	Psittacidae	Meyer's parrot	*Poicephalus meyeri*

Appendix B

Table 2: Relative abundances of bird species around Main Camp.

Vegetation type	Bird species common name	Abundance	Total
Acacia shrubland/ticket	Arrowmarked babbler	4	**52**
	Blue waxbill	2	
	Cape glossy starling	1	
	Barn swallow	3	
	Forktailed drongo	1	
	Grey lourie	2	
	Groundscrapper thrush	1	
	Laughing dove	6	
	Masked weaver	1	
	African Palm-swift	5	
	Redheaded weaver	2	
	Titbabbler	2	
	White helmetshrike	7	
	Whitebrowed sparrow-weaver	7	
	Whitecrowned shrike	4	
	Yellowbilled kite	4	
Baikiaea open woodland	Forktailed drongo	2	**25**
	Grey hornbill	2	
	Helmeted guinea fowl	4	
	Laughing dove	3	
	Meyer's parrot	6	
	Tropical boubou	1	

	White helmetshrike	4	
	Whitecrowned shrike	2	
	Yellowbilled hornbill	1	
	Bateleur	1	
	Blackeyed bulbul	3	
	Forktailed drongo	1	
	Laughing dove	7	
	Meyer's parrots	5	
	Neddicky	1	
Dichrostachys shrubland/thicket	African Palm-swift	2	**40**
	Redbilled francolin	4	
	Titbabbler	2	
	Whitebacked vulture	7	
	Whitebrowed sparrow-weaver	2	
	Yellowbilled hornbill	2	
	Yellowbilled kite	3	
	Blackcheeked waxbill	12	
Grassland	Blacksmith plover	2	**132**
	Blue waxbill	15	
	Cape turtle dove	6	
	Goldenbreasted bunting	8	
	Greater blue-eared glossy starling	3	
	Grey lourie	4	

	Greyheaded sparrow	4	
	Helmeted guinea fowl	23	
	Laughing dove	9	
	Pied babbler	2	
	Pied crow	2	
	Plumcoloured starling	3	
	Redbilled francolin	6	
	Redbilled woodhoopoe	1	
	Redheaded weaver	1	
	Violeteared waxbill	2	
	Whitebrowed sparrow-weaver	23	
	Yellowbilled hornbill	4	
	Yellowbilled kite	2	
	Blackeyed bulbul	1	
	Bradfield's hornbill	1	
Mixed open woodland	Cape turtle dove	1	**17**
	Emerald-spotted dove	1	
	Laughing dove	2	
	Longtailed shrike	3	
	Neddicky	4	
	Tropical boubou	1	
	Whitecrowned shrike	2	
	Yellowbilled kite	1	

Terminalia shrubland	Bateleur	1	**45**
	Blue waxbill	4	
	Cape turtle dove	2	
	Forktailed drongo	3	
	Greater blue-eared glossy starling	2	
	Laughing dove	2	
	Lilacbreasted roller	2	
	Longtailed shrike	9	
	Neddicky	1	
	Whitebrowed sparrow-weaver	16	
	Yellowbilled hornbill	2	
	Yellowbilled kite	1	