EFFECTS OF HABITAT STRUCTURE AND ALTITUDINAL GRADIENTS ON AVIAN SPECIES DIVERSITY AT KURRA FALLS FOREST, NIGERIA

TURSHAK, L.G.,[1] MWANSAT, G.S.[2]* and MANU, S.A.[2]

[1]Department of Science Laboratory Technology, University of Jos, Nigeria

[2]Department of Zoology, University of Jos, PMB 2084, Nigeria

*Corresponding author: *gmwansat@yahoo.com*

Abstract

All bird species are restricted to varying degrees in the range of habitats they occupy. They share at least a portion of their habitat ranges, but between habitats in a local or regional landscape mosaic, some species are replaced by others as the habitat-type or structure changes. This study was carried out at Kurra Falls Forest. The forest is a typical savanna woodlands interspersed with gallery forests, patches of grasslands, and rocky outcrops. The forest is also characterised by altitudinal gradients with elevations. Using line transect methods, the effect of habitat structure and altitudinal gradients on bird species diversity at Kurra Falls Forest were studied. A total of 175 bird species were recorded, two of which are among the four endemic birds to Nigeria. Tree height, tree number, and canopy cover together had a significant effect on bird species diversity. Bird species diversity increased with increase in tree height. A significant decline in bird species diversity with increased number of trees and canopy cover was noted. This result probably suggests an accumulation of forest edge species and generalist species in the less forested habitat. Few forest species inhabited the forest interior where high number of trees and low visible sky can be found. It is also possible that the dominant species of the forest interior might have out compete the subordinate forest interior species. In addition, species diversity did not significantly vary with altitude.

Keywords: birds, diversity, habitat structure, altitude.

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Introduction

Habitat, including the availability of shelter and food, determines the density of species, and therefore serves the basis for the conservation of several species (Martin, 1987). The tropical forest is the most bio-diversed biome in the world, it is estimated that for every temperate bird, there are approximately two tropical counterparts (Begon *et al,* 2001). Even among the comparatively well-studied birds and mammals, many tropical species have not received the careful attention needed for fully certified extinction. Of the 902 threatened birds that use forests, 93% occur entirely in the tropics (BirdLife International, 2000). In the same manner, tropical forests contain the highest number of endemic bird areas, and are home to the highest range-restricted bird species in the world (Fahrig, 2003; Stattersfield *et al.,* 1998). Like the world's other tropical and sub-tropical regions, sub-Saharan Africa has a high species diversity (over 2,300 bird species, which constitute about 20% of the world's total), a high proportion (408 bird species) of which are endemic to the continent (Stattersfield *et al,* 1998; BirdLife International 2000; Brooks *et al,* 2001).

Although, a lot of information abound on bio-diversity, our knowledge still remains highly incomplete and biased (Groombridge, 1992; UNEP, 1995). Most information is available for terrestrial temperate regions with far less data from other parts of the world, particularly from tropical Africa and other tropical regions of the world. (Stattersfield *et al,* 1998). Considerable attention has been directed towards bird population, sparked by concern over reported declines of species on a global scale (Robbins *et al,* 1989). Much of this attention is focussed on bird-habitat-relationships, more so with the increasing evidence (Balmford *et al,* 2001) that areas of outstanding conservation importance may coincide

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with areas of dense human population settlement or impact, although Hurlbert (2004) argued that human demands on bio-diversed areas need not be because species richness and agricultural productivity show opposing relationships with primary productivity. Therefore, the consequences of centres of species richness being associated with human settlement and impact calls for priority-setting studies aimed at identifying the near-minimum set of areas capable of representing all species (Balmford *et al,* 2001).

An important aspect of any avian census is measurement of habitat variables, and many studies have confirmed that the more complex the structure or composition of vegetation, the more likely it is that the habitat will contain more bird species (higher richness) or higher abundance (MacArthur and MacArthur, 1961; Pearson and Ralph, 1978; Cody, 1983; Ralph, 2003; Hurlbert, 2004). It is also known that areas with varied topography and climatic conditions support more species than uniform ones (Stattersfield *et al,* 1998). Pioneer studies have shown that, for terrestrial communities, the number and diversity of bird species are positively correlated with some vegetation variables (MacArthur, 1964; Karr and Roth, 1971). This result is probably biased by other ecological parameters such as the choice of a relatively undisturbed forest site as the study-site (Primack, 2006).

Studies of avian habitat use have strongly influenced both habitat management programmes and ecological theory. Avian habitat selection is essentially related to attributes of habitats that are selected for measurement in field studies and therefore a wise selection of variables is important (Rice *et al,* 1984).

In mountainous areas, species that overlap geographically may have different distribution along altitudinal gradients. For instance, in the Paramos of Venezuela where several species occur over broad altitudinal spans, some species are found only at low elevations while others only occur at high elevations (Wiens, 1997). Similarly, for narrowly distributed species, species richness is better predicted by altitudinal range, population density and altitudinal range have been shown to be positively correlated (Balmford *et al,* 2001). Although species occupancy may vary along altitudinal gradients, there are no sudden increases in the rate of species turnover at certain major habitat or community changes (Vuilleumier and Ewert, 1978).

Ecologically similar species commonly segregate according to habitat, especially among congeners (Cody, 1985). One example being habitat segregation in two species of Wrens, *Citothorus platensis* and *C. meridae. C. meridae* is a specie restricted to elevation of more than 3,000 m above sea level (asl.), whereas *C. platensis* is found only below 1,700 m asl. (Wiens, 1997). At another location, where *C.meridae* is absent, a different sub-species of *C. platensis* ranges from 2,200 to 3,275 m asl.

This study aimed to determine the effect of habitat structure and altitudinal gradient on avian species' diversity, and to compare species diversity between elevations.

Materials and methods

Study-area

The study was carried out at Kurra Falls Forest, 70 km south-west of Jos, Nigeria. It is located at 09°23′N, 08°42′E. The forest covers a total area of about 10 km square (Okoro pers. com.). The forest is a typical savanna woodland, interspersed with gallery forests, patches of grasslands, and rocky outcrops. The forest is also characterised by altitudinal gradients with elevations ranging from about 600 to 1,414 metres above sea level. The area contains some of the best remaining areas of natural Jos Plateau vegetation as well as some endemic and threatened bird species to the Jos Plateau and Africa. The Kurra Falls Forest is habitat to two of Nigeria's four endemic bird species, the Rock Firefinch *Lagonosticta sanguinodorsalis* and its brood parasite, Jos Plateau Indigobird *Vidua marye*.

Some common tree species in the forest include *Parkia biglobosa, Acacia albida, Khaya senegalensis, Vitex doniana, Ficus spp, Lophira lanceolata, Mangifera indica* and *Daniella oliver*. The forest is bordered by few villages, namely Jekko, Oshono, Aphalang, and Gashish. The Kurra Falls community and the National Electricity Supply Corporation (NESCO), a private electricity supply company, are the major stakeholders concerned with the management of the forest. An international tourism centre owned by the Federal Government of Nigeria is located in part of the forest, attracting both local and international tourists.

Bird survey methods

Line transects (Bibby *et al,* 2000) were used to register avian species composition of the entire Kurra Falls Forest at different elevations. Twenty 1,000 m transects were placed at random at different elevations. Each transect was visited twice. This means that an overall total of forty visits were made, and a total length of 20, 000 m was surveyed in the entire study-area.

During each visit, transects were walked slowly along predetermined routes (already existing forest trails, tracts, and paths), listening, looking for and recording bird species. The transects were divided into sections of 200 m, and count information was recorded separately for each section of the transects. Altitude readings were taken at each 100 m section of the transects with the help of Global Positioning System (GPS).

Surveys were carried out during early mornings, between 06:30 and 10:00 hours, and in the evenings, between 16:00 and 18:00 hours. The start and end time for each transect as well as the start and end time for each 200 m section was recorded. All birds observed or heard, including those in flight were recorded. A pair of 8x32 binoculars was used to confirm identification of birds located by eye. Birds observed but not recorded on transects were noted as present in the area and were not included in statistical analyses. Mammals sighted were also recorded.

Vegetation measurements

Vegetation variables were measured within each 200 m section of each transects. Within each 200 m section of each transect, a 10x10 m quadrat was chosen at random and the following vegetation variables were measured:

1. Number of trees (trees with >10 cm diameter trunk above 1 m in height; Manu 2002).
2. Number of shrubs.
3. Height of trees (estimated by eye).
4. Number of bushes.

Also, within the 10 x 10 quadrat, a 2 x 2 quadrat was taken (only once), and the following vegetation parameters were measured:

1. Percentage canopy cover (to the nearest 5%), estimated by eye (Jones *et al.,* 1996).
2. Percentage litter cover (to the nearest 5%), estimated by eye (Manu, 2002).
3. Percentage ground cover (to the nearest 5%), estimated by eye (Manu, 2002).
4. Number of saplings (trees with trunks less than 1cm in circumference and small tree trunks with 1-10 cm in circumference; Manu, 2002).
   The percentage canopy cover was estimated by viewing the sky through the canopy from the wrong side of a pair of binoculars.

Statistical analyses

Excel and SPSS (SPSS 2001 506 /id) software packages were used for statistical analyses. The data were tested for normality (One-sample Kolmogrorov Test). Bird species diversity was calculated using Shannon-Weiner diversity index (Begon *et al,* 2001).

Regression analysis with bird species' diversity as dependent variables were used to determine whether or not species' diversity was dependent on vegetation parameters. Correlated vegetation variables with low *p*-values were eliminated in the model one after the other until a significant *p*-value is obtained. Regression analysis and an independent sample *T*-test were carried out to determine the effect of altitude on species diversity. Natural logarithmic transformation for axes with slightly positive or negative relationships were carried out for purpose of clarity (Fowler and Cohen 1995).

Results

A total of 175 bird species of 54 families were recorded during this study. One hundred and sixty five of 175(94%) bird species were recorded on transects, while 10 of 175(6%) were recorded outside the transects.

One sample, Kolmogrorov Test, showed that except for number of shrubs, all variables were normally distributed: species diversity (z=0.685, n=20, p=0.737); tree height (z=0.519, n=20, p=0.950); tree number (z=0.777, n=20, p=0.581); percentage ground cover (z=0.461, n=20, p=0.984); percentage canopy cover (z=1.001, n=20, p=0.269); number of saplings (z=0.558, n=20, p=0.915); number of bushes (z=0.718, n=20, p=0.680); percentage litter cover (z=0.703, n=20, p=0.707); number of shrubs (z=0.1.423, n=20, p=0.035).

Correlation between vegetation variables

There was a very strong positive correlation between some vegetation variables: tree height and tree number (r=0.652, n=20, p=0.002); tree height and percentage canopy cover (r=0.785, n=20, p<0.001); tree height and percentage litter cover (r=0.630, n=20, p=0.003); tree number and percentage canopy cover (r=0.921, n=20, p<0.001); tree number and bushes (r=0.542, n=20, p=0.014); and percentage canopy cover and percentage litter cover (r=0.581, n=20, p=0.007).

Effects of vegetation variables on bird species diversity

Tree height, number of trees, and percentage canopy cover showed a significant relationship with species diversity (Table 1; Figures 1, 2 and 3). Species diversity increased with an increase in tree height (Figure 1) but decreased with increase in number of trees (Figure 2), and percentage canopy cover (Figure 3).

Effects of altitude on bird species diversity

Altitude did not significantly affect bird species diversity (Table 2; Figures 4 and 5).

Bird species' diversity did not vary significantly at 1,200 and 1,400 m asl. (Independent sample *t*-test: t=-0.221, f=0.888, df=18, p=0.827). 1,200 m asl. represents categories with altitudinal gradients of less than or equal to 1,200 m asl. while 1,400 m asl. represents categories with altitudinal gradients of greater than 1,200 m asl.).

Table 1: Regression analysis showing the effect of tree height, number of trees, and percentage canopy cover on species diversity.
Dependent variable: Species diversity.

Model	Sum of squares	*df*	*f*	*p*-value
Regression	0.478	3	3.425	0.043
Residual	0.745	16		
Total	1.223	19		

Adjusted r^2: 0.277
Predictor: Tree height, number of trees, and percentage canopy cover.

Table 2: Regression analysis showing the effect of altitude on bird species diversity.
Dependent variable: Species diversity.

Model	Sum of squares	*df*	*f*	*p*-value
Regression	0.003	3	0.042	0.841
Residual	1.220	18		
Total	1.223	19		

Adjusted r^2: 0.053.
Predictor: Altitude.

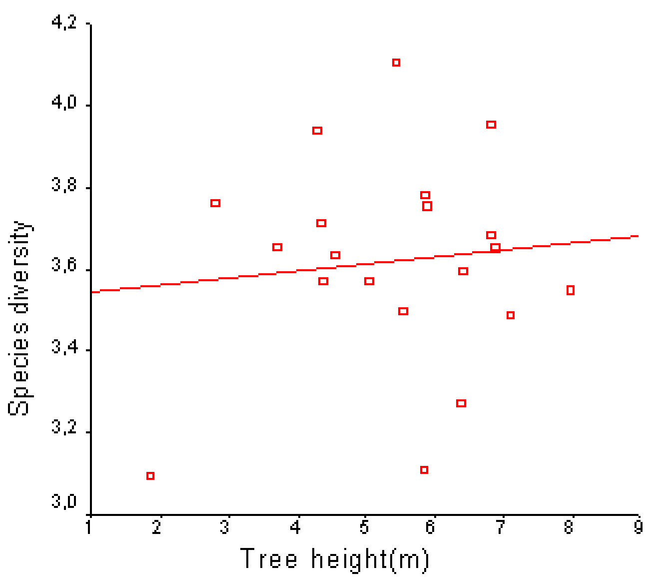

Figure 1: Effect of tree height on bird species diversity.

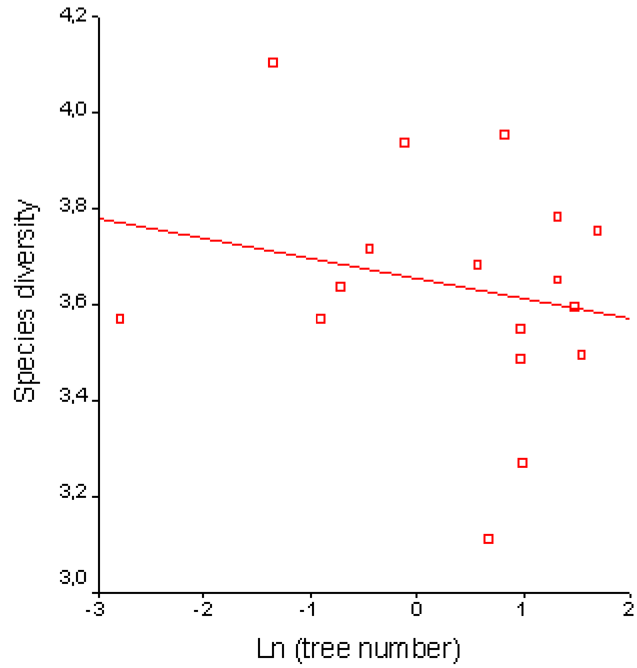

Figure 2: Effect of number of trees on species diversity.

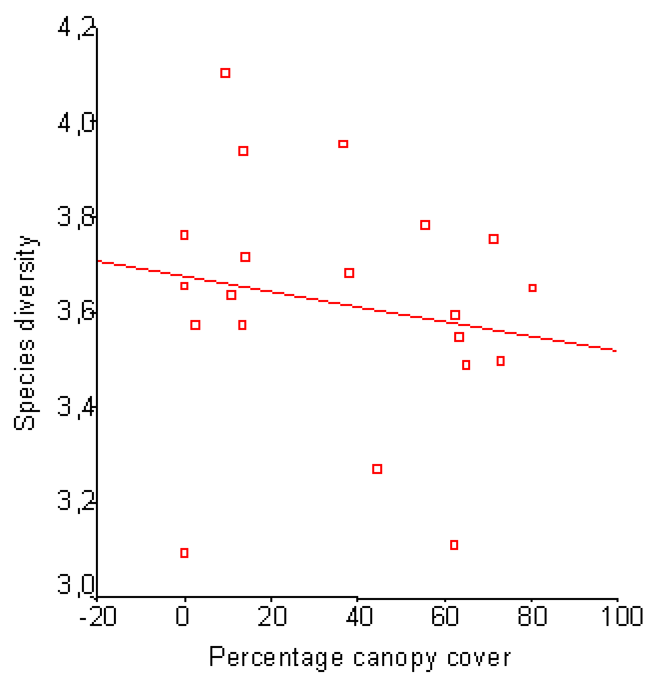

Figure 3: Effect of percentage canopy cover on species diversity.

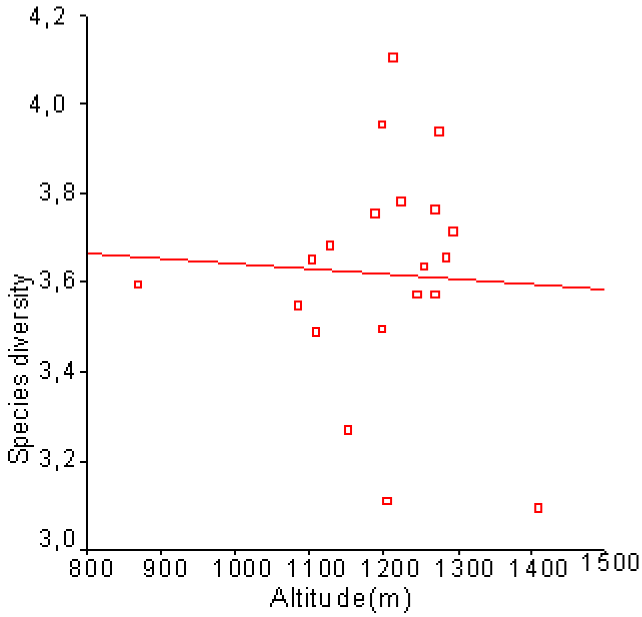

Figure 4: Effect of altitude on bird species diversity.

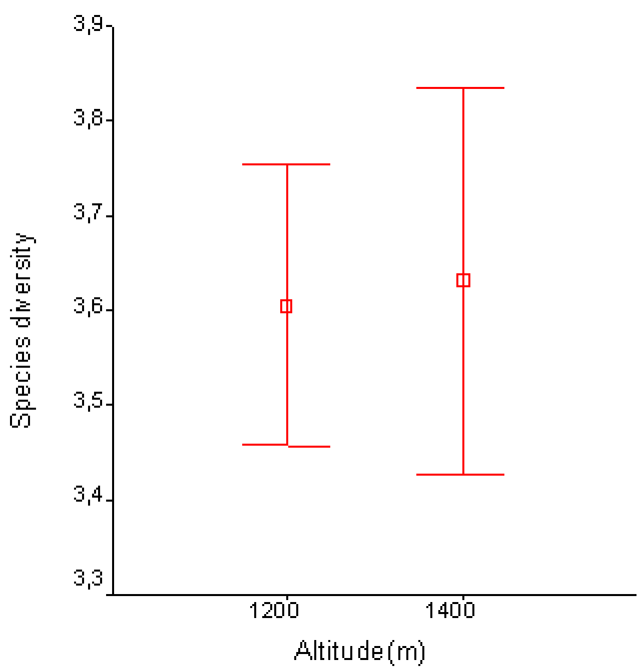

Figure 5: Effect of altitude on bird species diversity at two different elevations.

Discussion

Explaining species diversity in a given habitat is a basic ecological challenge and a wide variety of factors have been shown to explain species diversity of an area among different taxa and in various regions (Hurlbert, 2004). Therefore, understanding the factors that regulate the diversity of biological communities is fundamental in contemporary ecology.

As productivity varies between habitat types, so is species diversity and number, suggesting an important effect of habitat structure (Hurlbert, 2004). Species diversity did not vary when all vegetation variables were included in the model. However, species diversity varied when only tree height, tree number and percentage canopy cover were left together in the model. Again, species diversity did not vary with further removal of any of the three variables independently. This suggests that tree height, tree number, and percentage canopy cover are probably the most important factors determining the species diversity. Although other factors such as grazing and browsing, tree species, fruit and flowering plants, closest con-specific, diversity of foliage height, closest water body, closest tree, and weather parameters were not considered in this study, they may be important in explaining species diversity of the study-area. The study is limited in time to include all these parameters and therefore beyond the scope of this study.

Species diversity increased with increase in tree height. This means that the taller the trees the higher the species diversity. This was not unexpected because tree height has been shown to increase avian richness (Wilson *et al,* 1994). However, this may also be possible because of new foraging guilds that prefer an increase in tree height (Wilson *et al,* 1994). A number of bird foraging guilds were encountered during this study. Tall trees are likely to be large in size and because of this, they may contain a large amount of fruits and flowers. The fruits and flowers may in turn attract more bird species. In addition, flowers are known to attract a diversity of insects, this means a continuous supply of food for insectivorous birds (Manu, 2002). This probably supports many observations made high up in the trees. Many fruigivorous birds especially of the family Columbidae and Musophagidae, and the family Nectariniidae were sighted in taller trees than shorter trees.

There was a significant decline in bird species diversity with increased number of trees and percentage canopy cover. Contrary to this result, many studies have shown that some vegetation variables including tree density and canopy cover are good predictors of higher species diversity (Karr and Roth, 1971; Villard *et al,* 1991).

It is expected that as one advanced into the forest interior, more forest species should be recorded but this is not the case in this study. The forest edge, which is a transition between the forest interior and the non-forest interior, is known to create a diversity of habitats often occupied by forest edge species and generalist species. The results probably suggest an accumulation of forest edge species and generalist species in the less forested habitat with few forest specialist species inhabiting the forest interior where high number of trees and low visible sky can be found.

Furthermore, it has been shown that management of habitats with high species diversity with the assumption that the habitat is of high quality could be misleading. The results may probably not be far from the fact that dominant species in the forest interior (considered as the best habitat) may out-compete the subordinate species, thus precluding them to the forest edge or areas that are moderately degraded. This is in agreement with the reports of Van Horne (1983), Cresswell (1994) and Pomeroy and Dranzoa (1997) where moderate degradation led to higher species diversity.

Grazing and browsing pressures by livestock is detrimental to the ecosystem. It has been shown to remove a significant amount of the primary production of a natural system, prevent regeneration, reduce the structural diversity of habitats and plant species diversity with consequent reduction in availability of food and other essential requirements for birds (Collar and Stuart, 1985). This explains why the diversity and density of grasshoppers in Kalahari decline with increased grazing (Emlen *et al,* 1986). Similarly, grazing is a major disturbance in the Kurra Falls Forest (Pers. Obs.) which might also affect species diversity with detrimental effect on the forest specialist species probably because of their narrow adaptability and low dispersal rate.

Altitude had no significant effect on species diversity. This is contrary to studies that have shown that species diversity vary across altitudinal gradients (Vuilleumier and Ewert, 1978; Cody, 1985; Wiens, 1997; Balmford *et al,* 2001). However, Fjeldsa (1999) confirmed fairly constant bird species' richness over longer stretches along the eastern slope of Andes. Emlen *et al* (1986) reported similar pattern of homogeneous diversity trends of forest bird species across altitude of the deciduous forest of central North America. That is, they found no change in the overall species diversity across spans of altitudes.

These results, perhaps indicate that the altitudinal gradients in the study-area are not sufficiently heterogeneous to cause any variations in species diversity across spans of altitudes. This may make it unnecessary for bird species to segregate.

On the other hand, species may not overlap geographically and may not be narrowly distributed in the study-area (Balmford *et al* 2001). Species of the study-area may become generally adapted to the different habitat types such that variability in species richness is not significant (Manu, 2002). It could also be attributed to the number of generalist species as well as the forest visitors compensating for the difference that is expected across different altitudinal gradients.

Since an increase in habitat complexity facilitates the division of resources among different species (Hurlbert, 2004), and is also positively related to productivity, protection of the area will support and increase species diversity especially forest specialist species (Hurlbert, 2004) which are often invaded by generalist species when habitat is degraded, and these generalist species are typically widespread species of low conservation value (Pomeroy and Dranzoa, 1997).

It is not an exaggeration to say that Kurra Falls Forest is rich in bird species, considering the number of different species recorded in the area within such a short study time frame, and during which the Palaearctic migrants have migrated north. There are probably more species yet undiscovered and a more detailed work in the future is recommended, as this will increase our knowledge of the bird species present in the study-area, thus, might raise its conservation value.

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