SEASONAL CHARACTERISTICS OF AVIFAUNA IN NAIROBI METROPOLITAN LANDSCAPE

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Abstract
The landscape structure of Nairobi city is experiencing rapid transformation as once wild and pristine spaces are converted to anthropocentric uses. In order to understand how the changing urban structure affects urban habitats, the seasonal variation in occurrence and composition of avifauna within the metropolitan landscape of Nairobi city was investigated. The relationship between bird occurrence and spatial characteristics of surrounding urban matrix was quantified. Bird survey was conducted for two consecutive seasons in the wet and dry seasons. Landscape features within the study sites were derived from remote sensing image and used to account for bird distribution. Birds were classified according to their biological families and their naturally preferred habitat. Ordination analysis was done to find underlying correlation between species occurrence and site characteristics. About 50 different families of birds were observed between the two seasons with a total of 307 different species. Families of finches, raptors, warblers and weavers, sunbirds and thrushes were the most common. Bush and scrub habitats were most naturally preferred habitat at a rate of about 31%, followed by grassland species at about 20% and forest species at about 16% rate. Unique species recorded between the seasons constituted 22% and 17% of total observed for the dry and wet seasons respectively. The first axis of principle component analysis revealed a gradient of change from forested and woody sites to savannah vegetated sites while the second axis was change from sites with agriculture patches to sites with urban patches. The occurrence and distribution of the species was highly dependant on site use and management. As the city continues to expand, landscape and urban planners must promote urban designs that will integrate habitat conservation for healthy urban space development.

Key words: Urban landscape, site characteristics, species richness, habitat type, management

1.0 Introduction

Remnant habitats in urban areas are important in providing critical ecosystem services such as storm water control, habitat for wildlife and mitigating effects of urban heat and air pollution. Most urban landscapes especially in developing countries are being transformed to a less natural state at an alarming rate creating markedly different conditions for urban wildlife and avifauna. By preserving remnants of fragmented landscapes, valuable habitats and wildlife can be preserved as proved by various studies such as that of Fiona and Ralph (2005) and John et.al., (2005). Among other vertebrates, birds provide a useful mechanism to explore urban effects and responses to different urban designs (Bibby et al., 1998). Studies have shown that the avifauna community restructures its distribution pattern and responds by either adapting to or avoiding the resultant fragments according to the landscape scale and their inherent behavioral traits (Croci, 2008). Despite tropical habitats being considered to carry high avian diversity, there is paucity of information available and thus local knowledge and study is needed to enhance management policies that mitigate disturbance and urbanization impacts on habitats and bird communities (Chace and Walsh, 2006). Information on urban processes and their impacts for the city of Nairobi need to be availed and applied within a context of urban ecological planning system to meet the goals of sustainable cities and guarantee quality urban environment and contributing to localizing the agenda 21. The specific objectives of this study were to determine bird species composition in the urban landscape of Nairobi, Kenya, to validate whether significant differences in species composition occur between sites and seasons.

2.0 Materials and Methods

2.1 Study Area and Study Approach

The study site covered the area within latitudes $1^{o}10'$ and $1^{o}25'S$ and longitudes $37^{o}00'$and $36^{o}34'E$, (Figure 1). Elevation varies from about 1450 meters on the south eastern side to a high of about 2200 m in the north western side. Mean monthly rainfall varies from a low of 15 mm to a high of 212 mm. There are two temperature regimes highest in January at about $25^{o}C$ during the day and $12^{o}C$ at night and lowest in July at about $21^{o}C$ during the day and $11^{o}C$ at night. The total land area of the city and surrounding environs included in the study was about $1575km^2$. The area has experienced rapid land cover / land use changes due to population pressure, urban expansion, and various economic activities especially in the past two decades.

2.1.1 Avifauna

Using existing maps of Nairobi, sampling sites were selected through a systematic sampling method of the entire study area (Figure 1). A total of 20 sites, measuring about 4 km^2 each and representing different land use / land cover types of the landscape were surveyed for presence of birds. Bird identification and counting was done using point count technique as described by (Bibby *et. al*., 1998). Bird sampling was done after sunrise to capture the period when bird activity was high. All birds observed or heard within 50 m radius of the census station were recorded. Birds' censuses were conducted in the wet cold season of July, 2007, dry season of February, 2008 and repeated in 2009.

2.1.2 Environmental Data

A satellite image was used to develop a map of land cover types representative of the study area. In this case, Land sat TM image of year 2000 was used. A geographical positioning system (GPS) was used to obtain co-ordinates for training sites in order to apply a pixel-based supervised classification of the Land sat image using ERDAS Imagine software. The land cover classes applied in the study were based on the AFRICOVER land cover classification system. The descriptions of the land cover types were modified to suit the characteristics and land cover diversity of the study area. Overall image classification resulted into seven thematic land cover classes namely; water, agriculture, urban, forest and woods, savannah vegetation, riverine and barren surface. Land cover types constituted the environmental data for the sample sites that was derived through feature extraction of the classified satellite image. A centrally positioned point of each sample site relating to the bird census points, was placed on the classified image of the study area and was expanded to radius of 500 m using buffer command on ArcGIS 9.0 (ESRI) to give an output feature class image of each sample site. The area values for each of the land cover variable was computed and expressed as proportion of the total area of the 500 m radius polygon.

2.2 Data Analysis

The principle component analysis method was applied to identify environmental variables that best explained the variation in sample sites and hence influence pattern of bird distribution. Cluster analysis was then conducted in order to group similar sites on the PCA ordination plane. Birds were classified according to their biological families as presented by various illustrated checklists such as by Zimmerman *et al*., 1999, Ber Van Perlo, 1995 and Stevenson, 2002. The total abundance of all bird species observed in a given site and the number of different species observed was computed. Abundance was given as total count per site and species richness as the total number of different species observed. Bird species diversity for each censused site was computed using the Shannon-Weiver (1949) information theory formula. In order to determine whether or not the values for above variables differed between seasons and groups the Kruskal-Wallis one-way ANOVA test was applied. It tests the null hypothesis that multiple independent samples come from the same population using the mean ranks of the variables. Further, birds were categorized according to their naturally preferred habitat as described by existing check lists of the birds of Nairobi such as by Harvey, 1997 and Britton, 1980. Only the predominant preferred habitat was considered in this categorization. In this case seven categories were identified. Occurrence of birds with respect to status of residence was also used to account on birds' distribution. The predominant status that were considered were; resident, for species that can be seen in any month and probably breeds in or near Nairobi area; northern migrant, for species that migrate from the north such as Europe and western Asia as winter visitor or passage migrant (palaearctic); and African visitor for migrants from other parts of Africa (afrotropical). The Mann-Whitney U test was applied to test for significant differences between the cluster groups and between seasons

3.0 Results and Discussions

3.1 Site Characteristics and Bird Occurrence

Principle component analysis of the sites showed that the first three axes accounted for over 80% of the total variation (Table 1). The first axis represented a change from savannah vegetation cover to sites comprised of water patches. The second component showed a change from sites comprised of forest and wood cover type to sites comprised of agricultural, barren and urban patches (Figure 2). Cluster analysis of the sites conducted based on hierarchical cluster analysis resulted into four cluster groups. The cluster group membership and the mean land cover proportion of each land cover type is shown in Table 2. The sites were grouped as follows, cluster I sites, 1, 2, 4, 5, 6, 11, 12, 13 and 20; cluster II sites, 3, 9, 10 and 19; cluster III sites, 7, 8, 14, 15 and 16 and cluster IV sites 17 and 18. Cluster I is distinguished by low proportion of all other land cover types except savannah vegetation which was dominant at above 94%. Cluster II sites differ from other clusters by lack of water type of land cover and highest proportion of urban type of land cover. Cluster III features the highest proportion of forest and woods while cluster IV is distinguished by having the highest proportion of agriculture type of land cover.

In total, 290 birds were observed in the wet and 307 in the dry seasons, respectively. They represented about 55 different bird families. The families of raptors and warblers were markedly more common in the dry than the wet season although two family groups of avocets and stilts, and Gulls and Terns were absent in the dry season while all the family groups were represented in the wet season. Overall, bird abundance, species richness and diversity were 1023, 82 and 3.5 for the wet season and 885, 88 and 3.7 for the dry season, respectively. According to Mann-Whitney U test for difference between seasons, abundance was significantly higher in the wet than in the dry season. However, there was significantly high species richness and diversity in the dry than in the wet season. This could be attributed to the appearance of palearctic migrant species which appear this time of the year when winter sets in the northern hemisphere prompting certain bird species to migrate south towards the equator.

With cluster grouping, bird abundance was high in the wet season than in the dry season in all clusters except cluster IV with the highest land cover for agriculture (Table 2). Clusters with high proportion of savannah vegetation recorded high abundance of birds. In contrast, species richness was highest in the dry season in all clusters as compared to the wet season. Similarly, the highest species diversity occurred in the dry season especially in the clusters dominated with forest and agriculture. Kruskal-Wallis H test for differences between clusters was conducted for the three variables of bird abundance, species richness, and species diversity, by type of cluster group for the wet and dry seasons. The asymptotic significance estimates the probability of obtaining a chi-square statistic greater than or equal to the one displayed, if there truly are no differences between the group

ranks. Except for species richness for the dry season, the asymptotic significance was much lower than the calculated chi-square statistic in all cases implying that the ratings for abundance, species richness and species diversity, differed by cluster irrespective of the season.

Seasonal species-habitat distribution pattern

With respect to status of movement, more than 80% and 78% of the birds were resident birds in the wet and dry season, respectively. The most significant difference between seasons was in palaearctic migrant species, the highest rate being recorded in the dry than in the wet season (Table 3). Clusters I and II recorded the highest percentage of migrant species while clusters III and IV had the lowest rate of palaearctic migrant species in the wet season. This indicates that many migrant birds do take refuge in sites within Nairobi landscape either on their migratory route or as feeding points. The commonest palaearctic migrant species were Barn swallow, pied wagtail and Common sandpiper in the wet season and Yellow wagtail, Willow warbler and Isabelline wheatear in the dry season.

On the naturally preferred habitat, species related to bush habitat were most common at rate of 30.8% and 32.6% of all recorded species for the wet and dry seasons, respectively (Figure 3). The rate of occurrence was highest in cluster I, followed by cluster II, which matched the land cover composition of sites in these clusters marked by high savannah type of land cover which comprises dry bushed grassland with acacia shrubs, riverside shrubs, garden shrubs and hedges (Table 3). Majority of the sites in cluster I are located on the southern and south eastern parts of Nairobi that have natural savannah grasslands and acacia shrubs especially within the Nairobi national park. Three of the sites in cluster II are in urban core area and are rapidly urbanizing and comprise of ornamental garden shrubs and hedges with scattered patches of the original savannah type of vegetation. Shrub species with high frequency included, Northern pied babbler, Rattling cisticola, Rufous sparrow, Singing cisticola and White-browed sparrow-weaver in addition to Diederic cuckoo and Yellow-rumped seedeater that were observed only in the dry season. Grassland birds were the next most common with no significant differences between the seasons (Fig. 3). Clusters I and II recorded the highest rate, while cluster IV had the lowest rate. Frequent grassland species recorded included, Black-headed heron, Cattle egret, Grassland pipit, Red-billed quelea and Rufous-naped lark. Species of Pin-tailed whydah, Red-collared widowbird and Yellow wagtail were common in the dry season. Species with natural preference for forest and wooded areas were the third commonest of all recorded birds. Overall, more forest birds were recorded in the wet than in the dry season. Cluster III recorded the highest rate of forest related birds and unlike in the other clusters, the proportion recorded was higher in the wet than in the dry season (Table 3). Forest related species with highest frequency included African paradise flycatcher, Black saw-wing, Chin-spot batis, Little sparrowhawk, Olive thrush and Red-chested cuckoo. Species associated with wetlands such as swamps, streams, dams and sewerage ponds were most frequent among cluster I sites followed by sites of cluster III. They included, Common waxbill, Dark-capped yellow warbler, Grey heron, Hamerkop, Long-tailed cormorant and Malachite kingfisher. Aerial species that are usually seen in flight where they also obtain most of their food recorded high rates among sites of cluster I, followed by cluster II and then cluster III. The predominant aerial species were, Lesser striped swallow, Plain martin, Red-rumped swallow, Rock martin and Barn swallow. Aerial species such as Eurasian bee-eater. and Sand martin were recorded only in the dry season. Species for structures such as those that prefer buildings commonly in urban areas were lowest in proportion overall. Their occurrence was highest in cluster I and cluster II and least in cluster IV, (Table 3) and included House sparrow, Little swift and Speckled pegion. The final habitat category is diverse, for species that occur regularly and are frequently observed. All clusters had equally high proportion of diverse species such as Common fiscal, Red-billed fire finch, Baglafecht weaver, Common bulbul, pied crow, Sacred ibis and Black kite.

Evaluation for significant differences in habitat's species distribution between the two seasons along the different clusters was done using the Mann-Whitney test. Low difference between seasons was observed when sites were evaluated together without clustering. However the difference in site composition was apparent when bird distribution between seasons was analyzed among more similar site clusters. Thus cluster II distinguished by high proportion of urban area and bushed land and cluster IV distinguished by high proportion of agricultural area showed higher significant difference in species composition between the two seasons as compared to clusters I and III. Palearctic species increased in the dry season and most are aerial species, grassland and bush utilizing

species. Thus grassland, bush land and agricultural patches play a significant role of habouring migratory bird species in the dry season.

4.0 Conclusion and Recommendation

The analysis shows that diversity of landscape characteristics influence composition and distribution of avifauna in the study area with marked seasonal differences. Although high species abundance was recorded in the wet than in the dry season, species richness and diversity were higher in the dry than in the wet season. Distribution of resident species was low in sites dominated by agricultural activities. All palaearctic migrant species in sites with agricultural patches occurred only in the dry season showing the selective nature of the birds for these areas possible due to the high availability of grains and presence insect pests. Shannon species diversity was high in the cluster of sites with agriculture and forest patches than in cluster sites with urban and savannah patches especially in the dry season. Thus these sites are important for seasonal birds and high biodiversity. Vegetated sites and riparian sites have been observed in various studies to enhance occurrence of rare bird species in urban areas for example (Koide *et. al*., 2004) and in the urban periphery (Sandstrom *et. al*., 2006). While the abundance of bird species in the human inhabited areas was high, cluster II, variability as shown by species richness was low. Site specific differences influenced the type and level of occurrence of different bird species. Urban planners and managers in Nairobi can enhance seasonal bird diversity by integrating original natural land cover types into open space plans. This will require both local and regional based approach to land use planning informed by landscape metrics of the environment.

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Tables

Table 1: Principle components and eigenvectors of the land cover types

	Principal component		
	1	2	3
Eigen value	3.19	1.36	1.04
Percent of variance	45.63	19.40	14.90
Cumulative variance (%)	45.63	65.02	79.92
Land cover types	Eigenvectors		
Water	-0.417	0.055	-0.277
Agriculture	-0.393	-0.458	-0.134
Urban	0.101	-0.460	0.709
Forest & Woods	-0.359	0.496	0.415
Savannah	0.492	0.021	-0.417
Riverine	-0.347	0.365	-0.054
Barren Land	-0.413	-0.444	-0.232

Table 2: Proportion of the land cover types and species statistic within cluster groups

No. of sites	Cluster I (9)	Cluster II (4)	Cluster III (5)	Cluster IV (2)
Land cover type				
Water	0.07±0.2	0.00±0.00	0.53±0.74	0.83±1.17
Agriculture	0.03±0.09	2.60±3.24	5.57±5.95	*45.88±7.62*
Urban	1.09±2.09	*12.94±18.54*	0.81±0.96	0.42±0.39
Forest and Woods	0.26±0.55	4.46±4.85	*38.90±30.23*	4.35±3.92
Savannah Vegetation	*94.87±3.58*	71.66±11.91	41.23±28.35	29.80±0.23
Riverine	0.42±0.55	1.72±2.44	5.77±7.76	0.04±0.06
Barren Land	3.26±3.24	6.63±2.97	7.20±5.18	18.69±3.09
Species statistic				
abundance				
Wet	1063.1±337.9	1266.3±323.6	830.2±335.1	841.0±91.9
Dry	918.8±414.8	1002.0±225.5	703.2±242.6	953.5±82.7
richness				
Wet	83.0±22.9	84.8±43.4	86.6±11.1	69.0±14.1
Dry	89.1±29.8	92.8±53.1	88.0±10.5	83.0±8.5
diversity				
Wet	3.4±0.4	3.6±0.4	3.6±0.4	3.5±0.1
Dry	3.7±0.4	3.7±0.6	3.8±0.3	3.8±0.1

Table 3: Seasonal difference in level of occurrence of different species by cluster as a function of total recorded per category

Category	Percentage occurrence							
	Cluster I (9)		Cluster II (4)		Cluster III (5)		Cluster IV (2)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Status								
African migrant	73.0	74.3	35.1	54.3	35.1	22.9	13.5	25.7
Palaearctic migrant	75.0	88.0	25.0	84.0	12.5	64.0	0.0	44.0
Resident	82.4	89.7	69.2	74.6	69.2	66.7	36.7	44.1
Habitat	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Aerial	100.0	92.9	60.0	78.6	70.0	71.4	40.0	50.0
Structures	100.0	100.0	100.0	100.0	75.0	80.0	50.0	40.0
Wetland	92.7	97.2	39.0	55.6	53.7	52.8	31.7	33.3
Grasslands	87.8	94.5	61.2	63.6	42.9	47.3	14.3	23.6
Bush	89.0	85.4	69.5	76.4	50.0	52.8	25.6	37.1
Forest	37.3	63.4	54.9	70.7	90.2	80.5	29.4	53.7
Diverse	96.6	100.0	93.1	97.0	93.1	87.9	82.8	81.8

Figures

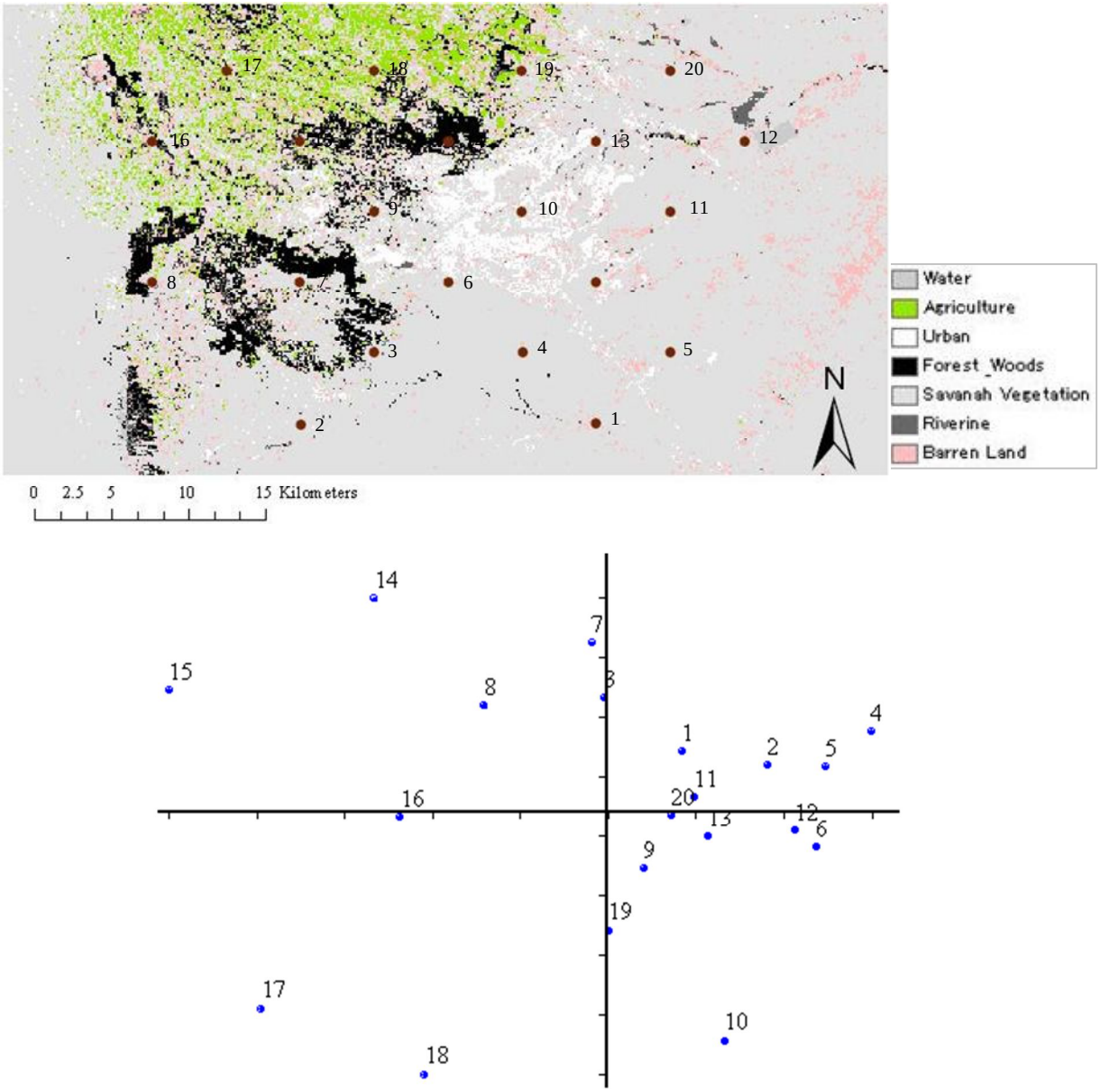

Figure 2: Principal component analysis of sample sites

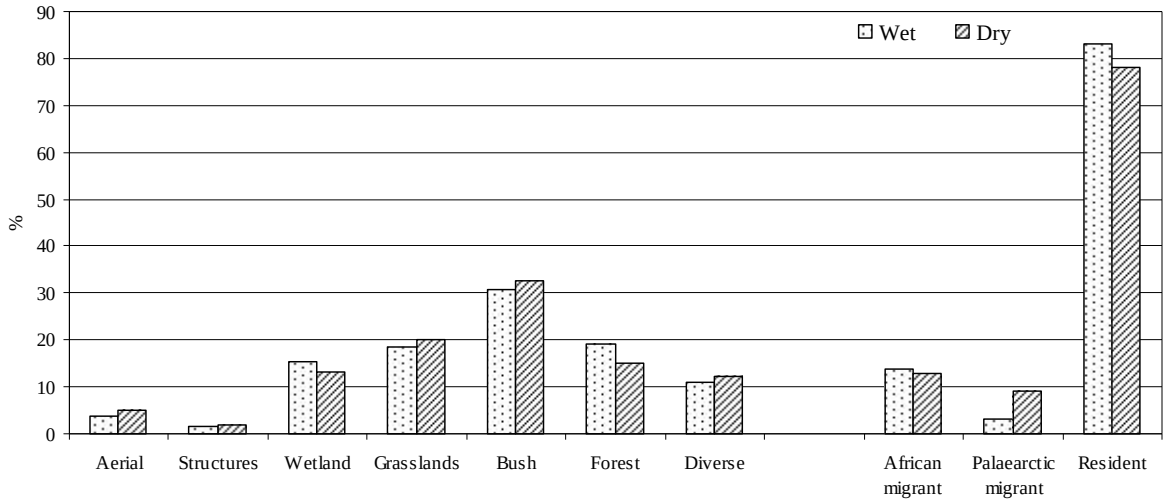

Figure 3: Seasonal variation in occurrence of different bird categories