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Research Paper

Comparative use of artificial structures and natural vegetation by birds in a built-up urban area in Ghana

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ABSTRACT. Our understanding of how birds use human supplementary resources, especially artificial structures and patchy vegetation within urban areas, is limited. Our study compared the use of artificial structures versus natural vegetation by birds in built-up areas in the Cape Coast Metropolitan Assembly (CCMA) in the central region of Ghana. Using point count technique, we recorded bird species and the activities performed as well as the substrates they use in residential and commercial areas within the CCMA. We found that the mean bird abundance that used artificial structures did not differ significantly from those that used natural vegetation. The mean species richness that used artificial structures was found to differ significantly from those that used natural vegetation. The study also found a significant difference in activities performed by bird species and the substrate type used for daily life activities. Across species, birds showed preference for trees, shrubs, and natural vegetation structures for perching, feeding, and singing, whereas artificial structures such as billboards, telecommunication masts, ceilings of buildings, pylons, buildings, opening in street lights, and windows of buildings were preferred for nesting. These results demonstrate that although not a replacement for natural resources, artificial structures, when combined with natural vegetation, could contribute significantly to the survival of urban birds. Conservation practitioners could encourage urban mosaic landscapes of built and green spaces to conserve and restore populations of birds.

Comparaison de l'utilisation de structures artificielles et de la végétation naturelle par les oiseaux dans une zone urbaine au Ghana

RÉSUMÉ. Notre compréhension de l'utilisation par les oiseaux des ressources anthropiques, en particulier les structures artificielles et la végétation éparse dans les zones urbaines, est limitée. La présente étude visait à comparer l'utilisation de structures artificielles et de la végétation naturelle par les oiseaux dans des zones urbaines de la région métropolitaine de Cape Coast (RMCC), dans la région centrale du Ghana. Au moyen de dénombrements par points d'écoute, nous avons relevé les espèces d'oiseaux et leurs activités, ainsi que les substrats qu'ils utilisaient dans les zones résidentielles et commerciales de la RMCC. Nous avons constaté que le nombre moyen d'oiseaux qui utilisaient des structures artificielles ne différait pas significativement du nombre moyen d'oiseaux qui utilisaient la végétation naturelle. La richesse moyenne des espèces qui utilisaient des structures artificielles était significativement différente de celle des espèces qui utilisaient la végétation naturelle. Nous avons également trouvé une différence significative entre les activités des espèces d'oiseaux et le type de substrat utilisé pour les activités quotidiennes. Toutes espèces confondues, les oiseaux ont montré une préférence pour les arbres, les arbustes et les structures végétales naturelles pour s'y percher, s'y nourrir et y chanter, tandis que les structures artificielles telles que les panneaux d'affichage, les mâts de télécommunication, les toits de bâtiments, les pylônes, les bâtiments, les ouvertures de lampadaires et les fenêtres de bâtiments étaient préférés pour y nicher. Ces résultats démontrent que, bien qu'elles ne remplacent pas les ressources naturelles, les structures artificielles, lorsqu'elles sont associées à la végétation naturelle, pourraient contribuer de façon importante à la survie des oiseaux urbains. Les spécialistes dédiés à la conservation et à la restauration de populations d'oiseaux devraient encourager les paysages urbains présentant une mosaïque d'espaces bâtis et d'espaces verts.

Key Words: *artificial structures; natural vegetation; urban birds; urban landscape*

INTRODUCTION

Within the past decades, a remarkable global phenomenon of rapidly increasing human population has resulted in extensive human migration from rural areas to cities (Grimm et al. 2008). This has led to a corresponding unpredictable change of natural ecosystems into widely fragmented regions partly covered by buildings, roads, and infrastructure that has resulted in a substantial increase in the expanse of land within human proximity across the world (Møller 2009). Consequently, urbanization has drastically changed many landscapes; it has increased the density of habitat patches by decreasing average patch size but has also increased the juxtaposition of highly contrasting habitat patches in most urban landscapes (Luck and Wu 2002, Müller et al. 2013). As such, these changes in landscape structure have resulted in the loss of habitat and have disrupted many ecosystem processes in urban areas (Grimm et al. 2008, Buyantuyev and Wu 2009).

Understanding the processes associated with fundamental land use changes has prompted the interest of many urban ecologists (Collins et al. 2021). Many of their concerns have focused on investigating the key habitat factors that are most important for

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the maintenance of biodiversity in urban environments (Castelli et al. 2021). For instance, a recent comparison of biodiversity levels between more than 100 cities around the world revealed that bird and plant species densities differ significantly between cities and are best explained by a city's urban land cover, age of the urban area, and intact urban vegetation cover (Aronson et al. 2014). Few studies have investigated the importance of man-made structures to bird communities in urban landscapes and the implications for ecological restoration in urban ecosystems (Fisk 1978, Mainwaring 2015, Pike et al. 2017, Vogel et al. 2018). For example, studies suggest that urbanization favors resident birds more than it does for migrants (e.g., Lancaster and Rees 1979) and omnivores (Dickman and Doncaster 1987), or species with broad environmental tolerance (Bonier et al. 2007). Other studies revealed that although urbanization favors hole and tree-nesting species, ground nesters may suffer (Møller et al. 2012). Researchers also found that artificial light can act positively on the density of birds and their inter-seasonal stability in urban centers whereas urban infrastructure (buildings, roads, refuse tips) had a positive effect on the inter-seasonal stabilization of the species composition of wintering birds (Ciach and Fröhlich 2017).

This shows that although not a substitute for natural ecosystems, urban areas may harbor important biodiversity (Angold et al. 2006). For instance, studies have shown that urban green spaces had high species richness (Croci et al. 2008, Caula et al. 2010, Sanz and Caula 2015, Jokimaki et al. 2016), high bird abundance (Palomino and Carrascal 2006, Ortega-Álvarez and MacGregor-Fors 2011), and increased chance of the occurrence of endangered species (Mörtberg and Wallentinus 2000, Alvey 2006, Kowarik 2011, Aronson et al. 2014). Gregory and Baillie (1998) reported that significant parts of the total bird population size of some species may occur in urban areas in the world. For example, three of Britain's thrushes (Blackbird, *Turdus merula*, Song Thrush, *Turdus philomelos*, and Mistle Thrush, *Turdus viscivorus*) of the genus Turdus and family Turdidae are largely restricted to built-up areas in eastern England (Mason 2000). Van der Meer et al. (2018) and Downs et al. (2021) also showed the persistence of species such as the Hadada Ibis (*Bostrychia hagedash*), African Woolly-necked Storks (*Ciconia episcopus*), and African Crowned Eagle (*Stephanoaetus coronatus*) in urban KwaZulu-Natal province in South Africa.

In urban landscapes, many species of birds are adapted to utilizing urban resources although others avoid them entirely (Johnston 2001, Chace and Walsh 2006). This may result from the absence of natural vegetation and structures to support their daily life activities. For instance, Balmori (2005) reported that storks are found to use pylons as nesting sites in the absence of large tall trees in urban areas. Anderson and Hohne (2007) also found similar observations for several raptors in South Africa whereas other studies have shown that human supplementary food contributes significantly to the high density of birds in urban ecosystems than in their neighboring natural environment (Galbraith et al. 2015).

Despite all this knowledge and the many studies that highlight the impact of urbanization on biodiversity, as well as the occurrences of birds in greater numbers within urban areas than their nearby natural ecosystems (Sodhi et al. 1999, Shochat et al. 2010), we know very little about how birds use artificial structures (electricity poles, pylons, roofs, buildings, etc.) differently from natural vegetation (including trees, shrubs, grass, etc.) in urban areas. We also know little about how these available resources within urban areas influence the occupancy and persistence of many fauna species including birds in tropical Africa. This knowledge gap restricts our understanding of birds' responses and uses of artificial structures compared to patchy vegetation in urban areas.

We examine the relative importance of artificial structures and natural vegetation to birds in urban areas in Ghana. To achieve this, we first surveyed the number and species of birds using site-level artificial structures and natural vegetation resources within Cape Coast Metropolitan Assembly (CCMA; Central Region, Ghana). Second, we compared the mean species richness (number of species) and total abundance (number of individuals) that were found using artificial structures relative to natural vegetation resources within the study area. Finally, we determined and compared the differences in activities performed by birds at the time of encounter and whether the number of bird species or the total number of individuals differed for those who use artificial resources from natural ones.

MATERIALS AND METHODS

Study area

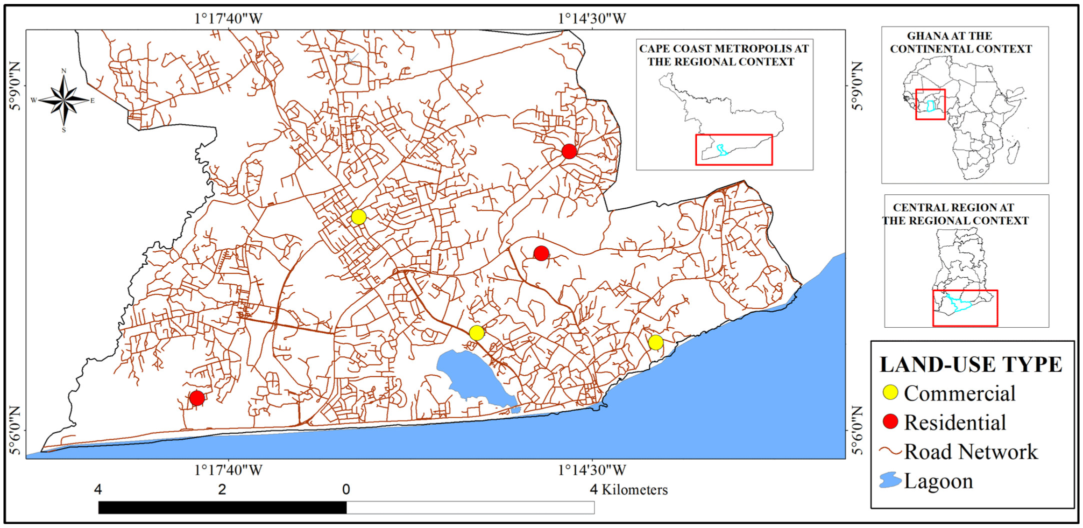
The study was conducted in the Cape Coast Metropolitan Assembly (5.1732° N, 1.2987° W) in the Central Region of Ghana (Fig. 1). Cape Coast Metropolitan Assembly covers a land area of approximately 124 km² with about 189,925 people and an annual population growth rate of 1.0% (Ghana Statistical Service 2021). The area is dominated by batholiths with undulating steep slopes resulting in valleys that serve as channels for various streams and rivers, with Kakum being the largest. These streams and rivers support various vegetation around them that in turn enable occupancy and persistence of many faunas.

Located within the Guinea-Congolian vegetation zone of West Africa, CCMA has a double maxima rainfall pattern ranging from 750 to 1000 mm, with the major wet season from May to July and the minor rainy season between September and October (Ghana Meteorological Agency 2021). The core of the metropolis is built up with a mosaic of residential areas, car parks, open markets, and offices of corporate bodies. Interspersed among these are green spaces of shrublands, grasslands, remnant native forest fragments, and coastal thickets. In recent times, existing forest fragments are restricted within government institutions such as universities and high schools. However, the future of these remnants is uncertain because of the ever-expanding infrastructure of many urban schools.

Landscape classification and data collection

ArcGIS version 10.6 (ESRI 2018) was used to classify the study area into residential and commercial areas based on the dominant characteristic variables including environmental noise, the proportions of area covered by buildings, distance to the city center, and human disturbance. This was done by processing and classifying 20% cloud-free satellite images downloaded from the USGS website using ENVI (Exelis) version 5.3 software (Exelis Visual Information Solutions, Boulder, Colorado, USA) and ArcGIS version 10.6. Three residential and commercial areas were

Fig. 1. Map of the study area (Cape Coast Metropolitan Assembly) showing the distribution of study sites and land use types. Commercial areas are areas dominated by artificial structures, and residential areas are areas with a mix of natural and artificial vegetation.



mapped out and selected for this study. The size of the selected sites ranged from 1.88 km² to 2.01 km²; the study sites were located at least 1.5 km apart. A total of 90 grid points, 200 m apart were generated using QGIS version 3.14.1 (www.qgis.org) and distributed randomly in the study area. This was to ensure the independence of sampling points within each site and reduce the chance of double counting of birds. The points were exported onto Global Positioning System (GPS) device, Garmin eTrex 10® and located on the field.

Birds and resource use survey

To document the avifauna within the built-up areas of CCMA, point count surveys were conducted twice daily between the hours of 0600 to 1000 and from 1500 to 1800 each day. We repeated the morning and evening surveys twice from January to February and twice from June to July to match the dry and wet seasons in the area and to also coincide with the non-breeding and breeding seasons of tropical birds (Moreau 1950). This was done to understand the influence of season on resource use by birds in the study area. The point count method was chosen because of the wide variety of habitats and the density of structures within the study sites (Rawat and Rao 2020), a relatively small radius of 50 m is deemed appropriate (Sutherland 2006, Hayes et al. 2020) to increase detection probability. At each point count station, 10 minutes were spent recording all birds and their activities within the 50 m radius. Bird counts from calls only without seeing them were not used in the analyses to investigate the relative use of artificial and natural resources because we could not verify the substrate type that the species could be using, although these records were necessary for the total bird inventory. Also, activities performed by birds such as perching, singing, nesting, or feeding and the structures (artificial or natural, i.e., shrubs, trees, telecom masts, electric poles, buildings, etc.) as well as part of the structure (i.e., the roof of building, ceiling of building openings in street light, flowers of the tree, etc.) on which the birds were found performing such activities were recorded for each species. In cases where a bird was found performing two or more activities at the same time (i.e., perching and singing, or perching and preening) the activity that was performed later was recorded. This was because, in most instances, passerines were found to perch before performing these activities. Habitat resources used by birds during the sampling period were grouped as either artificial structures or natural vegetation resources.

Natural vegetation resource for the purpose of this study was defined as a photosynthetic plant cover that develops with little or no human interference (Ramankutty and Foley 2010). It included green plants and exotic plant species, shrubs, small trees, large trees, fruiting and flowering plants, and grasses. Artificial resources are not natural plants, but birds used them daily in the urban setting. These included telecom masts, electric poles, buildings, walls, roofs, holes in buildings, electric meters, openings in air conditioners, as well as pylons. A bird was recorded to be using a particular resource when it was found perching and singing, nesting or perching, and feeding on the resource. The number of individual birds found using a particular resource was recorded.

Data analyses

We chose the open-source R statistical software version 4.1.0. (R Core Team 2021) for our analysis. Bird species richness and abundance were calculated using the package "vegan" (Oksanen et al. 2007) for each site relative to season, activities performed by birds, and the substrate categories to determine the variation in the use of artificial structures and natural vegetation by birds. This was further used to determine the variation in the frequency of activities performed by birds on artificial structures and natural vegetation. Frequency was calculated as the number of individuals recorded performing a particular activity per point count session. Species accumulation curve was used to illustrate the rate of species accumulation in the study area. We used multivariate analysis of variance (MANOVA) with bird abundance and richness as the response variables, season, activity, and substrate category as the explanatory variables to test for variation in activities performed by birds and the substrate category used. We used Indicator Species Analysis (ISA) using the "indicspecies" package (Cáceres 2020) to determine species that were strongly associated with a particular substrate category.

RESULTS

Overview of bird survey

We recorded a total of 3486 individuals comprising 78 species of birds from 33 families during this study (Appendix 1). These included 68 common residents, seven intra-African migrants, and three Palearctic migrants (Barn Swallow, *Hirundo rustica*, Melodious Warbler, *Hippolais polyglotta*, and Western Yellow Wagtail, *Motacilla flava*). The species accumulation curve approached an asymptote (Appendix 2) indicating that most of the bird species in the survey area appeared to have been recorded. Of all the birds recorded, 1753 (46.2%) individuals of 38 species belonging to 23 families were found using artificial structures, 1731 (45.6%) individuals of 71 species belonging to 33 families were found using natural structures and resources, although 310 (8.17%) of 31 species belonging to 18 families were recorded but not found to use any of the structures (artificial or natural) in the study area.

Family Corvidae, represented by two species (i.e., Pied Crow, *Corvus albus* and Piapiac, *Ptilostomus afer*) had the greater number of individuals, contributing 16.9% to the total bird population in CCMA (Table 1). Family Passeridae, Estrildidae, and Ploceidae contributed 14.7%, 11.4%, and 11.1%, respectively, whereas Family Acrocephalidae, Rallidae, and Scolopacidae each had a single recorded individual.

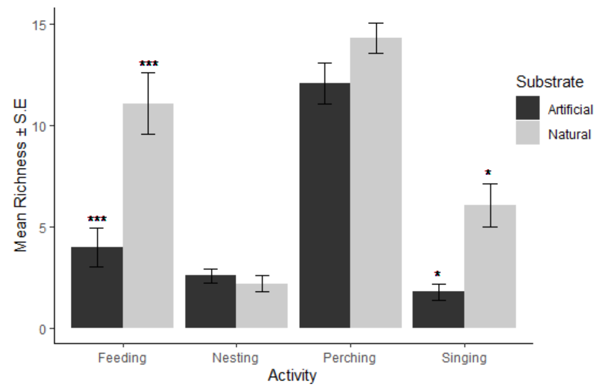
Variation in artificial structures and natural vegetation use by bird species in the CCMA

The mean bird abundance that used artificial structures did not differ significantly from those that used natural vegetation resources ($F_{8,80}$ = 0.27, p = 0.603). This also did not differ significantly between the wet and dry seasons ($F_{8,80}$ = 2.96, p = 0.089). However, there was a significant difference in the use of artificial structures versus natural vegetation structures by bird species richness ($F_{8,80}$ = 25.40, $p < 0.001$). The mean (± SE) number of species that used natural vegetation structures was 8.70 ± 0.85 compared to 5.40 ± 0.75 for those species that used artificial structures. We found a significant difference in activities performed by bird species and the substrate type used ($F_{8,80}$ = 6.01, $p < 0.001$). More bird species (Mean ± SE = 14.33 ± 0.74) perched on natural vegetation structures compared to the mean of 12.08 ± 1.02 species that did the same using artificial structures (Fig. 2). Surprisingly, a greater number of bird species (mean ± SE = 2.58 ± 0.34) preferred to nest on artificial structures than 2.20 ± 0.39 bird species that preferred nesting on natural vegetation structures. The greater bird species richness (6.08 ± 1.06) was found to sing while perching on natural vegetation structures compared to artificial structures (Mean ± SE = 1.78 ± 0.40; Fig. 2).

Table 1. Results of point count surveys done from June 2021 to February 2022 in the Cape Coast Metropolitan Assembly, Ghana, including species family, species richness (number of species), bird abundance (total number of individuals), rank abundance (hierarchical arrangement of the total number of individuals), and proportion (%).

Species Family	Species Richness	Bird Abundance	Rank Abundance	Proportion (%)
Corvidae	2	588	1	16.9
Passeridae	2	512	2	14.7
Estrildidae	5	397	3	11.4
Ploceidae	6	388	4	11.1
Columbidae	4	383	5	11.0
Pycnonotidae	5	350	6	10.0
Nectariniidae	4	183	7	5.2
Hirundinidae	3	156	8	4.5
Cisticolidae	7	93	9	2.7
Musophagidae	2	68	10	2.0
Accipitridae	5	64	11	1.8
Sturnidae	2	50	12	1.4
Motacillidae	2	43	13	1.2
Cuculidae	3	33	14	0.9
Apodidae	2	24	15	0.7
Alcedinidae	2	23	16	0.7
Turdidae	1	20	17	0.6
Ardeidae	1	18	18	0.5
Bucerotidae	3	18	19	0.5
Falconidae	1	17	20	0.5
Platysteiridae	1	10	21	0.3
Viduidae	1	10	22	0.3
Meropidae	2	7	23	0.2
Lybiidae	2	6	24	0.2
Zosteropidae	1	6	25	0.2
Laridae	1	5	26	0.1
Macrosphenidae	1	4	27	0.1
Malaconotidae	2	3	28	0.1
Fringillidae	1	2	29	0.1
Phoeniculidae	1	2	30	0.1
Acrocephalidae	1	1	31	0.0
Rallidae	1	1	32	0.0
Scolopacidae	1	1	33	0.0

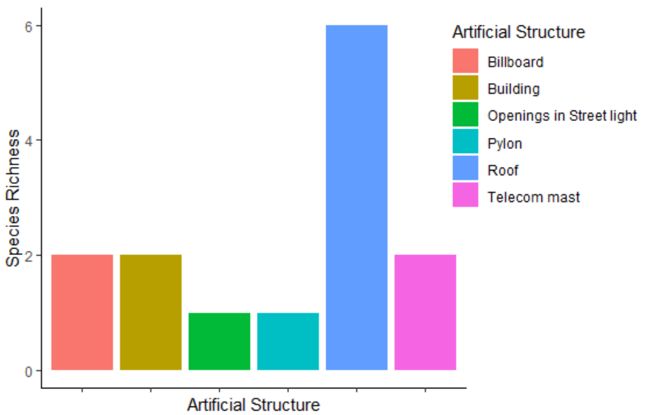
Fig. 2. Mean number of birds species and the activities performed on artificial and natural substrates. There is a significant difference in the type of substrate used during feeding ($p < 0.001$) and singing (p = 0.047) by bird species as indicated by *** and *, respectively.



Artificial structures used for nesting by birds in built-up areas

Of the nine species encountered nesting on artificial structures, two species (Northern Gray-headed Sparrow, *Passer griseus*, and Pied Crow) were found nesting on billboards. Pied Crow and Common Kestrel, *Falco tinnunculus* were nesting on telecommunication masts, and six species (Bronze Mannikin, *Spermestes cucullata*, House Sparrow, *Passer domesticus*, Laughing Dove, *Spilopelia senegalensis*, Little Swift, *Apus affinis*, Northern Gray-headed Sparrow, and Splendid Starling *Lamprotornis splendidus*) were found nesting in the ceilings of buildings, whereas one species each were recorded nesting on a pylon, on the walls of buildings, openings in street lights, and in windows of buildings (Fig. 3).

Fig. 3. Artificial structures used for nesting and the number of birds species that used the structures. Structures where birds were found nesting include openings in billboards, inside cracks in the walls and windows of buildings, inside the roofs of buildings, on top of pylons and telecommunication masts, and openings in street lights.



Bird species associated with artificial structures and natural vegetation

Indicator species analysis (ISA) of birds' use of artificial structures and natural vegetation showed that some species are significantly associated with specific substrate categories. Among the 82 species tested, 17 species showed significant associations with different substrate categories (Table 2). Three species (Laughing Dove, Northern Gray-headed Sparrow, and African Pied Wagtail, *Motacilla aguimp*) were identified as significantly associated with artificial structures, eight species were significantly associated with natural resources, and five species were significantly found not to be using any of the substrate categories (Table 2).

Table 2. Results of indicator species analysis of bird survey conducted from June 2021 to February 2022 in the Cape Coast Metropolitan Assembly, Ghana, including resources category, species common name, species scientific name, test statistics, and p-value.

Resources Category	Species Common Name	Species Scientific Name	Test Statistics	P-value
Artificial				
	Laughing Dove	*Spilopelia senegalensis*	0.48	< 0.01
	African Pied Wagtail	*Motacilla aguimp*	0.30	0.01
	Northern Grey-headed Sparrow	*Passer griseus*	0.41	0.02
Natural				
	Splendid Sunbird	*Cinnyris coccinigastrus*	0.54	< 0.01
	Copper Sunbird	*Cinnyris cupreus*	0.53	< 0.01
	Village Weaver	*Ploceus cucullatus*	0.52	< 0.01
	Black-necked Weaver	*Ploceus nigricollis*	0.50	< 0.01
	Tawny-flanked Prinia	*Prinia subflava*	0.46	< 0.01
	Senegal Coucal	*Centropus senegalensis*	0.41	0.02
	Western Plantain-eater	*Crinifer piscator*	0.41	0.02
	Grey-backed Camaroptera	*Camaroptera brevicaudata*	0.36	0.02
	Brown-throated Wattle-eye	*Platysteira cyanea*	0.32	0.05
None				
	African Palm Swift	*Cypsiurus parvus*	0.72	< 0.01
	Little Swift	*Apus affinis*	0.58	< 0.01
	Ethiopian Swallow	*Hirundo aethiopica*	0.43	0.01
	Hooded Vulture	*Necrosyrtes monachus*	0.35	0.03

DISCUSSION

The study found no significant difference between artificial structures and natural vegetation use as well as resource use across seasons by the bird abundance in built-up areas within the study area. This could be influenced by the dominance of species like the Pied Crow of the Family Corvidae that dominated the bird abundance in the area. The Pied Crow has been reported to be an urban adaptor that has adapted to utilize artificial resources very well (Londei 2010). Therefore, the dominance of species of the Corvidae family may have influenced the number of other birds that utilize resources in the study area. Also, the patches of natural vegetation such as trees and shrubs provided nesting material and nesting sites for Village Weavers, *Ploceus cucullatus* of the Family Ploceidae, which were also found to be significantly associated with natural vegetation within the urban area. It is therefore not surprising that we found no significant difference between artificial and natural resource use by bird abundance within the study area as these two species influenced the bird abundance.

However, the significant differences in the use of artificial structures versus natural vegetation structures by different bird species could be attributed to the presence of small sizes of natural vegetation in the residential and commercial areas that serve as the only refuges for many bird species (Fernández-Juricic 2001). According to Mohd-Taib et al. (2022), this mosaic vegetation (typically comprising trees and shrubs, and buildings) provides shelter and a roost site for different bird species, which could be why a significantly greater number of birds were found singing and perched on natural vegetation structures than artificial structures.

The difference found in activities between the substrate types was likely because of the type of artificial structures available. The greater concentration of buildings, electric poles, pylons, telecommunication masts, and other artificial structures provide a conducive substrate for these birds to perch and perform daily life activities. The greatest average number of individuals found perching did so on natural vegetation, whereas most of the species found feeding and singing used natural structures. These findings contradict findings from studies in Australia by Pike et al. (2017), who found more species using artificial structures during time budget activities such as perching, feeding, fighting, and preening. These opposing findings could be because of the difference in landscape, as our study area is a mosaic landscape whereas Melbourne in Australia is almost a homogeneous landscape with less natural vegetation.

The greater species richness found to use artificial structures than natural substrates for nesting is similar to the report of Mainwaring (2015) who found man-made structures widely used as nesting sites by a range of birds. Most of the natural vegetation in the study area has been replaced by artificial ones hence urban birds may have adapted to using man-made structures during an important part of their life such as nesting. Surface and substrate such as pylons and telecommunication masts are used frequently for nesting by Pied Crows and Common Kestrel in the absence of natural tall trees. This finding is consistent with studies in other regions that found pylons to provide numerous nesting sites for species such as White Stork, *Ciconia ciconia* of the family Ciconiidae (Balmori 2005), Common Raven, *Corvus corax* of the family Corvidae (Howe et al. 2014), White-backed Vulture, *Gyps africanus* of the family Accipitridae (Anderson and Hohne 2007) and 14 species of raptors in South Africa (Anderson 2000). Other species such as Bronze Mannikin, Laughing Dove, Northern Gray-headed Sparrow, and House Sparrow also used artificial substrates such as openings in ceilings of roofs of buildings, openings in air conditions, electric meters, and windows of some buildings during the breeding season for nesting. This shows that some species within the urban landscape may have undergone behavioral adaptations by making use of artificial structures to enable them to survive and thrive in these areas (Shochat et al. 2010). This modification in behavior results from a lack of access to natural resources.

The survival of species is sometimes limited by the availability of suitable nesting sites for breeding populations of birds. The primary advantage of man-made structures is that they often provide nesting sites in areas where natural nesting sites do not exist (Mainwaring 2015). However, the primary disadvantages of the use of man-made structures for nesting are that they sometimes act as ecological traps by attracting birds to nest in suboptimal areas (Downs et al. 2021). For example, studies have reported that the breeding success of White Storks on artificial structures such as pylons are lower (Balmori 2005, Tryjanowski et al. 2009). Also, the dangers associated with nesting on man-made structures are that the regular maintenance and cleaning of these structures leads to the dismantling of nests and hence, loss of nesting sites and sometimes chicks. Although our study found differences between man-made and natural structures use by bird species richness within an urban area in Ghana, further study should look into the effects these differences have on reproductive success and fitness.

CONCLUSIONS AND RECOMMENDATION

Our study is among the first to empirically test the comparative use of natural and man-made structures by birds in an urban mosaic landscape. Our study has shown that across species, birds show preference for trees, shrubs, and natural vegetation structures for perching, feeding, and singing whereas artificial structures such as billboards, telecommunication masts, ceilings of buildings, pylons, buildings, openings in street lights, and windows of buildings are preferred for nesting. This shows that although not a replacement for natural resources, artificial structures when combined with natural vegetation could contribute significantly to the survival of urban bird population. Conservation practitioners could encourage urban mosaic landscapes of built and green spaces to conserve and restore populations of birds. We recommend that further large and local-scale research aimed at determining artificial features that are important for the maintenance of bird diversity is required. Also, more studies need to examine the costs and benefits of man-made structures as nesting sites for birds. More specifically, studies that examine the population status and reproductive success of birds on man-made structures would be extremely informative for conservation practitioners and urban landscape management.

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Appendix 1: Avifaunal species recorded using point count surveys from (June 2021 to February 2022) in the Cape Coast Metropolitan Assembly, Ghana, including Species Family, Species Scientific Name and the Status of the bird.

Species Family	Species Scientific Name	Species Common Name	Species Status
Columbidae	*Treron calvus*	African Green Pigeon	Resident
Bucerotidae	*Lophoceros nasutus*	African Grey Hornbill	Intra-African migrant
Apodidae	*Cypsiurus parvus*	African Palm Swift	Resident
Bucerotidae	*Lophoceros fasciatus*	African Pied Hornbill	Resident
Motacillidae	*Motacilla aguimp*	African Pied Wagtail	Resident
Alcedinidae	*Ispidina picta*	African Pygmy Kingfisher	Resident
Turdidae	*Turdus pelios*	African Thrush	Resident
Zosteropidae	*Zosterops senegalensis*	African Yellow White-eye	Resident
Estrildidae	*Lagonosticta rufopicta*	Bar-breasted Firefinch	Resident
Hirundinidae	*Hirundo rustica*	Barn Swallow	Migrant
Rallidae	*Amaurornis flavirostra*	Black Crake	Resident
Malaconotidae	*Tchagra senegalus*	Black-crowned Tchagra	Resident
Ploceidae	*Ploceus nigricollis*	Black-necked Weaver	Resident
Accipitridae	*Elanus caeruleus*	Black-winged Kite	Resident
Ploceidae	*Euplectes hordeaceus*	Black-winged Red Bishop	Resident
Columbidae	*Turtur afer*	Blue-spotted Wood Dove	Resident
Estrildidae	*Lonchura cucullata*	Bronze Mannikin	Resident
Platysteiridae	*Platysteira cyanea*	Brown-throated Wattle-eye	Resident
Laridae	*Hydroprogne caspia*	Caspian Tern	Resident
Sturnidae	*Onychognathus fulgidus*	Chestnut-winged Starling	Resident
Pycnonotidae	*Pycnonotus barbatus*	Common Bulbul	Resident
Falconidae	*Falco tinnunculus*	Common Kestrel	Resident
Scolopacidae	*Actitis hypoleucos*	Common Sand Piper	Resident
Ploceidae	*Ploceus superciliosus*	Compact Weaver	Resident
Nectariniidae	*Cinnyris cupreus*	Copper Sunbird	Resident
Cuculidae	*Chrysococcyx caprius*	Diederik Cuckoo	Intra-African migrant
Lybiidae	*Lybius bidentatus*	Double-toothed Barbet	Resident
Hirundinidae	*Hirundo aethiopica*	Ethiopian Swallow	Resident
Macrosphenidae	*Sylvietta virens*	Green Crombec	Resident
Phoeniculidae	*Phoeniculus purpureus*	Green Wood Hoopoe	Resident
Nectariniidae	*Cyanomitra verticalis*	Green-headed Sunbird	Resident
Cisticolidae	*Camaroptera brevicaudata*	Grey-backed Camaroptera	Resident
Musophagidae	*Tauraco persa*	Guinea Turaco	Resident
Accipitridae	*Necrosyrtes monachus*	Hooded Vulture	Resident
Passeridae	*Passer domesticus*	House Sparrow	Resident
Cuculidae	*Chrysococcyx klaas*	Klaas's Cuckoo	Intra-African migrant

Appendix 1: Continue.

Species Family	Species Scientific Name	Species Common Name	Species Status
Columbidae	*Spilopelia senegalensis*	Laughing Dove	Resident
Meropidae	*Merops pusillus*	Little Bee-eater	Resident
Pycnonotidae	*Eurillas virens*	Little Greenbul	Resident
Apodidae	*Apus affinis*	Little Swift	Resident
Estrildidae	*Lonchura fringilloides*	Magpie Mannikin	Resident
Acrocephalidae	*Hippolais polyglotta*	Melodious Warbler	Migrant
Hirundinidae	*Cecropis senegalensis*	Mosque Swallow	Resident
Passeridae	*Passer griseus*	Northern Grey-headed Sparrow	Resident
Ploceidae	*Dryoscopus gambensis*	Northern Red Bishop	Resident
Nectariniidae	*Cinnyris chloropygius*	Olive-bellied Sunbird	Resident
Estrildidae	*Estrilda melpoda*	Orange-cheeked Waxbill	Resident
Cisticolidae	*Hypergerus atriceps*	Oriole Warbler	Resident
Corvidae	*Ptilostomus afer*	Piapiac	Resident
Corvidae	*Corvus albus*	Pied Crow	Resident
Bucerotidae	*Bycanistes fistulator*	Piping Hornbill	Resident
Estrildidae	*Lagonosticta senegala*	Red-billed Firefinch	Resident
Columbidae	*Streptopelia semitorquata*	Red-eyed Dove	Resident
Cisticolidae	*Cisticola erythrops*	Red-faced Cisticola	Resident
Accipitridae	*Falco chicquera*	Red-necked Buzzard	Intra-African migrant
Cisticolidae	*Prinia erythroptera*	Red-winged Prinia	Resident
Cuculidae	*Centropus senegalensis*	Senegal Coucal	Resident
Accipitridae	*Accipiter badius*	Shikra	Resident
Pycnonotidae	*Chlorocichla simplex*	Simple Greenbul	Resident
Cisticolidae	*Cisticola cantans*	Singing Cisticola	Resident
Sturnidae	*Lamprotornis splendidus*	Splendid Starling	Resident
Nectariniidae	*Cinnyris coccinigastrus*	Splendid Sunbird	Resident
Cisticolidae	*Prinia subflava*	Tawny-flanked Prinia	Resident
Malaconotidae	*Laniarius major*	Tropical Boubou	Resident
Ploceidae	*Ploceus nigerrimus*	Vieillot's Black Weaver	Resident
Ploceidae	*Ploceus cucullatus*	Village Weaver	Resident
Ardeidae	*Bubulcus ibis*	Western Cattle Egret	Resident
Musophagidae	*Crinifer piscator*	Western Plantain-eater	Resident
Motacillidae	*Motacilla flava*	Western Yellow Wagtail	Migrant
Meropidae	*Merops albicollis*	White-throated Bee-eater	Intra-African migrant
Viduidae	*Vidua wilsoni*	Wilson's Indigobird	Resident
Cisticolidae	*Cisticola marginatus*	Winding Cisticola	Resident
Alcedinidae	*Halcyon senegalensis*	Woodland Kingfisher	Intra-African migrant
Accipitridae	*Milvus aegyptius*	Yellow-billed Kite	Intra-African migrant

Appendix 1: Continue.

Species Family	Species Scientific Name	Species Common name	Species Status
Pycnonotidae	*Laniarius barbarus*	Yellow-crowned Gonolek	Resident
Fringillidae	*Crithagra mozambica*	Yellow-fronted Canary	Resident
Lybiidae	*Pogoniulus chrysoconus*	Yellow-fronted Tinkerbird	Resident
Pycnonotidae	*Atimastillas flavicollis*	Yellow-throated Leaflove	Resident

Appendix 2: Overall species accumulation curve showing the rate of species accumulation per sample visit for a point count surveys from (June 2021 to February 2022) in the Cape Coast Metropolitan Assembly, Ghana.