Scopus 42(1): 1–20, January 2022

Avian community changes along an urbanization gradient in Dar es Salaam, Tanzania, with a reversed trend for alien species

Jasson R. John and Qudra Kagembe

Summary

Dar es Salaam is the most populous city in Tanzania with over five million people, and has the fastest growing human population in East Africa. We examined the change in avian species richness and abundance along an urbanization gradient from city centre to peri-urban in order to provide insights into impacts of urbanization on native and non-native avifauna. Four major city exit/entry roads were used as reference transects in counting birds and recording selected urbanization indices at 63 circular points positioned at approximately 1 km intervals. A total of 1964 individuals from 71 species belonging to 36 families and nine orders were detected. Species-abundance patterns of native birds increased along the urbanization gradient from urban to peri-urban. However, the alien House Crow and House Sparrow showed reversed abundance trends from city centre towards peri-urban. These patterns were significantly related to the shift in urbanization indices; the number of pedestrians and vehicles, and percentage cover changes for buildings, pavements, bare land, and vegetation. Avian dietary guilds varied across the urban-peri-urban stretch and were significantly influenced by the vegetation cover. This study revealed that continuing urban development has a great impact on avian communities. We therefore recommend urban planning to be geared to controlling alien avian species population and increasing the vegetation cover.

Keywords: Alien species, biotic homogenization, dietary guilds, House Crow, urbanization

Introduction

The global human population continues to grow and is accompanied by rapid urbanization. Between 2011 and 2050, the world population is expected to increase by 2.3 billion, passing from 7.0 billion to 9.3 billion (United Nations 2011). At the same time, the population living in urban areas is projected to increase by 2.6 billion, passing 3.6 billion people in 2011 to 6.3 billion in 2050. Thus, the urban areas of the world are expected to absorb almost all the population growth expected over the next four decades while at the same time drawing in some of the rural population. By 2005, the global rate of urbanization (*i.e.*, the increasing number of people that live in urban areas) was 54 %; Africa and Tanzania stood at 40 % and 25 %, respectively (Chen *et al.* 2014, Tacoli *et al.* 2015). Globally, human population growth and urbanization threaten the existence of ecological systems and biodiversity resources (Zari 2014, Parris 2016). According to Juffe-Bignoli *et al.* (2014) rising human population and urbanization are central to expanding the built environment.

Persistence of biodiversity in urban and peri-urban areas is determined by the rate of expansion of the built environment (Shirgaokar 2016). Urbanization results in a change in habitat which may challenge any particular wildlife population to exist. For birds, urbanization has a great impact on species abundance, richness, distribution, and community composition (Blair & Lawton 1987, Blair 2004). Urbanization has a complex direct impact on native avian communities (Miller *et al.* 2001). Many native bird species which fail to adapt to the new habitats become locally extinct from urbanized habitats. The factors that determine which of the bird species co-exist with humans in urbanized areas include the presence of vegetation cover (Emlen 1974, Rosenberg *et al.* 1987). Additionally, some bird species such as crows, sparrows, starlings, pigeons, and doves, take advantage of human disposal materials and waste both from industrial and residential areas and hence tend to increase in abundance when there is increased human settlement and activities (Leedy 1979), and some of these will reach the stage of becoming invasive (Mathews & Brand 2004).

Studies on the avifauna in urban environments (Miller *et al.* 2001, Blair 2004) have shown that urbanized areas have a high diversity of exotic species and a low diversity of endemic species. Further studies (Kareiva *et al.* 1993, Rija *et al.* 2004) that describe how native birds respond to this change suggest that urbanization affects landscape heterogeneity and consequently, the distribution, abundance and resources upon which birds depend. Most bird species are influenced by composition of vegetation, which forms most of their habitat, and in turn provides cover and food resources. Therefore, loss and alteration of native habitats may lead to an increase or decrease in species number (Lee & Rotenberry 2005). Vegetation in highly urbanized and residential areas mostly occurs in patches in the form of trees, shrubs and herbaceous plants and increases with gradient from urban to peri-urban (Leedy 1979, Jokimäki 1999).

Birds have been seen as a symbol for conservation globally for ecological and evolutionary reasons and they play a significant role in people's perception of the natural environment in which they live (Gibson *et al.* 2011); they provide cultural, provisioning, supporting and regulating services to urbanites (Huong & Thu 2017). Birds are highly sensitive, conspicuous and mobile, and thus very suitable as a measure in understanding the impact of humans on biodiversity (Chazdon *et al.* 2009), especially in urban areas (Miller *et al.* 2001, Njoroge & Ndang'ang'a 2010). Dar es Salaam is a highly expanding city with over five million people and this population increases by over 5% each year (NBS 2012). The city of Dar es Salaam therefore shows an increasing level of urbanization coupled with the growth of spontaneous settlements (Baker & Baker 2002, Abebe 2011) that pose a great danger to biological communities and survival of nature. Dar es Salaam is not only the largest city in East Africa, but it also hosts an Important Bird Area (IBA), the Dar es Salaam coast (Baker & Baker 2002). Despite the high rates of urbanization and rapid increase in population in African cities in which many of them are located in biodiversity hotspots (Chamberlain 2017), studies showing the influence of urbanization on biological communities are scanty. In this study we examined the change in avian species richness and abundance along an urbanization gradient from city centre to peri-urban in Dar es Salaam, and correlated the urbanization gradient indices with avian dietary guilds.

Materials and methods

Study area

Dar es Salaam is located in the eastern part of the Tanzanian mainland at 6° 51′ S latitude and 39° 18′ E longitude. It covers a total area of 1800 km^2, of which 1350 km^2 is landmass including its offshore islands; the remainder of the area is covered by water. It occupies 0.19 % of the Tanzanian mainland, stretching about 100 km along the coast. The Indian Ocean borders it to the east, and the beach and shoreline comprise sand dunes and tidal swamps. The coastal shrubs, coastal swamps and mangroves, together with miombo woodland, represent the remnant natural vegetation type along the 100 km of coastline. Inland, the city is divided into three ecological zones, namely the upland zone comprising Pugu and other hills at 100–200 m in altitude to the west and north of the city, the middle plateau, and the lowlands areas (Dar es Salaam City Council 2004). Due to close proximity to the equator and the warm Indian Ocean, the city experiences tropical climatic conditions, typified by hot and humid weather with seasonal and daily variation throughout much of the year. The area experiences a bimodal pattern characterized by short rains from November to December and long rains during March and April. The average annual rainfall is approximately 1100 mm. Maximum relative humidity is high, 100 %. The maximum reported temperature for Dar es Salaam is 35.3 °C in March; the minimum is 12.7 °C in August (Bargman 1970).

The human population of Dar es Salaam has increased from 2.5 million in 2002 to approximately 4.3 million in 2012, and is still increasing at a rate of 4.39 % per annum, such that the metropolitan population is projected to reach 5.6 million by 2026 (NBS 2012). It was governed under three districts of Temeke, Ilala, and Kinondoni at the time of this study. The population in the metropolitan area grew from 843 090 in 1978 to 5 465 420 in 2016, of which 94 % are urbanites (the urbanization rate being 34 %) (Worrall *et al.* 2017). Development statistics place Dar es Salaam metropolitan as the most industrialized and urbanized city in Tanzania, as well as one of the top ten fastest growing cities globally (Ndetto & Matzarakis 2015). Approximately 70 % of the people in Dar es Salaam live in congested and unplanned settlements, especially in lowland areas, and they are expanding towards the peri-urban. The increase of people has created an urban sprawl (Baker & Baker 2002, Abebe 2011; Fig. 1), with natural habitat fragmenting to very small remnants that cannot easily support biodiversity (Mkalawa 2016).

Nonetheless, due to the presence of the Indian Ocean coast, and remnants of the original coastal thickets, Dar es Salaam is very rich in bird species. About 500 bird species have been recorded in Dar es Salaam and its surrounding areas (Harvey & Howell 1987, Wium-Andersen & Reid 2000), and the city and coastline are therefore designed as an IBA (Baker & Baker 2002). Some of the bird species occurring in Dar es Salaam are introduced species that have arrived in different ways: some have escaped from the controversial bird trade including lovebirds, parrots, and barbets, while others such as House Crow *Corvus splendens* and House Sparrow *Passer domesticus* were probably introduced intentionally. The population of the House Crow has increased to hazardous levels since its introduction (Harvey & Howell 1987, Baker & Baker 2002, Kimario *et al.* 2020), and this crow is blamed for the disappearance of several native bird species from core urban areas (Wium-Andersen & Reid 2000, Baker & Baker 2002).

Study sites and methods

According to Gombe *et al.* (2017), the Dar es Salaam metropolitan-built environment development pattern is most extensive along the four main roads, namely Nyerere/ Pugu heading to the airport and Kisarawe district, Bagamoyo leading to Bagamoyo, Morogoro that heads to Morogoro region, and Kilwa that stretches southwards to Lindi and Mtwara regions. Kilwa and Bagamoyo roads run parallel to the shoreline while Pugu and Morogoro roads are almost perpendicular to the shoreline and lead towards the hinterland (Fig. 1).

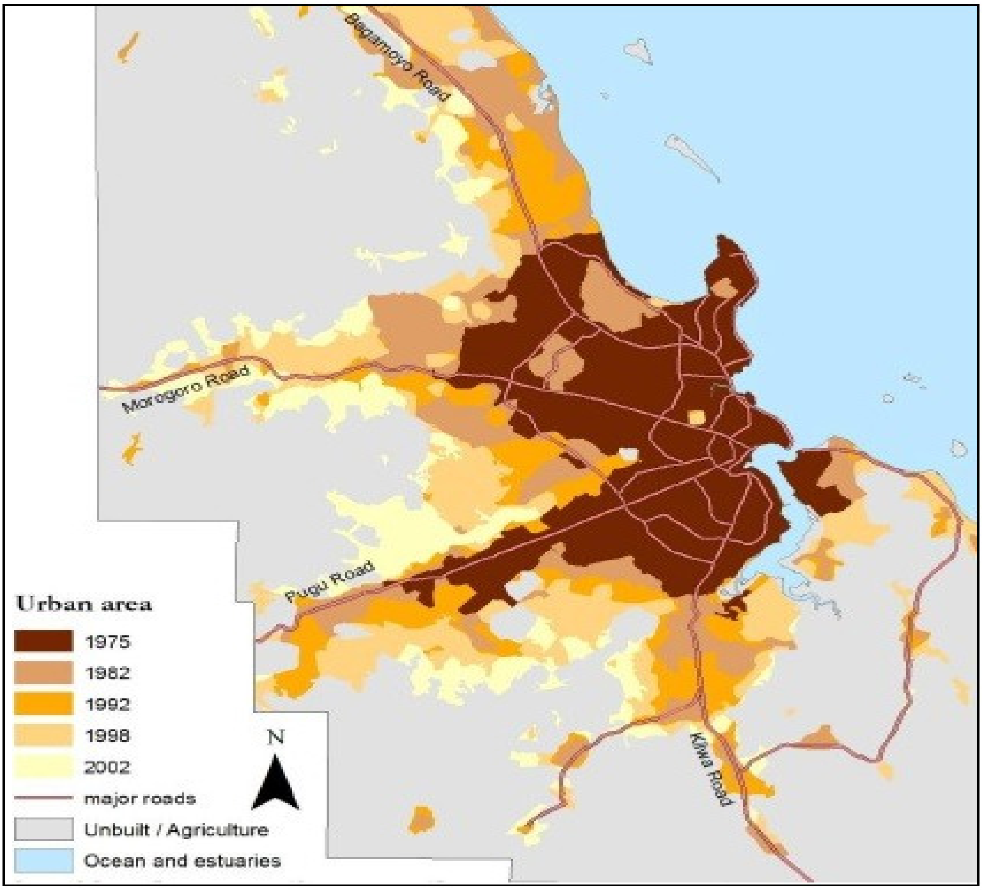

Figure 1. Urban sprawl in Dar es Salaam between 1971 and 2002 (Abebe 2011).

The four major roads feeding the city were used as transect lines (Table 1, Fig. 2). Survey points were located at an interval of about 1 km apart in each transect. Sometimes access to targeted sampling locations were denied by either buildings or restriction by owners, and the next close and suitable area was negotiated. These points were further placed beyond 100 m on either sides of the road (on open spaces with good visibility of up to 25 m from each direction) to avoid road bias from moving vehicles (Reijnen *et al*. 1995), noise pollution (Reijnen *et al.* 1995, Forman & Deblinger 2000, Wood & Yezerinac 2006), food and nutrients (Morgan *et al*. 2010) and vegetation strips along roads (Kociolek *et al.* 2011). A total of 20 minutes were spent at each point; the first 10 minutes were used for counting birds and the last 10 minutes were used to record the urbanization indices. All census points were georeferenced by a hand-held GPS and plotted on a map (Fig. 2).

Table 1. Transect name, length and number of survey points along each transect.

Transect	Transect name	Road length (km)	Number of sampling points
Transect 1	Bagamoyo Road	27	17
Transect 2	Morogoro Road	30	18
Transect 3	Nyerere Road	20	14
Transect 4	Kilwa Road	21	14

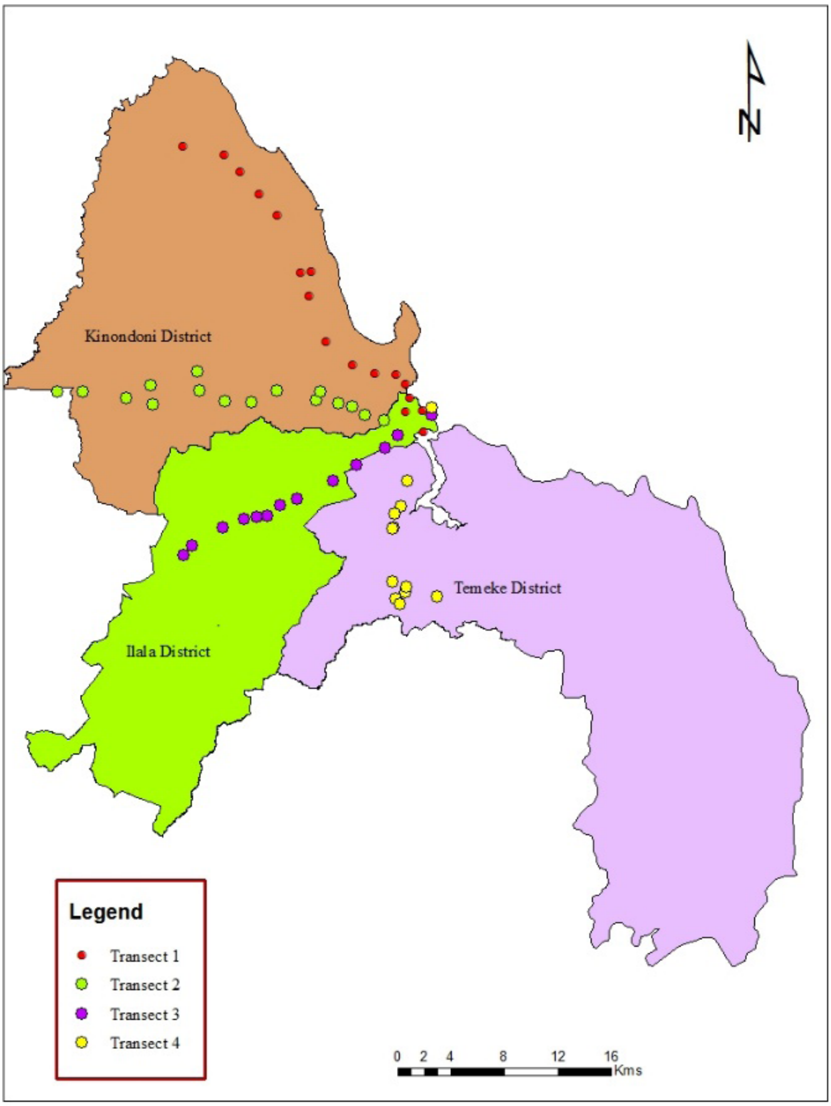

Figure 2. A map of Dar es Salaam showing transects and survey points. All transects started from city nuclei, near Dar es Salaam port.

All birds that were spotted within 25 m of the survey point were recorded (not much attention was put on birds in the air). Using a motorbike, each transect was surveyed twice during the same study period with reversed starting and ending points. We used binoculars (Bushnell 10 x 42) whenever needed to identify birds. The following urbanization indices were recorded within the 25 m radius: number of pedestrians and parked vehicles, and land cover (%) for pavements, building, vegetation, and bare land. Data collection was conducted between February and March 2016.

Data analysis

The average number of bird species from all points for all the four transects were plotted against the sampling points to obtain a line graph that shows how the species richness changed with urbanization. The same method was applied for abundance. Plotting of the House Crow and House Sparrow were also done excluding other species. Percentage cover of building, pavements, bare land and vegetation for all the four transects were used to plot a graph against distance from the city centre. Lastly line graphs to show how the number of pedestrians and vehicles changed with the urbanization gradient from the city centre to peri-urban were plotted. Pearson-product moment correlation coefficient was used to test for the linear correlation between birds and the urbanization indices, and species richness and abundances. The relationship between bird dietary guilds and urbanization indices was determined through direct gradient analysis using canonical correspondence analysis (CCA) in PAST version 4.03 (adopted from McCune & Mefford 1999). Dietary guilds were classified according to (Rija *et al.* 2014) (Appendix 1).

Results

Species richness and abundance patterns along the urbanization gradient

A total of 1964 individual birds comprising 71 species belonging to nine orders and 36 families were recorded along the urban-rural gradient (Appendix 1). The dominant families in terms of number of species were Estrilidae, Ploceidae, Nectariidae and Cisticolidae. Passerines constituted about 62% of all species observed. Several long-distance Palaearctic migrants were also recorded. They included Common Tern *Sterna hirundo*, Eurasian Golden Oriole *Oriolus oriolus*, Red-backed Shrike *Lanius collurio,* Lesser Grey Shrike *Lanius minor*, Great Reed Warbler *Acrocephalus arundinaceus*, Northern House Martin *Delichon urbicum* and Spotted Flycatcher *Muscicapa striata.*

The general trend showed an increase in species richness from the city centre to peri-urban. However, there were points with low and high peaks in species richness along the gradient (Fig. 3a,b). The abundance reduced from the city centre, flattening in between, and increased towards peri-urban habitats (Fig. 3c). On exclusion of the alien House Crow and House Sparrow, the abundance increased along the gradient of urbanization just as species richness did (Fig. 3d). Furthermore, species richness and abundance were significantly correlated ($r = 0.793$, $p = 0.009$) when House Crow and House Sparrow were excluded, and with a negative, but not significant correlation ($r = -0.283$, $p = 0.257$) when included. This suggested that the Central Business District (CBD) bird abundance was dominated by the two alien species, a sign of biotic homogenization, and their dominance decreased from the city centre towards peri-urban (Fig. 4).

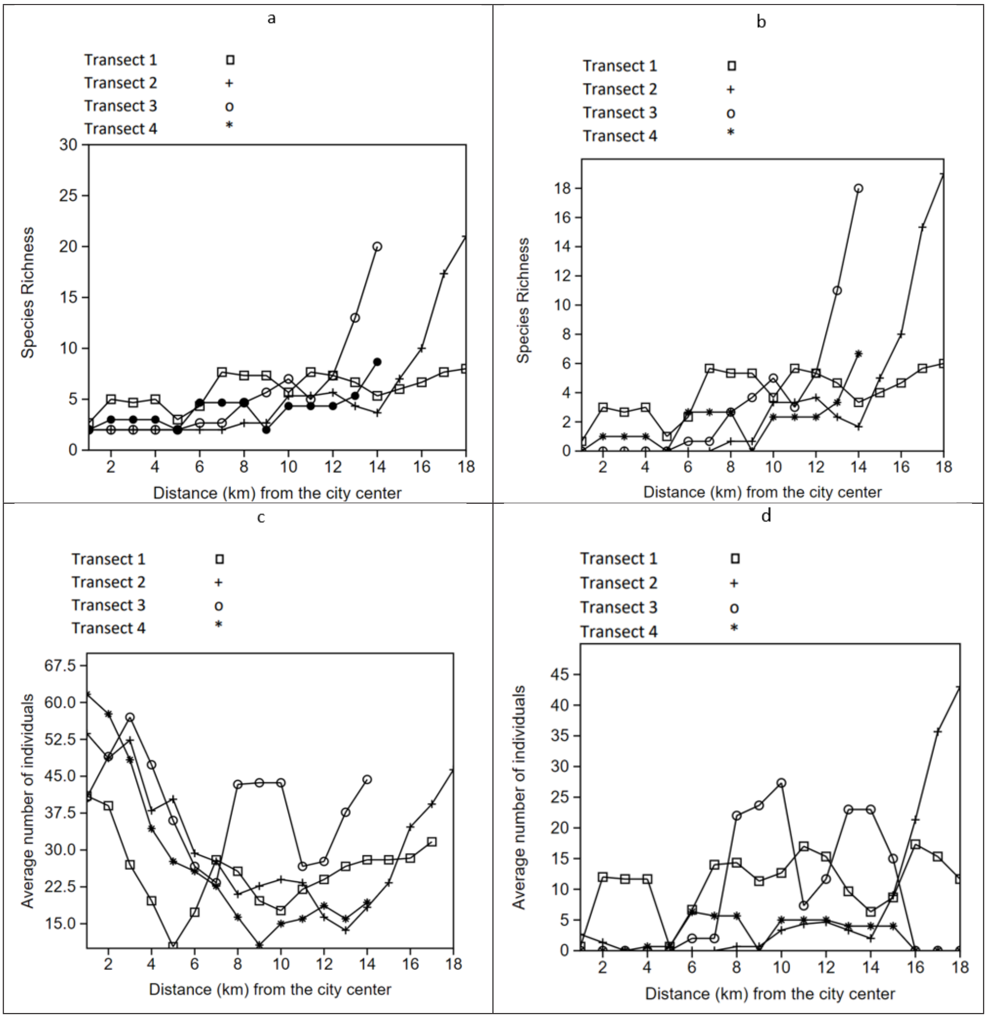

Figure 3. The patterns of bird species richness (a & b) and abundance (c & d) along the urbanization gradient in Dar es Salaam; (a) and (c) are with, whereas (b) and (d) are without, the two alien bird species, House Sparrow and House Crow.

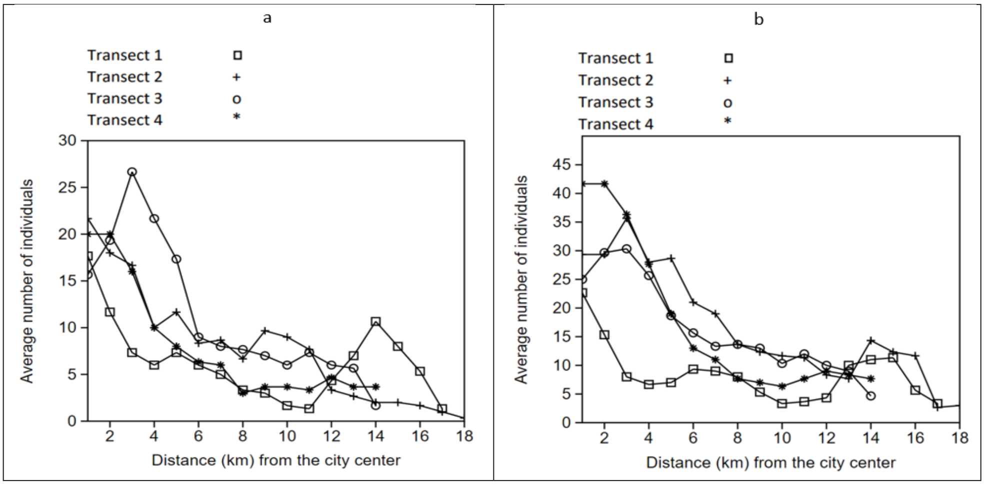

Figure 4. The House Crow (a) and House Sparrow (b) trends along the urbanization gradient from the city centre in Dar es Salaam.

Sampling points in natural patches (green spaces) had high species richness and a different composition of birds. In areas with wetlands (e.g. Msimbazi/Jangwani) and rivers and streams, species observed included Sacred Ibis *Threskionis aethiopicus*, Southern Masked Weaver *Ploceus velatus*, Hadada Ibis *Bostrychia hagedash*, Spectacled Weaver *Ploceus ocularis*, African Golden Weaver *Ploceus subaureus,* Wood Sandpiper *Tringa glareola*, Common Waxbill *Estrilda astrilda*, and Zanzibar Red Bishop *Eupletes nigroventris* (Appendix 2). A number of species were also found in vegetated open areas such as military barracks and cemeteries that included Bronze Mannikin *Lonchura culcullata*, Rattling Cisitcola *Cisticola chiniana*, Tawny-flanked Prinia *Prinia subflava*, Red-billed Firefinch *Lagonosticta senegela*, Blue-breasted Cordon-bleu *Uraeginthus angolensis*, Sombre Greenbul *Andropadus importunus* and Common Bulbul *Pycnonotus barbatus.* The only point that fell on the coastal beach (Selander Bridge, along Bagamoyo Road) had seabirds on the upper shoreline including Common Tern and Sooty Tern *Onychoprion fuscatus* (Appendix 2).

Urbanization indices and avian correlation

All the measures of land cover had a unimodal distribution except for the bare land which was low in highly urbanized areas, replaced by pavements and buildings. Generally, the percentage of area covered by building and pavements decreased while that of vegetation increased from the city centre to peri-urban (Fig. 5a). The number of parked vehicles and pedestrians decreased from city centre towards peri-urban (Fig. 5b). The percentage covered by buildings (r=-0.718, p=0.001) and pavements (r= -0.496, p=0.036), and number of vehicles (r=-0526, p=0.025), showed significant negative correlation with bird abundances, whereas vegetation (r= 0.748, p=0.0001) had a significant positive correlation. The correlation for species richness and urbanization indices was significant only with percentage cover by buildings (r=-0.632, p=0.005) and vegetation (r=0.603, p=0.008), respectively (Appendix 3).

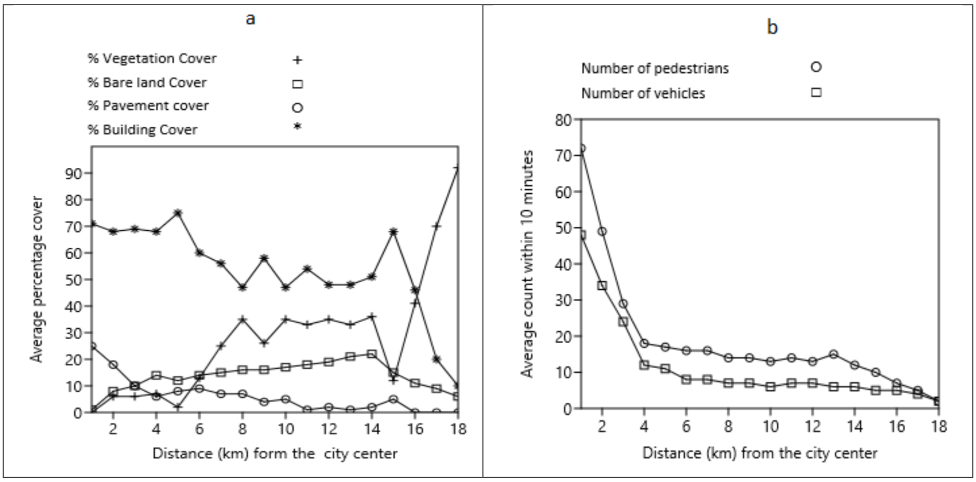

Figure 5. Urbanization indices from city centre to peri-urban in Dar es Salaam: percentages of land covered by buildings, pavements, bare land and vegetation (a) and the average number of pedestrians that were counted in ten minutes of time (b).

Influence of urbanization indices on bird species distribution

Bird dietary guilds were plotted against the axes of CCA plot to visualize their relationship with environmental variables. The CCA scatter plot (Fig. 6) detected a relationship between the distribution of bird dietary guilds and the percentage area covered by buildings, pavement, bare land, vegetation and the number of vehicles and pedestrians at the individual sampling points. In this study the first two ordination axes explained 83.1% and 11.4% of the variance in the species data with canonical eigenvalues of 0.793 and 0.107, respectively. The percentages indicate that the variation is well predicted by environmental variables. A Monte Carlo test using 100 permutations showed that the overall analysis and the two axes were significant (CCA, $p = 0.0393$). Axis 1, which accounted for 83.9% of the variance, was very successful in showing the relationship between environmental variables and distribution of bird dietary guilds.

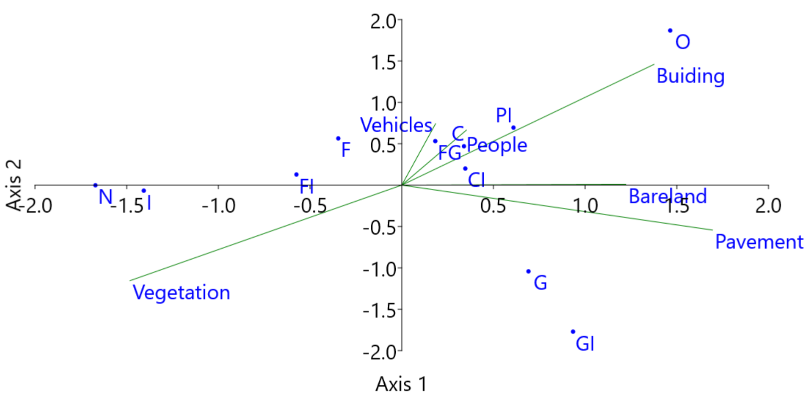

Figure 6. Ordination diagrams of canonical correspondence analysis. The arrows represent the direction of steepness of change of an urbanization index measure and are oriented towards the direction of the steepness increase of the index. The arrow length indicates the importance of the urbanization index in the model. The arrow direction indicates how well the index is correlated with various axes and the angle between axes indicate correlation. The location of bird dietary guilds relative to the arrows is determined by the impelling urbanization indices.

Dietary guilds that had the strongest positive association with Axis 1 were Omnivore (O) (r=1.444), followed by, Piscivore-insectivore (PI) (r=0.608), Frugivore-granivore (FG) (r=0.187), and Carnivore-insectivore (CI) (r=0.351). Also, positive association with Axis 1 were the percentage pavement cover (r=0.564), Building (r=0.451), Bare land (r=0.405), People (r=0.115), and Vehicles (r=0.058). Conversely, on a decreasing strength of association, Nectarivore (N) (r=-1.638), Insectivore (I) (r=-1.378), Frugivore (F) (r=-0.334), Granivore-insectivore (GI) (r=-0.556) were negatively associated with Axis 1. Percentage vegetation cover was also negatively associated with axis 1 (r=-0.487).

Generally dietary guilds for species that feed in more than one diet category including, Granivore-insectivores, Granivore-frugivores, Piscivore-insectivores, Frugivore-insectivore and guilds for species which can thrive well in urban habitats such as Omnivores (i.e. House Crow) and Granivores (i.e. House Sparrow) dominate the right portion of the plot. This part is also influenced by percentage cover for pavement, building, bare land, and number of people and vehicles. Insectivores, Frugivores and Nectarivores (i.e., sunbirds) fall in the left portion of the plot which is defined by the larger vegetation cover (Fig. 6).

Discussion

Species richness and abundance patterns along the urbanization gradient

Results from this study support the general hypothesis that while species richness increases from the city center to less urbanized habitats, native species' abundance decreases. This was correlated with the increase of vegetation cover from the city centre towards peri-urban. Species richness is usually lower in urban regions compared to rural areas, with the lowest diversities documented in urban core areas (McKinney 2002, 2008). In contrast, bird abundance had a bimodal pattern along the urbanization gradient where it started by decreasing from city and later increased as the urban habitats were changing to rural. This pattern was due to dominance of the two alien bird species, House Crow and House Sparrow, which were superabundant in urban core areas and whose numbers decreased from the city centre towards peri-urban but remained high in human populated town centres. This concurs with several studies (Nilon *et al.* 1995, Miller *et al.* 2001, van Rensburg *et al.* 2009, Chamberlain *et al.* 2017) which reported a decline in species with increasing urbanization but high abundance in a few species. In Pretoria, van Rensburg *et al* (2009) found few species in urban areas compared with semi-natural zones but lower abundance in semi-natural zones than urban, and the increase of the abundance in urban areas was a result of three alien bird species: Common Myna *Acridotheres tristis*, Feral Pigeon *Columba lavia,* and House Sparrow. However, a study in Kampala by Chamberlain *et al* (2017) on avian biomass did not find a correlation with urbanization gradient due to the presence of larger species in more urbanized areas. The bird communities in Kampala were increasingly dominated by scavengers, including the Marabou Stork *Leptoptilus crumeniferus*, exploiting human refuse.

Alien species, especially when they become an invasive, such as the House Crow in Dar es Salaam (Baker & Baker 2002), can stress and displace native urban adapters and could lead to biotic homogenization. The Pied Crow *Corvus albus*, for example, is becoming a rare bird in urban Dar es Salaam due to the competition with the House Crow. The Pied Crow used to be a common bird in Dar es Salaam area in mid 1980s

(Harvey & Howell 1987). The ecological impacts of the alien invasive House Crow in eastern Africa coastal areas have been intensively documented elsewhere (Ryall 1988, Archer 2001).

There were also ups and downs in the species-abundance patterns from city centre towards peri-urban. This was due to the presence of satellite urban centres and pockets of natural vegetation. The military base, wetlands, cemeteries, the university campus and gardens represent the few pockets of green spaces within Dar es Salaam. Birds usually take advantage of these natural remnants as refuge sites in response to urbanization (Emlen 1974). However, survey points that fell in populated centres such as Mbagala, Ubungo-Mbezi, Gongolamboto, had a lower bird species richness but a higher abundance, especially of the two alien bird species. This was due to the increase in buildings and pavements, with uncontrolled garbage disposal that favoured a few species of birds, especially the alien species. Such environments favour the few species that adapt to urban habitats and tolerant of human presence which are often exotics (Whitney & Adam 1980, Mathews & Brand 2004, van Rensburg *et al.* 2009).

Species richness peaked at the edge of the city and species found there were typically different from those found in urban areas and suburban areas (Appendix 2). These findings are supported by other studies (Graber & Graber 1963, Tomialojc 1970, Batten 1972, Emlen 1974, Guthrie 1974, Walcott 1974, Beissinger & Osborne 1982, Green 1984, Bezzel 1985, Rosenberg *et al.* 1987) but contrary to other findings (Huston 1979, Lancaster & Rees 1979, Aldrich & Coffin 1980, Jokimäki & Sauhenon 1993, Tilman 1982) which reported an increase in species richness at the intermediate levels of urbanization versus completely natural sites. This can be explained by the fact that this study (and most previous studies in urban areas) has examined species changes across relatively short distances. At the edge of the city, the percentage of land covered by vegetation was high compared to the percentage cover of buildings, pavements and bare land. This increase in vegetation cover and the presence of native vegetation at the edge of the city significantly increases diversity of food which, together with several other factors such as vegetation species composition, spatial scale and land use activities surrounding the areas of native vegetation, increase the likelihood and persistence of local native avifauna. Such habitats also act as stopover for long distance migrants.

Species composition, dietary guilds and urbanization

The results obtained from this study show that species composition also responded differently to the changes in resources brought by urbanization. Two alien species seen in the study had high abundances in the business and office areas though they were distributed throughout the study area. Normally these alien species, which reach high densities in urban areas, are tied to the urban and sub-urban development in their place of origin (Emlen 1974). The presence of wetland birds such as Cattle Egret, Hadada Ibis, Sacred Ibis, Wood Sandpiper, and Dimorphic Egret was attributed to the presence of swamps and riverine habitats that cross the city to the ocean. Such areas are frequently used by a diverse number of bird species for foraging, nesting and roosting due to the heterogeneity of microhabitats and available foods resources (Bradley 2001). This phenomenon was also reported by Emlen (1974), reporting water-dependent species flocking to Tucson's urban area because of the presence of pools and fountains.

It was observed from this study that most of the species in the study site were generalists; a likely effect of land use change in the study area. Harvey and Howell (1987) provide a detailed assessment of the birds of Dar es Salaam area which includes birds of dense coastal thickets such as Mouse-coloured Sunbird *Cyanomitra verreauxii*, Eastern Green Tinkerbird *Pogoniulus simplex* and Eastern Nicator *Nicator gularis* not encountered in this study. Granivores and omnivores had high abundances in the city centre. Omnivores mostly depend on human disposal for food and are favoured by the increase of human settlement. They survive on fruits from exotics, ornamentals and seeds, grain, bread, and scraps provided by people (Lancaster & Rees 1979, Tweit & Tweit 1986). The increase in vegetation cover towards the peri-urban supports the increase in number of insectivores and frugivores (Emlen 1974, Lancaster & Rees 1979, Beissinger & Osborne 1982). A few nectarivores, especially sunbirds, were found both in urban and peri-urban areas: this was due to the presence of green spaces and flowering plants in the city that provide food resources for most bird species.

Conclusion

The findings of this study suggest that the continuity of ex-urban development progressively reduces the habitats in which many bird species take refuge in response to urbanization and threatens their survival. Likewise, it has been observed that the superabundance of House Crow could pose a major threat to indigenous bird species and accelerate the avian homogenization in Dar es Salaam. Therefore, given the remarkable population increase of the House Crow in Dar es Salaam urban, and its known negative impacts in the East African coast, there is a need for long-term programmes to control its populations in urban areas, and for improved garbage management on which it depends for its survival. Despite the general increase of species richness from urban to peri-urban, some points with high species richness on more urban transects could be related to the presence of green patches and strips of vegetation. The existence of urban green spaces such as the military base, gardens, floodplains, and wetlands tend to buffer the effect of urbanization. These green spaces should be maintained, and the city authorities are encouraged to promote additional tree planting in both residential and public places.

Acknowledgements

We acknowledge the support given by the urban authorities in Dar es Salaam. Rajabu Mapunda advised on data analysis. Anthony Collins, Derek Pomeroy, Dan Chamberlain and one anonymous reviewer provided valuable comments and useful suggestions.

References

Abebe, F.K. 2011. *Modelling informal settlement growth in Dar es Salaam*. Master thesis. University of Twente, The Netherlands.

Aldrich, J.W. & Coffin, R. W. 1980. Breeding bird populations from forest to suburbia after thirty seven years. *American Birds* 34: 3-7.

Archer, A.L. 2001. Control of the Indian House Crow *Corvus splendens* in eastern Africa. *Ostrich Supplement* 15: 147-152.

Baker, N.E. & Baker, E.M. 2002. *Important Bird Areas in Tanzania: A first inventory*. Wildlife Conservation Society of Tanzania, Dar es Salaam.

Bargman, D.J. 1970. The climate of Dar es Salaam. *Tanzanian Notes & Records* 71: 55–64.

Batten, L.A. 1972. Breeding bird diversity in relation to increase urbanization. *Bird Study* 19: 157–166.

Beissinger, S.R. & Osborne, D.R. 1982. Effects of urbanization on avian community organization. *Condor* 84: 75–83.

Bezzel, E. 1985. Birdlife in intensively used rural and urban environments. *Ornis Fennica* 62: 90–95.

Blair, R. 2004. The effect of urban sprawl on birds, at multiple levels of organization. *Ecology and society* 9(5): 2. *[online] URL: http: //www.ecologyandsociety.org/vol9/iss5/art2/.*

Blair, R.B. & Lawton, J.H. 1987. Predation by domestic cats in an English village. *Journal of Zoology* 212: 439–455.

Bradley, C. 2001. Wetlands (third edition) by W.J. Mitsch & J.G. Gosselink. John Wiley & Sons, New York, 2000. Book Review. *River Research and Applications* 17(3): 295.

Chamberlain, D., Kibuule, M., Skeen, R. & Pomeroy, D. 2017. Trends in bird species richness, abundance and biomass along a tropical urbanization gradient. *Urban Ecosystem* 20: 629–638.

Chazdon, R. L., Peres, C. A., Dent, P., Sheil, D., Lugo, A.E., Lamb, D., Stork, N.E. & Miller, S.E. 2009. The potentials for species conservation in tropical secondary forest. *Conservation Biology* 23: 1406–1417.

Chen, M., Zhang, H., Liu, W. & Zhang, W. 2014. The global pattern of urbanization and economic growth: evidence from the last three decades. *PLoS One* 9(8): e103799. doi: 10.1371/journal.pone.0103799.

Dar es Salaam City Council. 2004. Dar es Salaam City Profile, City Directorate.

Emlen, J.T. 1974. An urban bird community in Tucson Arizona; derivation, structure, regulation. *Condor* 76: 184–197.

Forman, R.T.T. & Deblinger, R.D. 2000. The ecological road-effect zone of a Massachusetts (USA) suburban highway. *Conservation Biology* 14: 36–46.

Gibson, L., Lee, T.M., Koh, L.P., Brook, B.W., Gardner, T.A., Barlow J., Peres, C.A., Bradshaw, C.J.A., Laurence, W.E., Lovesoy, T.E., & Sodhi, N.S. 2011. Primary sources are irreplaceable for sustaining tropical biodiversity. *Nature* 478: 378–383.

Gombe, K.E., Asanuma, I., Park, J-G. 2017. Quantification of Annual Urban Growth of Dar es Salaam Tanzania from Landsat Time Series Data. *Advances in Remote Sensing* 6(3): 175–191.

Graber, R.A., & Graber, J.W. 1963. A comparative study on bird population in Illinois, 1906–1909 and 1956-1958. *Illinois Natural History and Survey Bulletin* 28: 377–527.

Green, R.J. 1984. Native and exotic birds in suburban habitats. *Australia Wildlife Research* 11: 181–190.

Guthrie, T. P. 1974. Sub-urban bird population in southern California. *American Midland Naturalist* 92: 461–466.

Harvey, W.G. & Howell, K.M. 1987. Birds of Dar es Salaam Area, Tanzania. *Le Gerfaut* 77: 205–258.

Huong, T.T. & Thu, H.T.T. 2017. ADB Regional Technical Assistance Project RETA 8564 Promoting Ecosystem Services and Sustainable Forest Carbon Financing in the Asia Pacific. Asian Development Bank.

Huston, M. 1979. A general hypothesis of species diversity. *American Naturalist* 113: 81–101.

Jokimäki, J. & Suhonen, J. 1993. Effects of urbanization on the breeding of bird species richness in Finland: a bio-geographical comparison. *Ornis Fennica* 70: 71–77.

Jokimäki, J. 1999. Occurrence of breeding bird species in urban parks: effects of park structure and broad-scale variables. *Urban Ecosystems* 3: 21–34.

Juffe-Bignoli, D., Burgess, N.D., Bingham, H., Belle, E.M.S., De Lima, M.G., Deguignet, M., Bertzky, B., Milam, A.N., Martinez-Lopez, J., Lewis, E., Eassom, A., Wicander, S., Geldmann, J., Van Soesbergen, A., Arnell, A.P., O'connor, B., Park, S., Shi, Y.N., Danks, F.S., Macsharry, B. & Kingston, N. 2014. *Protected planet report 2014*. UNEP-WCMC Cambridge, UK.11.

Kareiva, P., Kingsolver, J. & Huey, R. 1993. *Biotic Interactions and Global Change*. Sinauer Associates, Sunderland, MA, USA.

Kimario, E.P, John, J. & Pratap, H. 2020. Gonadosomatic index infers the breeding season of the House Crow *Corvus splendens* in Dar es Salaam. *Scopus* 40(1): 1–6.

Kociolek, A.V., Clevenger, C.C., St. Clair, C.C. & Proppe, D.S. 2011. Effects of road networks on bird populations. *Conservation Biology* 252: 241–249.

Lancaster, R.K. & Rees, W.E. 1979. Bird communities and the structure of urban habitats. *Canadian Journal of Zoology* 57: 258-268.

Lee, P. & Rotenberry, J.T. 2005. Relationships between bird species and tree species assemblages in forested habitats of eastern North America. *Journal of Biogeography* 32(7): 1139–1150.

Leedy, D.L. 1979. *An Annotated Bibliography on Planning and Management for Urban-Suburban Wildlife. Biological Service Program.* Fish and Wildlife Services. U.S. Department of the Interior.

Mathew, S. & Brand, K. 2004. *Africa America invaded: the growing danger of invasive alien species*. Global Invasive Species Programme (GISP), IUCN.

McCune, B. & Mefford, M.J. 1999. *Multivariate Analysis of Ecological Data*. Version 4.0. MjM

McKinney, M.L. 2002. Urbanization, Biodiversity, and Conservation. *Bioscience* 52: 883–890.

McKinney, M.L. 2008. Effects of urbanization on species richness: a review of plants and animals. *Urban Ecosystem* 11: 161–176.

Miller, J.R., Fraterrigo, J.M., Hobbs, N.T., Theobald, D.M. & Wiens, J.A. 2001. Urbanization, avian communities, and landscape ecology. Pp. 117–137. In: Marzluff, J., Bowman, R. & Donnelly, R. (eds): *Avian ecology and conservation in an urbanizing world*. Kluwer Academic Publishers, Norwell.

Mkalawa, C.C. 2016. Analyzing Dar es Salaam urban change and its spatial pattern. *International Journal of Urban Planning and Transportation* 31(1): 1138–1150.

Morgan, G.M., Boughton, R.K., Rensel, M.A. & Schoech, S.J. 2010. Road effects on food availability and energetic intake in Florida scrub-jays (*Aphelocoma coerulescens*). *The Auk* 127: 581–589.

National Bureau of Statistics (NBS). 2012. Official Census 2012. NBS, Dar es Salaam, Tanzania.

Ndetto, E.L. & Matzarakis, A. 2015. Urban atmospheric environment and human biometeorological studies in Dar es Salaam, Tanzania. *Air Quality, Atmosphere & Health* 8(2): 175–191.

Nilon, C.H., Long, C.L. & Zipperer, W.C. 1995. Effects of wildland development on forest bird communities. *Landscape Urban Planning* 32: 81–92.

Njoroge, J.B. & Ndang'ang'a, P. K. 2010. Seasonal characteristics of avifauna in Nairobi Metropolitan landscape. *Urban Ecosystem* 17: 61–75.

Parris, K.M. 2016. *Ecology of urban environments*. Wiley-Blackwell; John Wiley & Sons, Ltd. Melbourne, Australia.

Reijnen, R., Foppen, R., Braak, C.T. & Thissen, J. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. *Journal of Applied Ecology* 32: 187–202.

Rija, A.A., Said, A., Mwamende, K.A. & Hassan, S.N. 2014. Wet season bird species richness and diversity along urban-rural gradient in Morogoro municipality and surrounding areas, Tanzania. *Tanzania Journal of Forestry and Nature Conservation* 83(2): 1–13.

Rosenberg, K.V., Terrill, S.B. & Rosenberg, G.H. 1987. Value of sub-urban habitats to desert riparian birds. *Wilson Bulletin* 99: 642–654.

Ryall, C. 1988. The pest status of the Indian House Crow in Mombasa and a survey of its expansion of range. Proceedings of the VIIth Pan African Ornithological Congress.

Shirgaokar, M. 2016. Expanding cities and vehicle use in India: Differing impacts of built environment factors on scooter and car use in Mumbai. *Urban Studies* 53(15): 3296–3316.

Tacoli, C., McGranahan, G. & Satterthwaite, D. 2015. *Urbanization, rural-urban migration and urban poverty*. Human Settlements Group, International Institute for Environment and Development.

Tilman, D. 1982. *Resource competition and community structure.* Princeton New Jersey, USA: Princeton University Press.

Tomialojc, L. 1970. Quantitative studies of the synanthropic avifauna of Legnica and its environs. *Acta Ornithologica* 9: 293–392.

Tweit, R.C. & Tweit, J.C. 1986. Urban development effects on the abundance of some common resident birds of the Tucson area of Arizona. *American Birds* 40: 431–436.

United Nations. 2011. *World Urbanization Prospects. The 2011 Revision*. United Nations Department of Economic and Social Affairs/Population Division.

van Rensburg, B. J., Peacock, D.S. & Robertson, M.P. 2009. Biotic homogenization and alien bird species along an urban gradient in South Africa. *Landscape and Urban Planning* 92(3–4): 233–241.

Walcott, C.F. 1974. Changes in birdlife in Cambridge, Massachusetts from 1860-1964. *The Auk* 91: 151–160.

Whitney, G.G. & Adams, S.D. 1980. Man as a maker of new plant communities. *Journal of Applied Ecology* 17, 341–488.

Wium-Andersen, G. & Reid, F. 2000. *Birds of Dar es Salaam: Common Birds of Coastal East Africa.* The Aage V. Jensens Fode in Denmark.

Wood, W.E. & Yezerinac, S.M. 2006. Song Sparrow (*Melospiza melodia*) song varies with urban noise. *The Auk* 123: 650–659.

Worrall, L., Colenbrander, S., Palmer, I., Makene, F., Mushi, D., Kida, T., Martine, M. & Godfrey, N. 2017. *Better Urban Growth in Tanzania: A Preliminary Exploration of the Opportunities and Challenges.* Coalition for Urban Transitions, London and Washington, DC.

Zari, M.P. 2014. *Ecosystem Services Analysis in Response to Biodiversity Loss Caused by the Built Environment, S.A.P.I.EN.S* [Online], 7.1 | 2014, Online since 12 November 2014, connection on 10 March 2021. URL: http: //journals.openedition.org/sapiens/1684.

Jasson R. John
Department of Zoology and Wildlife Conservation, College of Natural and Applied Sciences, University of Dar es Salaam, P.O. Box 35064, Dar es Salaam. Email: wildornithology@udsm.ac.tz

Qudra Kagembe
TRAFFIC International, East Africa Office, Dar es Salaam. Email: mchaw3q@gmail.com

Scopus 42(1): 1–20, January 2022
Received 19 April 2021

Appendix 1. Bird species recorded along the gradient of urbanization in Dar es Salaam including the dietary guilds: Granivore (G), Frugivore (F), Omnivore (O), Insectivore (I), Piscivore (P), Nectarivore (N), Carnivore (C), Granivore-insectivore (GI), Frugivore-granivore (FG), Piscivore-insectivore (PI), Frugivore-insectivore (FI), and Carnivore-insectivore (CI).

Common name	Species name	Dietary Guild
Red-eyed Dove	*Streptopelia semitorquata*	F
Ring necked Dove	*Streptopelia capicola*	FG
Emerald-spotted wood-dove	*Turtur chalcospilos*	F
White-browed Coucal	*Centropus superciliosus*	I
African Sacred Ibis	*Threskiornis aethiopicus*	CI
Hadada Ibis	*Bostrichia hagedash*	CI
Cattle Egret	*Bubulcus ibis*	PI
Grey Heron	*Ardea cinerea*	PI
Dimorphic Egret	*Egretta dimorpha*	PI
Great White Pelican	*Pelecanus onocrotalus*	C
White-fronted Plover	*Charadrius marginatus*	CI
Wood Sandpiper	*Tringa glareola*	CI
Sooty Gull	*Larus hemprichii*	PI
Sooty Tern	*Onychoprion fuscatus*	PI
Common Tern	*Sterna hirundo*	PI
Long-crested Eagle	*Lophaetus occipitalis*	C
Speckled Mousebird	*Colius striatus*	FG
Blue-naped Mousebird	*Urocolius macrourus*	FG
Little Bee-eater	*Merops pusillus*	I
Lilac-breasted Roller	*Coracias caudatus*	I
Grey-headed Kingfisher	*Halcyon leucocephala*	I
Brown-hooded Kingfisher	*Halcyon albiventris*	I
Striped Kingfisher	*Halcyon chelicuti*	I
Red-fronted Tinkerbird	*Pogoniulus pusillus*	FI
Spot-flanked Barbet	*Tricholema lacrymosa*	F
Brown-breasted Barbet	*Pogonornis melanopterus*	F
Cardinal Woodpecker	*Dendropicos fuscescens*	I
Eurasian Golden Oriole	*Oriolus oriolus*	I
Black-backed Puffback	*Dryoscopus cubla*	I
Orange-breasted Bush-shrike	*Chlorophoneus sulfureopectus*	I
Tropical Boubou	*Laniarius aethiopicus*	I
Fork-tailed Drongo	*Dicrulus adsimilis*	CI
Red-backed Shrike	*Lanius collurio*	I
Lesser Grey Shrike	*Lanius minor*	I
Eastern Black-headed Batis	*Batis minor*	I
Pied Crow	*Corvus albus*	O
House Crow	*Corvus splendens*	O
Green-capped Eremomela	*Eremomela scotops*	I
Bleating Camaroptera	*Camaroptera brachyura*	I
Rattling Cisticola	*Cisticola chiniana*	I

Common name	Species name	Dietary Guild
Tawny-flanked Prinia	*Prinia subflava*	I
Great Reed Warbler	*Acrocephalus arundinaceus*	I
Northern House Martin	*Delichon urbicum*	I
Lesser Striped Swallow	*Cecropis abyssinica*	I
Sombre Greenbul	*Andropadus importunus*	F
Common Bulbul	*Pycnonotus barbatus*	FI
Black-bellied Starling	*Notopholia corusca*	F
Spotted Flycatcher	*Muscicapa striata*	I
Collared Sunbird	*Hedydipna collaris*	N
Scarlet-chested Sunbird	*Chalcomitra senegalensis*	N
Purple-banded Sunbird	*Cinnyris bifasciatus*	N
Variable Sunbird	*Cinnyris venustus*	N
Zanzibar Red Bishop	*Euplectes nigroventris*	GI
Yellow Bishop	*Euplectes capensis*	GI
Spectacled Weaver	*Ploceus ocularis*	GI
African Golden Weaver	*Ploceus subaureus*	GI
Southern Masked Weaver	*Ploceus velatus*	GI
Village Weaver	*Ploceus cucullatus*	O
Red-billed Firefinch	*Lagonosticta senegala*	GI
African Firefinch	*Lagonosticta rubricata*	GI
Blue-breasted Cordon-bleu	*Uraeginthus angolensis*	G
Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	G
Common Waxbill	*Estrilda astrild*	G
Bronze Mannikin	*Spermestes cucullata*	G
Black-and-white Mannikin	*Spermestes bicolor*	G
Village Indigobird	*Vidua chalybeata*	G
Cuckoo-finch	*Anomalospiza imberbis*	GI
House Sparrow	*Passer domesticus*	GI
African Pipit	*Anthus cinnamomeus*	I
African Pied Wagtail	*Motacilla aguimp*	I
Yellow-fronted Canary	*Crithagra mozambica*	G

Appendix 2. Distribution and abundance of bird species across the urbanization gradient in Dar es Salaam. Number of individuals and a census point are separated by a decimal point (e.g. 1.17, one individual was recorded at the 17 census point along a respective transect).

Common Name	Transect 1	Transect 2	Transect 3	Transect 4
Red-eyed Dove		1.18		
Ring necked Dove		1.18	3.14	
Emerald-spotted wood-dove	1.17		1.13	
White-browed Coucal				1.14
African Sacred Ibis			2.9	
Hadada Ibis			4.9	
Cattle Egret	3.3, 2.8, 2.14, 2.15, 1.16	1.17	2.7, 8.9, 1.10	1.11
Grey Heron	1.1, 2.8			1.14
Dimorphic egret	2.3			
Great White Pelican	1.3			
White-fronted Plover	3.3			
Wood Sandpiper				1.14
Sooty Gull	5.3			
Sooty Tern	17.3			
Common Tern	2.3			
Long-crested Eagle				1.11
Speckled Mousebird	5.11, 3.12	1.17, 3.18		4.3
Blue-naped Mousebird		1.17	1.11	
Little Bee-eater		1.16, 4.17	4.14	
Lilac-breasted Roller	1.12, 1.16		1.13, 2.14	1.14
Grey-headed Kingfisher	.15, 1.17		1.14	
Brown-hooded Kingfisher		2.18		
Striped Kingfisher		1.16, 1.17		
Red-fronted Tinkerbird			1.14	
Spot-flanked Barbet			2.14	
Brown-breasted Barbet		1.11		
Cardinal Woodpecker	1.8, 1.17			
Eurasian Golden Oriole		3.18		
Black-backed Puffback		1.18		
Orange-breasted Bush-shrike		1.18		
Tropical Boubou		2.13, 3.14		
Fork-tailed Drongo		2.17, 2.18	2.14	
Red-backed Shrike			1.13	
Lesser Grey Shrike		1.18		
Eastern Black-headed Batis			2.14	
Pied Crow			1.7	
House Crow	21.1, 11.2, 3.3, 6.4, 7.5, 7.6, 4.7, 4.8, 2.9, 3.10, 1.12, 7.13, 8.14, 12.15, 8.16, 1.17	20.1, 5.2, 9.3, 16.4, 5.5, 14.6, 6.7, 6.8, 8.9, 15.10, 4.11, 4.12, 2.13, 2.14, 3.15, 2.16	12.1, 23.2, 23.3, 34.4, 8.5, 10.6, 9.7, 5.8, 9.9, 7.10, 2.11, 13.12, 3.13, 1.14	18.1, 24.2, 18.3, 6.4, 6.5, 12.6, 1.7, 5.8, 3.9,.10, 5.11, 2.12, 7.13, 2.14

Common Name	Transect 1	Transect 2	Transect 3	Transect 4
Green-capped Eremomela		1.18		
Bleating Camaroptera		1.17	1.13	
Rattling Cisticola	2.8, 1.17	2.9, 2.14, 1.17, 2.18		1.7, 1.11
Tawny-flanked Prinia	1.8, 1.17	1.11, 2.18	1.13	1.14
Great Reed-warbler		1.17	5.13	
Northern House Martin	1.10			
Lesser Striped Swallow				3.7
Sombre Greenbul	1.8	1.18		
Common Bulbul	1.13, 1.16, 1.17	1.17, 4.18	1.13	1.14
Black-bellied Starling		1.14		
Spotted Flycatcher			1.14	
Collared Sunbird	1.5, 1.6, 1.11, 1.16	1.14, 2.18, 1.17		
Scarlet-chested Sunbird	1.8, 1.12, 1.17	1.16, 1.18	1.13	
Purple-banded Sunbird	1.8			
Variable Sunbird	1.18			
Zanzibar Red Bishop	8.8, 10.11, 4.17	7.16, 12.17, 9.18	3.7, 40.9, 3.13, 2.14	1.3, 4.7, 3.11
Yellow Bishop	1.17	5.17, 4.17	3.13	
Spectacled Weaver				1.7
African Golden Weaver	2.8, 2.11	3.16	2.10, 2.14	2.7
Southern Masked Weaver	1.3			
Village Weaver	1.17	1.17		
Red-billed Firefinch	2.10, 3.11, 3.14, 2.15	4.12, 2.16, 2.18	2.10, 2.11, 2.14	2.11, 4.14
African Firefinch		1.16		
Blue-breasted Cordon-bleu	2.11, 3.14	1.9, 1.11, 1.13, 8.17, 2.18	3.14	2.14
Red-cheeked Cordon-bleu	2.7, 1.8, 2.10, 2.12, 2.13, 2.16, 13.17	4.10, 2.11, 2.13, 3.14		
Common Waxbill			3.14	
Bronze Mannikin	1.6, 2.9, 4.10, 6.12, 6.16	2.11, 4.17, 5.18,	5.9, 2.10, 5.13	4.7, 4.11
Black-and-white Mannikin	2.12			
Village Indigobird	1.13, 1.14, 2.17	2.11	2.14, 2.17	2.11
House Sparrow	28.1, 12.2, 6.3, 8.5, 7.6, 13.7, 7.8, 4.9, 5.10, 4.11, 5.12, 12.13, 18.14, 8.15, 4.16, 1.17,	8.1, 40.2, 24.3, 43.4, 17.5, 26.6, 20.7, 11.8, 10.9, 16.10, 9.11, 9.12, 7.13, 7.14, 29.15, 1.16, 2.17, 1.18	19.1, 37.2, 33.3. 21.4, 23.5, 12.6, 12.7, 16.8, 13.9, 10.10, 8.11, 18.12, 4.13, 5.14	41.1, 43.2, 23.3, 25.4, 19.5, 15.6, 7.7, 11.8, 5.9, 5.10, 9.11, 9.12, 9.13, 7.14
African Pipit	2.3			
African Pied Wagtail	1.17			
Yellow-fronted Canary			2.14	

Appendix 3. Correlation of bird abundance, species richness, and urbanization indices in Dar es Salaam.

Urbanization indices	Abundance		Species Richness	
	p value	r value	p value	r value
Building	0.001	-0.718	0.005	-0.632
Pavement	0.036	-0.496	0.084	0.417
People	0.055	-0.473	0.088	-0.412
Vehicles	0.025	-0.526	0.08	-0.421
Bare land	0.131	0.37	0.109	-0.39
Vegetation	0.0001	0.748	0.008	0.603