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DEPARTMENT OF ENVIRONMENTAL SCIENCE

BIRD DIVERSITY BETWEEN A PROTECTED AREA AND URBAN REMNANT VEGETATION PATCHES: THE SLOSS DEBATE

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DEDICATION

This research project I dedicate it to Muzondo family. I would have not made it this far without their continuous support.

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ABSTRACT

The single large versus several small (SLOSS) protected areas debate of the 1970s and 1980s, has not yet reached a general understanding. There is ongoing debate about which model is better between the two for biodiversity conservation. This study adds to the SLOSS debate by looking at bird diversity between a single large protected area (Chivero Park) and several small urban vegetation remnant patches in Harare. Birds were sampled using point count method and 30 points were sampled at each site. Data was analysed using R software. Species richness (q=0), Shannon diversity (q=1) and Simpson diversity (q=2) were compared using *iNEXT*. Taxonomic and functional species composition dissimilarity were compared using analysis of similarity (ANOSIM). To visually display patterns in species composition between study sites, a non-metric multidimensional scaling (nMDS) ordination was applied. A total of 2612 individual birds, comprising of 138 species were recorded for the two sites. Species richness was similar between the sites, though Harare had higher Shannon diversity and Simpson diversity compared with Chivero Park. Taxonomic species composition and functional abundance composition were different between Harare and Chivero Park. However, functional species richness varied between sites, all the nine functional groups found in Southern Africa were represented in Chivero Park. African Fish Eagle (*Haliaeetus vocifer)* had the highest indicator value at Chivero Park due to presence of a lake while Pied crow (*Corvus albus)* a generalist species was the one with the highest indicator value in Harare. The findings from this study provide evidence that several small patches are home to a diverse bird species because of the diverse floristic habitat attributes that are found in an urban area. Urban areas support a lot of generalist bird species due to the presents of supplementary food from waste and litter. This study has revealed that several small remnant vegetation patches can support a diverse community of birds that are comparable or even better than single large protected areas. Therefore, conservation efforts should also be directed towards enhancement of conservation models that are based on several small patches.

Key words: SLOSS, single large, several small, diversity, fragmented patches, conservation,

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOSIM	Analysis of Similarities
nMDS	Non-metric multi-dimensional scaling
Q-Q plots	Quantile quantile plots
SLOSS	Single Large or several small
SL	Single Large
SS	Several Small

CHAPTER 1: INTRODUCTION

1.1BACKGROUND TO THE STUDY

Habitat fragmentation is an issue of concern in urban areas worldwide, as a result of land use changes (Fahrig, 2003; Imai, Nakashizuka and Oguro, 2017). It involves the division of large, contiguous areas of habitat into smaller patches well known as patches (Seress, 2015; Johnson, 2001). Apparently fragmentation increases the number of urban patches which supports species, but it is often accompanied by loss of habitat, hence attracting the question, is habitat fragmentation good for biodiversity? (Fahrig, 2018; Miller-Rushing, 2019).

The urban green patches are often categorized into city parks, wetlands, botanical gardens, golf courses and cemeteries (Silva *et al.*, 2015). They are significant as they filter pollutants and dust from the air, provide shade, lower temperatures and reduce erosion of the soil (De Toledo, Donatelli, & Batista, 2012; Threlfall & Kendal, 2017). Green patches also provide natural habitats for many different animal species which get displaced by urban expansion. City parks provide cultural services such as aesthetics, and recreation, which are important for human well-being (Rayner *et al.*, 2013).

Apparently several ecologists and conservationists have been arguing that fragmented patches have lower conservation value for species (Johnson, 2001; Gatesire *et al.*, 2014; Fletcher *et al.*, 2018; Miller-Rushing, 2019). Due to reduced space and increased isolation, patches may fail to sustain species population as compared to large protected areas (Burkey, 1989; Deshaye and Morisset, 1989). However, Fahrig, (2003, 2018; 2019) argued that fragmentation does not affect conservation of species or cause biodiversity loss, rather it increases the number of habitat patches where species can survive on. Therefore, protecting several small to medium-sized habitat fragments within managed landscapes might be a more effective strategy for biodiversity conservation (Miller-Rushing, 2019). Such arguments have led to the question of whether it would be beneficial for the conservation of species in one single large habitat or several small habitat patches (SLOSS) (Burkey, 1989; Deshaye and Morisset, 1989; Ovaskainen, 2002; Hokkanen, Kouki and Komonen, 2009; Tjørve, 2010).

The SLOSS debate is of great controversy due to different views and thoughts amongst ecologist, when it comes to conservation of habitats. Ecologist have tried to prove that habitat size has an effect on the conservation of species (Evans, Newson and Gaston, 2009; Johnson *et al.*, 2013; Silva *et al.*, 2015). Off late several studies have been supporting the fact that single large area supports greater value of species conservation as compared to several small patches (Lindenmayer *et al.*, 2015; Matthews, Cottee-Jones and Whittaker, 2016; Häkkilä *et al.*, 2018). Reasons being, there is reduced competition, reduced edge effect and increased habitat size (Häkkilä *et al.*, 2018). Still other studies have proven that more species are found in several small fragmented patches than in a single large protected area (Hokkanen, Kouki and Komonen, 2009; Tjørve, 2010; Fahrig, 2018). Although, the SLOSS debate has been addressed in a large number of empirical and theoretical studies, no clear conclusion has yet been reached (Hokkanen, Kouki and Komonen, 2009).Therefore, more research is needed to understand the SLOSS concept in varied environmental contexts in order to correctly inform conservation.

However, this project addresses the SLOSS debate in the context of bird diversity between a single large protected area (Chivero Recreational Park) and several small urban patches (Mukuvisi Woodlands, Cleveland Park, Harare Botanical Gardens, Harare Royal Golf Club, Africa Unit Square and Harare Gardens). Birds were selected as the target organism because they are sensitive to habitat changes and thus good indicators of ecosystem change (Imai, Nakashizuka and Oguro, 2017). This study aims to determine how bird diversity measures vary between a single large protected area and several small remnant urban patches. Precisely, the study attempts to answer the following questions: (1) which area support higher bird species richness, abundance and diversity between several small urban patches and a single large protected area? (2) Which area has the highest richness and abundance of bird functional groups?

1.2 PROBLEM STATEMENT

Large landscapes in urban areas are divided into smaller patches isolated from one another due to urban expansion. This causes undesirable effects on ecological environments such as habitat fragmentation and habitat loss. To date, no coherent conclusion has yet been reached on which one supports a greater conservation value between large protected areas versus several small patches. For this reason, important conservation purposes of habitats between large protected areas and several small patches remain relatively poorly understood.

1.3 JUSTIFICATION

Continuous urbanization is changing urban landscapes, increasing patch density and decreasing average patch size resulting in habitat loss and fragmentation. As a result of landscape changes, preservation of habitats to save as many species from extinction is a challenge (Tjørve, 2010). However, some ecologist and conservationist have argued that conservation of biodiversity should be based on habitat area. Therefore, they suggested that single large area are more appropriate for conserving species since they provide a large homogenous habitat for species as compared to several small patches. Whilst, Fahrig (2003, 2018), Fahrig *et al.*, (2019), Miller-Rushing (2019) and Tjørve, (2010) contradicts with the ecologist's and conservationist suggestion, arguing that several small patches (fragmented patches) can be used for conservation. Since, fragmented patches have an increased patch number and have different environmental setups which supports species with different habitat requirements. This study generates information on the importance of protecting a single large protected area versus several small remnant patches, and this information is critical for biodiversity conservation.

1.4 AIM

To determine bird species diversity between a protected area and remnant urban patches.

1.5 OBJECTIVES

- To determine bird species abundance, richness and diversity between a protected area and remnant urban patches.
- To determine bird functional richness and abundance in urban remnant patches and the protected area.
- To determine indicator species for the urban remnant patches and the protected area.

1.6 RESEARCH HYPOTHESIS

1. Bird species abundance, richness and diversity is expected to be highest in remnant urban patches. Urban areas offer a wide variety of patches for birds, for instance, backyard gardens, parks, cemeteries and woodland remnants (Threlfall and Kendal, 2017). Urban patches provide increased habitat diversity, higher spreading of risk and higher success of birds moving between patches (Fahrig et al 2019). Indeed, birds in urban areas do not only survive on natural food resources, they subsidize on supplementary food from home gardens and urban waste (Tryjanowski *et al.*, 2015).
2. Functional abundance, richness and diversity is expected to be higher in Lake Chivero and lower in urban patches. Urban areas usually have low availability of natural food resources, hence birds feed on supplementary food spread on the ground, households, restaurants or in litter bins (wastes) (Tryjanowski *et al.*, 2015). Therefore, mostly generalist species are often found to dominate in urban environments (Tryjanowski *et al.*, 2015).
3. Due to the presence of a large dam at Chivero Park, fish eating species are expected to have the largest indicator values while for the urban remnant patches species that scavenge from human generated waste are the expected indicators.

CHAPTER 2: LITERATURE REVIEW

2.1 BIRD

Birds are a group of endothermic vertebrates also known as Aves. They are found globally ranging in size from 5 cm (2 in) bee hummingbird to the 2.75 m (9 ft.) ostrich (Dorff, 2006). Also they are ranked the class of tetrapods with the most living species, at approximately ten thousand (Khatib and Serhal, 2016).

Bird species have wings giving most birds ability to fly, although some are flightless such as ducks and penguins (Dorff, 2006). In the avian family the non-flying birds and the duck have evolved to swimming making them species of the aquatic environment (Ramsey, 2010; Khatib and Serhal, 2016). However Ramsey, (1973) states that crows and parrots the most intelligent bird species in the avian taxonomy. Birds communicate with visual signs, sounds and bird melodies, in addition these visual signals, helps birds in breeding, hunting, flocking, and mobbing of predators (Whelan *et al.*, 2008).

Human activities have stirred up extinction of bird species since 17th century, and recent reports states that birds have gone extinct at an exceptionally high rate (G.Sibley and Burt L.Monroe, 2011). Today, one in eight bird species is threatened with global extinction, with 190 species critically endangered (Sekercioglu *et al.*, 2016).

2.2 ECOSYSTEM FUNCTIONS OF BIRDS

Birds exist throughout the globe (Aronson *et al.*, 2014). Birds are very important in the ecosystem they inhabit since they have various ecosystem functions (Whelan, Wenny.G. and Daniel, 2008). Their functions include, raptors, pollinators, scavengers, seed dispersers, and ecosystem engineers (Sekercioglu *et al.*, 2016)

Birds are bio indicators of a healthy environment (Tabur, 2000). Insectivore and raptors are essential for controlling disease and vectors. Pied Crow (*Corvus albus*), as scavengers they contribute to biomass recycling as well as reduce levels of disposable wastes (Whelan *et al.*, 2008). Also scavenging, is an important mechanism of waste disposal in many areas and prevents the outbreak of diseases that can occur through the accumulation of animal carcasses (Praveen and Nameer, 2015).

Frugivores birds are important for dispersal of seeds, after eating fruit, they carry the seeds in their intestines and deposit them in new places, these birds includes sunbirds, mockingbirds, orioles, and robins (Anderson *et al.*, 2018). Hence, such an activity improves genetic diversity of plants through dispersal. Plant pollination conducted by birds such as sunbirds humming birds and honey-eaters is also essential for plant growth (Tabur, 2013). They move pollen from flower to flower to help fertilize the sex cells and crossbreeding of flowering plants, (Gatesire *et al.*, 2014).

Birds are also involved in nutrient cycling, they exchange nutrients from place to place, this is very important for areas with inadequate nutrient availability for growth of plants (Whelan, Wenny.G. and Daniel, 2008). Mutualistic relationships between birds and wild animals is of great value to human beings. Some birds' perch on wild animals such as buffalo, elands and wildebeest in search of pests and insects that live on the animals an example of such birds is cattle egret (Tabur, 2013; Whelan *et al.*, 2008). This benefits the animals by removal of diseases causing parasites, at the same time supplying birds with readily available food source (Whelan *et al.*, 2008). Removal of parasites on animals lead to healthy and productive animals (Sekercioglu *et al.*, 2016).

2.3 HABITAT FRAGMENTATION

Land use change is impacting biodiversity across the planet, it has caused a decline in native vegetation such that most species depended on these woodlands now live in fragmented patches of degraded habitat (Fletcher *et al.*, 2018). Habitat fragmentation is the separation of a large, continuous habitats into a greater number of smaller patches of lower total area, isolated from each other by a matrix of dissimilar habitats (Johnson, 2001; Fahrig, 2003; Didham, 2004; Fletcher *et al.*, 2018). Fragmentation can occur naturally, as a result of fire or volcanic eruptions, but is mainly driven by human activities through urbanization, rural development, claiming new agricultural lands, logging and cutting down forests, construction of roads and railway tracks, development of housing projects and building water reservoirs. However fragmentation is not the key process operating in fragmented landscapes it is accompanied by habitat loss (Didham, 2004). As habitat fragmentation is associated with habitat loss it causes loss or reduction of total habitat area, reduction in habitat quality and increased extinction risk (Zaviezo, Grez, S, & Pérez, 2003). However fragmented patches are also important as they have a potential to increase species diversity as they shape speciation and evolution (Johnson, 2001). Geographical and reproductive isolation triggered by fragmentation leads to allopatric speciation, diversifying landscapes.

Subdivision of the same amount of habitat into many smaller pieces enhances the persistence of a predator-prey system (Fahrig, 2003).

2.4 FACTORS INFLUENCING BIRD DIVERSITY

Bird diversity is usually based on habitat selection, birds species are exposed to a variety of habitats of which just one is chosen for residence (Stephen D. Fretwell, 2014). However birds such as the sparrows are more abundant at locations with a high level of food spillage. Several studies proved that food abundance directly influence bird population distributions (Lancaster and Rees, 1979; BioScience, 2006; Kumar, P, Gupta, 2009). Other studies carried out shows that reduced food availability leads to lower genetic diversity, which further might reduce the viability of bird populations (Tonglei Y, 2013).

Imai, Nakashizuka, & Oguro, (2017) states that vegetation on its own also affect bird diversity, that is, high vegetation cover and more complex vegetation structure. They have a significantly positive impact on avian communities. Mature vegetation provides a natural barrier between birds and pedestrians, which reduces the negative impact of human disturbance on urban birds, assisting their ability to adapt to urban environments (G.Bideberi, 2013).

Climate change is driving significant changes in the phenology, distribution and abundance of several bird species (Oindo, By and Skidmore, 2001). Several tropical or sub-tropical seabird species, have suffered major declines due to rising sea temperature and increasingly intense El Nino events (BioScience, 2006). Climate change is also likely to exacerbate other threats such as habitat loss and invasive species. For example, eucalypt woodlands are threatened by more frequent fires which will facilitate habitat fragmentation therefore reducing habitats for several bird species (Low, 2007).

Reduction in area of a habitat patch can decrease its suitability for bird species to survive (Johnson, 2001; Fletcher *et al.*, 2018). It is obvious that the numbers of a species are likely to decline if its habitat is reduced due to fragmentation. There are some large-bodied birds with large territorial requirements, such as the northern harrier (*Circus cyaneus*) therefore once an area is fragmented due to human or natural activities, their survival is reduced (Johnson, 2001).

Abundance and richness of bird species is also affected by migration (Lawrence J. Nies, Joanna Burger, 2019). many bird species migrate between the northern or southern parts of the continent and equatorial regions to take advantage of seasonal rains and food abundance during both their breeding and non- breeding seasons an example of trans-equatorial migrants include northerly breeders such as Abdim's Storks (*Ciconia abdimii*) and southerly breeders such as Lesser Striped Swallows (*Hirundo abyssinica*) (Turpie, 2015).

2.5 SPECIES DIVERSITY

Is a combination of the number of species and their relative abundance (Bibi and Ali, 2013a). Species diversity is a measure of diversity that incorporates both the number of species in an assemblage and some measure of their relative abundances. Many species diversity indices can be converted by an algebraic transformation to Hill numbers (Gotelli, Nicholas J, 2013).

2.6 SPECIES ABUNDANCE

Species abundance is an ecological concept that refers to the relative representation of species in a particular ecosystem, it is usually measured as the large number of individuals found per sample (Gray, Anderson and Benecha, 2007).

2.7 SPECIES RICHNESS

The total number of species in an assemblage or a sample (Student Handout, 2013). The number of species per sample is a measure of richness. The more species present in a sample, the 'richer' the sample. Apparently, species richness in an assemblage is difficult to estimate from sample data because it is very sensitive to the number of individuals and the number of samples collected. Species richness is a diversity of order 0 meaning it is completely insensitive to species abundances (Gotelli, Nicholas J, 2013).

CHAPTER 3: METHODOLOGY

3.1 DESCRIPTION OF STUDY AREA

The study was carried out in Harare, the capital city of Zimbabwe and Chivero Park (Fig 3.1). Harare, is situated in north eastern part of Zimbabwe at an elevation of 1.483m above sea level (Chigumira *et al.*, 2014). The city lies on the coordinates17º 49' south and 31º 02' east. Harare experiences hot wet season from November to April, a cool dry season from May to July and a hot dry season from August to October. Harare has a temperature range between 10ºC and 30ºC and receives a mean annual rainfall between the range 600mm and 855mm (Muronda, 2008). The geology constitutes rocks of the igneous and metamorphic origin with granite being the dominant rock. Harare constitutes of paraferrallitic soils, which are rich in potassium, heavily leached, with low fertility and have substantial amounts of coarse sands and inert clay (Broderick, 2012). Vegetation type in Harare is characterised by miombo woodlands mainly *Brachystegia spiciformis, Julbernardia globiflora, and Parinari curatellifolia,* and there are some exotic species such as *Jacaranda mimosifolia* and some varsity grasslands dominated with *Heteropogon contortus* and *Hyparrehenia filipendula*.

Lake Chivero park is located in Zvimba District, which is 35 km south-west and downstream of Harare (Nhapi, 2009). The park lies 17° 54′ south and 30° 15' east. The park is 6100 ha including the lake (Wetlands, 2008). The park experiences hot wet summers and very cold winters, sometimes it rains in winter. The mean annual rainfall ranges between 700mm and 830mm (Nhapi, 2009) and temperature range between 13ºC and 29°C (Magadza, 2018). The park is dominated by *Brachystegia* woodland or miombo woodland. The dominant tree species are *Brachystegia spiciformis,* and *Julbernardia globiflora* scattered with *Terminalia sericea, Parinari curatellifolia* and *Monotes glaber*. The park is a home to over 400 bird species including migratory birds, over 22 mammals, 26 species of fish in the Lake, including five exotics then it is also home to crocodiles and water monitors, the largest lizard found in Zimbabwe (Wetlands of Zimbabwe, 1975).

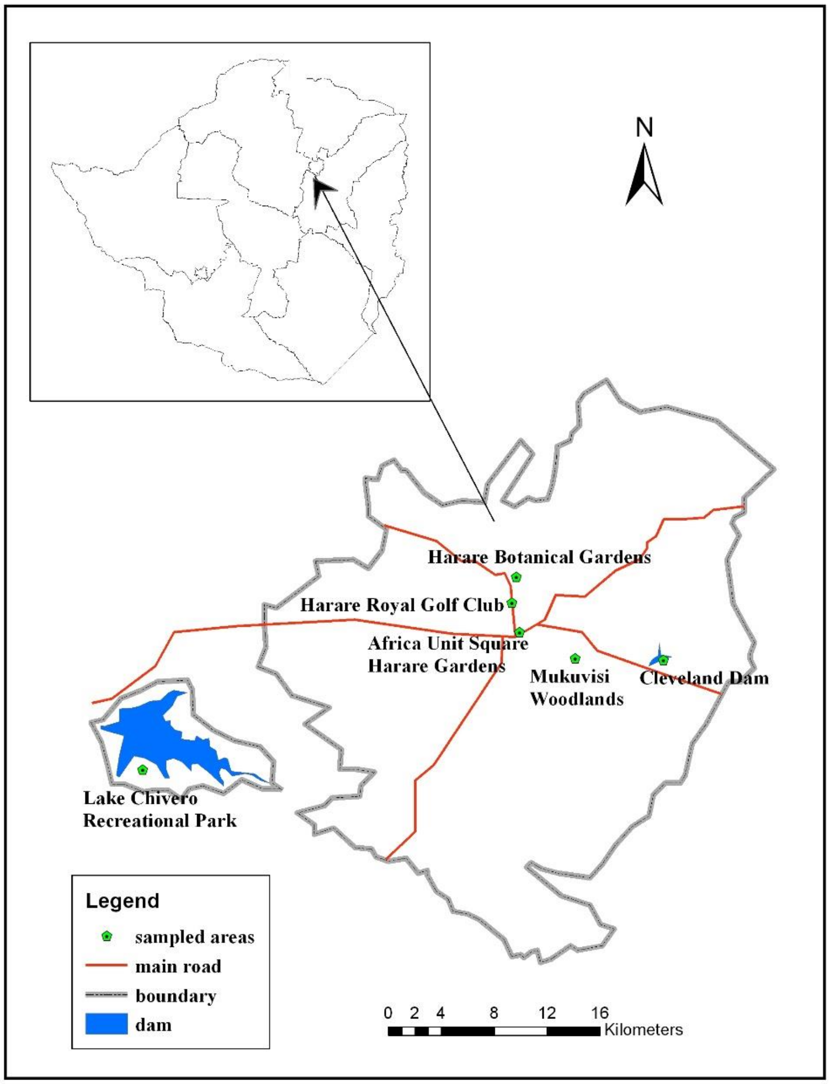

Figure 3. 1: Map showing location of the study sites, Harare and Lake Chivero Recreational Park.

3.2 DATA COLLECTION METHOD: BIRD SURVEY

Field investigations were conducted between the months of November 2018 and February 2019 which is a hot wet season in Zimbabwe. The study targeted this specific period in order to capture both resident and migratory species because that's the time when European migrants are around (Turpie, 2015). A total of 60 sampling points were surveyed between Harare and Chivero Park. Thirty points were marked in Chivero Park and the other thirty points in the remnant patches in Harare (Fig 3.2). Sampling points were randomly marked considering a minimum distance of at least 300m from each other (Ortega-Alvarez and MacGregor-Fors, 2009). Bird surveys were conducted early in the morning, between 06:00-9:30 am when birds are highly active which helped detection, lasting for three and a half hours from sunrise (Rayner *et al.*, 2013; Suri *et al.*, 2017). Counting at each point involved a five minutes habituation time which was followed by a 15 minutes counting time of all the birds in a radius of 150 m (Suri *et al.*, 2017). All the bird species that were seen or heard within the radius were recorded and a bird expert was present during the data collection period to identify bird species. A 10 x 50 pair of binoculars and a field guide book to birds of Southern Africa was used to identify some of the species that where not easily recognized (Chittenden *et al* ,2016).

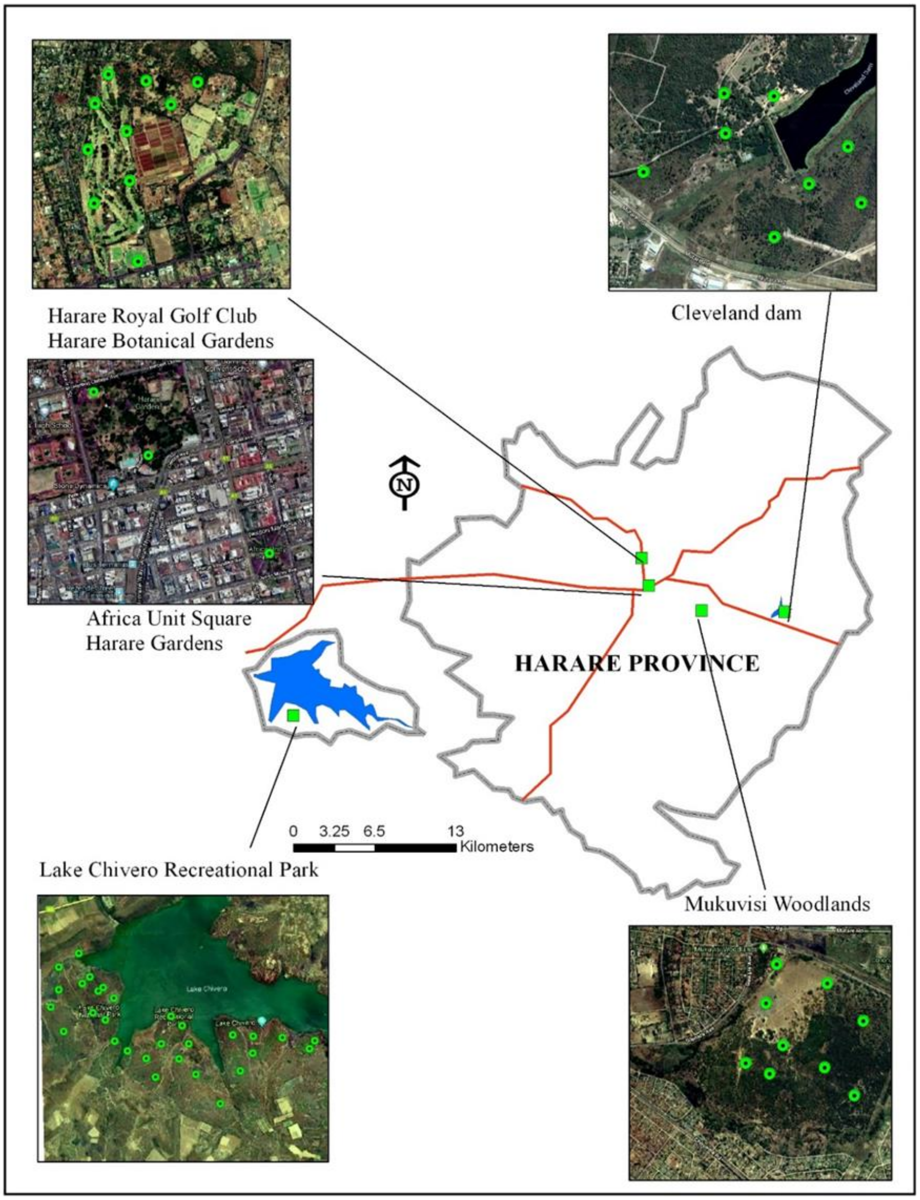

Figure 3. 2: The map is showing all the 60 sites that where sampled, 30 points in Lake Chivero and 30 points in remnant urban patches in Harare.

3.3 BIRDS ECOLOGICAL FUNCTIONAL GROUPS

Functional groups are aggregated units of species sharing an important ecological characteristic, playing an equivalent role in the community and showing either similar responses to the environment or similar effects on major ecosystem processes (Rayner *et al.*, 2013; Esler and Rebelo, 2014; Imai, Nakashizuka and Oguro, 2017; Mulwa, Böhning-gaese and Schleuning, 2019). All the birds identified across the study sites were categorized into nine ecological functional groups according to what they eat and their role in the environment using a bird field guide (Chittenden *et al* ,2016). A complete list of all the observed species and their assigned functional groups is provided in Appendix 2. The bird's ecological functions across the sites was compared with the functional groups found in the whole of Southern Africa (Table 3.1).

Table 3. 1: The table is showing nine ecological functional groups according to their description, function and codes categorized by bird field guide (Chittenden., *et al* (2016).

Code	Function	Description
F1	Insectivore	Insect dependent birds
F2	Seed dispersers	Birds that depend fruits such that they carry the seeds in there digestive tract, then they come out as droppings.
F3	Granivores	Birds that eat grain and seeds
F4	Raptors	Birds that hunt and feed on vertebrates that are large relative to the hunter
F5	Pollinators	Birds that like eating nectar
F6	Scavengers	Birds that feed on dead carcasses
F7	Nutrient movers	Aquatic birds which move between land and water transporting nutrients between the two habitats
F8	Grazers	Grass eating birds
F9	Ecosystem Engineers	Birds that dig burrows or cavities creating habitats for other species

3.4 DATA ANALYSIS

All analyses were performed in R software, version 3.4.1. Firstly data was tested for normality between the sites using quantile-quantile plots (Q-Q plots) (Appendix 1). *iNEXT* an R package was used to compare bird species richness and diversity. *iNEXT* produces rarefaction and extrapolation sampling curves for the three most widely used members of the Hill numbers family (species richness(S), Shannon diversity(H) and Simpson diversity (D)) (Hsieh et al., 2016). Hill numbers are used to characterize abundance based species diversity and richness of an assemblages (Hsieh, Ma and Chao, 2016). They are parameterized by a diversity order q, which determines the measures' sensitivity to species relative abundances that incorporate species richness and relative abundances (Chiu & Chao, 2014). The Shannon-Wiener and Simpson Index evaluate the bird species diversity (Bibi and Ali, 2013b). Hill numbers include the three most widely used species diversity measures as special cases: species richness (q = 0), Shannon diversity (q = 1) and Simpson diversity (q = 2) (Ban˜os, 2006).

Species richness is defined by the order q = 0, which counts species equally without regard to their relative abundances (Hsieh, T.C, Ma K.H, Chao, 2016), Shannon Weiner Index , in this case it is Shannon diversity (q=1) assumes that individuals are randomly sampled from an independent large population and all the species are represented in the sample (Bibi & Ali, 2013). It also calculates the species diversity in different habitat based on the abundance of the species. Simpson diversity, q=2 gives more weight to common or dominant species (Bibi & Ali, 2013). In this case, a few rare species with only a few representatives will not affect the diversity (Student Handout, 2013). Formula for Species Richness, Shannon Weiner and Simpson Diversity are as follows:

$\boldsymbol{Species\ Richness\ equation}$:

$$ {}^{q}\boldsymbol{D} = \left(\sum_{\boldsymbol{i=1}}^{\boldsymbol{S}} \boldsymbol{p_i^q} \right)^{\boldsymbol{1/(1-q)}} $$

Therefore: *S*-the total number of species in the assemblage

p_i -species relative abundance

Σ -sum of the calculations

q-Determines the sensitivity of the measure to the relative frequencies (q=1)

$$\boldsymbol{Shannon\,Weiner\,equation}: \qquad {}^{1}D = \lim_{q \to 1} {}^{q}D exp\left(-\sum_{i=1}^{s} p_i\right)$$

Therefore: D- species in proportion to their frequency

Σ - Sum of the calculations

S - The total number of species in the assemblage

p_i - The proportional abundance of species *i* in the sample

q - Sensitivity of the measure to relative abundance (q=1)

$$\boldsymbol{Simpson\ diversity\ equation}: \qquad {}^{2}D = \frac{1}{\sum_{i=1}^{s} p_i^2}$$

Therefore: Σ = sum of the calculations

S - The total number of species in the assemblage

p_i - The proportional abundance of species *i* in the sample

q - Sensitivity of the measure to relative abundance (q=2)

One-way analysis of similarity (ANOSIM) was performed to test for significant differences in assemblage composition between sites. ANOSIM produces an R-statistic value ranging from 0 to 1 as a measure of similarity between assemblages the closer this value is to 1, the more dissimilar the assemblages are (Davies, Eggleton, Rensburg, & Parr, 2015). An associated *p* value indicates whether the R-statistic is significant (Wenny *et al.*, 2011). Non-metric multidimensional scaling (NMDS) ordinations were then constructed to visually display patterns of species composition and birds ecological functional composition between the two study sites (Wenny *et al.*, 2011; Davies *et al.*, 2015). An independent t-test was used to determine whether there was a statistically significant difference in bird functional richness and abundance between the study sites. Analyses of indicator species was performed to determine bird's species for each site. They were identified using the indicator value (*IndVal*) method in R package *indicspecies*. This technique assesses specificity (uniqueness to a particular habitat) and fidelity (frequency of occurrence in that habitat) of a species to a particular habitat (McGeoch et al. 2002). Species with significant indicator values ≥60% were classified as indicators for each site (Davies *et al.*, 2015).

CHAPTER 4: RESULT

4.1 GENERAL DESCRIPTION

Across the 60 sites, 2612 birds from 138 species were recorded. A full list of all species, and their Latin names, is provided in Appendix 2. Between sites, Harare had the highest species abundance with 1324 and Chivero Park 1 288 (Table 4.1). African black swift (*Apus Barbatus)* with 22%, followed Grey-rumped Swallow (*Pseudhirundo griseopyga*) with 15% then African Fish Eagle (*Haliaeetus vocifer)* with five percent followed by Willow Warbler (*Phylloscopus trochilus*) with four percent and lastly Black-backed puff back (*Dryoscopus cubla)* with three percent were found to be the most abundant species in Chivero Park, while in Harare Pied Crow (*Corvus albus*) with 16% abundance followed by Feral pigeons (*Columba livia domestica*) with four percent then Dark capped bulbul (*Pycnonotus tricolor*) with nine percent , Abdm's Stork (*Ciconia abdimii*) with four percent and lastly Streaky-headed seedeater (*Crithagra gularis*) with five percent were the most abundant.

Table 4. 1: Table showing bird species richness and abundance between study sites.

Measures	**Chivero Park**	**Harare**
Number of species (S)	99	97
Number of samples (n)	30	30
Number of individuals (N)	1288	1324

4.2 TAXONOMIC DIVERSITY

4.2.1 SPECIES RICHNESS, DIVERSITY AND SAMPLE COVERAGE

The two study site had similar species richness, q = 0 (Fig 4.1a, left panel). For Shannon diversity (q =1) and Simpson diversity (q = 2), Harare was more diverse as compared with Lake Chivero. Sampling was complete for the two study sites (Fig 4.1b). After sampling about 35% of the points at each site, Harare had a higher species richness compared with Chivero, but after covering 80% of the points species richness was similar (Fig 4.1c, left panel). After sampling 25 and 35 % of the points, Harare had a significantly higher Shannon (q = 1) and Simpson (q = 2) diversity indices (Fig 4.1c, middle and right panels, respectively).

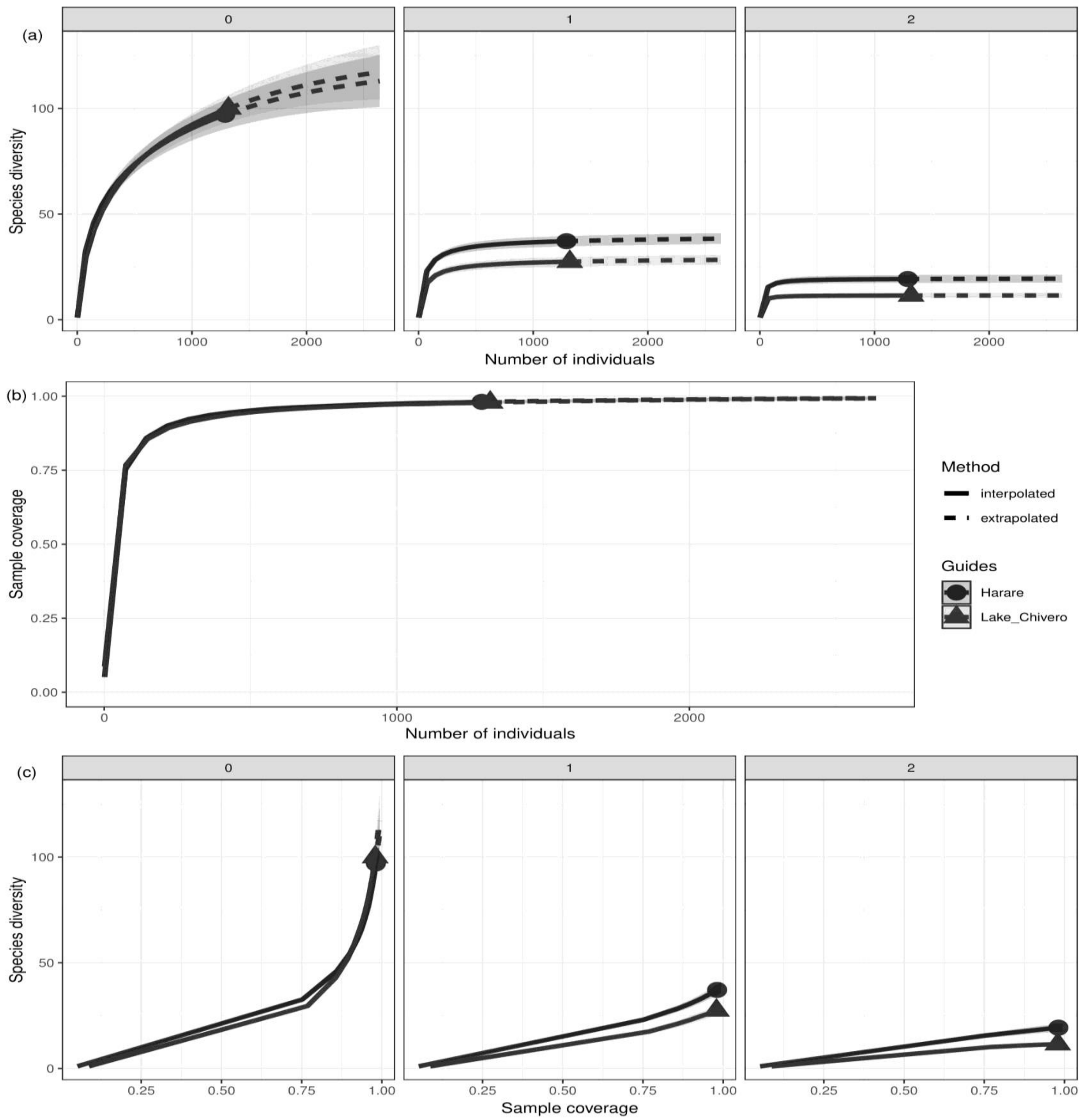

Figure 4. 1:Two types sampling curves for comparing bird species diversity based on abundance data from study sites: a) Sample-size-based R/E curve showing the relationship between species diversity and bird abundance for order q=0 (left panel), q=1 (middle panel), and q=2 (right panel) (c) Coverage-based R/E curve for the measure of species diversity with respect to sample coverage for order q=0 (left panel), q=1 (middle panel), and q=2 (right panel). The diversity estimates are computed at 95% confidence interval (shaded area). The solid dot represents the reference sample. (b) Sample completeness curves linking curves in (a) and (c)

4.2.2 SPECIES ABUNDANCE

Bird taxonomic abundance was significantly higher *($t = 0.062561$, $df = 272$, $p = 0.04$)* in Harare compared with Chivero (Fig 4.2).

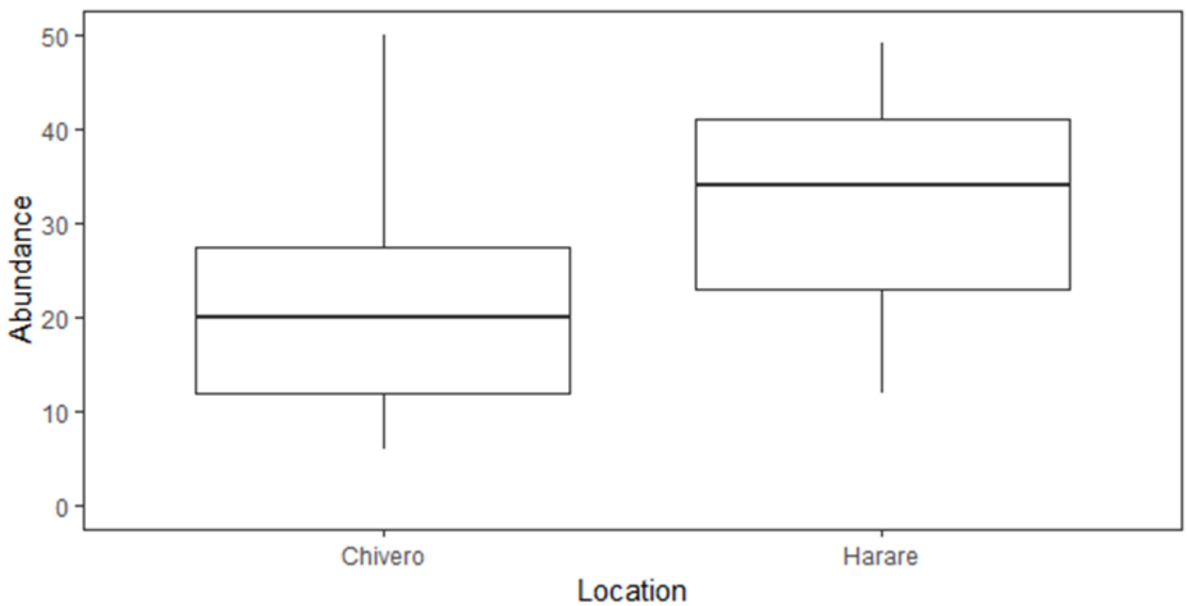

Figure 4. 2: Box plot of mean ± SE abundance of birds recorded at Chivero and Harare.

4.2.3 SPECIES ASSEMBLAGE COMPOSITION

Analysis of similarities revealed that there was a significant dissimilarity in bird species assemblages between Chivero and Harare (R = 0.6362). Sampling points from the two study sites visually displayed separately in the nMDS diagram (Fig 4.3). Sampling points within Harare are widely spaced indicating a high variability in bird species composition among sites (Fig 4.3).

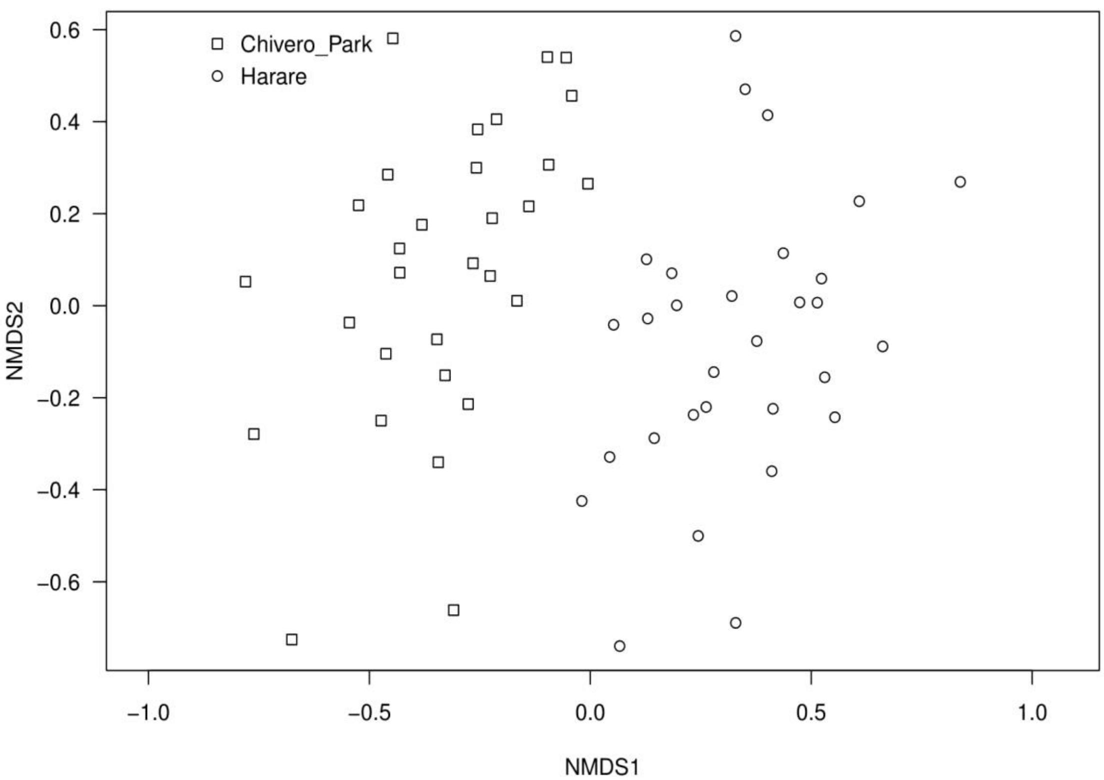

Figure 4. 3: Non-metric multi-dimensional scaling ordination of bird species assemblages sampled between Chivero Park and Harare.

4.3 FUNCTIONAL TRAITS

4.3.1 BIRDS ECOLOGICAL RICHNESS

All the nine bird functional groups that are found in Southern Africa where also found across the study sites (Figure 4.4). Insectivore, seed dispersers, raptors, granivores and nutrient movers were the most common functional groups across all the study sites similar to Southern Africa. Nutrient movers had higher proportion for Southern Africa compared with Chivero Park and Harare. Scavengers had higher proportion in Harare compared with Southern Africa and Chivero Park. Southern Arica had higher proportion of ecosystems compared to Chivero Park but, ecosystem engineers were absent from Harare.

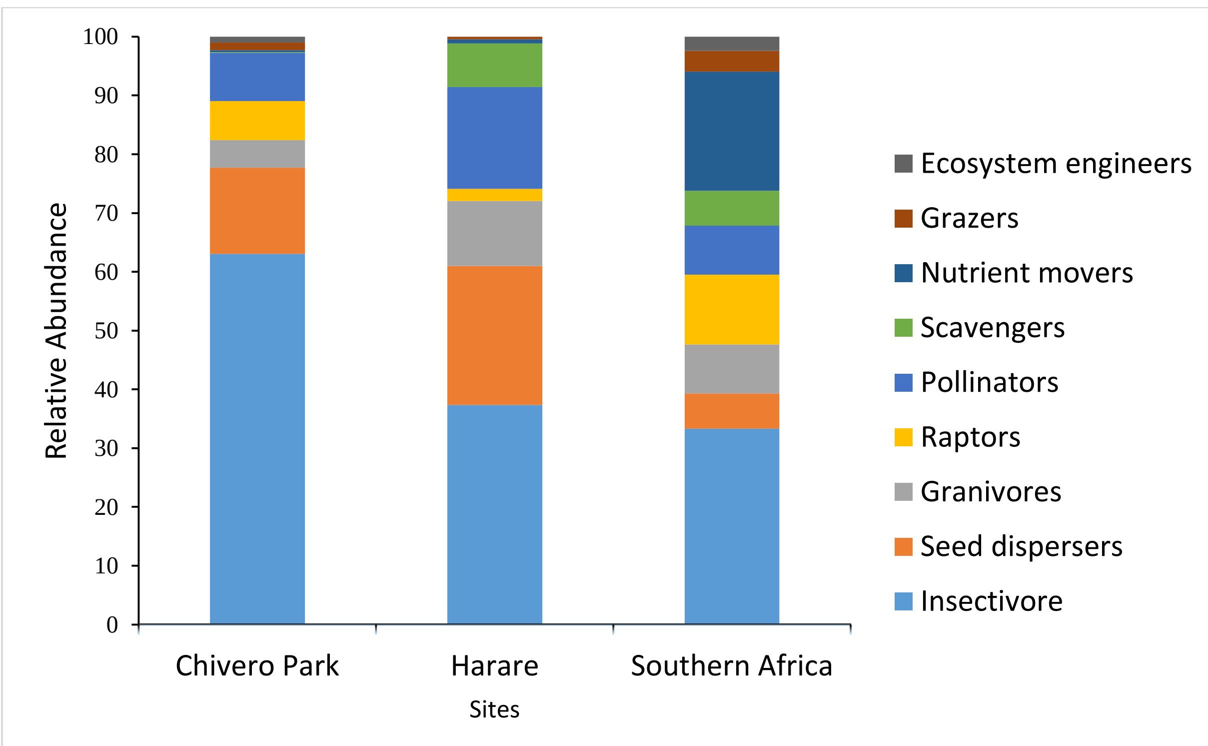

Figure 4. 4: Bird functional groups for species recorded at Chivero Park and Harare and all species in Southern Africa.as per Cumming G.S, & Child, M. F. (2009). Some bird species fall in more than one ecological functional group.

4.3.2 RICHNESS AND ABUNDANCE OF BIRD'S ECOLOGICAL FUNCTIONAL GROUPS.

Analysis of similarities revealed that there was no significant dissimilarity between functional abundance in Chivero and Harare (R=0.204) (Fig 4.5a). Moreover, there was significant difference of functional abundance between Chivero and Harare (*R* =0,562) (Fig 4.5b). NMDS showed that the two sites were different for the functional species richness (Fig 4.5a). Furthermore, the functional abundance of the species was also different between the two sites (Fig 4.5b). There was no significant difference in bird functional abundance *(t = -1.465, df = 58, p = 0.148)* between Chivero and Harare (Fig 4.6a). However, bird functional richness was signifi cantly higher *(t = -3.9958, df = 58, p = 0.000184)* in Harare compared with Chivero (Fig 4.6b).

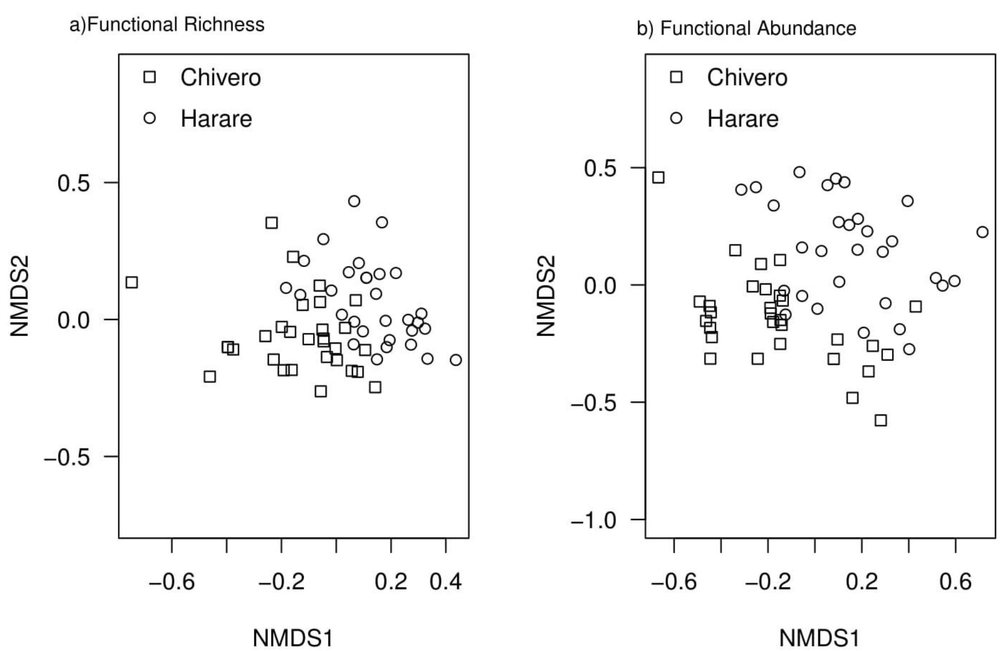

Figure 4. 5: Non-metric multi-dimensional scaling (nMDS) ordinations of richness and abundance of bird's ecological functional groups assemblages across the sites.

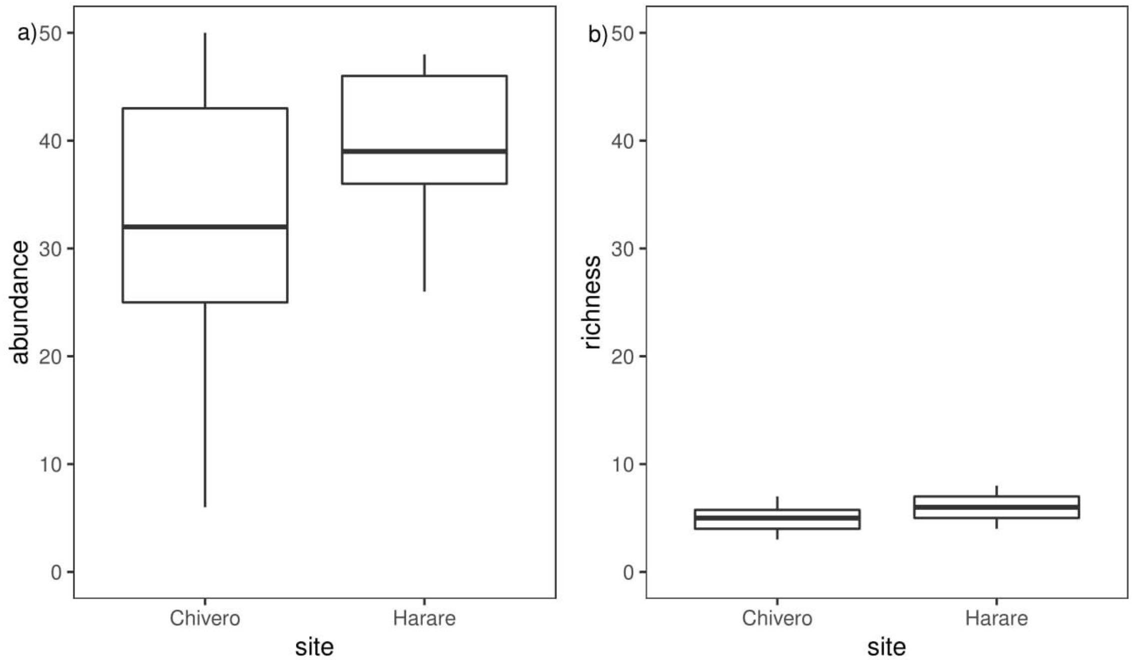

Figure 4. 6: Box plot of mean ± SE functional richness and abundance of birds recorded at Chivero and Harare.

4.4 INDICATOR SPECIES

Lake Chivero had four indicator species whilst Harare had eight indicator species that scored indicator values > 60% (Table 4.2). African Fish Eagle (*Haliaeetus vocifer*) was the strongest indicator for Lake Chivero followed by the Willow warbler *(Phylloscopus trochilus)* and Black backed-puff (*Dryoscopus cubla)* (Table 4.2). The top indicators for Harare that scored indicator values > 60% are Pied crows (*Corvus albus),* Streaky headed seedeater (*Crithagra gularis),* and Abdm's Stork (*Ciconia abdimii)* (Table 4.2).

Table 4. 2: Indicator species identified for Lake Chivero and Harare with significant indicator values above 60%, a perfect indicator is 100% although there are no indicator species which are perfect.

Site	**Bird Species**	**Scientific names**	**Indicator Value (%)**
Chivero Park	African Fish Eagle	*Haliaeetus vocifer*	84
	Black backed puff-back	*Dryoscopus cubla*	82
	Willow warbler	*Phylloscopus trochilus*	73
	White bellied sunbird	*Cinnyris talatala*	67
Harare	Pied Crow	*Corvus albus*	89
	Streak headed seed eater	*Crithagra gularis*	76
	Abdm’s stork	*Ciconia Abdimii*	71
	Blue waxbill	*Uraeginthus angolensis*	69
	Purple crested Lorie	*Gallirex porphyreolophus*	68
	Red eyed dove	*Streptopelia sermitorquata*	66
	Huglin’s Robin	*Cossypha heuglini*	69
	Kurrichane Thrush	*Turdus Libonyana*	68

Chapter 5: DISCUSSION

The study has revealed that current wildlife conservation efforts do not coincide with areas of the highest bird abundance and diversity. Species diversity and abundance was higher in remnant urban patches (Harare) compared with the single large protected area (Lake Chivero), currently receiving conservation efforts. These results corroborate some previous studies that found small patches harboring higher species diversity compared with single large protected areas (Ovaskainen, 2002; Tjørve, 2010; Fahrig, 2018; Häkkilä *et al.*, 2018). However, species richness was similar between the two conservation areas.

Bird taxonomic diversity was higher in Harare than in Chivero, this was a result of high abundance of generalist species contributing to the high diversity. In different studies similar findings were attributed to relatively high number of nonnative species specifically migratory birds present in urban areas and probably because it was breeding season (Häkkilä et al., 2018; Imai et al., 2017; Yuan & Lu, 2016), although it was not investigated in this study. Lack of difference in bird richness between the two sites is an indication that birds can equally survive in the two environments and probably due to the mobility of birds the two sites can interchange species (Zakaria, Rajpar and Sajap, 2009). Indeed, the sampled patches in Harare and Chivero were all of the same physiognomic type, the miombo woodland, dominated by trees of the family *Caesalpinioideae*.

Higher bird abundance in Harare patches than Chivero is attributed to difference in habitats (McKinney, 2006; Silva *et al.*, 2015). Remnant urban patches are surrounded by suburbs with a great floristic diversity accompanied by mixed plant species, natives and exotics, shrubs and large trees (Tryjanowski *et al.*, 2015). This provides important stimuli for bird life such as fruits, seeds, nectar, domestic residues, insects and small mammals (Gatesire *et al.*, 2014). Hence bird species with different habitat requirements made use of this great diversity in floristic composition in urban areas (Yuan and Lu, 2016). Abundance is likely to be explained by availability of supplementary food sources in urban patches which supports a greater number of generalist birds such as Pied Crow *(Corvus albus*) that eat different kinds of food, from insects to seeds and trash (Wilkinson and Christine, 2010).

Functional richness composition varied slightly between Harare and Chivero. The sites revealed to be rich in functional composition, recording all the functional groups that are found in Southern Africa (Rayner *et al.*, 2013; Praveen and Nameer, 2015; Girma *et al.*, 2017). Diverse vegetation in

Lake Chivero had a strong and pervasive effect on species functional richness and abundance (Girma *et al.*, 2017). This led to the occurrence of all the nine functional groups found in Southern Africa. Functional groups such as insectivore, grazers, and raptors were the most abundant at Lake Chivero. This was a result of large forested area, which contained microhabitats for insects, such as streamside areas, woodlands and grasslands as compared to remnant urban patches. Thus favoring insectivorous bird species which eat insects like mosquitoes, larvae, ants, parasitoids, dung beetles, pollinating bees and wasps (Zakaria, Rajpar and Sajap, 2009). Raptors, such as falcons and other birds of prey where also abundant in Chivero. Probably because these species prefer an environment with no shrubs and also open areas and grasslands (Imai, Nakashizuka and Oguro, 2017). These habitats facilitate easy detection of prey, just like the African fish eagle these species where found in low numbers in urban remnant vegetation patches due to low or insufficient food availability to support their diets. The lake in the protected area attracted nutrient movers, a functional group consisting primarily of aquatic birds such as African wattled Lapwing *(Vanellus senegallus)* and Southern Masked weaver (*Ploceus velatus)* and also plenty grazer species, a functional group which relies more on water bodies.

Eight functional groups were then recorded in Harare excluding ecosystem engineers, an observation consistent with other studies (Zakaria, Rajpar and Sajap, 2009; Gatesire *et al.*, 2014; Seress, 2015). Presents of fruiting trees, nectar producing flowers and seasonal flowering plants in remnant urban patches provided food that attracted frugivores, seed dispersers, insectivore and omnivorous birds such as pigeons, sunbirds, bulbuls, orioles and starling (Clergeau *et al.*, 2007). However, existence of a variety of functional groups is not only a good indicator of the health of a biotic community, but it signifies the degree to which various ecological functions are being performed across the sites (Suri *et al.*, 2017).

Few species emerged as indicators for single large protected area (Table 4.2). The availability of water within Chivero Park was positively related to water bird abundance. Therefore, fish eating species such as African fish eagle (*Haliaeetus vocifer*) were the most common in Lake Chivero Park. Occurrence of the African fish eagle was associated with open woodlands near the lake and alongside the lake shore, where this species can easily perch during hunting (Beadell *et al.*, 2009). Whilst in remnant urban patches, the pied crow (*Corvus albus*) which is a generalist species was the most common species in Harare. Its occurrence is likely explained by its ability to adapt to human dominated landscapes (Gatesire *et al.*, 2014; Yuan and Lu, 2016). This finding was similar to findings by Gatesire *et al* (2014). Unlike many other bird species in the area the pied crow was observed in every vegetation patch. In addition, pied crows were found in high abundance where its food sources, including small reptiles, small mammals, grain, peanuts, carrion, scraps of human food, fruits, insects, and other small invertebrates, were most available (Gatesire *et al*., 2014).

The study findings expand the growing observation that several small patches can conserve more species compared with single large protected areas. This study shows the importance of protecting not only the large homogenous habitats but also remnant patches that have proved to be important hosts of biodiversity, birds in particular in this case.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSION

The study findings confirmed that several small patches had higher species diversity and abundance compared with single large protected area, although species richness was similar between the study sites. Apparently food availability and heterogeneous habitats in remnant urban patches supported this results as it accommodated several species populations with different habitat requirements (Tryjanowski *et al.*, 2015; Yuan and Lu, 2016). Bird functional richness varied between Chivero Park and Harare. Functional richness in Chivero Park was represented with all the nine functional groups found in southern Africa while eight functional groups where observed in Harare, excluding ecosystem engineers. African Fish Eagle, fish eating species had the largest indicator value at Chivero Park a result that is attributed to presence of a lake its primary food source. Pied Crow was most popular in remnant urban vegetation patches as generalist species that easily adapt to human populated environments (Gatesire *et al.*, 2014). They also scavenge from human generated waste. Furthermore, study findings emphasizes that patch size should not be used as a sole indicator of biodiversity conservation importance of an area. It is therefore essential to conserve both single large and several small patches to cover species diversity and to maintain viable populations of different plant and animal species.

6.2 RECOMMENDATIONS

1. Vegetation patches in urban areas should be governed by environmental laws so as to encourage conservation and preservation of biodiversity.
2. Urban vegetation patches should be left unaltered when land is prepared for development in urban areas because they maintain biodiversity and environmental processes.
3. Formation of a cooperation among different stakeholders which involves ecologists, land surveyors, municipal council, social scientists, environmentalists, communities and biologist is required to ensure conservation of species within urban remnant urban patches.

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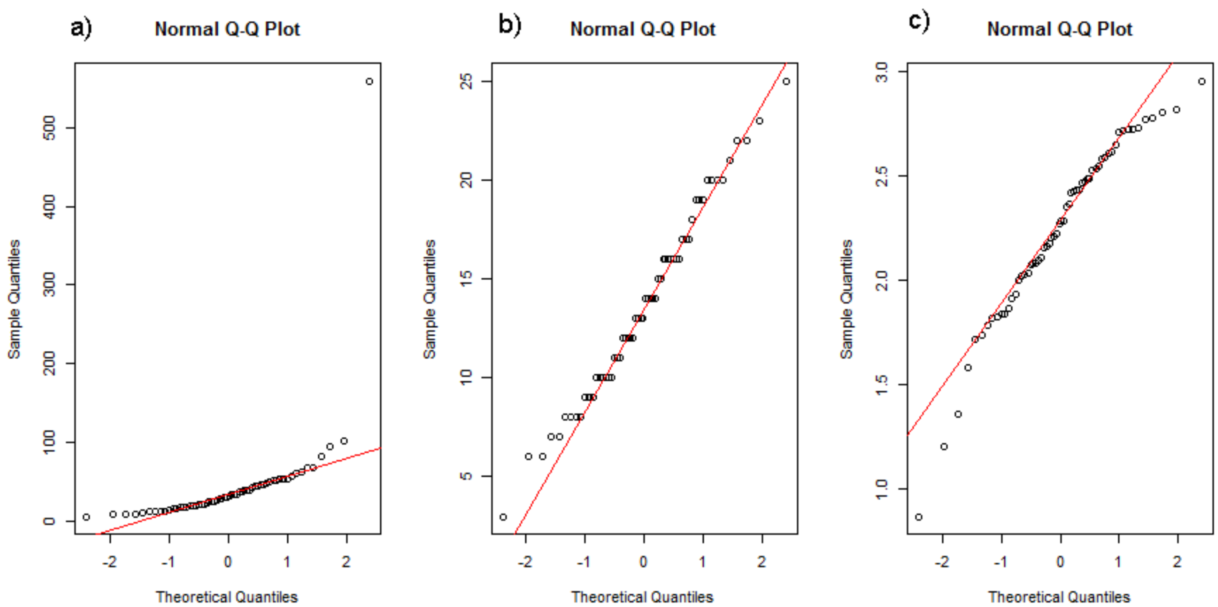
APPENDICES

Appendix 1. Q-Q Plots showing data normality of bird species across the study sites (a) abundance, (b) richness and (c) diversity.



Appendix 2. A lists of all the observed bird species that contributed to differences in species richness between Chivero Park and Harare. Functional Groups: FG1-Insectivores, FG2-Seed dispersers, FG3-Granivores, FG4-Raptors, FG5-Pollinators, FG6-Scavengers, FG7-Nutrient movers, FG8-Grazers and FG9-Ecosystem engineers.

Bird Species	**Scientific names**	**Site**	**Functional groups(FG)**
Abdm's Stork	*Ciconia abdimii*	Harare	FG1
African black swift	*Apus Barbatus*	Chivero, Harare	FG1
African Couckoo Hawk	*Aviceda cuculoides*	Harare	FG1
African Fish Eagle	*Haliaeetus vocifer*	Chivero	FG4
African Golden Oriel	*Oriolus aurutus*	Chivero, Harare	FG1,FG2,FG3,FG8

African Grey Hornbill	*Lophoceros nasutus*	Chivero, Harare	FG1,FG2,FG4
African Hoopoe	*Upapa africana*	Chivero	FG1
African Jacana	*Actorphilornis africarnus*	Chivero	FG1
African mash Warbler	*Acrocephalus baeticatus*	Harare	FG1
African openbill stork	*Anastomus lamelligerus*	Chivero, Harare	FG1
African Palm Swifts	*Cypsiurus parvus*	Harare	FG1
African paradise Fly Catcher	*Terpsiphone viridis*	Chivero, Harare	FG1
African sacred ibis	*Threskiomis aethiopicus*	Harare	FG1
African sedge warbler	Acrocephalus schoenobaenus	Harare	FG1
African spotted creeper	*salpornis salvadori*	Harare	FG1
African Stone chat	*Saxicola torquatus*	Harare	FG1
African wattled lapwing	*Vanellus senegallus*	Harare	FG1,FG7
African yellow white-eye	*Zosterops senegalensis*	Chivero, Harare	FG1,FG2,FG3,FG8
Amethyst Bulbul	*Pycnonotus barbatus*	Chivero	FG1,FG2
Amur Falcon	*Falco amurensis*	Harare	FG1,FG4
Arrow-marked babblers	*Turdoides jardineii*	Chivero, Harare	FG1,FG2,FG4,FG5
Ayres Cisticola	*cisticola ayresii*	Chivero	FG1
Bar-throated Apalis	*Apalis thoracica*	Chivero, Harare	FG1
Black Crake	*Amaurornis flavirosta*	Chivero, Harare	FG1,FG2,FG3FG4,FG8
Black crowned tchagra	*Tchagra senegalus*	Chivero, Harare	FG1,FG4
Black headed oriole	*Oriolus larvatus*	Chivero	FG1,FG2,FG5
Black shouldered kite	*Elanus caeruleus*	Harare	FG4
Black Sunbird	*Leptocoma aspasia*	Chivero, Harare	FG1,FG2,FG5
Black-backed Puff back	*Dryoscopus cubla*	Chivero, Harare	FG1,FG2
Black-collard Barbet	*Lybius torquatus*	Chivero, Harare	FG2
Black-throated canary	*Crithagra atrogularis*	Chivero, Harare	FG1
Blue wax bill	*Uraeginthus angolensis*	Chivero, Harare	FG1,FG3
Broad-billed Roller	*Eurystomus glaucurus*	Chivero	FG1
Brown hooded Kingfisher	*Halcyon albiventris*	Chivero, Harare	FG1,FG4

Brown Snake Eagle	*Nilaus afer*	Chivero	FG4
Brubru	*Nilaus afer*	Chivero, Harare	FG1
Buzzard Coots	*buteo hamirostra*	Chivero	FG4
Cap Turtled Dove	*Streptopelia capicola*	Chivero, Harare	FG2,FG3
Cape Glossy Starling	*Lamprotornis nitens*	Chivero	FG1,FG2
Cattle Egret	*Bubulcus ibis*	Chivero, Harare	FG1
Chinspot Batis	*Batis molitor*	Chivero, Harare	FG1
Common Fiscal shrike	*Lanius collaris*	Harare	FG1,FG6
copper sunbird	*Cinnyris cupreus*	Harare	FG5
Crested Barbet	*Trachyphonus vaillantii*	Chivero,Harare	FG1,FG2
Croacking Cisticola	*Cisticola natalensis*	Chivero,Harare	FG1,FG2
Crowned Plover	*Vanellus coronatus*	Chivero	FG1
Dark-capped bulbul	*Pycnonotus tricolor*	Chivero,Harare	FG1,FG2,FG5
Diederick Cuckoo	*chrysococcyx caprius*	Harare	FG1
Egyptian goose	*Alopochen aegyptiaca*	Chivero,Harare	FG7,FG8
Emerald-spotted wood dove	*Turtur chalcospilos*	Chivero	FG1,FG2
European Bee-eaters	*Merops apiaster*	Chivero,Harare	FG1
European Hobby	*Falcon subbteo*	Chivero	FG1
European Nightjar	*caprimulgus europeans*	Chivero	FG1
Feral Pigeons	*Columba livia domestica*	Harare	FG1,FG2,FG3
Fork tailed drongo	*Dicrurus adsimillis*	Chivero, Harare	FG3
Gabar Goshawk	*Micronisus gabar*	Harare	FG4
Gadern Warbler	*sylvia borin*	Chivero	FG1,FG2
Greater blue-eared starling	*Lamprotornis chalybaeus*	Harare	FG1,FG2
greater honeyguide	*indicator indicator*	Chivero	FG1
Green-wood Hoopoe	*Phoeniculus purpureus)*	Chivero,Harare	FG1
Grey backed bleating warbler	*camaroptera brachyura*	Chivero	FG1
Grey go away bird	*Corythaixoides concolor*	Chivero,Harare	FG2
Grey Rumped Swallow	*Pseudhirundo griseopyga*	Chivero	FG1
Hamerkop	*Scopus umbretta*	Harare	FG1
Helmeted Guinea Fowl	*Numida meleagris*	Chivero,Harare	FG1,FG3
Heuglin"s Robin	*Cossypha heuglini*	Chivero,Harare	FG1,FG2
Klaas's Cuckoo	*Chrysococcyx klaas*	Chivero,Harare	FG1
Kurrichane thrush	*Turdus libonyana*	Chivero,Harare	FG1

Lanner Falcon	*Falco biarmicus*	Chivero	FG1,FG4
Laughing Doves	*Spilopelia senegalensis*	Harare	FG2,FG3
Lesser Honeyguide		Harare	FG1
lilac breasted roller	*Corocias caudate*	Chivero	FG1
Little bee-eater	*merops pusillus*	Chivero	FG1
Little Rush Warbler	*Bradypterus baboecala*	Chivero	FG1
Little Swifts	*Apus affinis*	Harare	FG1
Lizard Buzzard	*Kaupifalco monogrammicus*	Chivero,Harare	FG1,FG4
Long-billied crombec	*Sylvietta rufescens*	Harare	FG1,FG2,FG5
long-crested eagle	*lophaetus occipitalis*	Harare	FG4
Marsh Owel	*Asio Capensis*	Chivero	FG1
Meyer's Parrot	*Indicator minor*	Chivero	FG1,FG2,FG5,FG8
Miombo Blue-eared Starling	*Lamprotornis elisabeth*	Chivero,Harare	FG1
Miombo double-collard sunbird	*Cinnyris manoensis*	Chivero,Harare	FG1,FG5
Mocking Cliff-chat	*thamnolaea cinnamomeiventris*	Chivero	FG1,FG2,FG5
Natal Francolin	*Pternistis natalensis*	Chivero,Harare	FG1,FG2
Orange breasted bush shrink	*Chlorophoneus sulfureopectus*	Chivero,Harare	FG1
Orange breasted Waxbil	*Amandav subflava*	Chivero	FG1,FG2
Peregrine Falcon	*falco peregrinus*	Harare	FG1,FG4
Pied crow	*Corvus albus*	Harare	FG1,FG2,FG5,FG6
Plum colored starling	*cinnyricinculuc leucogaster*	Chivero	FG1,FG2,FG3,FG8
Purple crested lourie	*Gallirex porphyreolophus*	Chivero, Harare	FG2
Rattling Cisticola	*Cisticola chiniana*	Chivero,Harare	FG1
Red chested cuckoo	*cuculus solitarius*	Chivero,Harare	FG1
Red eyed dove	*Streptopelia semitorquata*	Chivero,Harare	FG3
Red Faced Cisticola	*Cisticola erythrops*	Chivero,Harare	FG1
Red-billed firefinch	*Lagonosticta senegala*	Harare	fG3
Red-headed Weaver	*Anaplectes Weaver*	Chivero	FG1,FG2
Red-Winged Starling	*Onychognathus morio*	Harare	FG1,F2
Reed Cormorant	*microcarbo africanus*	Chivero,Harare	FG1,FG4,FG8
Rufous Naped Lark	*Mirafra Africana*	Chivero,Harare	FG1,FG2
Scarlet-Chested Sunbird	*Chalcomitra senegalensis*	Chivero,Harare	FG1,FG5
Senegal Coucal	*centropus senegalensis*	Chivero,Harare	FG1
Shikra	*acipter badius*	Chivero	FG1,FG4
Southern Black Tit	*Melaniparus niger*	Chivero	FG1

Southern black-flycatcher	*Melaenornis pammelaina*	Chivero,Harare	FG1
Southern Grey headed Sparrow	*Passer diffusus*	Chivero,Harare	FG1,FG2,FG6
Southern Masked-weaver	*Ploceus velatus*	Chivero,Harare	FG1,FG3,FG5,FG7
Southern Red bishops	*Euplectes orix*	Harare	FG1,FG3,FG5
Speckled mousebird	*Colius striatus*	Harare	FG2,FG5,FG8
Spectacled Weaver	*Ploceus ocularis*	Chivero,Harare	FG1
Spur-winged goose	*Plectropterus gambensis*	Harare	FG2,FG8
Steppe Buzzard	*Buteo vulpinus*	Chivero,Harare	FG1,
Streak headed Carrion	*Milvago chimachima*	Harare	FG1,FG2,FG3,FG6,FG8
Streaky-headed seedeater	*Crithagra gularis*	Harare	FG1,FG2,FG3,FG5
Tawny-flanked prinia	*Prinia subflava*	Chivero,Harare	FG1,FG5
Terrestrial Brownbul	*Milvago chimachima*	Harare	FG1
Three-Streaked Tchagra	*Tchagra jamesi*	Chivero,Harare	FG1
Tropical boubou	*Laniarius aethiopicus*	Chivero,Harare	FG1,FG2,FG4,FG5
Variable Sunbird	*Cinnyris venustus*	Chivero,Harare	FG1,FG5
White breasted cuckoo-shrike	*Coracina pectoralis*	Harare	FG1
White crested helmet shrike	*Prionops plumatus*	Chivero,Harare	FG1,FG2
White-backed vulture	*Gyps africanus*	Chivero	FG6
White-bellied Sunbird	*Cinnyris talatala*	Chivero,Harare	FG,FG5
White-browed Robin-chat	*Cossypha heuglini*	Harare	FG1
White-faced whistling-ducks	*Dendrocygna viduata*	Chivero,Harare	FG1,FG2,FG8
Whyte's barbet	*stactolaema whytii*	Harare	FG2
Willow Warbler	*Phylloscopus trochilus*	Chivero,Harare	FG1
Wire-Tailed Swallow	*Hirundo smithii*	Harare	FG1
Yellow bellied Egret	*Ardea brachyrhyncha*	Harare	FG1,FG4
Yellow bellied Sunbird	*Neodrepanis hypoxantha*	Chivero,Harare	FG1,FG5
Yellow build egrets	*Ardea brachyrhyncha*	Chivero	FG4
Yellow fronted canary	*Crithagra mozambica*	Chivero,Harare	FG1,FG3
Yellow throated long claw	*Macronyx croceus*	Chivero,Harare	FG1
Yellow-crowbed Bishop	*Euplectes afer*	Chivero	FG1
Yellow-fronted Tinkerbird	*Pogoniulus chrysoconus*	Chivero,Harare	FG2
Yellow-throated Seedeater	*crithagra flavigula*	Chivero	FG2,FG3
Yellow-throated sparrow	*Gymnoris xanthocollis*	Chivero,Harare	FG1,FG2,FG5
Zitting Cisticola	*Cisticola juncidis*	Chivero,Harare	FG1