

**SUB-HABITAT STRUCTURE PREFERENCES BETWEEN BUILT
ENVIRONMENTS AND REGENERATED FORESTS IN LUSAKA
NATIONAL PARK WITH RESPECT TO BIRD SPECIES DIVERSITY,
SPECIES RICHNESS AND RELATIVE ABUNDANCE**

Tusankine Mbao

**A research proposal submitted to the University of Zambia in partial fulfillment
of the requirements for the award of Master's Degree in Ecological Public
Health**

THE UNIVERSITY OF ZAMBIA

©2024

Copyright Declaration

No part of this work is reproduced, stored in any retrieval system, or transmitted in electronic, mechanical, photocopying, recording, or otherwise without prior written consent from the author and is expected only for academic purposes.

©Tusankine Mbao

All rights reserved

Declaration

I, Tusankine Mbao, do hereby declare to the Senate of the University of Zambia that this dissertation is my original work and has not been submitted either wholly or in part for any degree award to any other University.

.....

.....

Signature

Date

Certificate of Approval

This dissertation of Tusankine Mbao has been approved as fulfilling the requirements for the award of a Master of Science degree in Ecological Public Health by the University of Zambia.

Professor Musso Munyeme

Supervisor	Signature	Date
------------	-----------	------

Internal Examiner 1	Signature	Date
---------------------	-----------	------

Internal Examiner 2	Signature	Date
---------------------	-----------	------

External Examiner	Signature	Date
-------------------	-----------	------

ABSTRACT

Forests play a crucial role in order to maintain terrestrial ecological diversity. In this study, two distinct forest types—built environments (Forest Reserve 27) and regenerated forests (Lusaka National Park)—in Lusaka, Zambia, are compared with respect to their bird species diversity and concentration. Predicting the bird species' preferred sub-habitat structure is another objective of this study. For the purpose of evaluating species richness and species diversity, two ecological indicator indices were employed: the Simpsons Diversity Index (D) and the Shannon Weiner Diversity Index (H'). Eight days in all, four days at each site, were dedicated to gathering data. To acquire data, an analytical experimental strategy utilizing transect formulation, georeferencing, and mapping in a naturalistic observational study. In addition, International Union for Conservation of Nature red list categories were examined, order categorization, diet, habitat type, and migration status. Forest 27 and Lusaka National Park, yielded a total of 241 individual bird sightings. These totalled 79 observations, of which 35 (at 95% confidence interval 33.6-45.6%) came from Forest 27 and 44 (55.7%) from Lusaka National Park (95% confidence interval 44.4 – 66.4%). The species richness and species diversity of Lusaka National Park were measured at $H' = 3.5$ and $D = 28.5$, respectively, whereas Forest 27 saw $H' = 3.2$ and $D = 23.1$ for species richness and diversity, respectively. Although they highlight different facets, Simpson's and Shannon-Wiener diversity indices both quantify biodiversity. While Shannon-Wiener takes into account both richness and evenness, with higher values suggesting higher diversity, Simpson's concentrates on dominance, with higher values indicating lower diversity. It was concluded that a variety of variables; These include climate, fragmentation, noise pollution, affecting Forest 27 are probably responsible for Lusaka National Park's greater species richness and diversity. This covers government policies on the forest reserve: 1. Sustainable use – Utilization of forest resources in a sustainable manner must be the focus as well as balancing wood extraction with the preservation of ecosystem services such as biodiversity conservation and carbon sequestration. 2. Biodiversity Protection- forest reserves are designed for the safeguard of threatened species and important ecosystems. In regards to forest reserves and protected areas, policy re-evaluation would be advised. Conservation strategies should focus on a variety of ground-nesting,

canopy nesting and insectivorous bird species that are negatively impacted by logging. Conducting another assessment a few years from now would be recommended to further conclude whether Lusaka National Park would still compete or hold a higher amount of diversity and abundance compared to forest 27 or other forest reserves in the Lusaka area.

Dedication

I would like to dedicate this dissertation to my parents, who continuously push me to further my knowledge.

To my Family members who have assisted me in more ways that I could count throughout my research.

To my Professors for the guidance and assistance provided throughout my Postgraduate program.

To my friends and those that became friends through this process, your support was and still is much appreciated.

To my mentors, who first introduced me to the passion I have for avian species.

Lastly to every person that I met during my research who provided assistance, thank you.

Acknowledgements

I would like to thank God for the gift of life and knowledge, that makes it possible for me to successfully complete my studies.

Furthermore, I would like to thank my principal supervisor, Professor Musso Munyeme for his support and guidance throughout the research. To Dr Chaona Phiri I also wish to extend my gratitude for her advice concerning the research work. It was a great pleasure receiving advice and support from such professionals.

I would also like to extend my gratitude to ACEIDHA for their financial assistance during my research work and the Department of National parks and Wildlife for their permission and assistance during my data collection in the Lusaka National Park.

Table of Contents

Copyright Declaration	i
Declaration	ii
Certificate of Approval	iii
Acknowledgements	viii
LIST OF TABLES	xi
LIST OF FIGURES	xii
LIST OF APPENDICES	xiii
ACRONYMS AND ABBREVIATIONS	xiv
CHAPTER ONE	1
INTRODUCTION	1
1.0 Background	1
1.2 Problem statement	4
1.3 Justification of Study	4
1.4 Operational Definitions	5
1.5 Study Objectives	6
1.5.1 General Objective	6
1.5.2 Specific Objectives	6
1.5 Research Questions	7
CHAPTER TWO	8
LITERATURE REVIEW	8
2.0 Literature review	8
2.1 Economic Importance and Deforestation of Forests in Zambia	8
2.2 Biodiversity in Zambia	9
2.3 Key policies On Biodiversity in Zambia	11
2.4 Conservation Value of Regenerated Forest Habitats for Endemic Birds	11
2.5 Ecosystem services provided by avian species	13
CHAPTER THREE	15
MATERIALS AND METHODOLOGY	15
3.0 Material and Methods	15
3.1 Study Site	15
CHAPTER FOUR	21
RESULTS	21
4.1 Descriptive Results	21

4.2 Distribution & Density under the two study sites	22
4.3 Conservation Status	25
4.4 Habitat Preference	27
4.5 Migration Status	28
4.6 Order Classification	29
4.7 Diet Type	30
CHAPTER FIVE	32
DISCUSSION	32
CHAPTER SIX	41
CONCLUSION AND RECOMMENDATIONS	41
REFERENCES	42
APENDICES	49

LIST OF TABLES

Table 4.1 International Union for Conservation of Nature red list categories.....	26
Table 4.2 International Union for Conservation of Nature red list overall.....	26
Table 4.3 Comparison of Habitat type between the two study sites.....	27
Table 4.4 Order Classification of total bird species observed.....	29
Table 4.5 Diet Type of all bird species observed.....	30

LIST OF FIGURES

Figure 3.1 Map of Lusaka National Park.....	15
Figure 3.2 Lusaka National Park.....	16
Figure 3.3 Wildlife captured at Lusaka National Park.....	16
Figure 3.4 Map of Forest 27.....	17
Figure 3.5 Landscape of Forest 27.....	18
Figure 4.1 Bird Species in Forest 27 and Lusaka National Park regression line.....	21
Figure 4.2 Correlation analysis graph Lusaka National Park and Forest 27.....	23
Figure 4.3 Box plot and whiskers of species Lusaka National Park and Forest 27...24	
Figure 4.4 Box plot and whiskers at genus Lusaka National Park and Forest 27.....	25
Figure 4.5 Habitat preference of total bird species observed.....	28
Figure 4.6 Migration Status.....	29
Figure 4.7 Sunburst of order classification.....	30

LIST OF APPENDICES

Appendix 1: Shannon- Weiner diversity index (Lusaka National Park).....	49
Appendix 2: Simpsons Diversity index (Lusaka National Park).....	50
Appendix 3: Shannon-Weiner diversity index (Forest 27).....	51
Appendix 4: Simpsons diversity index (Forest 27).....	52
Appendix 5: Pin-tailed whydah (Lusaka National Park.....	53
Appendix 6: Kurrichane Thrush (Lusaka National Park).....	53

ACRONYMS AND ABBREVIATIONS

GLMM	Generalized linear mixed models
GPS	Global positioning system
RF	Regenerated Forest
FAO	Food and Agriculture Organization of the United Nations
ZFD	Zambia Forestry Department
ILUA	Integrated land-use Assessment
CSO	Central Statistical Office
GRZ	Government of the Republic of Zambia.
UNEP	United Nations Environmental Program
BWZ	Bird Watch Zambia
ZFD	Zambia Forest Department
GDP	Gross Domestic Product
CNP	Cusuco National Park
LFR	Lambusango Forest Reserve
REDD	Reducing Emissions Deforestation and Forest Degradation
IUCN	International Union for the Conservation of Nature
SD	Short Distance
MD	Medium Distance
LD	Long Distance
YR	Year Round
R	Resident
GR	Granivore
IN	Insectivore
FR	Frugivore
OM	Omnivore

CHAPTER ONE

INTRODUCTION

1.0 Background

Numerous studies have looked into how growing cities affect local and regional bird populations in the wake of increasing urbanization. Ecologists have generally found that native avian species suffer from increased urbanization (Aronson et al., 2014). Perhaps the most direct cause of a species' decline in the context of urbanization is the fragmentation and loss of native bird habitat that follows from the conversion of forest habitat to urban areas (Mckinney, 2006). This is particularly true for specialist species that cannot effectively adapt to fill new functional niches in urban environments or that need extensive forested regions to reproduce (Luck and Smallbone, 2010).

Large swathes of lowland forests that were formerly removed for farming have since recovered. For forest-dwelling birds, the ecological benefit of second-growth regeneration may be contingent upon the age of the forest. As well as the corresponding vegetative structure, and the point at which the forest can support avian demography akin to those of pristine fragments are frequently thought to be dynamic, meaning they undergo regular turnover (Laurance et al. 2011). Numerous factors contribute to Zambia's deforestation and forest degradation. According to the Reducing of Emissions from Deforestation and Forest Degradation (REDD+) approach, unsustainable charcoal manufacturing and conversion to agricultural land are the two main causes of Zambia's deforestation and forest degradation (Vinya et al. 2012). There are four primary causes: fires, infrastructure (urbanization, settlements, and industrialization); wood extraction (charcoal production, fuelwood gathering, and logging); and agricultural growth. A similar list of drivers is found in other literature sources. However, out of all the literature, the two primary drivers are wood extraction and agriculture, these seemed to be applicable everywhere throughout Zambia, whereas the other drivers such as mining infrastructure in the key mining provinces had local or regional significance (Wathum et al. 2016). Every year, there is a net loss of forest cover in the tropics as a result of deforestation brought on by logging, increased agriculture, and cattle grazing (FAO, 2012).

Studies of population dynamics known as "urban-rural gradients," which follow transects from comparatively undeveloped city outskirts to densely populated downtown areas, reveal that native bird species richness and density decline with increased development (Blair, 1999). However, numerous studies have demonstrated that when infrastructure includes remnants of natural vegetation or urban forest fragments surrounded by an urban matrix, a wide variety of native forest bird species continue to use the habitat and breed in heavily developed areas (Hostetler and Holling, 2000; Hostetler and Knowles-Yanez, 2003; Donnelly and Marzluff, 2006).

Urban parks and well-manicured riparian buffers are examples of conserved or replanted areas embedded within cities that protect birds from human disturbance and are crucial urban stopover habitat refuge for numerous migrating species (Pennington, Hansel and Blair, 2008; Pennington, Hansel, and Blair, 2011). Nevertheless, the converted areas are left to organically regenerate after they are depleted and abandoned (Nepstad, et al., 1991).

Consequently, secondary forests account for a growing share of the total forest cover. Secondary woods might soon be the only thing left in some countries (Laurance and Bierregaard, 1997). Although the focus of conservation has primarily been on creating reserves to safeguard mature forests, there is growing recognition of the significance of disturbed habitats, including secondary forests, for the preservation of species (Vandermeer and Perfecto, 1997; Chazdon, 2008). Prior research has provided explanations for the variations in bird species richness and assemblage composition between mature and secondary forests. These explanations have included: 1) substrate diversity; 2) food resource abundance; 3) competitive species interactions; and 4) site characteristics (Wiens, 1989). Tropical birds frequently select their habitat based on the availability of food (Loiselle and Blake, 1991) and the microhabitat characteristics of their nest locations (Borges and Stouffer, 1999). Prior research has demonstrated that colonizer species like bulbuls (Sodhi and Smith, 2007) dominate the species composition of the understory bird population in the early stages of forest recovery (less than 10 years after disturbance). After being left intact for roughly 20–40 years, the recovery rate of forest specialist birds in regenerated forests (RF) increases over time.

Compared to Regenerated forests, primary forests have a larger density of uncommon species in their delicate ecosystem. When the surrounding forest is logged, the undisturbed habitat serves as a sanctuary that allows forest-dependent birds to survive in a hostile environment. The conditions of the surrounding habitat, or matrix, wherein the presence of corridors, the history of land use, the age of the matrix, and the distance to the source populations can determine the balance between extinction and the persistence in forest fragments, is one factor that governs the dynamic nature of the bird population in these areas (Renjifo 2001; Eweers and Didham 2006; Stouffer and Bierregaard 2007; Sodhi et al. 2011; Wolfe et al. 2015). Since this information is only available through journal articles and technical reports, decision-makers are largely unable to evaluate the effects of various urban designs on avian species and wildlife in general, despite the many potential benefits of doing so (Ahern, 2012).

The intricacies of which species could use leftover habitat when land is divided are not fully addressed by broad conservation measures, such as preserving big forest tracts (Hostetler and Holling, 2000; Hostetler and Knowles-Yanez, 2003). Rather, these approaches might ignore more specialized, fine-grained conservation choices that can help certain species or groups. When land is divided, city planners and developers could be made to assume that there aren't many opportunities for them to preserve bird habitat. Based on this, a hypothesis was put up in this study to investigate if bird species richness is higher in areas with the highest and most variable abundance of food and cover resources (fruits, flowers, insects, and woody understory). This ecological study aimed at comparing the species richness between built environments and regenerated forests and examine how they are distributed throughout each environment. The study also investigated if sub-habitats within the built environments boost bird richness in comparison to the regenerated forest. Utilization of this data to estimate the influence of alternative land use methods on birds.

Species' phenotypic characteristics are important in influencing their contribution to ecosystem services and functioning (Clare et al., 2016). Functional diversity describes the variation of these qualities (Mason et al., 2005; Tilman, 2001) and may thus be valuable for understanding how their persistence or extinction affects ecosystem-level processes (Petchey and Gaston, 2006). Bird community structure is closely related to

physiognomic attributes of vegetation, and there are well-known relationships between species richness and structural diversity of habitat that is important to birds (MacArthur and MacArthur, 1961; Macnally, 1990; Monadjem and Virani, 2016; Tu et al., 2020; Wiens and Rotenberry, 1981), as well as other taxa (McCleery et al., 2018; Rivera-Pedroza et al.) Birds also provide a variety of critical environmental services, such as pest control and pollination (Chain-Guadarrama et al., 2019).

1.2 Problem statement

Secondary forests are on the rise in Zambia due to large amounts of deforestation. If biodiversity in built environments is not managed well and some portions of the area are not kept in their original condition to conserve the remaining species, then there will be a decline of the richness and abundance of avian species in built environments. Studying bird species abundance and diversity across different types and stages of forest environments provides critical information for conservation, ecosystem management, and understanding ecological processes. The study aimed at investigating the composition of avian species found in the built environment in comparison to those found in the regenerated forest (Lusaka National Park) bearing in mind factors affecting the composition of these species.

1.3 Justification of Study

The effects of habitat type (Built Environment and Regenerated Forest) on bird abundance are being investigated. This study will aid in determining the species resources of all birds in both built environments and Regenerated Forests, as well as priority birds. This ecological study aims to compare the species richness of the Regenerated forest's numerous micro-ecosystems and examine how they are distributed throughout Regenerated forests in comparison to the micro-ecosystems found in built environments. The study will also investigate if sub-habitats within the built environments boost bird richness in comparison to the regenerated forest. It will further utilize this data to estimate the influence of alternative land use methods on birds and the surrounding factors affecting avian species population in both built environment and Regenerated forests respectively.

The study will also show that connected forests protect birds better than forest fragments within the built environment matrix and that larger fragments are more

successful than smaller ones by any metric. Birds are an important part of our ecosystem because, inside ecosystems exist trophic webs, which are energy fluxes from producers to consumers and eventually to top predators. These trophic webs' organisms control one another, keeping the entire ecosystem in balance. Birds fill a wide range of ecological roles, including consumers and predators. Birds maintain healthy prey stocks by preying on other species. This study would help us determine whether habitat heterogeneity is important in determining bird species richness and functional groups. Also, to acquire a better knowledge of the amount of bird species loss as a result of Urban area creation and management.

1.4 Operational Definitions

Habitat - This refers to the natural environment or home of an animal, plant or organism. In this study we are referring to the natural environment of the birds.

Heterogeneity - The term "heterogeneity" refers to the difference between components that make up a whole. There is variability in the trait under examination when heterogeneity is present.

Species - classification made up of related organisms that have similar traits and are able to reproduce.

Species Diversity - The quantity of different species found in a given area is referred to as the species diversity.

Birds - vertebrate animals with flight adaptations. Many can also run, jump, swim, and dive.

Built Environment - The phrase "built environment" refers to the surroundings created by humans that serve as the backdrop for human activity. These surroundings can range in size from parks or green spaces to buildings, neighborhoods, and cities, frequently including the infrastructure supporting them.

Regenerated Forest - The process of secondary succession at the community and ecosystem levels that occurs on cleared land that was once wooded is known as "forest regeneration."

Urbanization The process by which individuals move from rural to urban regions, the percentage of people living in rural areas declines accordingly, and societies adjust to this shift.

Sub-habitat - A distinct component of a habitat

Species Distribution - The range, or geographic area, of a given species can vary based on the scale of observation, ranging from individuals within a population to the entire species' range.

Shannon-Weiner diversity Index - In ecology, the Shannon-Wiener index, commonly represented as H' , is a commonly used statistic to measure species diversity within a community by taking into account both species richness and evenness (the relative abundance of each species).

Simpsons Diversity Index - is a measurement of the correlation between the number of individuals within each species (species evenness) and the number of distinct species in an environment (species richness). A high D value indicates a stable and highly biodiverse ecosystem.

1.5 Study Objectives

1.5.1 General Objective

To determine sub-habitat structure preferences between built environments and regenerated forests within the Lusaka National Park in relation to comparative abundance, species richness, and diversity of avian species.

1.5.2 Specific Objectives

- i. To comparatively determine the composition of bird species between built environments and regenerated forests (Lusaka National Park).
- ii. To assess the species richness and diversity between built environments and regenerated forests (Lusaka National Park).

1.5 Research Questions

In line with the above general and specific objectives, the precise research question for this study were as follows:

- i. What factors within the built environments and regenerated forest affect bird species diversity and abundance?
- ii. In contrast to regenerated woods, will there be notable changes in bird species, richness, and composition in constructed habitats (Lusaka National Park)

CHAPTER TWO

LITERATURE REVIEW

2.0 Literature review

2.1 Economic Importance and Deforestation of Forests in Zambia

Zambia's forests are a vital part of the country's natural capital, offering advantages to rural and urban residents, the national economy, and the international community. The estimated amount of forested area left in the nation, out of its overall land area of 75.3 million hectares (ha), ranges from 39 million ha (Central Statistical Office 2013) to 50 million ha (Kalinda et al. 2008) and even 53 million ha (Zambia Forestry Department 2000). According to an analysis of land cover change from 2000 to 2014, the official yearly deforestation rate was calculated to be 0.6%, or a loss of about 276,021 hectares annually. This figure is cited and approved as Zambia's official deforestation rate. In 2015, it was estimated that the average amount of forest area cut per family nationwide was 0.73 hectares. Lusaka Province had the highest rate of forest clearance for agriculture, while Luapula Province had the lowest rate; this suggests that higher-income provinces removed more forest land than lower-income provinces (Clearing House Mechanism 2018).

Zambia has the fifth-highest per capita rate of deforestation worldwide and the second-highest rate in Africa. The manufacturing of charcoal, the growth of agriculture and human settlements, and the illicit logging industry are the main causes of this deforestation. Forests make a direct contribution to the national economy provided ecosystem services are accounted for. For comparative purposes, in 2010 the agricultural industry, forestry (9.9%), construction (10.9%), mining (12.9%), and wholesale and retail commerce (18.9%) contributed the most to Zambia's GDP (Aongola et al. 2009). A study conducted by United Nations Environmental Programme indicates that charcoal, sediment retention, erosion control, non-wood forest products, ecotourism, and several other services, including the provision of industrial round wood, pollination services, and carbon storage, are the most significant advantages that forests offer to Zambia's economy (United Nations Environmental Programme 2011).

The fact that woods support livelihoods in Zambia is among their most significant roles. More than 60% of rural Zambian households are dependent on forests, which sustain over a million jobs. The idea of sustainable development has steadily slipped from the global agenda to that of the "green economy" as the significance of natural capital has come to be recognized. The goal of a green economic route is to attain sustainable development that is egalitarian and resilient while preserving the environment and the services it offers. Preventing the loss of biodiversity and ecosystem services, as well as encouraging energy efficiency, are important steps in this regard, with the primary objectives being social fairness and human well-being (United Nations Environmental Programme 2011).

Natural resources are abundant in Zambia and essential to the country's population and economic growth. The nation has made a commitment to growth and development in order to improve living conditions and lower poverty. Since forests account for a sizable amount of Zambia's natural capital, they are crucial to achieving these objectives. In addition, Zambia's forests regulate the ecosystem by storing and sequestering carbon, controlling water flows and quality, preventing erosion, retaining sediment, facilitating pollination, and controlling disease. They also offer auxiliary services for leisure, tourism, and other cultural endeavours. These assets will thus be lost as a result of the depletion and degradation of forests, and this loss must be weighed against any potential rewards from competing activities.

2.2 Biodiversity in Zambia

Zambia is blessed with a wealth of natural resources and an extraordinarily diverse biological range. The bulk of Zambians, particularly those who reside in rural regions, rely heavily on the exploitation of biological resources for their livelihood, just like in other developing nations. Zambia's biological resources have rapidly degraded since the early 1980s as a result of overexploitation, pollution, fires, and other human activities. Zambia is located in the Zambezian regional centre of endemism, which is bordered to the north by the Guinea-Congolian region and to the south and southwest by the Karoo-Namib region. Inter-regional transitions create wide ecotones with a mixture of plants from nearby endemism centres. With an estimated 3,543 species of wild flowering plants, 242 mammals, 757 birds, 74 amphibians, 156 reptiles, and 490 fish species, Zambia is rich in natural resources and biological diversity. The country

has established over 480 forest reserves, 20 national parks, and 40 Game Management Areas, among other protected areas. The network of protected areas is estimated to cover 286,161 km², or 37.8% of the country's total land area. The most important ecosystems in Zambia for the country's economy and rural livelihoods are forests, agro-ecosystems, and wetlands (Anon, n.d.).

Unplanned farming has an impact on woodland ecosystem structure, while uncontrolled late burning has a significant impact on forest ecosystem structure. One hundred is the estimated number of species of cultivated plants. Seventy-five percent (75%) are considered exotic because they are relatively new arrivals that have not yet been fully integrated into the conventional cropping system. Ten percent (10%) are naturalized, and fifteen percent (15%) are indigenous. (Environmental State, 2000). An estimated 733 bird species, belonging to 84 families, have been identified. Of the total species, 100 are native to Zambia, while the remaining 76 are uncommon or sporadic. Game Management Areas, National Parks, and Bird Sanctuaries of Zambia are home to twenty-two (22) different kinds of protected birds. Ecosystems depend heavily on biodiversity to function properly. These functions include the cycling of nutrients and water, the preservation of soil from erosion, the stabilization of the climate through carbon sequestration, and the pollination process, which produces crops. Forests are a significant carbon dioxide sink. Zambia has one of the largest carbon pools in Southern Africa in its forests and woods, however little is known about the annual loss of forest cover.

Animals are essential to the germination and spread of seeds, which allows plants to regenerate, and plants also give animals with habitats. Zambia's biodiversity is still not well enough understood scientifically to ensure appropriate conservation and utilization to inform sound decision-making. For instance, appropriate estimate of the maximum economic yield of renewable resources requires sufficient and reliable data. The government created forest reserves to preserve forest resources for local communities' sustainable usage in local forests and to safeguard significant catchment regions and biodiversity in national forests. In Zambia, there are 432 forest reserves totalling 7.4 million hectares. In Forest Reserves, settlement and cultivation are typically prohibited, and the removal of any plant is only allowed with a license.

2.3 Key policies On Biodiversity in Zambia

Over the years, Zambia has created a variety of national policies, laws, programs, and acceded to international conventions, regional agreements, and protocols that support the protection of biodiversity and the sustainable management of natural resources and the environment. These include, among other things, the National Forest Policy (2014), the Wildlife Act (2015), the Fisheries Act (2011), the Environmental Management Act (2011), which is the parent environmental law that imposes stringent requirements for EIA and Strategic Environmental Assessment (SEA) for any large-scale development project, and the Forest Act (2015). In order to encourage the preservation and conservation of wetlands, the National Policy on Wetlands was also enacted in 2018 (Anon, n.d.).

The primary tool for managing biodiversity in Zambia is the Second National Biodiversity Strategy and Action Plan (NBSAP-2). "By 2025, biodiversity is valued, conserved, restored, and wisely used, maintaining ecosystem services, sustaining a healthy environment, and delivering benefits essential for all Zambians and the Zambian economy," is the vision statement for NBSAP-2, which will run from 2015 to 2025 (Government of the Republic of Zambia et al., 2015). It consists of 45 Strategic Interventions, 18 Targets, and 5 Strategic Goals. The following are strategic goals: (i) mainstream biodiversity across government and society to address the root causes of biodiversity loss; (ii) lessen direct pressures on biodiversity and encourage sustainable use; (iii) improve biodiversity status by protecting species, ecosystems, and genetic diversity; (iv) increase the benefits of biodiversity and ecosystem services for everyone; and (v) improve implementation through knowledge management, capacity building, and participatory planning (Government of the Republic of Zambia et al., 2015).

2.4 Conservation Value of Regenerated Forest Habitats for Endemic Birds

According to (Martin 2010), though they are becoming more common, tropical secondary forests may not be able to preserve indigenous birds. Although the outcomes of earlier research have varied, they have all been limited to discrete geographic areas. This is significant because various external variables have varying effects on different ecosystems, which may have an impact on conservation potential. In a study conducted on the Conservation Value of secondary forest habitats on endemic birds in tropical

ecosystems. They analysed the differences in endemic bird richness between primary and secondary forest habitats in two widely distinct tropical ecosystems using consistent survey methods (Martin and Blackburn 2010) This provided a more global framework for assessing the secondary forest's conservation importance. Research was done at Cusuco National Park (CNP), a cloud forest reserve in Honduras, and Lambusango Forest Reserve (LFR) on Buton Island, Sulawesi.

A 50 m radius point count was used to survey the bird communities in both woods. After that, vulnerability analyses of avifaunal assemblages based on ecological theory revealed that endemic species in LFR were more vulnerable to disturbance than those in CNP. The endemics in CNP were less tolerant of mild habitat change than those in LFR, which is in contrast to the findings from our vulnerability evaluations. The conclusion of this study suggested that when assessing the conservation significance of secondary forests, they advised taking into account both local and regional biogeographical and ecological aspects. Examples of these factors that may be significant include the influence of figs, patterns of human habitation, and differential community richness.

In another study conducted, the primary cause of biodiversity loss globally is land-use change, which is especially true in the tropics where natural habitats are converted into expansive monocultures or diverse landscape mosaics with little or no conservation value (Martin 2010). They assessed the conservation value of a landscape mosaic in north-eastern Madagascar, a biodiversity hotspot and the hub of the world's vanilla production, using birds as an indicator taxon. By performing point counts across seven common land-use types—forest- and fallow-derived vanilla agroforests, woody and herbaceous fallow that are a part of a shifting cultivation system, rice paddies, forest fragments, and contiguous old-growth forests—they evaluated the richness and composition of bird species (Martin 2010).

The highest species richness was found in old-growth forests, which they attribute to a large proportion of endemic species. Whereas fallow-derived vanilla agroforest was most akin to woody fallow, species richness and community composition in forest-derived vanilla agroforest were similar to those in forest fragments. The least number of species were found in rice paddies and herbaceous fallow open land uses. The diversity of endemic bird species across woody fallows, vanilla agroforests, and forest fragments was positively associated with the amount of forest cover at the landscape

scale. It was concluded that whereas forest- and fallow-derived vanilla agroforests serve different but equally important roles in the protection of birds, fallow-derived agroforests are less significant since they remove fallow land from the cycle of shifting cropping, potentially halting future degradation. Agroforests developed from forests, on the other hand, contribute to the degradation of forests but may prevent the complete loss of tree cover from forest fragments. Going beyond the vanilla example, future research might potentially explore the land-use history of agroforests.

2.5 Ecosystem services provided by avian species.

Birds may be found in practically every ecosystem on the planet. Even if you don't see the birds themselves, there is always proof of them wherever you go. Birds' presence is indicated by things like holes pecked in tree bark by woodpeckers or the remains of a nest. While such marks may appear minor, the activities of birds can have tremendous effects for the habitats they inhabit in many circumstances, making them immensely crucial in the overall functioning of many ecosystems. Avian species provide supporting services to our ecosystem, these services are required for all other ecosystem services to be produced. This includes nutrient cycling and formation of soil (Anderson and Polis, 1999).

Nutrient cycling has been seen in a variety of settings. Birds can transport nutrients from one location to another by spreading their activities throughout multiple habitats, which is especially important in areas where plant growth is limited by nutrient availability. When birds roosted on the islands in the Gulf of California, the guano deposits they left behind offered nutrients to the plants on the island, according to a study conducted on the islands in the Gulf of California. As a result, plants on seabird islands grew higher and quicker, and were far more productive than those on non-bird islands. Because the quality of these plants influences the quantity of consumers and the structure of the food web, these birds influenced a bottom- up effect on the food web by regulating primary productivity (Anderson and Polis, 1999).

From an ecological standpoint the study conducted on the islands in the Gulf of California demonstrates the complicated ways in which seemingly diverse environments are linked and can affect one another. In his 1971 book *The Closing Circle*, one of the environmental movement's pioneers, Barry Commoner, outlined four ecological rules. One of these is the assumption that "everything is connected to

everything else," which is well proven, for example as birds serve as a conduit for nutrients between aquatic and terrestrial environments (Hill, 2021).

Birds can also stimulate primary productivity in other ways, which helps ecosystem's function, as demonstrated by birds in salt marshes. During their spring migrations, lesser snow geese and Canada snow geese stop at salt marshes in Alaska. They stomp the ground when foraging in these marshes, tearing up leaf litter and incorporating it into the soil. Because of the lower particle size and increased contact with the soil, there is more breakdown, which liberates nitrogen from the leaf litter and allows it to circulate through the ecosystem (Zacheis et al, 2002). Birds can also be beneficial in agricultural systems by regulating pests. There were fewer insects in Guatemalan coffee farms with higher abundances of insectivorous birds, resulting in less herbivorous damage to crop leaves (Greenberg et al, 2000).

Another way that birds provide regulatory services is through the promotion of forest growth. This is significant for people because trees can trap carbon, preventing it from entering the atmosphere and contributing to climate change. Birds can fulfil this duty by disseminating plant seeds while foraging. When they select a seed or fruit off a plant and fly away with it, the seed is transported to a new location where it can germinate. This behaviour is an important method for seed dispersal in many plants and, by distributing seeds, can increase the genetic variety of plants in a specific area. Animals can carry seeds more than 40 meters distant from the source tree in some situations (Godoy and Jordano, 2001).

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.0 Material and Methods

3.1 Study Site

The study was conducted on two sites, the Primary site being Lusaka National Park, figure 3.1, figure 3.2 and figure 3.3 and the secondary site, Built Environment (Forest Reserve 27) figure 3.4 and figure 3.5. The Lusaka National Park ($15^{\circ}31'04''S$ $28^{\circ}25'29''E$) is located About 30 kilometres to the southeast of Lusaka city. Founded in 2011 and accessible to the public in June 2015, it is the most recent national park. At 6,715 hectares, it's also the smallest national park in Zambia. Lusaka National Park is a regenerated forest managed by Department of National Parks and Wildlife, who have integrated different types of wildlife within the park such as; Giraffe, Sable antelope, Bushbuck, Impala, and plenty more. It was established over an area that was forest reserve and is entirely fenced (Zambia tourism).

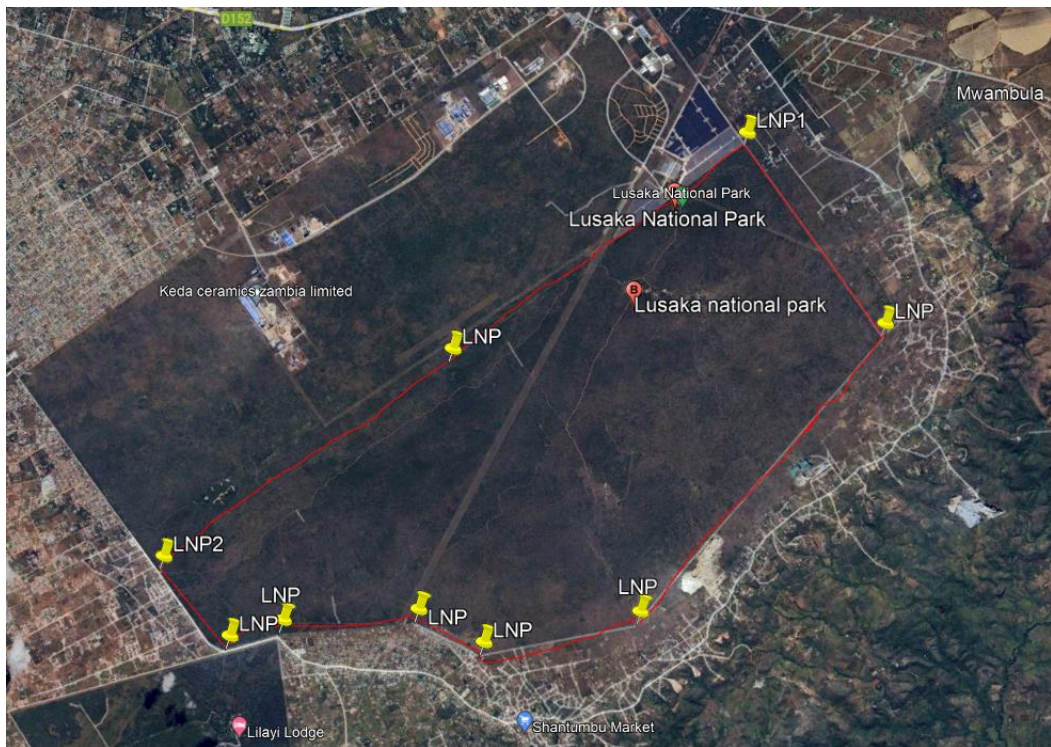


Figure 3.1 (Map of Lusaka National Park obtained from Google earth Pro Application)



Figure 3.2 (Lusaka National Park water point captured
by Tusankine Mbaou)



Figure 3.3 (Lusaka National Park- Wildlife captured by Tusankine Mbaou)

The secondary site was the Built Environment represented by Forest Reserve 27. This area is located in the about 30 kilometres from Lusaka City centre. In order to save the headwaters of the Chalimbana River, which drains the majority of the region east of the city and runs eastward to its confluence with the Chongwe River south of Chongwe town, the Lusaka East Forest Reserve, also known as Local Forest 27, was established. The highest point in the reserve is the survey beacon

Namabiuro, which is located close to Trotover Farm at 1342 meters. The lowest point is the Chalimbana crossing the eastern boundary at 1220 meters. Lusaka Forest No. 27 was created in 1957. Despite the forest's long history, many Zambians were unaware of it until parts of it were excised or subdivided in 2017–2018, and 2019 (parts of Forest No. 27 in Lusaka East were excised by Statutory Instruments (S.I.s) No. 62 of 2017, No. 59 of 2018, and the most recent SI No. 13 of 2019). In actuality, a sizable chunk of Forest 27 is still protected, despite the widespread misconception that it has been degazetted completely. It has only been separated into sections for the purpose of residential and commercial development. The recent distribution of residential plots in the forest region is the main cause of the widespread knowledge of it.

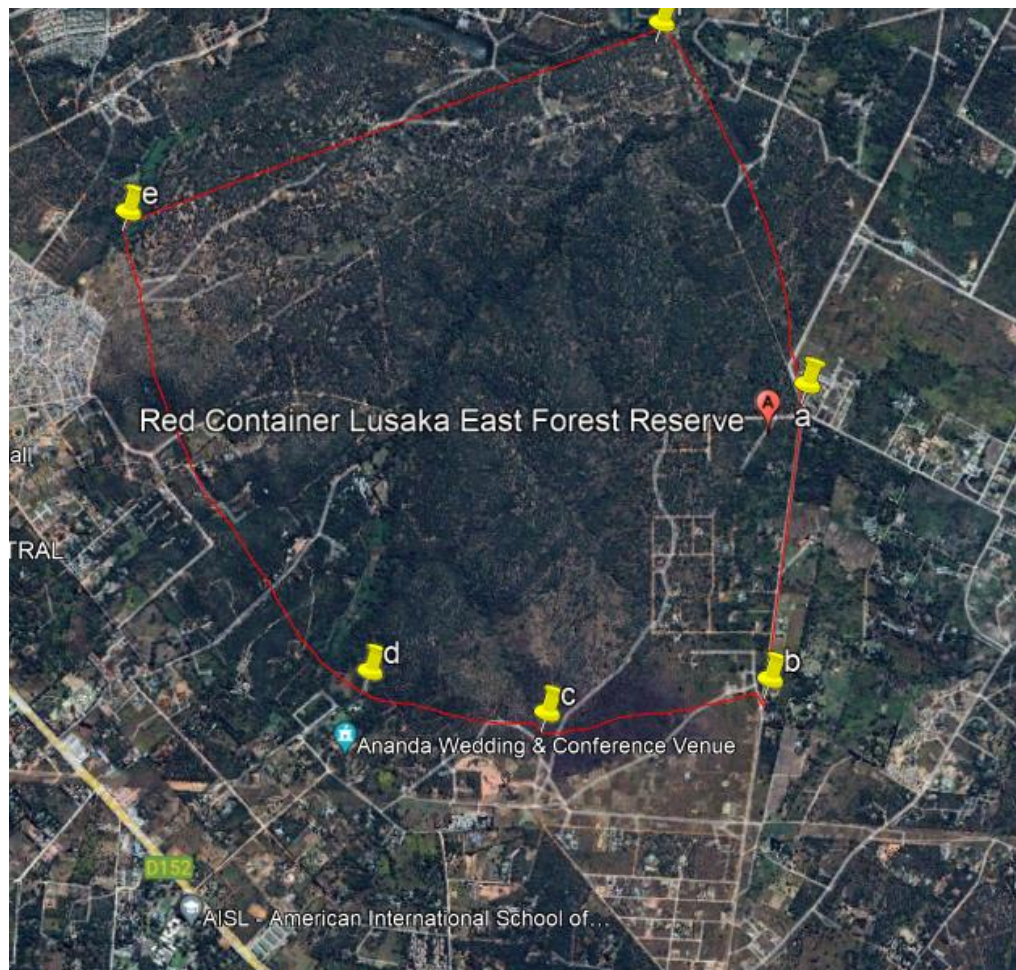


Figure 3.4 (Built Environment – Lusaka East Forest Reserve/ Forest 27 obtained from Google Earth Pro)



Figure 3.5 (Lusaka East Forest Reserve, captured by Tusankine Mbaao)

The established forces in Lusaka before independence, believed in the 1950s that planting trees would provide a number of environmental advantages. The two main Forests, Forest 26 (Now Lusaka National Park) in Lusaka South and Forest 27 in Lusaka East, were set aside for this reason. The protection of two recharge zones for Lusaka's subterranean water system was the main driver behind the establishment of these two Forests. The places where the aquifer layers meet the earth surface are known as recharge zones. Aquifers are an ideal entrance site for water that percolates through the aquifer to accumulate underground as underground water because they are composed of limestone, a permeable rock. The water table is kept in place by this aquifer layer.

3.2 Study Design

A Naturalistic observational study will be carried out to better understand the distribution and structure preference of the birds in the two different ecosystems. The study was conducted with an analytical experiment approach, using mapping, plotting, georeferencing and a combination of point counts and line transects where

used in the two different land types. The study was conducted on two types of land: Regenerated Forest and Built environments (Forrest reserve 27). To reflect whether there is a difference in avian species due to the fact one land type possess native flora and fauna while the other is restored. The two sites are 12 kilometres apart. The 3 lines transect measuring about 2 kilometres were formulated for the Built environment (Forest reserve 27) while 2 line transects were formulated measuring about 2 kilometres for the Lusaka National Park.

In both the National Park and the Built environment (Forest reserve 27) point counts were conducted in two different areas within the sites respectively. This was done due to the fact the during trial sampling, they concentration of avian species in the National Park for example was around water points, and very low sighting during surveys along line transects. To make an even count we also conducted point counts in the Built environment (Forest reserve 27). We surveyed avian species and vegetation on all line transects and point counts per site. Using the mean abundances for each species, we calculated species diversity as the Shannon-Wiener (Shannon) diversity index (H_0) and Simpson diversity index (D) in vegan. We then constructed generalized linear mixed models (GLMMs) in the lme 4 package, function 'glmer' for species richness and 'lmer' for Shannon diversity, to examine variations in observed species richness and diversity in the different locations, Lusaka National Park and Built Environment (Forrest reserve 27) (Bates et al., 2015).

3.3 Bird Surveys

The bird counts trial begun in November 2023 (beginning of the rain season) while the actual data recorded session began at the end of February 2024. This is presumed to be during raining season in Zambia, though during the period of the year little to no rain was present. Average temperatures were between 27-30 degrees Celsius determined using a mobile weather application (Apple weather). Four days of surveys were conducted per site, the surveys were conducted in the early hours of the morning, time was between 6am-9am. The majority of bird species that use lowland deciduous woodland for breeding may be identified after six visits, and a solid grasp of the number and distribution of species present can be attained. Therefore, eight visits are thought to constitute a proportionate survey

effort for both freshwater and terrestrial ecosystems. For this reason, a total of eight survey visits were done in both the Lusaka National Park and the Built Environment (Forest reserve 27). Counts along line transects and point counts were conducted every morning and during every survey session. A random sequence was followed when visiting the sites. To give the birds time to settle, we waited a few minutes before beginning a transect in Forest 27. In the National Park, we drove between transects and point counts for five to ten minutes. After that, we walked at a steady pace, recording every bird heard and seen within 100 meters on either side. Bird species were observed using a Nikon D56312 BJ binocular and captured using a Canon 60D with 70mm – 200mm and 10mm – 45mm lenses. The Vocal recordings were taken through a mobile application – The Cornell Lab Merlin Bird ID, all captured and recorded birds were referenced through the Birds of Zambia application and written down in logbooks alongside the corresponding GPS coordinates. This process took an hour for each transect/point count.

According to (McCleery et al. 2018), we did not record birds flying overhead unless they are particularly feeding over that land-use (such as swifts and swallows foraging over the same region, as opposed to birds flying above the site that are plainly transiting from one area to another). All bird counts took place in the early morning (sunrise), between 6am to 9am for the morning. Counting was recorded in one-hour intervals which were denoted as T1 (6am to 7am) T2 (7am to 8am), T3 (8am to 9am). Bird surveys will not be undertaken if the weather is rainy or windy (Bibby et al., 2000). Ethical considerations of this study were sought from Excellence in Research Ethics and Science Converge plot No. 272, Cnr Olive Tree Meanwood Road.

CHAPTER FOUR

RESULTS

4.1 Descriptive Results

A total of 241 individual birds were spotted from the two study regions, Forest 27 and Lusaka National Park (LNP). These comprised 79 observations in total, of which 44 (55.7%) came from Lusaka National Park at 95% confidence interval (44.4 – 66.4%), and 35 came from Forest 27 at 95% confidence interval (33.6 – 55.6%). When species distribution was taken into account, a proportionate collinearity of fitted values at 95% Confidence Interval indicated was demonstrated with LNP having higher values of similar species (Figure 4.1).

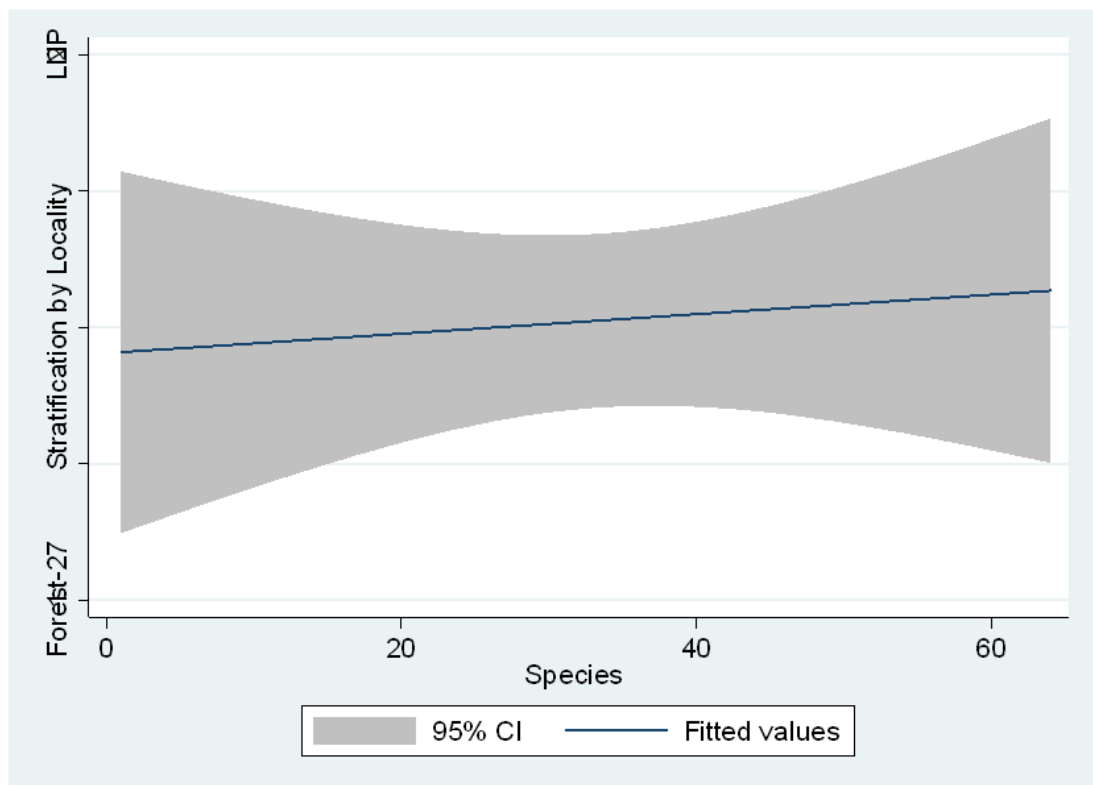


Figure 4.1: Bird species in Forest 27 and LNP when quantified along a regression line, they showed collinearity

4.2 Distribution & Density under the two study sites

A total of 15 birds from forest 27 were identified at the genus level as *Cisticola* based on the individual observations of 241 birds; these birds were all members of the same species, *Cisticola erythrops*. With twelve observations, the genus *Prionops* had the second-highest number: nine were of the species *Prionops plumatus* and three were of *Prionops retzii*. The genus *Sylvietta* ranked third with a total of seven, all belonging to the same species, *Sylvietta rufescens*. With 20 birds in total 15 of which belonged to the species *Muscicapa striata*, 3 to *Muscicapa boehmi*, and 2 to *Muscicapa caerulescens*—the genus *Muscicapa* recorded the highest number of species in Lusaka National Park. The genus *Melaenornis* had the second-highest number of recorded birds, with six species—*Melaenornis pallidus* and four species—*Melaenornis pammelaina*. The other two genera that were in the third place each recorded nine birds in total. The genus *Crithagra* recorded nine birds, all of which were members of the same species, *Crithagra mozambica*. Additionally, nine birds from two distinct species—eight *Streptopelia capicola* and one *Streptopelia semitorquata*—were recorded for the genus *Streptopelia*.

The species richness and species diversity of Lusaka National Park were measured at $H' = 3.5$ and $D = 28.5$, respectively, whereas Forest 27 saw $H' = 3.2$ and $D = 23.1$ for species richness and diversity, respectively. When the overall sightings of the bird species was taken into consideration, a non-significant difference between species was observed in the two study areas (Figure 4.2).

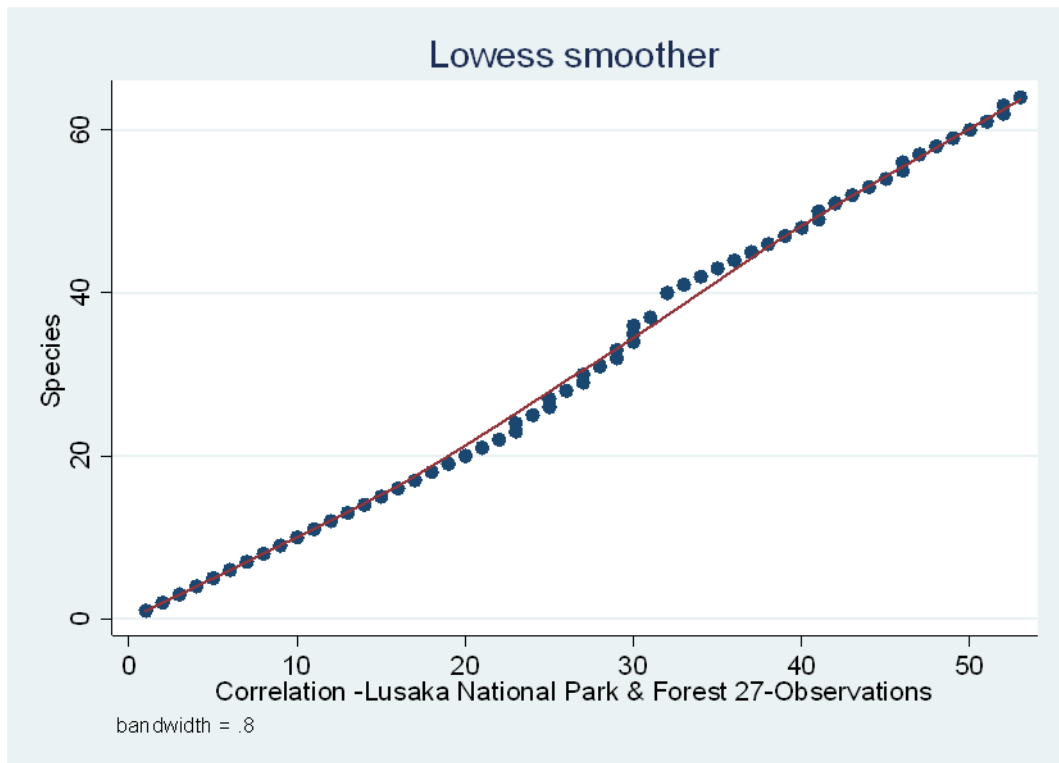


Figure 4.2: Correlation analysis graph between species observed in Lusaka National Park and Forest 27.

To further look closely between Lusaka National Park and Forest 27, Box plot and whiskers were constructed and they indicated that both the upper and lower limits of species observed within Lusaka and Forest 27 did not vary. The Box plot of Lusaka National Park was wider than Forest 27 by 25%, indicating a higher species density and distribution within Lusaka National Park than Forest 27 (Figure 4.3).

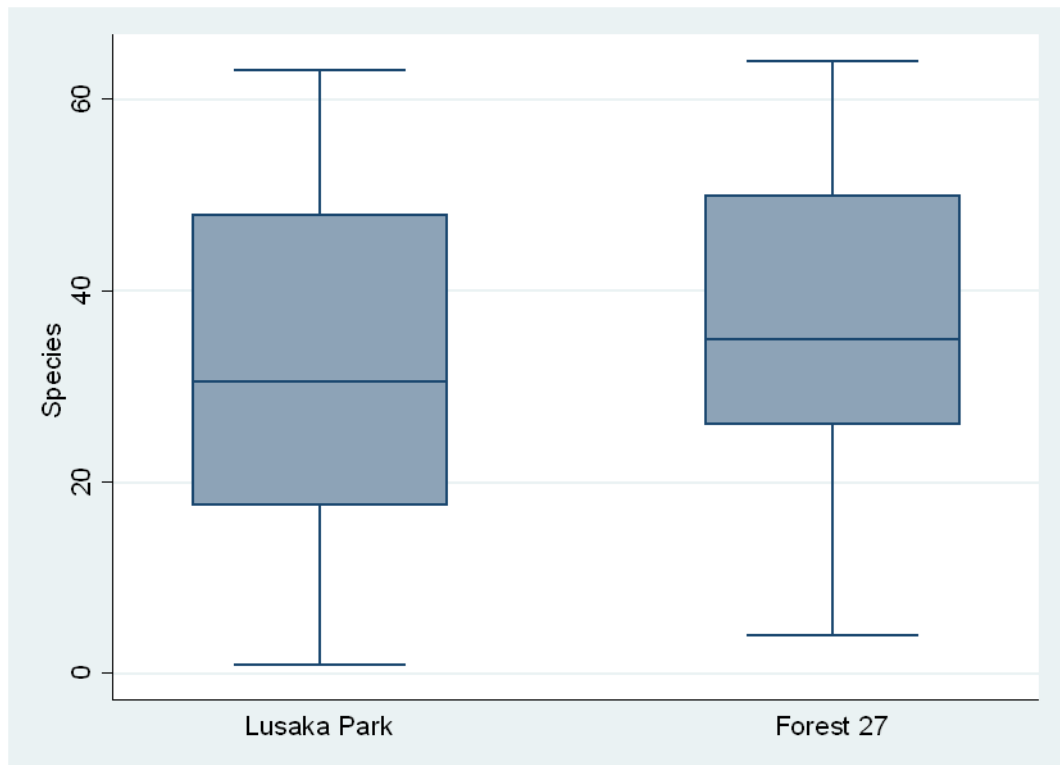


Figure 4.3: The Box plot and whiskers indicating the upper and lower limits of species observed within Lusaka and Forest 27.

When genus level assessment was conducted using the Box plot and whiskers, the results indicate that both the upper and lower limits at genus level observed within Lusaka and Forest showed slight variation with the Box plot of Lusaka National Park being wider than Forest 27 by 25%, indicating a higher genus distribution within Lusaka National Park (Figure 4.4).

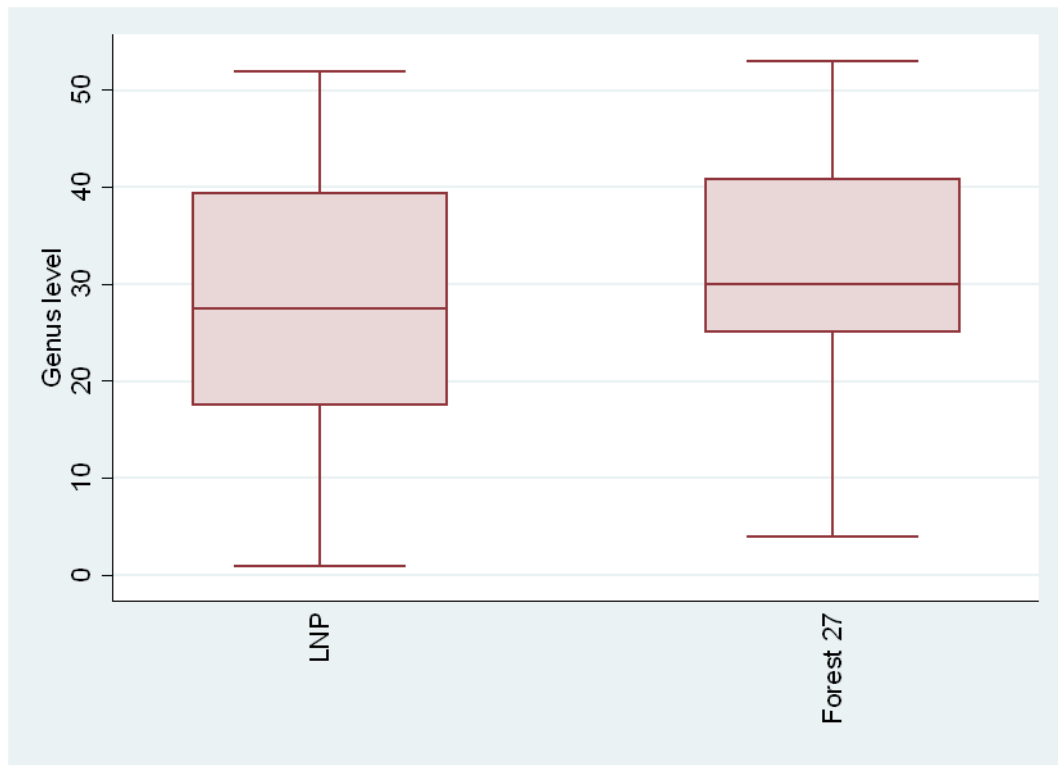


Figure 4.4: The Box plot and whiskers indicate that both the upper and lower limits at genus level observed within Lusaka and Forest 27 indicating a higher genus distribution within Lusaka National Park.

4.3 Conservation Status

Bird species have been placed into categories depending on their conservation status around the world. Table 4.1 shows the conservation status of birds' species found in the two study sites. Table 4.2 shows a proportion of the two population of birds observed and their conservation status. Least Concern – Unknown: Extremely Low risk: does not fall into a higher risk category and is not anticipated to face a danger anytime soon, many and widely distributed taxa. The population trend 'Unknown' Absence of knowledge about their population condition, classification, or the effects of threats. Least Concern- Stable: Low risk, many and widely distributed taxa, the population trend 'Stable' refers to a population with a constant rate of natural expansion. Least Concern- Rapid Decline: Low risk many and widely distributed taxa, the population trend 'Rapid Decline' refers species abundance being reduced drastically over the last century. Least Concern- Increasing: Low risk, many and widely distributed taxa, the population trend 'Increasing' refers to the increase in

abundance over the last century. From the two study sites, the majority of the birds are under the low-risk category (Table 4.1).

Table 4.1: International Union for Conservation of Nature (IUCN) – Red list Categories for Birds observed in Lusaka National Park and Forest 27 respectively.

IUCN Classification	Lusaka National Park	Forest 27	Total
Least Concern-Unknown	2	1	3
Least Concern-Stable	25	22	47
Least Concern-Rapid Decline	10	10	20
Least Concern-Increasing	7	2	9
Total	44	35	79

Table 4.2: International Union for Conservation of Nature (IUCN) – Red list Categories for overall Birds observed.

IUCN Classification	<i>n</i> = 79	Proportion (%)	95% Confidence Interval
Least Concern-Unknown	3	3.8	1.2 – 11.4
Least Concern – Stable	47	59.5	48.1 - 70
Least Concern-Rapid Decline	20	25	16.8 – 36.3

Least Concern- Increasing	9	11.4	5.9 -21
--------------------------------------	---	------	---------

4.4 Habitat Preference

Table 4.3, Pearson’s chi square comparing habitat type between Lusaka National Park and Forest 27 showed that there is no significant difference in the two different sites when it pertains to habitat type. Though bird species were observed on more different types of habitats in Lusaka National Park compared to Forest 27. Overall habitat type percent proportions of represented totals are shown in Table 4.3 showed that trees where the most inhabited habitat type by bird species in both areas combined

Table 4.3. Comparison of Habitat type between the two study sites

Habitat Type	Lusaka National Park	Forest 27	Total
Tree	27	31	58
Ground	6	0	6
Shrub	2	2	4
Water	1	0	1
Dead Standing tree	3	1	4
Rock	1	0	1
Tree/Ground	2	0	2
Tree/DST/Ground	1	0	1
Tree/Shrub	1	1	1

On overall combined habitat preference of the bird species observed under the two study areas, 73% of the birds were sighted from trees (Figure 4.5).

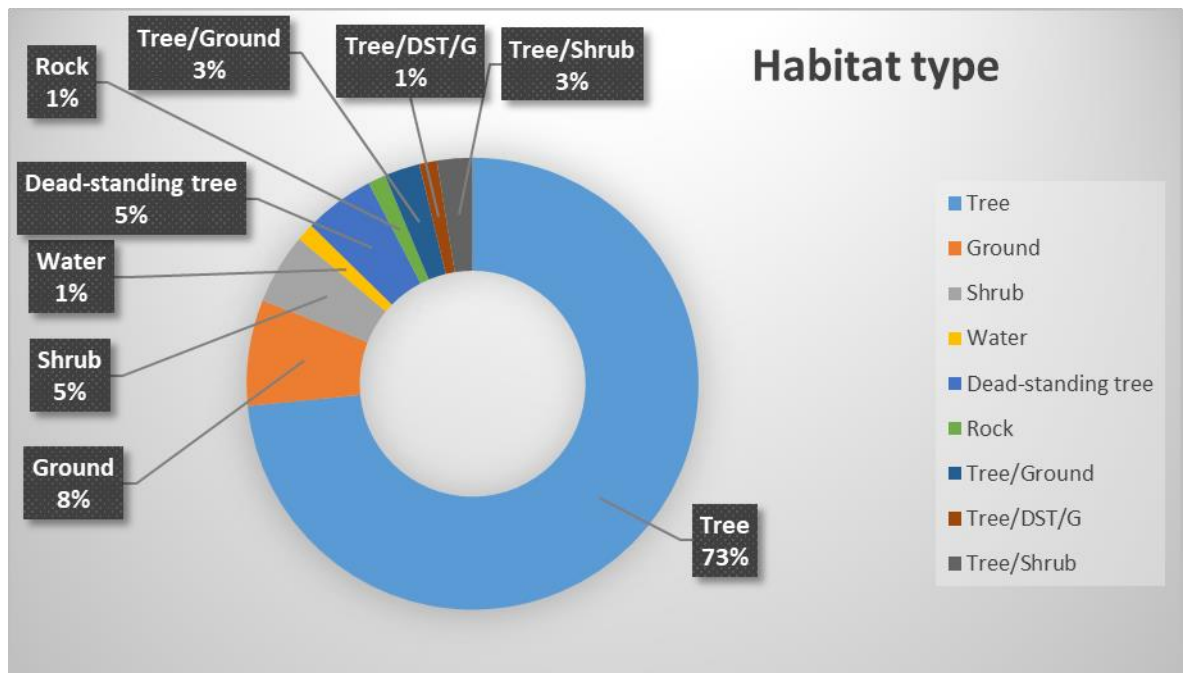


Figure 4.5: Habitat preference of total birds observed represented by proportion percentage.

4.5 Migration Status

Figure 4.6 shows a 3D pie chart representing the migration status of the total birds observed by percent proportion. The Migrant status is recorded using the duration they spend migrating before most species start breeding. The migration status recorded is denoted as follows: SD- short distance (37% of the observed bird species were categorised under this group of short distance or local migrants), tens of kilometres are usually involved in this kind of migration. MD- Medium Distance, bird species that migrate hundreds of kilometres. LD – Long distance, birds that migrate thousands of kilometres. YR- Year-round, birds that migrate irregularly year-round were the least at 4% of the observed total species. R- Resident, birds that do not migrate but are commonly found in a particular region. A sizable portion of the birds observed are Palearctic migrants- Any bird species, or group of species, that breeds in Asia or Europe and routinely migrates south during the nonbreeding season.

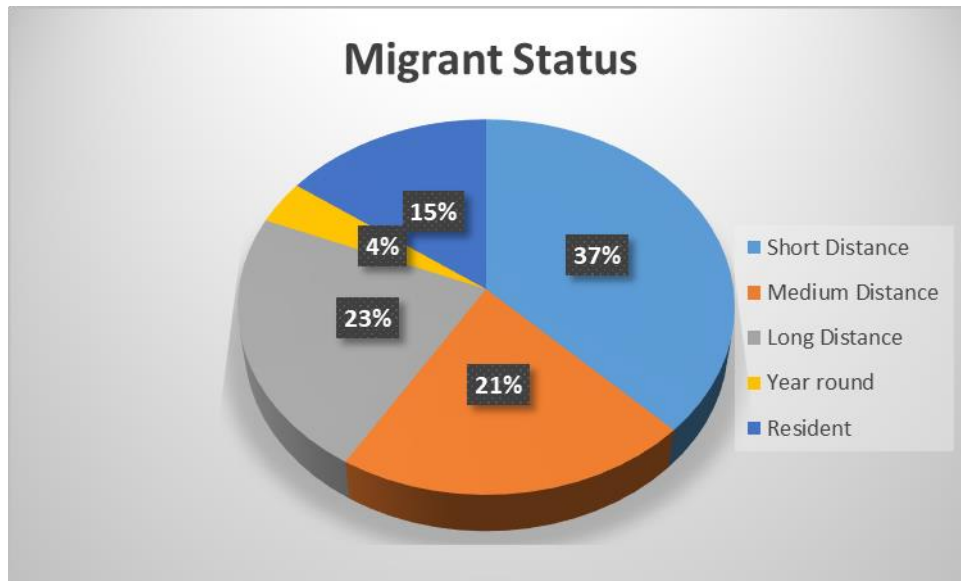


Figure 4.6: Migration status, represented by proportion percentage.

4.6 Order Classification

Table 4.4 shows the order of classification of all bird's species observed. The highest observed order from a combination of both sites was order Passeriformes with 70.89% of the total population at 95% confidence interval (60 – 80). Figure 4.7 presents the data in a sunburst chart.

Table 4.4: Order Classification of total bird species observed.

Order	<i>n</i> = 79	Proportion (%)	95% Confidence Interval
Passeriformes	56	70.89	60 – 80
Bucerotiformes	1	1.27	0.2 – 9
Grutiformes	1.	1.27	0.2 – 9
Columbiformes	4	5.06	2 – 13
Coraciiformes	6	7.59	3.4 – 16.1
Piciformes	7	8.86	4.2 -17.7
Anseriformes	1	1.27	0.2 – 9
Accipitriformes	1	1.27	0.2 – 9
Galliformes	2	2.53	0.6 – 10

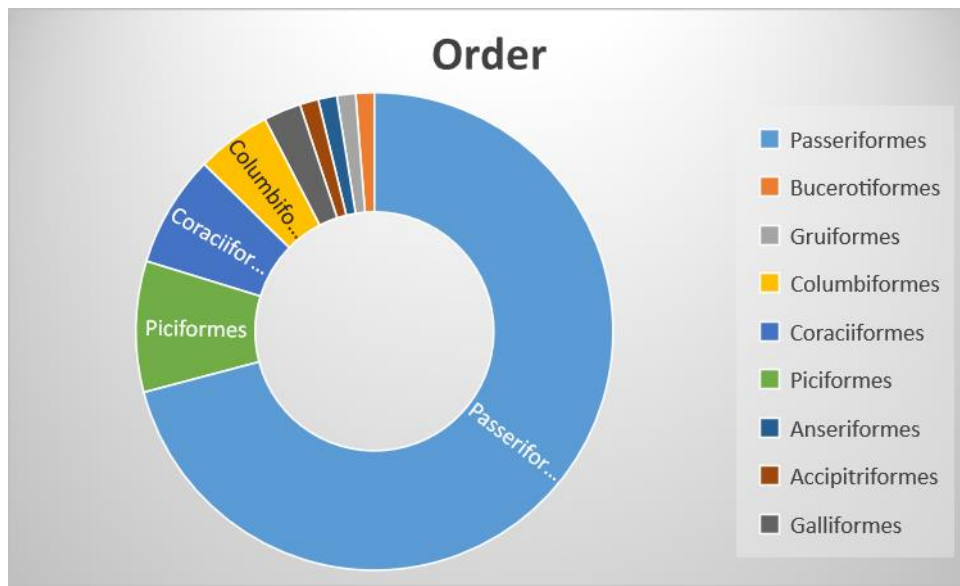


Figure 4.7: Sunburst of Order classification represented by proportion percentage.

4.7 Diet Type

Table 4.5 represents the diets of all the bird species observed. The highest diet type were the insectivores making up 49.37 % of the total population at 95% confidence interval (38.3 – 60.5).

Table 4.5: Diet type of all bird species observed.

Diet	<i>n</i> =79	Proportion (%)	95% Confidence Interval
Insectivore	39	49.37	38.3 – 60.5
Frugivore	2	2.53	0.6 – 10
Granivore	1	1.27	0.2 – 9
Carnivore	1	1.27	0.2 – 9
Omnivore	2	2.53	0.6 – 10
Insectivore/Frugivore	16	20.25	13 – 31
Insectivore/Granivore	9	11.39	6 – 21
Insectivore/Herbivore	1	1.27	0.2 – 9
Insectivore/Carnivore	3	3.80	1.2 – 11.4
Granivore/Insectivore/Frugivore	5	6.33	2.6 – 14.6

Insectivore - Animals whose main food source is small insects only, Frugivore – Animals whose main food source is fruits only, Granivore – Animals whose main food source is seeds and grain only, Carnivore – Animals with a main food source of small reptiles and other animals only, Omnivore – an animal whose main food source derives from both plant and animal origin, Insectivore/Frugivore – an animal whose main food source comprises of both insects and fruits, Insectivore/Granivore – an animal whose main food source comprises of insects, seed and grain, Insectivore/Herbivore – an animal whose main food source comprises of both insects and plants, Insectivore/Carnivore – an animal whose food source is derived from both insects and other animals, Granivore/Insectivore/Frugivore - an animal whose main food source comprises of insects, seed and grain, and fruits.

CHAPTER FIVE

DISCUSSION

This study has shed some light on the intricate relationships between habitat structures, avian biodiversity within the Lusaka National Park and Forest 27. Lusaka National Park is a regenerative forest which is playing a crucial role in the biodiversity of avian species near the city, whilst Forest 27 was previously a pristine forest, but is rapidly becoming more of a built environment. This study has shown that the bird assemblages in both study sites display similar structures in terms of density, distribution as well as forest habitats intimating on responses linked with the landscape context as well as land use. However, a closer observation has shown that Lusaka National Park yielded more bird species than Forest 27. This may in part indicate loss of diversity in the built area and increase of the same in the regenerating forest. However, these results are very interesting as this is a first study to determine the effects of habitat fragmentation alongside restoration on the avian species.

When quantified along a regression line the two sites showed collinearity, meaning since there is a significant correlation between them, it is challenging to accurately estimate each of their independent regression coefficients, but these results can form a strong baseline study of fragmentation and restoration happening alongside each other. These findings from this particular study are in congruent with (Basil et al., 2021) findings that structurally similar sites of the same habitat type may to some extent show resilience and less variability in the abundance, species richness or diversity but with loss of certain key species, the entire population structure changes. Observations under this particular study therefore indicates the likelihood of the built environment not having reached a tipping point where the keystone species are lost.

With the information obtained from this study we can also conclude that Lusaka National Park yielded higher species diversity than Forest 27, using the Simpson Reciprocal Index and Shannon Weiner Diversity Index. The Shannon-Wiener diversity index is based on Claude Shannon's formula for entropy and estimates species diversity. The index considers both relative abundance (evenness) and the total number of species (richness) that exists in a given ecosystem. The Simpson Reciprocal Index is used to find innate characteristics, compare communities: A location with a high index value is likely stable, has a wide range of niches, and faces little competition

(high richness and evenness). The species richness and species diversity of Lusaka National Park were measured at $H' = 3.5$ and $D = 28.5$, respectively, whereas Forest 27 saw $H' = 3.2$ and $D = 23.1$ for species richness and diversity, respectively.

This study also determined the conservation status and population trend globally of the avian species observed, for this we utilised the International Union for Conservation of Nature (IUCN) Red list, an important metric for assessing the condition of biodiversity worldwide. More than just a list of species and their status, it is an effective instrument that may both inform and spur action for policy changes and biodiversity conservation, both of which are essential to safeguarding the natural resources that are essential to human survival. To help in the decision-making process related to conservation, it offers data on threats, usage and/or trade, habitat and ecology, population size, range, and conservation activities. The data we obtained was utilised further to find out which site holds more bird species with a threatened conservation status and a decreasing, Increasing or stable population trend. Lusaka National Park observed more species with an Increasing population trend. Both sites recorded the same number of observations with a declining population trend. We deduced that 59.5 % of the total bird species observed were of conservation status- least concern and population trend – stable. Only 25% of the total birds observed is of conservation status – least concern and population trend – rapid decline. The population trend of the bird species observed could be because of different factors affecting bird -: Threats include poaching, fires, nest raiding by egg and chick collectors, droughts brought on by climate change, and habitat degradation from diminishing wetlands (Species – Bird Watch Zambia, n.d.). 90% of the loss of forest cover in Zambia is attributable to subsistence and commercial agriculture production, and economic forces account for a greater portion of the variables affecting biodiversity loss in the country.

In Zambia, the annual rate of deforestation ranges from 79,000 to 270,000 hectares of the total forest cover. This is primarily because of the country's 3.2% annual increase in urbanization, which is expected to exacerbate the rate of deforestation as more infrastructure is developed for things like housing, energy, transportation, and irrigation Policy and regulatory considerations, such as the recent degazetting of six (6) forest reserves, mostly for the sake of infrastructural development, intensify threats to forest resources. There are 5 broad categories of key causes of biodiversity change

in Zambia. These include social, environmental, cultural, and demographic; political; scientific and technological; economic; policy and regulatory; and social and environmental (Mabeta et al., 2018). An increasing number of studies (Slingenberg et al., 2009; Burkmar and Bell, 2015; Habibullah et al., 2016) have concluded that agriculture—both on a subsistence and commercial scale—is the primary cause of habitat degradation and biodiversity loss. Due to smallholder and commercial farmers' shifting cultivation and extensification, agriculture expansion is thought to be responsible for 90% of Zambia's loss of forest cover (Mwitwa et al., 2003; Campbell et al., 2012).

When comparing habitat type between Lusaka National Park and Forest 27 we used the Pearsons's chi square, and there was no significant difference in the two different sites when it pertains to habitat type. Though bird species were observed on many more different types of habitats in Lusaka National Park compared to Forest 27. Overall habitat type proportions (%) showed that trees were the most inhabited habitat type by bird species in both areas combined. Due to the general absence of various forest specialists, the fauna composition of reforested regions is generally not comparable to what it was before the disturbance in the area. (Staturf et al. 2014) suggest that one plausible explanation for this could be the delayed development of particular microhabitats in reforested areas. Consequently, the restoration of ecosystem function may prove to be somewhat challenging for Restoration Reserves alone. But by manually adding the unavailability of microhabitats, active management of the region could facilitate the recolonization of habitat specialists (Christie et al., 2013, Santos et al., 2016).

To ensure the recolonization of species that nest in cavities, artificial microhabitats like nest boxes might be constructed. Alternatively, simple microhabitats such hollow logs, wood debris, and pebbles could be introduced. According to (Christie et al. 2013, Santos et al., 2016), the reptile species Napoleon's skink (*Egernia napoleonis*) was able to establish a colony in Jarrah forests in south-western Australia, following the introduction of tiny heaps of woody debris in the reforested areas. According to (Cockle et al. 2010, Santos et al., 2016), the installation of nest boxes increased the number of nesting species in both logged and primary subtropical Atlantic Forests. This suggests that installing nest boxes could be a useful strategy for boosting the number of cavity nesting species in such areas. But sometimes, even active

management cannot help restore the local wildlife. In the case of Costa Rican bats, for example, the installation of artificial bat roosts in grazing land had little impact on forest regeneration since the bats rarely visited the roosts (Reid et al., 2013, Santos et al., 2016).

The study also depicted the migration status (proportion %) of the total population of the bird species observed. Majority of the bird species observed were short distance migrants (37% of the observed bird species were categorised under this group of short distance or local migrants), tens of kilometres are usually involved in this kind of migration. Birds migrate for different reasons, shifting from areas of low or decreasing resources to areas of high or increasing resources this could be food or nesting, other causes include photoperiodism (the increase of day length), instinct and gonadal changes and seasonal variation. There is likely an ever-increasing rate of environmental change occurring globally, leading to both habitat loss and deterioration. Additionally, ecosystems may experience latitudinal alterations as a result of global warming. The ability of populations to adapt to these changes and, in the current setting, in particular, their ability to easily modify their migratory paths as needed, is a crucial question. The organisms that exist now are descended from ancestors who formerly underwent significant climatic change. They do, however, now face a plethora of novel, man-made difficulties, such as the swiftly changing climate. Many bird species rely on endogenous mechanisms to regulate their migration and reproduction.

These mechanisms have been subjected to intense selection over a long period of time to ensure that arrival and departure from breeding grounds are synchronized with moderate temperatures, peak food availability, and nesting site availability (Carey, 2009). According to (Mesa and Mesa, 2024) there was a bigger mismatch between migration and green-up in birds that migrated farther. The reason for this, according to the researchers, is that birds cannot tell what the weather is like farther away, such as whether spring is arriving at their destination earlier than it did at their winter headquarters, even if they are monitoring temperature and other migration cues at their winter home. Additionally, long-distance migrants frequently depend more on their genetic programming for guidance on when to go out on their travels. A bird population's ability to successfully migrate and reproduce could be seriously impacted by mismatches in food sources, snow cover, and other factors brought on by climate

change, unless the bird population can adapt to the new circumstances. Birds that are resident (non-migratory) also encounter difficulties when variations in temperature and/or precipitation patterns lead to inconsistencies in food and nesting. Communities are expected to undergo a significant transformation due to extinctions and shifts in range distributions, since forecasts indicate that many of the current climates will vanish and new ones will emerge in the future.

In this study some light was shed on order classification of the bird species observed. From the total bird species observed, majority were **Passeriformes** - Any bird in the largest order and most prevalent avian group on Earth today, the Passeriformes. Four toes, three pointing forward and one backward, distinguish passeriform birds from other perching birds. Occurring on all continents except Antarctica and most oceanic islands, passerines are thought to be the most highly evolved of all birds. They have seen an enormous evolutionary radiation in relatively recent geological time. Land birds in the Passeriformes family are small to medium-sized, with an overall length that varies from 7.5 to 117 cm (3 to 46 inches). Some of the New World's smallest species are among them. Their range of dietary adaptations is quite diverse. For part of their life, at least, the majority are insectivorous. (Gill et al., 2024).

Bucerotiformes - These birds are found in Papua New Guinea, Asia, and Africa. The long, stiff bills of the birds in this group are their most distinguishing characteristic. There are certain birds in this order that have noticeable casques over their bills, hornbills in particular. These birds have a variety of plumages, ranging from cream and white to black and brown. The hands and legs of the birds are naked and typically have vibrant colours. The main food source for these birds is insects, which they collect from the ground or locate beneath the bark using their pointed bills. A portion of the birds contribute significantly to the spread of the tree by eating fruit and seeds as well (Order Bucerotiformes | Hornbills and Hoopoes | BioExplorer.Net, 2021).

Gruiformes - Although the gruiform are an old group with a rich fossil history, many of their families are currently rare and have a limited range. Although there are members of the order on every continent, the Rallidae family, which includes the 138 extant species of rails, gallinules, and coots, is the only family with a global distribution. The size of gruiform birds varies. Structure-wise, gruiformes differ

greatly; some are suited to life in or near water, while others are better suited for terrestrial life. While several Gruiformes species are flightless, several have good flight. The enormous diversity of food that the Gruiformes consumes is in line with the large range of habitats that they use. Gruiformes are omnivores in general, however they eat more animal than vegetable food. (Gill et al., 2024).

Columbiformes - Pigeons and doves, both extinct and alive, belong to the family Columbidae. There is no biological difference implied by the name's pigeon and dove, which are interchangeable. All pigeons are easily identified, with a few highly specialized ground-dwelling species excluded. Their sizes vary, with some birds as big as a female turkey and others as small as an Australian starling, or diamond dove. With the exception of a few marine islands, the Arctic, and the Antarctic, they are essentially worldwide. They must eat a lot during each feeding day because they mostly survive on low-protein and low-nutrient items including seeds, buds, leaves, and fruits. (Gill et al., 2024).

Coraciiformes - Any bird belonging to the 10 families that make up the Order Coraciiformes, which includes motmots, bee-eaters, and kingfishers. The roller-like birds are diurnally active during the day and can grow up to 160 cm (63 inches) in length, which is roughly the size of a tiny sparrow (10 cm, or 4 inches). Their bodies are compact, with huge heads, short to medium-length necks, rather long bills, small feet, and plenty of wings. Every one of these birds frequently perches in a tree, where some of them graze; others fly around looking for food; still others walk or hop on the ground. The group consumes berries and fruit as well as tiny vertebrates and invertebrates, including insects. (Gill et al., 2024).

Piciformes - Any bird of the Order Piciformes, which is comprised of the well-known woodpeckers and their relatives the piculets and wrynecks. With the exception of Australia and Antarctica, this arboreal group of about 450 species is found throughout the world; only the woodpecker family is widely distributed outside of tropical regions. Because Piciformes has a large number of insect-eating species, it is significant commercially. A few species that harm trees or consume fruit. The rufous piculet (*Sasia abnormis*) is one of the smallest species in the Piciformes family, with an overall length ranging from 8 to over 63 cm (3.1 to 24.8 inches), and the largest species is the toco toucan (*Ramphastos toco*). (Gill et al., 2024).

Anseriformes - Any of the more than 160 species that make up the Anseriformes order of birds, which includes the three species of the Anhimidae family—the screamers—as well as the ducks, geese, and swans (family Anatidae). The family Anatidae is made up of over 147 species of medium-to big birds that are typically found in freshwater or marine environments. The largest Anatidae member is almost 60 times heavier than the smallest, indicating a wide range in size within the family. The majority are very large birds, weighing 250 grams (0.5 pounds) and measuring around 30 centimetres (1 foot) in length. The bill has a medium length, usually broad, somewhat flattened tip, and rounded tip with a small hook. However, the shape of the bill varies greatly, appropriate for birds whose diets are as dissimilar as grass, fish, and tiny plankton. (Gill et al., 2024).

Accipitriformes - This order has about 250 species divided into three families. These avian predators are these. They have powerful talons, strong, curved beaks, and great eyesight. They range in size from medium to giant. They are excellent flyers, frequently gliding overhead on thermals or warm air. For the most part, species build their nests in trees and mate with the same person every year. Usually, male and female pairs reside with them. With the exception of Antarctica, they are widespread worldwide and can be found in a variety of habitats, such as marshes, rainforests, tundra, deserts, and taiga (Hawks, Eagles, Kites, and Allies (Order Accipitriformes), n.d.).

Galliformes - Any of the gallinaceous (i.e., chicken- or fowl-like) birds belong to the Order Galliformes. There are roughly 290 species in the order, the most well-known of which are the peacock, quail, partridge, turkey, and chicken. The majority of galliformes are medium-sized birds, 40–60 cm (16–24 inches) long and 500–2,500 grams (1–5.5 pounds) in weight. They range in size from that of a pigeon to that of a domestic chicken. The galliforms are an order of plants that live in many different types of vegetation, such as open grasslands, dense and open forests, scrub and second-growth woods, and flooded riparian (river) forests. The majority of galliformes species are essentially vegetarians, although they also consume a variety of other invertebrates, including worms and insects, in enormous quantities. (Gill et al., 2024).

Lastly, some light was shed on the dietary preference of the bird species observed in both sites. Several food types that are typically not identified, such as granivore-insectivore (GR/IN) and frugivore-insectivore (FR/IN), can now be recognized according to the classification method we utilised. This will prevent frequent contradictions, such as the classification of birds (e.g., *Tachyphonus*) who eat both fleshy fruits and insects as omnivores (Willis 1979) and of species (e.g., *Coryphospingus*) that eat both seeds and insects as granivores (Willis 1979, Poulin et al. 1994, Lopes et al., 2016).

Based on the scheme shown here, over a thousand different types of diets can be identified; nevertheless, while most combinations are theoretically viable, they hardly ever occur in nature. Two food groups are frequently insufficient to adequately characterize a bird species' diet. The term "omnivore" is often used to characterize birds with a variety of diets, but we do not believe that this is a good way to characterize, for instance, a bird's diet that primarily consists of vegetable matter, rarely ingesting animal matter (like some geese), or a bird's diet that primarily consists of animal matter (like some seabirds). The definition of an omnivore is a "heterotroph that feeds on both plants and animals, and thus operates at a range of trophic levels." This is why we believe that. We can suggest three different diet types that include a range of dietary categories: (1) Herbivores, which mostly consume plant matter; (2) Faunivores, which primarily consume animal matter; and (3) Omnivores (OM), which primarily consume both plant and animal matter (Lopes et al., 2016).

According to a recent study by (Catterall et al. 2012), the mix of avifaunal species in ecological restoration plantings recovered quickly in the first ten years, reaching roughly half of target forest values. The second ten years saw moderate development and significant inter-site variance. The analysis of site-specific longitudinal data in research verifies that there was minimal advancement in avifaunal recovery in the second decade. (Freeman et al. 2009) conducted a long-term analysis of a more localized set of replanted sites in a tropical environment and found a similar initial quick development followed by lack of further avifaunal recovery.

Research on animal recovery in replanted regions is generally lacking (Block et al., 2011). This may be due to the belief that once the flora is restored, wildlife will naturally return to the replanted areas (Thompson and Thompson, 2004). Reforested

lands must also offer suitable habitat for native fauna if Restoration Reserves are to be developed in order to decrease habitat loss and increase biodiversity. This is because animals play a significant role in ecosystem function. Reforested areas typically exhibit comparable bird richness to reference forest areas, although their bird composition will typically shift (Munro et al., 2011, Catterrall et al., 2012, Freeman et al., 2015, Santos et al., 2016). Birds typically respond well to reforestation. Some animal species, however, find it more difficult to recolonize sites that have been reforested. According to data on Australia's recovered mining regions, species richness and abundance of mammals, reptiles, amphibians, and arthropods are typically lower in reforested areas (reviewed in Critescu et al., 2012). Very little prior multi-site research has been done on the paths of biodiversity development after active ecological restoration of tropical forests (as opposed to passive regrowth).

Limitations

This study posed few limitations but detrimental ones to be able to collect the data of the full representation of the population of the areas.

Bird observations were only possible in close proximity to the water stations during the data collection process at Lusaka National Park. We only went to three of the four water spots because the road leading to the fourth point was inaccessible for our 4x4 and was farther from the other three. Due to travel to the site and the need to gather data collecting helpers, observations did not begin until approximately six in the morning. The temperature increases from 8 a.m. onwards caused birds to soar farther into the forest interior, which is why the data collecting took three hours.

Forest 27 has its own set of restrictions as well. Birds were also withdrawing deeper into the forest due to the increased temperatures. Due to travel to the location, bird observations also began at six in the morning. Right next to the forest reserve, a sizable building project was under way when the data was being collected, and heavy mechanical work started as early as 6:30 am. Other citizens were present in the reserve for leisure activities, which added to the noise level during the collecting.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

In summary, even though Forest 27 is a forest reserve, the Lusaka National Park has a higher species diversity and richness than the Forest 27. This difference can be attributed to a number of factors, including the urbanization of the Forest 27 area and the government's recent review of its gazetted forest reserve policies. After years of unclear rules about the land on which the forest is located, Forest 27 was only recently degazetted. As a result, parts of the forest have been subdivided into residential and commercial plots, leaving just a small portion of the original forest. During data collection of this site, it was quite noticeable how small the forest reserve is becoming. From an interior part of the forest, you are able to hear construction vehicles outside the reserve.

We can further conclude that Lusaka National Park is currently working well in terms of avian species diversity and abundance as a regenerated forest compared to forest 27.

Recommendations

Another assessment a few years from now would be recommended to further conclude whether Lusaka National Park (Restored Forest) would still compete or hold a higher amount of diversity and abundance compared to Forest 27 or other forest reserves in the Lusaka area. Another would be to re-evaluate our policies when it comes to forest reserves and protected forests. Strategies for conservation should concentrate on the various ground-nesting, cavity-nesting, canopy-nesting, predatory, and insectivorous bird species that are negatively impacted by logging. Plans for managing forests that prioritize protecting certain focal species or guilds will also help a wide range of other animal species.

REFERENCES

- Ahern, J. 2012. Urban landscape sustainability and resilience: the promise and challenges of integrating ecology with urban planning and design. *Landscape Ecology*, 28(6), 1203–1212.
- Allender, C. 2011. The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture. Rome: Food and Agriculture Organization of the United Nations (2010), pp. 370, *Experimental Agriculture*, 47(3), 574–574.
- Anderson, W.B. and G.A. Polis, 1999. Nutrient fluxes from water to land: seabirds affect plant nutrient status on Gulf of California islands. *Oecologia*. 118(3): p. 324-332.
- Anon (n.d.) Biodiversity / Zambia | Interactive Country Fiches.
- Aongola, L. Bass, S., Chileshe, J., Daka, J., Dalal-Clayton, B., Liayo, I., Makumba, J., Maimbolwa, M., Munyinda, K., Munyinda, N., Ndopu, D., Nyambe, I., Pope, A. and Sichilongo, M. 2009. Creating and protecting Zambia's wealth: experience and next steps in environmental mainstreaming. Natural Resource Issues No. 14. International Institute for Environment and Development. London, UK
- Archer, J. M. J., Hostetler, M. E., Acomb, G., and Blair, R. 2019. A systematic review of forest bird occurrence in North American forest fragments and the built environment. *Landscape and Urban Planning*, 185, 1–23.
- Aronson, M. F., Sorte, F. A., Nilon, C. H., Katti, M., Goddard, M. A., Lepczyk, C., ... Dobbs, C. 2014. A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. *Proceedings of the Royal Society B: Biological Sciences*, 281.
- Bates, D., McCachler, M., Bolker, B.M., Walker, S.C., 2015. Fitting linear mixed-effects models using lme4. *J. Stat. Software* 67, 1–48.
- Battin, J., 2004. When good animals love bad habitats: Ecological traps and the conservation of animal populations. *Conserv. Biol.* 18, 1482-1491.
- Bibby, C.J., Burgess, N.D., Hill, D., Mustoe, S., 2000. *Bird Census Techniques*, second ed. The Wilson Bulletin. Academic Press, London.
- Borges, S. H., and Stouffer, P. S. 1999. Bird communities in two types of anthropogenic successional vegetation in central Amazonia. *Condor* 101: 529–536.
- Blair, R. B. 1999. Birds and butterflies along an urban gradient: Surrogate taxa for assessing biodiversity? *Ecological Applications*, 9, 164–170.

- Block, W. M., Franklin, A. B., Ward, J. P., Ganey, J. L., and White, G. C. 2011. Design and Implementation of Monitoring Studies to Evaluate the Success of Ecological Restoration on Wildlife. *Restoration Ecology*, 9(3), 293–303.
- Carey, C. 2009. The impacts of climate change on the annual cycles of birds. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1534), 3321–3330.
- Catterall, C., Freeman, A. N. D., Kanowski, J. J., and Freebody, K. 2012. Can active restoration of tropical rainforest rescue biodiversity? A case with bird community indicators. *Biological Conservation*.
- Chain-Guadarrama, A., Martínez-Salinas, A., Aristizabal, N., Ricketts, T.H., 2019. Ecosystem services by birds and bees to coffee in a changing climate: a review of coffee berry borer control and pollination. *Agric. Ecosyst. Environ.* 280, 53–67
- Chazdon, R. L. 2008. Beyond Deforestation: Restoring Forests and Ecosystem Services on Degraded Lands. *Science*, 320(5882), 1458–1460.
- Christie, K., Stokes, V. L., Craig, M. D., and Hobbs, R. J. 2013. Microhabitat Preference of *Egernia napoleonis* in Undisturbed Jarrah Forest, and Availability and Introduction of Microhabitats to Encourage Colonization of Restored Forest. *Restoration Ecology*, 21(6), 722–728.
- Clare, D.S., Spencer, M., Robinson, L.A., Frid, C.L.J., 2016. Species-specific effects on ecosystem functioning can be altered by interspecific interactions. *PloS One* 11, 1–17.
- Clearing House Mechanism 2018. Sixth National Report: Zambia
- Cockle, K. L., Martin, K., and Drever, M. C. 2010. Supply of tree-holes limits nest density of cavity-nesting birds in primary and logged subtropical Atlantic forest. *Biological Conservation*, 143(11), 2851–2857.
- Cristescu, R. H., Frère, C., and Banks, P. B. 2012. A review of fauna in mine rehabilitation in Australia: Current state and future directions. *Biological Conservation*, 149(1), 60–72.
- Donnelly, R., and Marzluff, J. M. 2006. Relative importance of habitat quantity, structure, and spatial pattern to birds in urbanizing environments. *Urban Ecosystems*, 9(2), 99–117.
- Ewers, R. M., and Didham, R. K. 2006. Confounding factors in the detection of species responses to habitat fragmentation. *Biological Reviews*, 81(01), 117.

Freeman, A. N., Catterall, C. P., and Freebody, K. 2015. Use of restored habitat by rainforest birds is limited by spatial context and species' functional traits but not by their predicted climate sensitivity. *Biological Conservation*, 186, 107–114.

Gill, F., Storer, R. W., and Rand, A. L. 2024. Bird | Description, Species, Classification, Types, and Facts. *Encyclopaedia Britannica*.

Godoy, J.A. and P. Jordano, 2001. Seed dispersal by animals: exact identification of source trees with endocarp DNA microsatellites. *Molecular Ecology*. 10(9): p. 2275-2283.

Government of the Republic of Zambia, Ministry of Lands, Natural Resources and Environmental Protection, Ngimbu, C., NIRAS-Zambia, Kokwe, M., Matakala, P., Chidumayo, E., Mwila, G., Phiri, C., Phiri, C., Mudenda, H. and Siangulube, F. 2015 ZAMBIA'S SECOND NATIONAL BIODIVERSITY STRATEGY AND ACTION PLAN (NBSAP -2).

Hawks, Eagles, Kites, and Allies (Order Accipitriformes). (n.d.). iNaturalist.

Hill, J. 2022. Birds & Ecosystem Services | EnvironmentalScience.org. Birds & Ecosystem Services | EnvironmentalScience.org. Retrieved October 10, 2022, from

Hostetler, M., and Holling, C. S. 2000. Detecting the scales at which birds respond to structure in urban landscapes. *Urban Ecosystems*, 4, 25–54.

Hostetler, M., and Knowles-Yanez, K. 2003. Land use, scale, and bird distributions in the Phoenix metropolitan area. *Landscape and Urban Planning*, 62, 55–68.

Jones, J. E., Kroll, A. J., Giovanini, J., Duke, S. D., Ellis, T. M., and Betts, M. G. 2012. Avian Species Richness in Relation to Intensive Forest Management Practices in Early Seral Tree Plantations. *PLoS ONE*, 7(8), e43290.

Jumbe, C., Bwalya, S. and Husselman, M. 2008 Contribution of dry forests to rural livelihoods and the national economy in Zambia. Paper to Governing shared resources: Connecting local experience to global challenges. 12th Biennial Conference of the International Association for the Study of Commons, Cheltenham, UK.

Kalinda, T., Bwalya, S., Mulolwa, A. and Haantuba, H. 2008. Use of Integrated Land Use Assessment (ILUA) data for environmental and agricultural policy review and analysis in Zambia. Report Prepared for the Forest Management and Planning Unit of the Forestry Department, FAO & the Zambian Forestry Department, Ministry of Tourism, Environment and Natural Resources, Zambia.

- Ke, A., Sibiya, M.D., Reynolds, C., Mccleery, R.A.M.A., Fletcher Jr., R.J., 2018. Landscape heterogeneity shapes taxonomic diversity of non-breeding birds across fragmented savanna landscapes. *Biodivers. Conserv.* 27, 2681–2698.
- Laurance, W. F. and Bierregaard R.O. Jr. 1997. Tropical forest remnants. Ecology, management, and conservation of fragmented communities. The University of Chicago Press, Chicago, USA. xv + 616 pp. ISBN 0-226-46899-2. *Journal of Tropical Ecology*, 15(3), 379–379.
- Laurance, W. F., Camargo, J. L., Luizão, R. C. C., Laurance, S. G., Pimm, S. L., Bruna, E. M., Stouffer, P. C., Williamson, G. B., Benítez-Malvido, J., Vasconcelos, H. L., Van Houtan, K. S., Zartman, C. E., Boyle, S. A., Didham, R. K., Andrade, A., and Lovejoy, T. 2011. The fate of Amazonian forest fragments: A 32-year investigation. *Biological Conservation*.
- Loiselle, B. A., and Blake, J. G. 1991. Temporal Variation in Birds and Fruits Along an Elevational Gradient in Costa Rica. *Ecology*, 72(1), 180–193.
- Lopes, L. E., Fernandes, A. M., Medeiros, M. C. I., and Marini, M. N. 2016. A classification scheme for avian diet types. *Journal of Field Ornithology*.
- Luck, G. W., and Smallbone, L. T. 2010. The impact of urbanization on taxonomic and functional similarity among bird communities. *Journal of Biogeography*, 38, 894–906.
- MacArthur, R.H. and MacArthur, J.W., 1961. On bird species richness. *Ecology*, 42, pp.594-598.
- MacNally, R. C. 1990. Modelling Distributional Patterns of Woodland Birds along a Continental Gradient. *Ecology*, 71(1), 360–374.
- Martin, D., Bertasi, F., Colangelo, M. A., de Vries, M., Frost, M., Hawkins, S. J., Macpherson, E., Moschella, P. S., Satta, M. P., Thompson, R. C., and Ceccherelli, V. U. 2005. Ecological impact of coastal defence structures on sediment and mobile fauna: Evaluating and forecasting consequences of unavoidable modifications of native habitats. *Coastal Engineering*, 52(10–11), 1027–1051.
- Martin, T. E., and Blackburn, G. A. 2010. Impacts of Tropical Forest Disturbance Upon Avifauna on a Small Island with High Endemism: Implications for Conservation. *Conservation & Society/Conservation & Society*.

- Mason, N. W. H., Mouillot, D., Lee, W. G., and Wilson, J. B. 2005. Functional richness, functional evenness and functional divergence: the primary components of functional diversity. *Oikos*, 111(1), 112–118.
- McCleery, R., Monadjem, A., Baiser, B., Fletcher, R., Vickers, K., and Kruger, L. 2018. Animal diversity declines with broad-scale homogenization of canopy cover in African savannas. *Biological Conservation*, 226, 54–62.
- McKinney, M.L. 2006 Urbanization as a Major Cause of Biotic Homogenization. *Biological Conservation*, 127, 247-260. - References - Scientific Research Publishing.
- Mesa, N., and Mesa, N. 2024. Climate change is happening too fast for migrating birds. *High Country News*
- Monadjem, A., and Virani, M. Z. 2016. Habitat associations of birds at Mara Naboisho Conservancy, Kenya. *Ostrich*, 87(3), 225–230.
- Munro, N. T., Fischer, J., Barrett, G., Wood, J., Leavesley, A., and Lindenmayer, D. B. 2011. Bird's Response to Revegetation of Different Structure and Floristics—Are “Restoration Plantings” Restoring Bird Communities? *Restoration Ecology*, 19(201), 223–235.
- Nepstad, D.C., Serrao, E. A. S, Uhl, C. 1991. Recuperation of a degraded Amazonian landscape: forest recovery and agricultural restoration. *Biological Conservation*, 62(2), 148.
- Nor Hashim, E., and Ramli, R. 2013. Comparative Study of Understorey Birds Diversity Inhabiting Lowland Rainforest Virgin Jungle Reserve and Regenerated Forest. *The Scientific World Journal*, 2013, 1–7.
- Order Bucerotiformes | Hornbills and Hoopoes | BioExplorer.Net. (2021, June 14). Bio Explorer.
- Petchey, O. L., and Gaston, K. J. 2006. Functional diversity: back to basics and looking forward. *Ecology Letters*.
- Pennington, D. N., and Blair, R. B. 2011. Habitat selection of breeding riparian birds in an urban environment: Untangling the relative importance of biophysical elements and spatial scale. *Diversity and Distributions*, 17, 506–518.
- Pennington, D. N., Hansel, J., and Blair, R. B. 2008. The conservation value of urban riparian areas for landbirds during spring migration: Land cover, scale, and vegetation effects. *Biological Conservation*, 141, 1235–1248.

- Reid, J. L., Holste, E. K., and Zahawi, R. A. 2013. Artificial bat roosts did not accelerate forest regeneration in abandoned pastures in southern Costa Rica. *Biological Conservation*, 167, 9–16.
- Renjifo, L. M. 2001. Effect of natural and anthropogenic landscape matrices on the abundance of subandean bird species. Pontificia Universidad Javeriana.
- Rivera Pedroza, L.F., Escobar, F., Philpott, S.M., Armbrecht, L., 2019. The role of natural vegetation strips in sugarcane monoculture: ant and bird functional diversity responses. *Agric. Ecosyst. Environ.* 284, 1-10.
- Santos, P., Marques, F. C., Lima, M. R., and Anjos, L. D. 2016. The importance of restoration areas to conserve bird species in a highly fragmented Atlantic forest landscape. *Natureza and Conservacao*.
- Sodhi, N. S., and Smith, K. G. 2007. Conservation of tropical birds: mission possible? *Journal of Ornithology*, 148(S2), 305–309.
- Sodhi Navjot S., Şekercioğlu Çağan H., Barlow Jos, and Robinson Scott K. 2011. *Conservation of Tropical Birds* Wiley-Blackwell, Chichester, United Kingdom. 312 pp. ISBN 9781444334821. *The Auk*, 129(1), 182–183.
- Stanturf, J. A., Palik, B. J., and Dumroese, R. K. 2014. Contemporary forest restoration: A review emphasizing function. *Forest Ecology and Management*, 331, 292–323.
- Stouffer, P. C. 2007. Density, Territory Size, and Long-Term Spatial Dynamics of a Guild of Terrestrial Insectivorous Birds Near Manaus, Brazil. *The Auk*, 124(1), 291–306.
- The IUCN Red List of Threatened Species. (n.d.). IUCN Red List of Threatened Species
- Thompson, S. A., and Thompson, G. G. 2004. Adequacy of rehabilitation monitoring practices in the Western Australian mining industry. *Ecological Management & Restoration*, 5(1), 30–33.
- Tilman, D. 2001. Functional Diversity. *Encyclopedia of Biodiversity*, 3, 109-120. - References - Scientific Research Publishing. (n.d.).
- Tu, H. M., Fan, M. W., and Ko, J. C. J. 2020. Different Habitat Types Affect Bird Richness and Evenness. *Scientific Reports*, 10(1).
- UNEP 2011. *Toward a Green Economy – Pathways to Sustainable Development and Poverty Eradication*. Geneva: Switzerland

- Vandermeer, J., and Perfecto, I. 1997. The Agroecosystem: A Need for the Conservation Biologist's Lens. *Conservation Biology*, 11(3), 591–592.
- Wathum, G., Seebauer, M., Carodenuto, S., and Zambia Integrated Forested Landscape Program 2016 Drivers of deforestation and forest degradation in Eastern Province, Zambia.
- Wiens, J. A. 1989. Spatial Scaling in Ecology. *Functional Ecology*, 3(4), 385.
- Wiens, J. A., Van Horne, B., and Rotenberry, J. T. 1987. Temporal and spatial variations in the behavior of shrubsteppe birds. *Oecologia*, 73(1), 60–70.
- Wolfe, J. D., Powell, L. L., Johnson, E. I., Hines, J. E., Nichols, J. D., and Stouffer, P. C. 2015. Heterogeneous movement of insectivorous Amazonian birds through primary and secondary forest: A case study using multistate models with radiotelemetry data. *Biological Conservation*, 188, 100–108.
- Zacheis, A., R.W. Ruess, and J.W. Hupp., 2002. Nitrogen dynamics in an Alaskan salt marsh following spring use by geese. *Oecologia*, 130(4): p. 600-608.
- Zhu, Z., and Waller, E. 2003. Global Forest Cover Mapping for the United Nations Food and Agriculture Organization Forest Resources Assessment 2000 Program. *Forest Science*, 49(3), 369–380.

APENDICES

Appendix 1: Shannon-Weiner diversity index (Lusaka National Park)

Lusaka National Park				
Species	No	Pi	ln pi	pi ln pi
Campephaga flava	4	0.030534	-3.4889	-0.10653
Muscicapa boehmi	3	0.022901	-3.77659	-0.08649
Halcyon leucocephala	2	0.015267	-4.18205	-0.06385
Muscicapa caerulescens	2	0.015267	-4.18205	-0.06385
Chlorocichla flaviventris	1	0.007634	-4.8752	-0.03722
Melaenornis pallidus	6	0.045802	-3.08344	-0.14123
Crithagra mozambica	9	0.068702	-2.67797	-0.18398
Pycnonotus tricolor	7	0.053435	-2.92929	-0.15653
Anaplectes rubriceps	2	0.015267	-4.18205	-0.06385
Vidua macroura	1	0.007634	-4.8752	-0.03722
Phyllastrephus terrestris	1	0.007634	-4.8752	-0.03722
Uraeginthus angolensis	5	0.038168	-3.26576	-0.12465
Motacilla flava	6	0.045802	-3.08344	-0.14123
Lanius souzae	1	0.007634	-4.8752	-0.03722
Tchagra australis	2	0.015267	-4.18205	-0.06385
Numida meleagris	6	0.045802	-3.08344	-0.14123
Streptopelia capicola	8	0.061069	-2.79576	-0.17073
Streptopelia semitorquata	1	0.007634	-4.8752	-0.03722
Coracias garrulus	1	0.007634	-4.8752	-0.03722
Muscicapa striata	15	0.114504	-2.16715	-0.24815
Ficedula albicollis	2	0.015267	-4.18205	-0.06385
Anthus cinnamomeus	2	0.015267	-4.18205	-0.06385
Merops persicus	1	0.007634	-4.8752	-0.03722
Oriolus auratus	2	0.015267	-4.18205	-0.06385
Ispidina picta	2	0.015267	-4.18205	-0.06385
Sarothrura rufa	2	0.015267	-4.18205	-0.06385
Lesser Honeyguide	2	0.015267	-4.18205	-0.06385
Lybius torquata	2	0.015267	-4.18205	-0.06385
Melaenornis pammelaina	4	0.030534	-3.4889	-0.10653
Myioparus plumbeus	1	0.007634	-4.8752	-0.03722
Chlorophoneus sulfureopectu	1	0.007634	-4.8752	-0.03722
Dicrurus adsimilis	3	0.022901	-3.77659	-0.08649
Dendrocygna viduata	1	0.007634	-4.8752	-0.03722
Vidua obtusa	1	0.007634	-4.8752	-0.03722
Sylvietta rufescens	4	0.030534	-3.4889	-0.10653
Cossypha heuglini	2	0.015267	-4.18205	-0.06385
Ceryle rudis	1	0.007634	-4.8752	-0.03722
Passer griseus	6	0.045802	-3.08344	-0.14123
Turdus libonyana	2	0.015267	-4.18205	-0.06385
Chalcomitra senegalensis	2	0.015267	-4.18205	-0.06385
Prodotiscus regulus	1	0.007634	-4.8752	-0.03722
Indicator indicator	2	0.015267	-4.18205	-0.06385
Acrocephalus arundinaceus	1	0.007634	-4.8752	-0.03722
Oena capensis	1	0.007634	-4.8752	-0.03722
Sum	131	1		-3.45746
H			H'	3.457459

Effective Number of Species (ENS) = EXP (H') 31.73623

Appendix 2: Simpsons diversity index (Lusaka National Park)

Lusaka National Park			
Species	No	n-1	n(n-1)
Campephaga flava	4	3	12
Muscicapa boehmi	3	2	6
Halcyon leucocephala	2	1	2
Muscicapa caerulescens	2	1	2
Chlorocichla flaviventris	1	0	0
Melaenornis pallidus	6	5	30
Crithagra mozambica	9	8	72
Pycnonotus tricolor	7	6	42
Anaplectes rubriceps	2	1	2
Vidua macroura	1	0	0
Phyllastrephus terrestris	1	0	0
Uraeginthus angolensis	5	4	20
Motacilla flava	6	5	30
Lanius souzae	1	0	0
Tchagra australis	2	1	2
Numida meleagris	6	5	30
Streptopelia capicola	8	7	56
Streptopelia semitorquata	1	0	0
Coracias garrulus	1	0	0
Muscicapa striata	15	14	210
Ficedula albicollis	2	1	2
Anthus cinnamomeus	2	1	2
Merops persicus	1	0	0
Oriolus auratus	2	1	2
Ispidina picta	2	1	2
Sarothrura rufa	2	1	2
Lesser Honeyguide	2	1	2
Lybius torquata	2	1	2
Melaenornis pammelaina	4	3	12
Myioparus plumbeus	1	0	0
Chlorophoneus sulfureopectus	1	0	0
Dicrurus adsimilis	3	2	6
Dendrocygna viduata	1	0	0
Vidua obtusa	1	0	0
Sylvietta rufescens	4	3	12
Cossypha heuglini	2	1	2
Ceryle rudis	1	0	0
Passer griseus	6	5	30
Turdus libonyana	2	1	2
Chalcomitra senegalensis	2	1	2
Prodotiscus regulus	1	0	0
Indicator indicator	2	1	2
Acrocephalus arundinaceus	1	0	0
Oena capensis	1	0	0
Total	131		598

Simpson Diversity Index = 28.47826

Appendix 3: Shannon-Weiner Diversity index (Forest 27)

Forest 27				
Species	No	Pi	ln pi	pi ln pi
Malaenoris pallidus	6	0.054545	-2.90872	-0.15866
Muscicapa boehmi	4	0.036364	-3.31419	-0.12052
Calamonastes undosus	2	0.018182	-4.00733	-0.07286
Motacilla aguimp	4	0.036364	-3.31419	-0.12052
Muscicapa caerulescens	2	0.018182	-4.00733	-0.07286
Prionops plumatus	9	0.081818	-2.50326	-0.20481
Lanius souzae	2	0.018182	-4.00733	-0.07286
Cercotrichas leucophrys	7	0.063636	-2.75457	-0.17529
Chalcomitra senegalensis	4	0.036364	-3.31419	-0.12052
Pycnonotus tricolor	3	0.027273	-3.60187	-0.09823
Prodotiscus regulus	6	0.054545	-2.90872	-0.15866
Coracina pectoralis	2	0.018182	-4.00733	-0.07286
Prinia subflava	2	0.018182	-4.00733	-0.07286
Muscicapa striata	1	0.009091	-4.70048	-0.04273
Pogoniulus chrysoconus	4	0.036364	-3.31419	-0.12052
Myioparus plumbeus	2	0.018182	-4.00733	-0.07286
Tchagra australis	3	0.027273	-3.60187	-0.09823
Sylvia borin	2	0.018182	-4.00733	-0.07286
Zosterops senegalensis	3	0.027273	-3.60187	-0.09823
Sylvietta rufescens	7	0.063636	-2.75457	-0.17529
Batis molitor	2	0.018182	-4.00733	-0.07286
Motacilla flava	1	0.009091	-4.70048	-0.04273
Numida meleagris	1	0.009091	-4.70048	-0.04273
Cinnyris talatala	1	0.009091	-4.70048	-0.04273
Rhinopomastus aterrimus	1	0.009091	-4.70048	-0.04273
Merops persicus	2	0.018182	-4.00733	-0.07286
Streptopelia capicola	1	0.009091	-4.70048	-0.04273
Melaenornis pammelania	1	0.009091	-4.70048	-0.04273
Cisticola erythrops	15	0.136364	-1.99243	-0.2717
Lybius torquatus	2	0.018182	-4.00733	-0.07286
Pernis apivorus	1	0.009091	-4.70048	-0.04273
Pitta angolensis	1	0.009091	-4.70048	-0.04273
Lanius humeralis	1	0.009091	-4.70048	-0.04273
Eremopterix leucotis	2	0.018182	-4.00733	-0.07286
Prionops retzii	3	0.027273	-3.60187	-0.09823
sum	110	1		-3.24818
H			H' =	3.248181

Effective Number of Species (ENS) = EXP (H') 25.74347

Appendix 4: Simpsons diversity Index (Forest 27)

Forest 27			
Species	No	n-1	n(n-1)
Malaenoris pallidus	6	5	30
Muscicapa boehmi	4	3	12
Calamonastes undosus	2	1	2
Motacilla aguimp	4	3	12
Muscicapa caerulescens	2	1	2
Prionops plumatus	9	8	72
Lanius souzae	2	1	2
Cercotrichas leucophrys	7	6	42
Chalcomitra senegalensis	4	3	12
Pycnonotus tricolor	3	2	6
Prodotiscus regulus	6	5	30
Coracina pectoralis	2	1	2
Prinia subflava	2	1	2
Muscicapa striata	1	0	0
Pogoniulus chrysoconus	4	3	12
Myioparus plumbeus	2	1	2
Tchagra australis	3	2	6
Sylvia borin	2	1	2
Zosterops senegalensis	3	2	6
Sylvietta rufescens	7	6	42
Batis molitor	2	1	2
Motacilla flava	1	0	0
Numida meleagris	1	0	0
Cinnyris talatala	1	0	0
Rhinopomastus aterrimus	1	0	0
Merops persicus	2	1	2
Streptopelia capicola	1	0	0
Melaenornis pammelania	1	0	0
Cisticola erythrops	15	14	210
Lybius torquatus	2	1	2
Pernis apivorus	1	0	0
Pitta angolensis	1	0	0
Lanius humeralis	1	0	0
Eremopterix leucotis	2	1	2
Prionops retzii	3	2	6
Total	110		520

Simpson Diversity Index = 23.05769

Appendix 5: Pin-tailed whydah (Lusaka National Park)



Appendix 6: kurrichane Thrush (Lusaka National Park)



