

**IMPACTS OF ANTHROPOGENIC ACTIVITIES ON BIRDS AND THEIR
HABITATS IN AND AROUND LAKE SOLAI, KENYA**

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KENYA**

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DECLARATION

Declaration by the Candidate

This thesis is my original work and has never been presented for the award of an academic degree in any other university and should not be copied or reproduced in any format without written authority from the author and/or University of Eldoret.

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DEDICATION

This work is dedicated to my parents Kimeli Chemjor and Esther Marigat, whose enduring commitment, resilience, encouragement and sacrifices have laid the foundation for my academic journey. Your unwavering belief in the power of education has been my guiding light. To my brothers Wicliffe, Victor and Nimrod thank you for your steadfast support, understanding and belief in me, even when the path seemed uncertain. Your presence has been a constant source of strength. Lastly, this work is also dedicated to all wildlife conservationists working to protect and preserve nature. Your dedication inspires hope for a more sustainable and harmonious world.

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ABSTRACT

Birds serve as vital indicators of ecosystem health and biodiversity, yet knowledge of their distribution, diversity, and threats in habitats surrounding ecosystems such as Lake Solai, Nakuru County, Kenya, remains limited. Lake Solai supports a diverse assemblage of resident and migratory avifauna but faces increasing anthropogenic pressures, including pollution, grazing, agricultural expansion, and urbanization. This study aimed to evaluate bird distribution and feeding guilds across habitat types, assess species richness and diversity, compare relative bird densities, and identify anthropogenic threats affecting avian communities in and around Lake Solai. Field data were collected using point count and line transect surveys, generating a comprehensive checklist of bird species that included taxonomic identification, habitat associations, IUCN conservation status, migratory status, feeding guilds, and forest dependency. Species richness and diversity were analyzed using sample-based rarefaction-extrapolation curves (iNEXT platform) and the Shannon-Wiener diversity index (H'), with Hutcheson's t-test evaluating significant differences. Sørensen's similarity index quantified species overlap among habitats, while one-way ANOVA compared bird densities. Threat assessments were based on structured questionnaires and analyzed using descriptive statistics and Chi-square tests of goodness of fit and independence in IBM SPSS software (version 20). Bird species diversity varied across habitats, with wetlands and settlements showing the lowest diversity ($H' = 3.723$ – 3.774), intermediate diversity in farmlands ($H' = 3.938$), and the highest diversity in forests and grasslands ($H' = 4.087$ – 4.151). Hutcheson's t-tests indicated significant differences between most habitat pairs, except for forests vs. grasslands and settlements vs. wetlands. One-way ANOVA revealed no statistically significant differences in bird density across habitats ($F = 0.832$, $df = 4$, $p = 0.525$). Chi-square analysis of reported threats showed significant variation in frequency among threat types ($\chi^2 = 296.796$, $df = 10$, $p < 0.001$). In conclusion, bird species diversity in and around Lake Solai is strongly influenced by habitat type, whereas density varies with habitat structure and resource availability. Habitat degradation, climate change, human disturbance, and pollution were identified as primary anthropogenic pressures. Conservation recommendations include the protection and restoration of wetlands and forests through formal designation as conservation areas, implementation of habitat-based conservation planning, promotion of reforestation and catchment protection, pollution control, and community-led habitat monitoring. Integrating climate-smart agriculture, environmental education, and participatory management within local livelihoods will enhance community ownership and foster long-term ecological resilience. Long-term monitoring of avian populations to evaluate the impacts of environmental change on biodiversity and maintain ecosystem balance in the Lake Solai ecosystem.

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LIST OF ABBREVIATIONS

AM	Afrotropical migrants
ANOVA	Analysis of Variance
CBD	Convention on Biological Diversity
CBNRM	Community-Based Natural Resource Management
CBO	Community-Based Organization
CMS	Convention on Migratory Species
CR	Critically Endangered
DF	Degrees of Freedom
EN	Endangered
FA	Farmlands
F	Forests
G	Grasslands
IBA	Important Bird Area
ICTZ	Intertropical Convergence Zone
IUCN	International Union for Conservation of Nature
LC	Least Concern
NT	Near Threatened
R	R Statistical Software
P-value	Probability Value
PM	Paleartic migrants
SD	Standard Deviation
SE	Standard Error

S	Settlements
SPSS	Statistical Package for Social Sciences
SSI	Sorenson's Similarity Index
VU	Vulnerable
W	Wetlands

DEFINITION OF OPERATIONAL TERMS

Anthropogenic Activities-Human activities that alter natural ecosystems and environmental factors, such as agriculture, urbanization, deforestation, and pollution.

Avifauna-The collective bird species found in a particular region or habitat.

Breeding Season-The time of year when birds reproduce, often tied to food availability and habitat conditions.

Disturbance-Any temporary, short term or permanent changes in environmental conditions that causes a pronounced change in an ecosystem, especially when it involves habitat changes that lead to extinctions due to habitat fragmentation.

Edge Effect-The ecological changes that occur at the boundary between different habitat types, often impacting species composition.

Endemic Species-Species that are native to and found only within a specific geographical area.

Feeding Guild-A group of bird species that exploit the same class of food resources in a similar way.

Flyway-A migratory route used by bird species during seasonal movements, often spanning continents.

Foraging Behavior-The set of actions performed by birds to search for and acquire food.

Habitat-A natural environment where a species or community lives, providing the necessary conditions for survival and reproduction.

Habitat Degradation-This is where a natural habitat becomes incapable of supporting its native species due to human or environmental factors.

Habitat Fragmentation-This is the division of large, continuous habitats into smaller, isolated patches, often reducing biodiversity.

Indicator Species- Species whose presence or absence reflects specific environmental conditions, often used to assess ecosystem health.

Invasive Species- These are non-native species that spread rapidly and can disrupt native ecosystems and species.

IUCN Red List Status- It is the global classification of species based on their risk of extinction.

Migratory Birds- These are birds that travel between breeding and non-breeding areas on a seasonal basis.

Nesting Site- Specific locations used by birds for laying and incubating eggs and raising chicks.

Riparian Zone- The interface between land and a river or stream, often rich in biodiversity and important for bird habitats.

Species Diversity- A measure that considers both the number of species and their relative abundance in a community.

Species Richness-The number of different species recorded in a particular area or ecosystem.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Birds are an important constituent and an important link in the food chain of any ecosystem. They are indicators of biological diversity hence serve as important gauges of biodiversity and ecological health (Müller et al. 2020). Environments with large numbers of birds also have many different organisms. Birds play vital ecological roles including regulating insect populations, facilitating seed dispersal, and contributing to plant pollination, thereby maintaining ecosystem balance and functionality (Mariyappan et al. 2023). Therefore, for effective conservation and management of these ecosystems, it is crucial to understand bird distribution and abundance in an ecosystem. A survey of the birdlife of any environment will definitely give a clue to the health status of that environment in terms of biodiversity (Cianconi et al. 2022).

According to Strebel et al. (2022), abundance of bird species is largely influenced by the spatiotemporal distribution of some key environmental resources. Various studies elsewhere in the world have attempted to study factors that affect bird abundance and distribution at spatial and temporal scales (Gizachew, 2021). Among them is seasonality which plays a major role in determining the abundance and distribution of birds since it affects food and cover availability of bird population, which in turn affects breeding success and their survival.

However, bird populations are increasingly threatened by human-induced changes, including habitat loss, fragmentation, pollution, and land-use change (Sodhi et al. 2011).

Different land uses can affect the availability and quality of habitat, food resources, and nesting sites for birds, which can in turn influence their populations. Modern agricultural practices such as intensive farming, pesticide use, and land conversion can negatively impact bird populations (Douglas et al. 2023). The removal of hedgerows and trees, which provide important nesting and foraging habitats for birds, can result in reduced bird diversity and abundance (Montgomery et al. 2020). Urbanization can result in the loss of habitat and reduced bird populations (Tscharntke & Batáry, 2023). Despite this, some agricultural practices such as organic farming can support higher bird diversity and abundance (Kirk et al. 2020).

Species sensitivity to the habitat type could alter the diversity, abundance, and distribution of birds in an area. Natural wetlands provide important habitats for many bird species including migratory birds. Wetland loss and degradation due to human activities such as drainage, agricultural expansion, and urbanization have contributed to declines in wetland bird populations (Mereta et al, 2021). As such bird species diversity and richness are directly correlated with habitat diversity of both biological and structural features (Basile et al. 2021).

The higher number of birds observed in terrestrial habitats may be attributed to such habitats having greater resources such as food and nesting sites which enhance their ability to support more birds. As Davison et al. (2021) noted, one of the main causes of biodiversity loss and ecological deterioration is changes in land use. Bird populations and their habitats can be affected by land use changes, such as habitat fragmentation, urbanization, and agricultural intensification which can shift their distribution and abundance (Gaüzère et al. 2020). Urbanization, in particular has been shown to have

negative effects on bird abundance and diversity, with urban areas having fewer species and individuals compared to natural or rural areas (Sun et al. 2022).

Urbanization is one of the greatest challenging factors to wildlife conservation, this is as a result of the numbers of species lost or threatened (Rehman, 2024). Studies by Szabó et al. (2023) found that both the richness and abundance of native species including plants, mammals, insect and amphibians decrease in response to urbanization. Biodiversity is greatly reduced when large areas of natural habitat are fragmented. The expansion of cities causes the fragmentation of natural habitat through the development of infrastructure such as roads, houses and industry (Zipperer et al. 2020). In many cases all that remains are small remnant patches of the original habitat contained within the confined of the city . Urban areas typically have fewer trees and green spaces than natural areas, and the remaining vegetation may be fragmented, reducing connectivity and access to resources for birds (Von Thaden et al. 2021). However, some bird species have adapted to urban environments and can thrive in city parks and gardens (Vasquez & Wood. 2022).

Lake Solai is a freshwater lake located in the Rift Valley region of Kenya and is characterized by a range of ecosystems including grasslands, shrublands, and wetlands, which support diverse avian species. The lake and its surrounding wetlands support a diverse array of bird species, including both resident and migratory birds. Lake Solai is an important stop over for waterfowls migrating from Lake Bogoria to Lake Nakuru. However, these habitats are increasingly under threat due to various anthropogenic and environmental factors. Bird species in this region face multiple challenges that jeopardize their populations and the ecological balance of their habitats.

Although there has been significant research in recent decades on avifauna and threats to biodiversity in their habitats, little research has been done in Lake Solai. Understanding the distribution, species richness and diversity, relative density and threats facing birds and their habitats is essential for effective conservation and management of the biodiversity in the area. This study aimed to investigate the foregoing aspects to provide insights that can inform targeted conservation efforts.

1.2 Statement of the problem

Birds are key indicators of ecosystem health and biodiversity, which necessitates a thorough understanding of their diversity, richness, relative density, distribution, and threats for effective conservation efforts (Fraixedas et al. 2020). However, significant knowledge gaps on the foregoing remains, particularly on wetland ecosystems in Kenya's Rift Valley, yet bird populations continue to decline due to habitat loss, climate change, pollution, and other anthropogenic pressures (Gebreegziabher et al. 2024).

Despite its importance, current data on bird species richness, diversity, relative density, distribution, and threats around Lake Solai are limited, as most avian research in the region has primarily targeted larger Rift Valley lakes such as Nakuru, Bogoria, Baringo and Naivasha. This knowledge gap hinders tailored conservation and management strategies for Lake Solai's unique biodiversity context. Assessing species richness, diversity, relative density, and distribution is critical for evaluating the health of bird populations and their habitats. Without localized studies, Lake Solai's ecosystems face increased risk of degradation, threatening biodiversity and ecological services.

1.3 Justification and significance of the study

Lake Solai, a critical ecosystem in Kenya's Rift Valley supports a wide variety of resident and migratory bird species. This important wetland is under increasing pressure from pollution, overgrazing, farming activities and urbanization, which increasingly fragment and degrade habitats impacting birds nesting and foraging areas. As an understudied wetland within the African-Eurasian Flyway, it lacks data on bird species richness, diversity, relative density, distribution, and threats, impeding tailored conservation efforts and risking biodiversity loss.

This study aimed to close the gap by assessing bird species richness, diversity, relative density, distribution, and threats to inform conservation and sustainable management. It will identify priorities for threatened species, human-wildlife interactions, and support evidence-based land management and sustainable development, balancing conservation with local livelihoods. By contributing to avian ecology knowledge in smaller wetlands, the research will aid regional biodiversity conservation and long-term monitoring, providing critical data for policymakers, conservationists, and stakeholders to preserve Lake Solai's ecological integrity.

This study enhances the understanding of how anthropogenic activities influence bird richness, diversity, abundance and habitat quality in and around Lake Solai. The findings provide baseline data for avian conservations and habitat management in a region facing increasing human pressure. The results will support conservation planning and promote local coexistence between local livelihoods and biodiversity around Lake Solai.

1.4 Objectives of the study

1.4.1 Main objective

To investigate the impacts of anthropogenic activities on bird species distribution, diversity, and density in and around Lake Solai, Kenya.

1.4.2 Specific objectives

- i. To evaluate the distribution of birds and compare birds' feeding guilds across different habitat types in and around Lake Solai.
- ii. To assess bird species richness and diversity in habitats in and around Lake Solai.
- iii. To compare the relative density of birds in habitats in and around Lake Solai.
- iv. To determine anthropogenic threats affecting birds and their habitats in and around Lake Solai.

1.5 Hypotheses of the study

- i. HO₁: There is no significant variation in bird species distribution and feeding guild composition across different habitat types in and around Lake Solai
- ii. HO₂: There is no significant difference in bird species richness and diversity in the habitats in and around Lake Solai.
- iii. HO₃: There is no significant difference in bird density in habitats with varying land use or human activity in and around Lake Solai.
- iv. HO₄: There is no significant difference in the frequency of perceived anthropogenic threats influencing birds and their habitats in in and around Lake Solai .

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This literature review examines the current state of knowledge on bird ecology, focusing on the threats to bird populations and their habitats. It integrates global and regional perspectives, with an emphasis on the ecological significance and conservation challenges of Lake Solai, Kenya. The review aimed to provide a comprehensive understanding of these issues, identify knowledge gaps, and inform effective management and conservation strategies.

2.2 Background information

Birds are integral to maintaining ecological balance and biodiversity, contributing significantly as pollinators, seed dispersers, scavengers, and indicators of environmental health (Sekercioglu, 2006). Their ecological roles make them crucial for ecosystem functioning and human well-being. Despite this, global bird populations are increasingly threatened by habitat loss, climate change, pollution, and invasive species (Lees et al. 2022). These threats are driven by anthropogenic activities, with profound implications for avian species and the ecosystems they inhabit.

Globally, bird populations have experienced alarming declines. A recent study by Rosenberg et al. (2019) revealed that North America alone has lost nearly 3 billion birds since 1970, highlighting the urgency for conservation interventions. Similarly, the decline in migratory species due to habitat fragmentation, illegal hunting, and changing climatic conditions has been widely documented (Newton, 2023). While these threats are universal,

their severity and impacts vary across regions, necessitating tailored conservation approaches.

In Kenya, wetlands such as Lake Solai play a vital role in supporting avifauna, particularly migratory and resident species. However, these ecosystems are under pressure from agricultural expansion, pollution, and unsustainable land use, which threaten bird habitats and biodiversity (Odada & Olago, 2006). Despite global and local conservation efforts, knowledge gaps remain regarding the specific threats and ecological dynamics of birds in such areas, limiting the effectiveness of interventions.

2.3 Distribution of birds

The distribution of birds has been described as the spatial pattern of where different bird species are found across geographical areas (Callaghan et al. 2023). It involves understanding the presence, abundance, and range of bird species within specific habitats, ecosystems, regions, or even globally. Bird distribution is influenced by various factors such as climate, habitat availability, food resources, breeding requirements, migration patterns, and interactions with other species. From a global perspective, patterns of bird distribution reflect broad biogeographical processes shaped by climate gradients, habitat heterogeneity, and evolutionary history (Jetz et al. 2012).

Africa is home to a diverse range of bird species, including endemic species found only on the continent, such as the African grey parrot and the shoebill. The distribution of birds across Africa is heavily influenced by the presence of varied habitats, among them the Congo Basin, East African savannas, and coastal wetlands like the Zambezi Delta (Brown et al. 2020). The distribution is also influenced by seasonal variations, with many species

dependent on the availability of resources such as water and food. However, habitat degradation caused by human activities such as agriculture and pollution poses a significant threat to these ecosystems, leading to declines in bird diversity and abundance.

Wetlands are biodiversity hotspots supporting a diverse array of bird species, including residents and migrants. Wetlands such as the Okavango Delta and Lake Victoria are crucial habitats for waterbirds including pelicans, herons, egrets, and flamingos. These areas also serve as critical stopover sites for Palearctic migratory birds during their seasonal journeys (Odada & Olago, 2006).

In West and Central Africa, wetlands such as the Niger Delta, Inner Niger Delta, and Lake Chad Basin provide essential habitats for numerous waterbird species, supporting both Afrotropical residents and Palearctic migrants (Dodman & Diagana, 2006). Ghana coast waterbird census (2023). The 2023 national coastal waterbird census along Ghana's coast (West Africa) reported on selected wetland sites (including several Ramsar sites) and provided important data on wintering/stopover waterbirds along the East Atlantic Flyway.

Kenya is known for its rich bird diversity due to the variety of ecosystems, ranging from coastal mangroves to highland forests and savannas. Wetlands such as Lake Victoria, Lake Naivasha, and Lake Solai support numerous waterbirds, while the savanna regions are home to species like ostriches and secretary birds. Kenya is also a critical stopover site for migratory birds along the East African migration corridor (Mohamed et al. nd.).

The avifauna of Kenya includes a total of 1157 confirmed species as of October 2022 (Clements et al. 2022). Of these, 11 are endemic and 4 have been introduced by humans. According to IUCN (2008), habitat loss is the main threat facing 85% of all the bird species

documented in the IUCN Red List. Although human activities have allowed the expansion of a few species, they have caused population decreases or extinction in many other species (Mogaka et al. 2019). Globally, many bird species are declining, with 1227 species listed as threatened by BirdLife International and the IUCN (Vié et al. 2009). According to Mogaka et al. (2019), birds reside in a wide range of ecological positions with some as generalists, while others are highly specialized in their habitat or requirements for foraging. They occupy different niches even within a lone habitat.

Kenya's diverse habitats including forests, grasslands, farmlands, savannas, and montane ecosystems are vital for sustaining its rich birdlife by providing essential foraging, nesting, and breeding sites for both resident and migratory species. Forests such as the Mau and Aberdare support many forest-dependent and endemic birds like the Taita Apalis (*Apalis fuscigularis*), while grasslands and savannas host open-country species such as the Secretary bird (*Sagittarius serpentarius*), many of which are sensitive to land-use changes (Ndang'ang'a et al. 2013) Farmlands and agroecosystems, though human-modified, remain important for generalist species and offer ecological services such as pest control and seed dispersal (Attwood et al. 2017).

2.4 Relative density of birds

Relative density is an important ecological metric that measures the proportion of individuals of a particular bird species relative to the total number of birds counted within a specific area or community (Bibby, 2000). This gives insights into the structure and composition of bird communities, indicating which species are dominant or rare within ecosystems. Unlike absolute density, which focuses on the number of individuals per unit

area, relative density emphasizes on comparing abundance among species, which is crucial for understanding interspecific relationships and community dynamics (Magurran, 2013).

Assessing relative density is fundamental to avian ecology and conservation biology because it helps reveal how species utilize habitats, respond to environmental gradients, and cope with anthropogenic pressures (Sutherland, 2006). Bird communities are shaped by numerous factors such as habitat quality, food availability, predation, competition, and human activities. These factors influence the relative density of species by affecting their survival, reproduction, and movement patterns (Morrison et al. 2020).

Habitat heterogeneity plays a vital role in determining bird relative densities. Complex habitats with diverse vegetation structures generally support higher relative densities of specialist species by providing abundant resources and suitable niches (Sekercioglu, 2012). Habitat degradation, fragmentation, and land-use changes often lead to a decline in relative densities of sensitive species, while more generalist or invasive species may increase in relative abundance (Fahrig et al. 2011). These shifts can result in altered community compositions and potentially reduced ecosystem functionality.

Relative density data are widely used to monitor bird populations and assess biodiversity health across ecosystems including forests, wetlands, grasslands, and agricultural landscapes. They also help identify indicator and keystone species whose population trends serve as proxies for overall ecosystem condition (Gregory & Van Strien, 2010). By analyzing changes in relative densities over time, researchers can detect early warning signs of ecological disturbances, enabling timely conservation interventions.

Research in wetland ecosystems has shown that relative density of waterbirds can fluctuate in response to changes in water levels, pollution, and human disturbance, providing a basis for wetland conservation and restoration efforts (Elphick et al. 2010). Wetlands and adjacent habitats such as those surrounding Lake Solai serve as important stopover and breeding sites for both resident and migratory birds. According to Osoro et al. (2020) land-use changes and environmental degradation affect bird relative densities.

2.5 Birds' richness and diversity

2.5.1 Birds richness

Species richness is a key way to quantify biodiversity. It shows how many different types of birds live in a certain habitat or ecosystem (Magurran, 2013). It is a very important sign of how healthy an ecosystem is, and it is typically used to decide which areas should be protected first (Gaston, 2000). Habitat diversity, resource availability, climate stability, and disturbance regimes are just a few of the environmental elements that affect richness (Rahbek & Graves, 2001). According to Tews et al. (2004), areas with complex vegetation structure and a variety of microhabitats tend to have more species because they provide niches for many different species.

Tropical areas around the world always have the most bird species since the weather is good and the habitats are complicated (Jetz et al. 2012). On the other hand, temperate and boreal zones usually have fewer species, but they may have more migratory birds during certain times of the year, which makes the areas richer for a short time (Newton, 2023). Island and isolated ecosystems often have distinctive patterns of species richness that are

affected by things like the size of the area, how isolated it is, and its evolutionary history (Whittaker & Fernández-Palacios, 2007).

In Africa, the number of bird species is closely tied to the variety of environments like savannas, marshes, forests, and mountains (Fjeldså & Bowie, 2021). Many endemic species live in biodiversity hotspots like the Albertine Rift and the East African Rift Valley, which makes the region very rich (Plumptre et al. 2007). Wetlands like Lake Nakuru and Lake Victoria are home to many different types of waterbirds. They are also important stopover or breeding places for migratory birds (Okeyo-Owuor et al. 2012). Despite this, smaller wetlands like Lake Solai have not gotten much attention, even though they may support a lot of birds because they have a variety of habitats.

Changes in land use and disturbance of the environment have complicated effects on species richness. The Intermediate Disturbance Hypothesis (Katuwal, 2013) states that moderate disturbance generally promotes richness by making habitats more diverse and letting species with different ecological needs live together. On the other hand, intense or long-lasting disturbances like deforestation or urban sprawl usually lower species richness by removing or making habitats simpler (Newbold et al. 2015).

Research in Kenya has demonstrated that cultivated landscapes and broken-up woods can keep a modest number of birds as long as the structural habitat features are kept (Fardila & Sjarmidi, 2012). It's important to understand these processes in order to manage habitats in places like Lake Solai, where human activities affect the health of the environment.

2.5.2 Bird diversity

Many bird species are habitat specific and respond especially to habitat structure (Mason et al. 2019). Birds are one of the most diverse vertebrate groups, with over 11,000 species distributed across various ecosystems. The highest bird diversity is found in tropical regions, particularly in rainforests such as the Amazon, Congo, and Southeast Asia. These areas are home to diverse groups, including parrots (*Psittacidae*), hummingbirds (*Trochilidae*), and tanagers (*Thraupidae*), attributed to stable climates, abundant resources, and habitat complexity (Stotz, 1996). In contrast, temperate regions have fewer species but often support large populations of migratory birds that seasonally move between breeding and non-breeding grounds.

Africa supports remarkable bird diversity due to its varied ecosystems including savannas, forests, wetlands, and deserts. Key biodiversity hotspots such as the Albertine Rift, Ethiopian Highlands, and Rift Valley lakes harbor numerous endemic and migratory species. Wetland ecosystems like Lake Victoria, Lake Nakuru, and the Okavango Delta are crucial for waterfowl diversity, including pelicans (*Pelecanus spp.*) and flamingos (*Phoenicopterus spp.*) (Odada & Olago, 2006). Savannas and forests host a wide range of species, from ostriches (*Struthio camelus*) to turacos (*Musophagidae*). Bird diversity in Africa is closely linked to climate patterns and habitat availability, with significant seasonal variation influenced by rainfall and resource abundance.

Different land use practices influence the habitat, structure and composition of species (Seymour & Dean, 2010). Alvarez-Alvarez et al. (2022) noted that distribution of birds in different land use types where they found more species in cultivated land, followed by

forests, fences and pasture land. Although the land use and other aspects of environments are interrelated, forest always has higher species richness of birds than other land cover (Fardila & Sjarmidi, 2012).

According to Rimal (2006) many species of birds are found in disturbed habitats than undisturbed ones. Similarly Katuwal (2013) after analyzing the species richness and composition of breeding birds concluded that more species richness can be found in moderately disturbed area than in disturbed one. It also reported having higher alpha diversity in moderately disturbed areas but higher beta diversity in the disturbed landscape. The writer also found higher species richness of birds in exploited forest, followed by natural forest, cultivated land and least in meadow, which accepted the intermediate disturbance hypothesis. Bird diversity is peak at intermediate level of human settlement primarily because of colonization of intermediately disturbed forest by early successional native species (Marzluff, 2008).

Lake Solai ecosystem supports a mix of resident and migratory birds including flamingos (*Phoeniconaias minor*), pelicans (*Pelecanus onocrotalus*), and various waders such as stilts (*Himantopus himantopus*). The surrounding riparian zones and grasslands provide habitats for terrestrial species and raptors, contributing to the overall diversity. Factors such as water quality, salinity, and habitat integrity may influence bird diversity at Lake Solai. Seasonal fluctuations in water levels may affect the availability of feeding and breeding grounds, while human activities like agriculture, deforestation, and grazing pose significant threats to habitat quality. Despite these challenges, the lake remains a critical refuge for birds, particularly during migratory seasons.

Biodiversity has been found to decrease where agriculture has expanded, with an estimation, based on forecasts of biome conversions, that 27-44% of bird species could be lost to agricultural expansion from Neolithic to 2050 (Teyssèdre & Couvet, 2007) .

2.6 Birds feeding guilds

2.6.1 Classification of feeding guilds

Bird feeding guilds have been described as functional groups of species utilizing the same class of food resources similarly, regardless of their taxonomic groups (Korňan & Kropil, 2014). Guilds provide a framework for understanding community structure beyond simple species lists, offering insights into how ecological roles are distributed among species (Poiani et al. 2000). Feeding guilds classifications includes categories such as insectivores (insect-eating), frugivores (fruit-eating), granivores (seed-eating), nectarivores (nectar-feeding), carnivores (vertebrate predators), scavengers (carrion-feeding), piscivores (fish-eating), and omnivores (generalist feeders that consume multiple food types) (Hockey et al. 2005, Wilman et al. 2014)

The classification can be refined further by considering foraging strata (e.g., ground, canopy, water), dietary specialization and seasonal shifts in diet (MacNally, 1995). In ecological research, assigning birds to feeding guilds enables functional analysis of communities and improves understanding of ecosystem-level responses to environmental change.

2.6.2 Ecological roles of feeding guilds

Each feeding guild uniquely contributes to ecosystem functioning. Insectivorous birds play a critical ecological role of regulating insect populations thereby influencing pest dynamics and forest health (Dinesh et al. 2022) . Frugivores are vital in seed dispersal and plant regeneration in forested ecosystems (Jordano, 2014). Nectarivores serve as pollinators, particularly in tropical systems with bird-pollinated plants (Cronk & Ojeda, 2008). Granivores influence seed predation and plant community composition, while scavengers contribute to nutrient cycling by breaking down carcasses (Hulme & Benkman, 2002).

Omnivores, although generalists, can be important indicators of ecosystem resilience due to their dietary flexibility. Functional diversity the range of feeding strategies within a community is increasingly used to assess ecosystem health and resilience under environmental pressure (Flynn et al. 2009).

Avian feeding guilds particularly insectivores and understory foragers respond sensitively to vegetation structure and canopy complexity, highlighting their potential as ecological indicators of forest integrity (Gebremichael et al., 2022). Similarly, research from the temperate forests of the Garhwal Himalaya in India revealed that insectivorous birds dominated community composition, accounting for over half of all species recorded, underscoring their critical role in regulating insect populations and maintaining ecosystem balance (Kumar et al. 2022). These findings reinforce the idea that shifts in vegetation composition and habitat heterogeneity directly influence the structure and function of avian feeding guilds, which in turn affect key ecological processes such as pest control, seed dispersal, and nutrient cycling.

Eskuche-Keith et al. (2025) examined demersal fish communities in the Southern Ocean and found that morphological traits such as jaw structure and fin morphology strongly delineate trophic guilds and determine their ecological roles in energy transfer and benthic-pelagic coupling. This functional trait approach provides a powerful framework for linking species' ecological niches to broader ecosystem processes.

2.6.3 Feeding guilds as indicators of habitat quality

Feeding guild often serve as a sensitive indicator of habitat quality and ecological integrity. Specialized guilds, such as insectivores and nectarivores, are often more vulnerable to environmental change due to their reliance on specific food resources and microhabitats (Sekercioglu, 2012). Studies have shown that insectivorous birds decline more rapidly in response to habitat fragmentation, degradation, and pesticide use, particularly in agricultural and urbanized landscapes (Bregman et al. 2014).

Conversely, granivores and omnivores tend to be more adaptable and often increase in abundance in disturbed environments, including farmlands and human settlements (Clough et al. 2009). As a result, land use change often leads to functional homogenization whereby diverse bird communities are replaced by a few dominant generalist species, reducing the range of ecological functions performed (Devictor et al. 2008).

2.6.4 Land use change and its effects on feeding guild structure

Land use change driven by agricultural expansion, settlement growth, deforestation, and infrastructure development, significantly alters the composition and availability of food resources across landscapes (Tscharntke et al. 2012). In farmlands, the shift from natural

vegetation to monocultures reduces insect abundance, fruit availability, and floral diversity, thereby disproportionately affecting insectivores, frugivores, and nectarivores. Pesticide application further limits the foraging success of sensitive guilds (Benton et al. 2003).

Urbanization and settlements can introduce novel food sources such as human waste and food scraps that are easily exploited by omnivores and scavengers (Chace & Walsh, 2006). Studies in East Africa and globally have shown that feeding guild shifts are often parallel to land cover gradients. In Kenya, Farwig et al. (2006) reported that frugivore richness declined significantly with increased forest edge and fragmentation. In Uganda, bird community studies in agroecosystems revealed higher proportions of granivores and omnivores in intensively cultivated areas compared to forest edges (Naidoo, 2004).

Around Lake Solai, the mosaic of land use types including forests, wetlands, farmlands, settlements, and grasslands presenting a dynamic system for assessing how feeding guilds respond to human activity. Categorizing bird species into feeding guilds can help identify patterns of resource use, guild dominance, and the extent to which land use intensification is altering ecological roles. This functional approach complements traditional taxonomic diversity assessments and supports more nuanced interpretations of ecological change. Ultimately, understanding how feeding guilds are distributed across land use types around Lake Solai can inform habitat restoration strategies, sustainable land management, and targeted conservation of bird species and the ecosystem functions they provide.

2.7 Threats facing birds and their habitats

2.7.1 Threats to birds

Anthropogenic activities are the main cause of the growing threats to birds populations, which has resulted in a major reduction in bird variety and abundance globally (Fergus et al. 2013). These threats can be categorized into habitat loss and degradation, climate change, pollution, invasive species, hunting and trapping, and human-wildlife conflicts.

2.7.1.1 Habitat loss and degradation

Degradation and loss of habitat are among the largest risks to bird populations. Natural ecosystems including wetlands, woodlands, grasslands, and coastal areas, have been extensively destroyed as a result of human activities such as agriculture, urbanization, and infrastructure development (Lead et al. 2005). Birds depend on these habitats for vital resources including food, habitat, and nesting grounds. Bird populations can become even more isolated due to habitat fragmentation, which frequently follows habitat loss. This reduces their genetic diversity and makes it harder for them to obtain food supplies or mates (Fahrig, 2003). Furthermore Cooper, (2015) reports that deforestation reduces tree cover that provides shelter and foraging grounds, likely causing local extinctions of sensitive bird species.

2.7.1.2 Climate change

Climate change poses an emerging threat to bird populations globally, affecting migration patterns, breeding cycles, and the availability of food sources. Rising temperatures can alter the distribution of suitable habitats, forcing birds to migrate to new areas or adapt to

different conditions (Sekercioglu et al. 2008). Changes in the timing of food availability due to climate shifts may disrupt migratory and breeding patterns, particularly for species dependent on specific environmental cues for migration and reproduction (Both et al. 2004). Furthermore, extreme weather events, such as storms, droughts, and flooding that are associated with climate change, can directly harm bird populations and degrade their habitats (Visser et al. 2009) or reduce juvenile survival rates.

Changes in temperature and rainfall patterns disrupt the phenology of plant and insect species, thereby affecting bird species that rely on these resources. Dunee et al. (2025) reported that erratic rainfall and prolonged droughts have led to the drying up of wetlands affecting water-dependent birds like the African Jacana (*Actophilornis africanus*).

2.7.1.3 Pollution

Pollution is a major threat to birds, with multiple forms impacting their health and survival. Chemical pollutants, particularly pesticides and herbicides can reduce the availability of food sources for birds and cause direct poisoning (Mitra et al. 2021). These chemicals enter food chains through contaminated prey affecting both adult birds and their offspring. Pesticide use in agricultural practices poses a direct threat to birds through poisoning and indirect effects on their food supply. Birds of prey such as the Augur Buzzard (*Buteo augur*), are particularly susceptible to secondary poisoning after consuming contaminated prey. Mitra et al. (2021) observed that the use of organophosphates and other toxic pesticides have led to a decline in populations of insectivorous birds. The study also showed that chemical runoff into wetlands contaminates water sources, impacting waterbirds and aquatic invertebrates, which serve as their primary food source.

Oil spills, industrial waste, and plastic debris also pose significant threats to birds, especially marine species. For instance, seabirds ingest or become entangled in plastic waste, leading to injury, poisoning, or death (Wilcox et al. 2016). Noise pollution, particularly from urban and industrial sources, can disrupt bird communication and breeding behaviors, further exacerbating population declines (Slabbekoorn, 2013). Pollution not only causes direct mortality but also has sub-lethal effects such as impaired reproduction, altered foraging efficiency, disrupted hormone regulation, and reduced immune function, which collectively compromise birds' long-term survival and population viability. These impacts have been widely documented across marine species, where ingestion of pollutants and debris reduces fitness and breeding success (Lehmler et al. 2018). Similarly, chemical compounds leaching from plastics accumulate in bird tissues, causing physiological stress and toxicological effects that threaten population health (Anjana et al. 2020).

2.7.1.4 Invasive Species

The introduction of non-native species, whether intentional or accidental poses significant threats to bird populations by outcompeting native species for resources, introducing diseases, or preying on eggs, young, or adult birds. Invasive predators such as rats, cats, and mongooses have been particularly destructive to island bird species which evolved in the absence of such threats (Spatz et al. 2023). For example, the introduction of rats to seabird colonies has caused the decline of numerous seabird species globally (Borrelle et al. 2023). Similarly, invasive plants can alter the structure of bird habitats, reducing the availability of nesting sites or food sources (Rai et al. 2022).

In Kenya, invasive plant species such as prickly pear cactus (*Opuntia stricta*) and *Lantana camara* have increasingly altered native habitats, leading to significant impacts on bird communities. *Opuntia stricta* forms dense thickets that suppress native vegetation and restrict foraging movement, resulting in the decline of native flora and associated fauna (Shackleton et al. 2017). Similarly, *Lantana camara* invasion in woodland and riparian areas reduces the availability of food and nesting sites for ground and shrub-nesting birds, ultimately altering community composition (Li et al. 2021). Surveys conducted in parts of central and northern Kenya further indicate that the spread of invasive alien plants continues to threaten biodiversity and disrupt ecological functions across diverse habitats (Beale et al. 2020).

2.7.1.5. Hunting and trapping

Hunting and trapping have been longstanding threats to bird populations, particularly in regions where certain bird species are prized for their meat, feathers, or as pets. Legal and illegal hunting practices including the use of nets, traps, and firearms, have led to the decline of many bird species including migratory species that are caught along their migratory routes. In Africa, Asia, and Europe, migratory birds are often targeted for consumption leading to unsustainable harvesting (Deniau et al. 2022). Illegal wildlife trade also poses significant threat to bird species, with birds being captured and sold as exotic pets or for traditional medicine (Dutta, 2023).

2.7.1.6. Human-wildlife conflict

Human-wildlife conflict, particularly in areas where birds interact with agricultural activities or human settlements poses additional threats to bird populations. In some cases,

birds are considered pests like falcons and eagles on chicken, particularly when they damage crops or livestock (Priya et al. 2022). As a result, they are often killed directly or poisoned or displaced. In other instances, bird populations may be impacted through increased predation pressures by domestic animals, such as cats and dogs, which are allowed to roam freely (Haaksma, 2022). These conflicts can lead to direct harm to bird species or force them to abandon critical habitat areas in search of safer places.

2.7.2 Threats to habitats for birds

Bird habitats around the world face numerous challenges, with anthropogenic activities and environmental changes being major contributors to habitat loss and degradation (Okorundu et al. 2022). Wetland ecosystems which are vital for numerous bird species are particularly vulnerable to these threats. Globally, the loss of wetlands, the destruction of forest habitats, and the fragmentation of landscapes are all driving significant declines in bird populations (Şekercioğlu et al. 2023). Lake Solai faces unique challenges due to its ecological importance and the pressures of surrounding human activity.

2.6.2.1. Habitat loss and degradation

Habitat loss is one of the most pressing threats to birds globally, affecting more than 80% of bird species that are declining (Lees et al. 2022). Wetlands, forests, grasslands, and coastal ecosystems which are key bird habitats are rapidly disappearing due to human activities. Wetlands, which provide critical breeding, feeding, and migration stopover habitats for various bird species, are particularly at risk from drainage for agriculture, urbanization, and industrial development (Donnelly et al. 2022). Large-scale agricultural expansion and infrastructure development have significantly reduced wetlands in Asia and

South America, leading to the decline of many bird species such as migratory shorebirds and waterfowl (Şekercioğlu et al. 2023).

In Lake Solai, wetland degradation has also been observed. Local agricultural activities, including irrigation farming and livestock grazing, have led to encroachment of human settlements into the critical wetland zones. This results in the destruction of wetland vegetation, which serves as both food and nesting sites for birds. The drainage of the wetland for agricultural expansion has disrupted seasonal flooding patterns, which is a key ecological feature that many wetland birds such as waders and ducks depend on for breeding and feeding.

2.7.2.2. Climate change and its impacts on bird habitats

Climate change is increasingly becoming a key driver in bird habitat alteration. Global temperature rise, altered precipitation patterns, and more frequent extreme weather events such as drought or flooding have already begun to negatively impact bird species and their habitats. Birds that are highly dependent on specific climatic conditions for migration and breeding are particularly vulnerable (Bhagarathi et al. 2024). Changes in rainfall pattern and temperature can lead to mismatches in the timing of bird migration and the availability of food resources, which severely affect reproductive success.

In wetland ecosystems, climate change impacts may be particularly pronounced. Additionally, extreme weather events such as droughts and floods can disrupt the delicate balance of wetland habitats, reducing food availability and nesting opportunities (Moursy & Thabit, 2025). Consequently, climate change is expected to exacerbate habitat

degradation in wetlands globally, with the potential to alter the migratory patterns and survival rates of bird species.

2.7.2.3. Invasive species and habitat transformation

Invasive species whether plants, animals, or microorganisms are a significant threat to native bird habitats worldwide. Invasive plant species can outcompete native vegetation, altering habitat structure and reducing the availability of suitable resources for birds (Grzędzicka & Reif, 2020). Invasive animals species, including predators such as rats and domestic cats, further threaten bird populations by preying on eggs, chicks, and adults (Morozov, 2022). These invasive species often thrive in disturbed habitats, causing significant shifts in ecosystem structure.

Wetlands have severely been negatively impacted by the spread of invasive plant species such as *Typha* (bulrushes) and *Phragmites* (common reed), which degrade the quality of bird habitats by reducing open water areas and displacing native vegetation. Invasive species, therefore, present both a direct and indirect threat to bird populations by altering habitat features and introducing new risks to native bird species (Evans *et al.* 2021).

2.7.2.4. Pollution and degradation of water quality

Pollution is a widespread threat to bird habitats, particularly in areas near agricultural or industrial developments. In wetlands agricultural effluents such as fertilizers, pesticides, and herbicides, can lead to eutrophication, reducing water quality and causing algal blooms. These algal blooms deplete oxygen levels and disrupt aquatic food chains, affecting fish and invertebrate populations, which are vital food sources for many wetland

birds (Dhananjayan et al. 2020). The accumulation of pollutants in water and sediments can also directly harm birds that are likely to ingest contaminated food or water (Work, 2022).

2.7.2.5. Overgrazing and habitat degradation

Overgrazing is a really significant threat to bird habitats, especially in regions where livestock farming coexists with critical ecosystems. Overgrazing by livestock leads to the destruction of vegetation, causing soil erosion, compaction, and the degradation of water retention capacity in wetlands. In wetland areas like Lake Solai, grazing in riparian zones exacerbates habitat loss by trampling aquatic vegetation and causing sedimentation in water bodies, further reducing the quality of the habitat (Skovlin, 2021).

Overgrazing is known to have major consequences for grasslands and wetlands, where the loss of vegetation reduces food and nesting sites for birds (Lees *et al.* 2022). Nyuma & Churu, 2022 found that overgrazing in semi-arid areas like Solai reduces the availability of insects and seeds. Trampling by livestock can destroy nests and reduce breeding success (Kraus et al. 2022). The ongoing challenge is finding a balance between the needs of local communities and the conservation of wetland ecosystems.

2.7.2.6. Human-wildlife conflict and nesting disturbances

Human-wildlife conflict is a pervasive issue, particularly in areas where human populations are increasing and habitats are shrinking. In many parts of the world, birds are seen as pests, especially by farmers who view them as threats to crops (Katuwal et al. 2021). This perception could lead to direct persecution, such as shooting, poisoning, or trapping.

Human activities, such as urban development, road construction, and tourism, threaten bird habitats in Solai. Increased human presence often leads to habitat encroachment, noise pollution, and direct disturbance, causing stress and reducing breeding success among bird species. Avni, (2020) reported that urban sprawl into formerly wild areas in Nakuru County has led to a decline in bird diversity due to habitat fragmentation and increased human-wildlife conflict.

2.8 Conservation of birds and their habitats

Birds play a critical role in maintaining ecological balance and they contribute significantly to cultural, economic, and scientific values. However, the alarming rate of habitat degradation and other anthropogenic pressures necessitates urgent conservation efforts (Prakash & Verma, 2022). Conservation strategies for birds and their habitats focus on habitat restoration, legislative frameworks, community involvement, and adaptive management approaches. This section explores the principles, strategies, and actions involved in bird and habitat conservation, with an emphasis on the importance of maintaining the ecological integrity of bird habitat.

2.8.1. The importance of bird habitat conservation

Birds are good indicators of the health of ecosystems because they are sensitive to changes in their surroundings. For feeding, reproducing, and migrating, many species depend on particular types of habitats, with wetlands, forests, grasslands, and coastal regions being especially important. Bird species that ranging from common to severely endangered are affected by habitat loss and degradation, which are the main drivers of declining bird populations (Betts et al. 2022). Thus, maintaining bird populations and protecting the

ecological services that birds offer to ecosystems depend on the conservation of bird habitats (Westrip, 2022).

Wetlands are among the most productive ecosystems globally, providing habitats for a wide range of bird species, including migratory shorebirds, waterfowl, and waders. These ecosystems are crucial for the maintenance of biodiversity, as they support high densities of organisms, many of which are important food sources for birds (Butt et al. 2021). However, wetlands are among the most threatened ecosystems worldwide, with increasing pressure from agricultural expansion, urbanization, and water pollution. In many regions, wetlands have been drained or altered, severely affecting the species that depend on them including bird species (Ballut-Dajud et al. 2022). Similarly, forests and grasslands support a variety of bird species, with tropical forests hosting the highest diversity of birds. Protecting these habitats from deforestation, fragmentation, and land-use change is essential for maintaining biodiversity. The degradation of birds' habitats often leads to declines in biodiversity and the disruption of ecosystem functions such as nutrient cycling, seed dispersal, and pest control (Mariyappan et al. 2023)..

2.9.2. Key strategies for bird conservation

2.9.2.1 Habitat protection and restoration

One of the most effective ways to conserve birds is through habitat protection and restoration. Establishing protected areas such as national parks, nature reserves, and bird sanctuaries helps safeguard critical habitats from human encroachment and degradation. International conventions such as the Ramsar Convention on Wetlands and the Convention

on Biological Diversity (CBD), support the designation of protected areas and the implementation of conservation policies.

Habitat restoration is vital for recovering degraded ecosystems (Arneth et al. 2021). Restoration efforts may include replanting native vegetation, removing invasive species, restoring natural hydrological processes in wetlands, and mitigating the effects of climate change (Taillardat et al. 2020). These actions can significantly improve habitat quality, providing birds with the resources they need for feeding, nesting, and migration.

2.9.2.2 Promoting sustainable land use

Sustainable land-use practices help mitigate conflicts between human activities and bird conservation. Agricultural intensification has been a major driver of habitat loss, particularly in tropical and subtropical regions (Tefera et al. 2024). Conservation agriculture, agroforestry, and buffer zones around key habitats have been successful in balancing agricultural productivity with ecological integrity.

Sustainable land-use practices that integrate biodiversity conservation into agricultural and urban planning are essential for maintaining bird habitats (Wang et al. 2021). Agroforestry, organic farming, and low-impact grazing practices are examples of land-use strategies that can coexist with bird conservation. These practices help minimize habitat destruction, reduce pollution, and maintain ecological connectivity between fragmented habitats.

2.9.2.3 Invasive species management

Invasive species are a major threat to bird habitats as they outcompete native flora and fauna, alter habitat structure, and disrupt ecological processes. Effective management of

invasive species is a critical component of bird conservation efforts (Duenas et al. 2021). This can involve removing invasive plant species, controlling the spread of non-native predators, and restoring habitats to their native conditions.

Invasive plant species such as *Typha* and *Phragmites* could be targeted for removal to restore the natural structure of wetland habitats (Rodrigo, 2021). Similarly, controlling populations of invasive predators, such as domestic cats and dogs, would also help reduce predation pressure on bird species that nest in these areas.

2.9.2.4 Climate change mitigation

Climate change is a significant threat to bird conservation globally. Birds are highly sensitive to temperature and precipitation changes, which influence migration patterns, breeding success, and habitat availability (Li et al. 2022). International agreements such as the Paris Agreement aim to mitigate climate impacts by reducing greenhouse gas emissions and promoting adaptive conservation strategies.

In wetland ecosystems, adaptive measures such as water management systems that mimic natural hydrological cycles can mitigate the effects of climate variability. For example, the restoration of floodplains in Europe has enhanced the resilience of wetlands to climate change (Markus-Michalczyk & Michalczyk, 2023). Adaptive water management and the planting of climate-resilient vegetation could enhance the ecosystem's capacity to support diverse bird populations under changing climatic conditions. Mitigation strategies include reducing greenhouse gas emissions through the promotion of renewable energy, reforestation, and enhancing carbon sequestration through soil management practices.

2.9.2.4 Community engagement and education

Engaging local communities in bird conservation efforts is essential for long-term success of conservation particularly in regions where human activities directly impact bird habitats (McMahon et al. 2024). Educating communities about the importance of birds and their habitats fosters a sense of ownership and responsibility for local ecosystems. Community-based conservation programs, which involve local people in habitat protection, monitoring, and restoration activities, have proven to be effective in many regions. Programs such as the *Community-Based Natural Resource Management* (CBNRM) in Southern Africa demonstrate the effectiveness of involving communities in wildlife conservation (Foyet, 2024).

In the Lake Solai area, involving local farmers and pastoralists in conservation activities could reduce human-wildlife conflicts and encourage the adoption of sustainable land-use practices that benefit both birds and human livelihoods. Furthermore, educational programs that raise awareness about the ecological and economic importance of bird conservation could inspire broader support for protection efforts.

2.9.3. Global efforts in bird conservation

Globally, several organizations and initiatives are dedicated to the conservation of birds and their habitats. The International Union for Conservation of Nature (IUCN) has established the Red List of Threatened Species, which provides a comprehensive overview of the conservation status of bird species worldwide (Lees et al. 2022). The World Migratory Bird Day and the Convention on Migratory Species (CMS) work to raise

awareness about the challenges facing migratory birds and encourage international cooperation for their conservation.

BirdLife International is another key global organization focused on bird conservation. Through its network of partners in over 100 countries, BirdLife International supports the establishment of protected areas, the restoration of habitats, and the development of sustainable policies for bird conservation (Lansley et al. 2025). The organization also works to address key threats such as climate change, invasive species, and illegal hunting.

Habitat restoration programs including reforestation, wetland rehabilitation, and the creation of bird-friendly agricultural landscapes have improved bird population stability and enhanced ecosystem services (Johnson et al. 2011). Technological tools such as satellite tracking, automated acoustic monitoring, and citizen science platforms allow researchers to monitor migratory routes, population trends, and habitat use at scales previously impossible, enabling timely interventions (Runge et al. 2015). These approaches emphasize that effective bird conservation requires not only protecting species but also maintaining and restoring the ecological processes that support them.

Initiatives like the African-Eurasian Migratory Waterbird Agreement (AEWA) and the East Asian-Australasian Flyway Partnership foster transboundary cooperation for habitat protection, policy harmonization, and threat mitigation (Lewis, 2016). Global organizations such as BirdLife International also contribute to large-scale monitoring, habitat protection, and awareness campaigns, addressing threats such as invasive species, climate change, and illegal hunting (Subbarayan, 2025). These coordinated efforts demonstrate that conservation success depends on both local action and international

partnerships, highlighting the need for continued investment in research, policy, and community engagement to counteract ongoing declines in bird populations.

CHAPTER THREE

MATERIALS AND METHODS

3.1 The Study Area

3.1.1 Location and size

Lake Solai is a shallow alkaline lake located in a semi-arid region of the Eastern Rift Valley. It occurs to the North Eastern part of Nakuru town and off the Nakuru-Nyahururu road, approximately 50 km from Nakuru town (Nyaga et al. 2019). It lies between $0^{\circ} 30' 0''$ North and $36^{\circ} 9' 0''$ East at an elevation of 1667m height above sea level (Figure 1). The lake has a maximum depth of 1.5 m and a total area of 9 km^2 that fluctuates depending on the meteorological condition in the surrounding area (Goman et al. 2017).

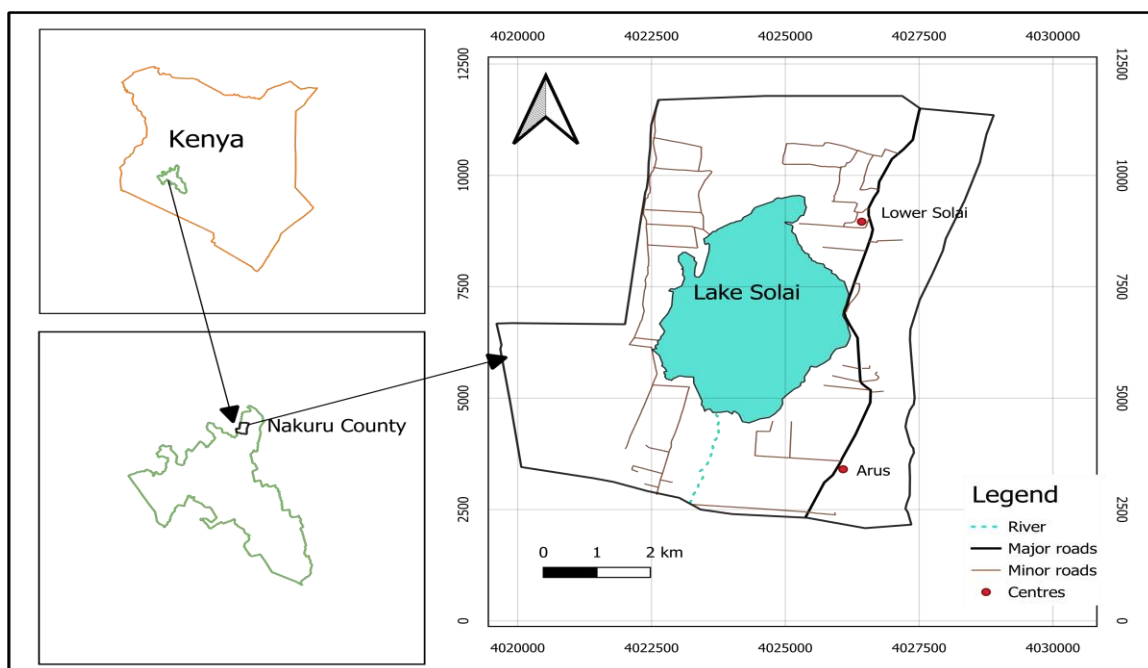


Figure 1 Map of Lake Solai and its surroundings. (Source: Author 2025)

3.1.2 Climate

The Intertropical Convergence Zone (ITCZ) migrates seasonally, causing two rainy seasons and regulating the regional climate (Liu et al. 2022). According to Herrnegger et al. (2021). Lake Solai watershed gets between 700 and 900 mm of precipitation per year. The hydrologic budget is negative because of the high potential evapotranspiration ($\ll 1,800$ mm/year) (Nyaga et al. 2019). Due to the impacts of evaporation, precipitation, groundwater seepage, and seasonal and interannual fluctuations, the lake consequently undergoes unique modifications (De Bock et al. 2009).

Lake Solai sometimes dry out during the dry season, while the playa responds seasonally to local climatic variables like El Nino that cause the lake extension (Mutua & Runguma, 2020). During the dry season in the area, the community mostly graze cattle on the surrounding area, while maize is farmed through along a number of the stream systems (Nyaga et al. 2019).

3.1.3 Topography, geology and drainage

The geology of Lake Solai area is underlain by basement rocks and Cenozoic volcanics (Mwaura, 2018). Lake Solai is fed by four major perennial rivers and emerging from the eastern elevated fault block are the Kasururei and Maji Tamu (Goman et al. 2017). Maji Tamu (Chesebet) serves as the lake's main water source and empties into the southern end, where it creates a tiny delta, which disappears during severe dry seasons. The Kamolo and Chemuka rivers are spring-fed and originate from the escarpment's slopes, although a large portion of their flow infiltrates the earth and is stored there as groundwater (Herrnegger et al. 2021). Lake Solai doesn't have any surface outflow. In the past few years most of the

rivers that feed it have been entirely used for irrigation by the community upstream and little or no water manages to feed the lake except during the rainy season.

3.1.4 Flora and Fauna

Acacia woodland is found to the west and south of Lake Solai, although the trees are under stress from charcoal production (van der Plas et al. 2019). *Cynodon dactylon* dominates the herbaceous zone beneath the acacia woodlands. Saline swamps are present to the east and south, which are dominated by *Sporobolus robustus* closest to the lake edge and by *Cyperus laevigatus* in regions that experience prolonged drying phases. An open water wetland occurs on the delta of the Maji Tamu. Here vegetation is characterized by rooted plants (*Typha domingensis*, *Cyperus dives*, and *Leersia hexandra*) and a floating aquatic flora (*Pistia stratiotes* and *Ludwigia stolonifera* (Goman et al. 2017).

Lake Solai holds different wildlife species such as vervet monkeys, colobus monkeys, hares, mongooses, rock hyraxes, hyenas and reptiles such as pythons, cobras, puff adder and monitor lizards. It is an important stop over for waterfowls migrating from Lake Bogoria to Lake Nakuru Birds found in the area include; black crowned cranes, Lesser flamingos, greater flamingos, black winged stilts, Eurasian curlews, sacred ibises, Hadada ibises, great white pelicans, African jacanas, herons and lilac breasted rollers.

3.1.5 Soils

Surveys conducted in the Lake Solai area indicate that the soils were formed through a series of catastrophic eruptions from Mt. Menengai during the Miocene, Pliocene, and recent geological periods (Dam & Victoria, nd.). These resulted in easily draining

conditions that gave rise to peculiar reddish brown to crimson or yellowish red loamy soils, the most recent of which were prominently banded with pumice stones.

3.1.6 Socio-economic activities

The socio-economic activities in Solai area include crop agriculture, livestock keeping, fishing activities and offering boat rides. Most of the goods sold are farm produce such as, sorghum, maize, beans, millet, sorghum, vegetables and now fish. The fish which was introduced into the Lake by the county government in 2019 has not only been of nutritional benefit to the community but are now a source of income to those who venture into fishing activity. The community also engages in business activities around the lake including sale of foodstuffs and merchandize targeting visitors who come to tour the lake. Boat riding activities are also available in the lake.

3.2 Research design

In this study, the research design refers to the systematic plan used to collect, analyze, and interpret data on bird species and habitat characteristics around Lake Solai. It provides a structured framework that ensures reliable and valid assessment of the relationships between anthropogenic activities, bird distribution, and habitat conditions.

This study adopted a descriptive ecological survey design to explore distribution, richness, diversity, relative density and threats across different habitats surrounding Lake Solai. By focusing on direct field observations and participatory techniques, the study effectively captured variations in bird richness and density across space and habitat types.

3.2.1 Selection of study sites

To effectively capture habitat-based differences in bird richness and density, five primary habitat types were purposively selected: wetlands, forests, grasslands, farmlands, and settlements. These habitats were chosen based on their ecological characteristics, observed bird activity, and representation across the landscape. Site selection considered accessibility, historical bird use, and variation in land use intensity, ensuring a balanced representation of both natural and anthropogenic conditions.

The diversity in habitats provided a solid basis for understanding species richness, assessing relative bird densities, and evaluating the influence of habitat features across the Lake Solai ecosystem.

For anthropogenic threats to birds and their habitats, data was collected in five villages surrounding Lake Solai namely, Majitamu, Tuiyotich, Machine, Kapndege and Kasururei. The sampled villages comprised of a total population of 609 households. The sample size of 100 households was determined using Yamane, (1973) formula:

$$n = \frac{N}{1 + N((e))^2}$$

where n is the sample size, N is the population size (609 households), and e is the margin of error (9%). This margin of error was selected to balance statistical reliability with field realities such as limited time, budget, and personnel. This value falls within the scientifically acceptable range of 5%–10% for small population studies in the social and environmental sciences. In total, 100 households were selected from the five villages.

The total household size across the five villages was 609 distributed as Majitamu (173), Kapndege (132), Kasururei (124), Tuiyotich (98) and Machine (82). The distribution of households was estimated by assuming an average household size of five individuals, based on regional demographic data (Statistics, 2019) (Table 1). According to Nelly et al. (2021) each village's sample size was determined by the proportion of the cluster's population relative to the total population multiplied by household sample size .

Table 1. Proportion of sample based on the target population of each village around Lake Solai.

Village	Population	Sample size	% of households
Kasururei	124	20	20
Majitamu	173	28	28
Kapndege	132	22	22
Tuiyotich	98	16	16
Machine	82	14	14
Total	609	100	100

3.3 Data collection

3.3.1 Point count method

Bird data were collected using standardized ecological survey methods specifically line transects and point counts, which facilitated the systematic recording of bird species presence and abundance. To understand specific threats facing bird and their habitats, qualitative tools such as structured questionnaires were employed. Data for this study were

collected between July and December 2024 within the Lake Solai area and its surrounding habitats.

The study focused on five habitat types surrounding Lake Solai: settlements, grasslands, forests, wetlands and farmlands. Point count method was used to collect data on bird composition, distribution, diversity and abundance (Bibby, 2000).

A systematic sampling method was applied, where counting points were established within each habitat type, each with a 25meter radius and spaced 100 meters apart to ensure comprehensive spatial coverage while minimizing overlap. The first sampling point in each habitat was selected randomly to reduce bias, with subsequent points placed systematically at 100-meter intervals following a predetermined transect pattern of 500M. Point counts were conducted daily between 6:30 am and 10:30 am, which is a realistic timeframe when avian activity is typically at its peak.

Upon reaching a point, 2-5 minutes was provided for the birds to settle in case of any disturbances (Swift et al. 1984). Ten minutes was used to count and record all birds observed or heard within 30m radius as recommended by Terborgh et al. (1990) and Robinson et al. (2020). Unidentified calls were recorded for further identification. The process was repeated across all sampling points within each habitat. The next point was surveyed immediately after completing the 10-minute count, following the systematic 100-meter spacing until all points in the habitat were covered. Binoculars were used to enhance the accuracy of bird identification and counting within each point. Birds were identified to the species level and their taxonomic groups properly categorized based on field guides (Stevenson & Fanshawe, 2020).

3.3.2 Questionnaires

Questionnaires were used to collect views from community members on threats facing birds and their habitats around Lake Solai. Villages bordering the lake including Majitamu, Tuiyotich, Machine, Kapndege and Kasururei were subjected to the questionnaire survey. One hundred questionnaires with both open and closed-ended questions were administered to one hundred households systematically selected where every 6th household from 609 households from the five villages was selected. This interval was derived by dividing the total population by the sample size.

The questionnaires were administered on-site by researcher to ensure completion and accuracy in responses.

3.4 Habitat description

3.4.1. Settlement habitat

Settlements around Lake Solai consist of human-modified areas characterized by residential and infrastructural development (Figure 2). These include clusters of homesteads (typically mud, corrugated iron sheets and stone walls with mostly having iron sheets roofing), small shops or trading centers, and a network of access roads, often unpaved and dusty, facilitating local movement. Vegetation in these areas is sparse and heavily altered due to human activity. Planted trees, such as fast-growing species like Southern silky oak (*Grevillea robusta*) are common for shade, timber, or boundary marking, while fences made of wood, wire, or thorny shrubs like Acacia species are used to demarcate property lines. Small patches of ornamental plants or kitchen gardens with

crops like kale or tomatoes may exist near homes, while natural vegetation is largely cleared or replaced. Soil compaction from foot traffic and construction is prevalent, and the landscape often includes scattered debris, small waste piles, or livestock pens for goats and chickens. These areas experience high disturbance levels, with noise from human activity, vehicle movement, and domestic animals, which can deter sensitive wildlife. However, some adaptable species such as house sparrows (*Passer domesticus*) or small rodents may thrive in these modified environments, exploiting food scraps or nesting in structures.



Figure 2: Settlement habitat around Lake Solai.(Source: Author, 2024)

3.4.2. Grassland habitat

Grasslands are open expanses dominated by natural grasses and scattered shrubs normally located slightly away from the lakeshore (Figure 3). This habitat is characterized by grasses such as *Themeda triandra*, buffel grass (*Cenchrus ciliaris*), and *Eragrostis superba*, forming a continuous cover that can reach 0.5–1 meter in height during the rainy season. Scattered shrubs such as desert date (*Balanites aegyptiaca*) or small Acacia bushes may be present, but canopy cover is less than 10%. The soil is often sandy or loamy, with patches of bare ground exposed during dry periods, and termite mounds are common, providing microhabitats for small reptiles like agama lizards (*Agama sinaita*). Human impacts include overgrazing by livestock, which can lead to grass depletion and soil compaction, and occasional burning to promote new growth, which alters species composition.



Figure 3: Grassland habitat around Lake Solai (Source: Author, 2024)

3.4.3. Forest habitat

The forest habitat around Lake Solai comprises semi-natural dry woodland patches, characterized by a mix of native tree species that form a moderately closed canopy (Figure 4). Dominant tree species include umbrella thorn acacia (*Acacia tortilis*), whistling thorn acacia (*Vachellia drepanolobium*), known for its symbiotic relationship with ants and fever tree (*Acacia xanthophloea*), often found in slightly wetter areas. The forest floor is uneven, with patches of bare soil, termite mounds, and occasional rocky outcrops, this adds to the structural diversity of the forest. These woodlands support a variety of bird species, including seed-eaters like the red-billed quelea (*Quelea quelea*), insectivorous birds like the grey-backed camaroptera (*Camaroptera brevicaudata*), and raptors such as the African harrier-hawk (*Polyboroides typus*), which may use the trees for nesting. Despite their ecological value, these forests face disturbances from human activities, including firewood collection, charcoal burning (which removes larger trees), and grazing by cattle and goats, leading to trampling of undergrowth and soil erosion. These pressures reduce habitat quality but the forests still retain key features such as nesting sites, shade, and food sources, making them critical for biodiversity conservation.



Figure 4: Forest habitat around Lake Solai. (Source: Author, 2024)

3.4.4. Wetland habitat

The wetland habitat fringe Lake Solai, and encompass both permanent and seasonal marshy areas along the lake's edges (Figure 5). The wetland are defined by water-saturated soils, often with a high organic content, and a water table that fluctuates with seasonal rainfall, creating zones of standing water or muddy substrates. Vegetation is dominated by hydrophytic plants adapted to wet conditions, including tall reeds (*Typha* spp., *Typha domingensis*), sedges (*Cyperus* spp. *Cyperus papyrus*), and aquatic grasses *Echinochloa pyramidalis*. These plants form dense stands, often 1–2 meters tall, providing cover and nesting sites for waterfowl like the African jacana (*Actophilornis africanus*) and herons (*Ardea* spp.). Submerged or floating plants, such as water lilies (*Nymphaea*), may also be present in shallow waters, supporting aquatic invertebrates like dragonfly larvae and fish, which in turn attract predators like kingfishers. The wetlands are rich in biodiversity,

hosting amphibians like the African clawed frog (*Xenopus laevis*), reptiles such as the Nile monitor (*Varanus niloticus*), and a variety of insects, including mosquitoes, which thrive in the wet conditions. Seasonal flooding can expand these wetlands, connecting them to the lake's edge, while dry periods may reduce them to isolated patches. Human impacts include water extraction for irrigation, trampling by livestock, and occasional harvesting of reeds for thatching, which can degrade the habitat but also create open patches that some species exploit.



Figure 5: Wetland habitat around Lake Solai (Source: Author,2024)

3.4.5. Farmland habitat

Farmlands surround Lake Solai and consist of cultivated or previously cultivated lands used primarily for crop agriculture (Figure 6). Common crops include maize (*Zea mays*), beans (*Phaseolus vulgaris*), and horticultural produce like tomatoes, onions, or cabbages,

depending on market demands and seasonal conditions. These farmlands are heavily human-modified, with fields varying in size from small subsistence plots (0.5–2 hectares) to larger commercial farms. Vegetation cover and structure depend on the farming cycle: during planting and growth phases, fields may have dense crop cover, while post-harvest, they may be bare or covered with stubble. Some farms incorporate agroforestry, with scattered trees like *Acacia* or *Moringa oleifera* for shade or windbreaks, and hedgerows of thorny shrubs to separate plots. Soil management practices vary, with some areas showing signs of erosion due to poor contouring, while others use terracing or mulching to retain moisture. Farmlands attract species that can exploit agricultural resources, such as granivorous birds like the village weaver (*Ploceus cucullatus*), which feed on spilled grain, and insects like grasshoppers, which may become pests. However, pesticide use and habitat simplification reduce overall biodiversity, making these areas less suitable for sensitive species. Small patches of fallow land or abandoned fields may revert to secondary growth, hosting grasses and opportunistic plants like blackjack (*Bidens pilosa*), which can support some wildlife temporarily.



Figure 6: Farmland habitat around Lake Solai (Source: Author,2024)

3.5 Data analysis and presentation

All the collected data was entered in excel sheets and analyzed by using appropriate statistical tools. Statistical analyses were performed using R statistical software, version 4.4.2 and IBM SPSS software version 20.

3.5.1 Distribution of birds and feeding guilds

3.5.1.1 Distribution of birds

Species identification was verified using authoritative field guides (Stevenson & Fanshawe, 2020) , supplemented by the Checklist of the Birds of Kenya (2019), which was also used to assign migration status. Forest dependency classifications followed (Bennun et al. 1996). Records from eBird and BirdLife International further supported the checklists. The checklist was descriptive and tabulated to show species distribution across

habitats and their conservation or ecological classifications, serving as a foundational resource for subsequent analyses.

3.5.1.2 Feeding guilds

Bird species observed during the study were classified into feeding guilds to better understand their ecological roles and resource use across land use. All the bird species from our checklist were grouped into seven feeding guilds which were based on descriptions of major food items taken by respective bird species as outlined by (Hockey et al. 2005) and also further informed by Gray et al. (2007) classifications . The feeding guilds included: carnivores (predate on vertebrates), frugivores (fruits eaters), granivores (feed on seeds), herbivores (feed on vegetative materials such as leaves, shoots, roots, flowers, and bulbs), insectivores (feed on insects and other invertebrates), nectarivores (nectar feeders), and omnivores (feed on a combination of both plant and animal materials comprising more than one major food item).

To assess the diversity of bird feeding guilds across habitats, the Shannon Diversity Index (H') was calculated as:

$$H' = \sum_{i=1}^s -(P_i * \ln P_i)$$

where p_i is the proportion of individuals belonging to the i^{th} species (or feeding guild) out of the total individuals observed, and S is the total number of species (or guilds). This index accounts for both species' richness and evenness within feeding guilds

To test for significant differences in diversity between feeding guilds, Hutcheson's t-test was used. This test compares Shannon indices by accounting for their variances, using the formula:

$$t = \frac{H_a - H_b}{\sqrt{S^2 H_a + S^2 H_b}}$$

where H_a and H_b are the Shannon indices of the two groups being compared, and $S^2 H_a$ and $S^2 H_b$ are their respective variances. This allows statistical inference on whether differences in diversity are significant.

3.5.2 Comparison between species richness and diversity in habitats around Lake Solai

3.5.2.1 Species richness and rarefaction

Species accumulation curves were first drawn to visualize the rate at which new bird species were recorded as sampling effort increased within each habitat type. These curves helped assess whether sufficient sampling effort was achieved to capture the majority of species present. Species richness was calculated as the total number of unique bird species recorded within each habitat type. However, because raw richness is sensitive to sample size and effort, sample-based rarefaction and extrapolation curves were generated using the iNEXT Online platform (Chao et al. 2014). This enabled comparison of species richness across habitats under standardized sampling completeness. The rarefaction curves were based on Hill numbers ($q = 0$), which represent species richness regardless of species abundance.

3.5.2.2 Shannon-Wiener diversity index (H')

Data on avian species diversity in the five habitats was calculated using the Shannon diversity (H') index. Species richness is a biologically appropriate measure of alpha (α) diversity and is usually expressed as number of species per sample unit (Whittaker, 1972). The Shannon diversity index (H') was calculated using the following equation.

$$H' = \sum_{i=1}^s -(P_i * \ln P_i)$$

Where: H' = the Shannon diversity index, P_i = fraction of the entire population made up of species i, S = numbers of species encountered, Σ = sum from species 1 to species S.

3.5.2.3 Comparison of diversity indices using Hutcheson's t-test

To determine if differences in Shannon-Wiener diversity indices between habitats were statistically significant, Hutcheson's *t*-test (Hutcheson, 1970) was employed. This test compares two Shannon indices by accounting for the variance of each estimate.

$$t = (H_a - H_b) / \sqrt{(S^2 H_a + S^2 H_b)}$$

Where H_a and H_b are Shannon indices for two habitats and $S^2 H_a$ and $S^2 H_b$ are their respective variances. To account for the increased risk of Type I error due to multiple comparisons, a Bonferroni correction was applied. With ten pairwise comparisons made, the significance level (α) was adjusted to $p < 0.005$

3.5.2.4 Sorenson's similarity index.

Sorenson's similarity index (Sorensen, 1948) was used to compare similarity of bird species across the five habitats.

$$Cs = 2J/a + b$$

Where; a= number of species found in site A, b= number of species in site B and J= number of species shared by the two sites

The index ranges from 0 (no similarity) to 1 (complete similarity). This was used to generate a similarity matrix comparing all five habitats pairwise.

3.5.3 Comparison of relative density of birds in habitats around Lake Solai.

Relative density was calculated to quantify the proportion of individuals of each bird species relative to the total number of birds recorded within each habitat. This measure provides insight into the dominance and distribution patterns of bird species across the five habitat types: forest, grassland, wetland, farmland, and settlement.

The relative density for each species within a habitat was calculated using the formula:

$$RD = (n_i / N) \times 100$$

where n_i is the number of individuals of species i in a given habitat, and N is the total number of birds observed in that habitat. This expresses the species' abundance as a percentage of the total bird population in each habitat.

Before conducting inferential statistical tests, the data were examined to ensure that assumptions for parametric analysis were met. The Shapiro-Wilk test (Shapiro & Wilk, 1965) was applied to assess the normality of the relative density data. The test statistic W is calculated as:

$$W = \frac{([\sum (a_i \times x_{n+1-i})]^2)}{\sum (x_i - \bar{x})^2}$$

where x_i represents the ordered sample values, \bar{x} is the sample mean, and a_i are constants based on the expected normal order statistics. A significant result indicates that the data deviate from a normal distribution.

Levene's test (Levene, 1960) was then used to assess the homogeneity of variances across habitats. The test statistic W is given by:

$$W = \frac{[(N - k) \times \sum n_i (\bar{Z}_{i.} - \bar{Z}_{..})^2]}{[(k - 1) \times \sum \sum (Z_{ij} - \bar{Z}_{i.})^2]}$$

where $Z_{ij} = |X_{ij} - \bar{X}_{i.}|$ represents the absolute deviations of observations from their group means, k is the number of groups, and N is the total number of observations. Non-significant results suggest unequal variances, which meets parametric test assumptions.

A one-way Analysis of Variance (ANOVA) was then used to test for significant differences in the relative density of bird species across five habitat types.

3.5.4 Assessment of threats to birds and their habitats

Data collected from questionnaires on perceived threats to birds and their habitats around Lake Solai were cleaned, coded and entered into Microsoft Excel then exported into the

Statistical Package for the Social Sciences (SPSS version 20) for analysis. Descriptive statistics were computed to summarize socio-demographic characteristics and threat frequencies. Chi-square test of goodness fit was conducted to assess whether there was statistically significant difference on frequency of perceived threats. To test associations between categorical variables (village, age, gender, economic activities) and perceived threats, Chi-square tests of independence (χ^2) were conducted using the formula:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

where O is the observed frequency and E is the expected frequency under the null hypothesis of independence. Statistical significance was evaluated at $\alpha=0.05$.

For significant Chi-square results, contingency tables were examined to interpret the distribution of perceived threats across different economic activities.

Results are presented using tables, graphs and quantitative descriptions.

CHAPTER FOUR

RESULTS

4.1 Distribution of bird species and feeding guilds in habitats around Lake Solai

4.1.1 Distribution of bird species

Among the 212 bird species recorded, 11 species were identified as generalists, occurring in all five habitats surveyed. A total of 32 species were recorded in 4 habitats; 30 species were found in 3 habitats and 40 sharing two habitats. No species were found to be specialists to settlements. Farmlands had six specialists' species, 15 species were restricted to grasslands, 18 species to forests and 60 being wetlands specialists (Table 2). A total of 71 bird families were recorded across all habitats. Family richness was highest in grasslands (38 families), followed by forests (36), farmlands (29), wetlands (29), and settlements (26). A comprehensive checklist is captured in Appendix 1.

Table 2: Bird species distribution across habitat uses categories around Lake Solai

HABITAT USE CATEGORY	NUMBER OF SPECIES
Generalists (found in all the 5 habitats)	11
4 Habitats	32
3 Habitats	30
2 Habitats	40
Wetlands	60
Forests	18
Grasslands	15
Farmlands	6
Settlements	0
Total	212

A total of 7 bird species recorded in the study area are listed under the IUCN Red List as species of conservation concern while 205 were of Least Concern. These comprise 2 Vulnerable species (VU) the Southern Ground Hornbill (*Bucorvus leadbeateri*) and Curlew Sandpiper (*Calidris ferruginea*). While 2 were endangered species (EN), the Grey-crowned Crane (*Balearica regulorum*) and Secretary Bird (*Sagittarius serpentarius*). Near Threatened species (NT) were (3) Fischer's Lovebird (*Agapornis fischeri*), Lesser Flamingo (*Phoeniconaias minor*), and Eurasian Curlew (*Numenius arquata*). These species occurred across diverse habitats, with wetlands supporting the highest number of 5 species, while forests and grasslands had 3 species each and farmlands 1 species. (Table 3).

Table 3: IUCN-listed bird species around Lake Solai.

Common name	Family name	Scientific name	IUCN redlist status	Habitats	Forest dependency	Migration status
Southern Ground Hornbill	Bucorvidae	<i>Bucorvus Leadbeateri</i>	VU	F, FA	Non f	
Grey-crowned Crane	Gruidae	<i>Balearica Regulorum</i>	EN	W, F, G, FA, S	F	
Fischer's Lovebird	Psittaculidae	<i>Agapornis Fischeri</i>	NT	W, F, G, S	f	
Secretary Bird	Sagittariidae	<i>Sagittarius Serpentarius</i>	EN	G	Non f	
Lesser Flamingo	Phoenicopteridae	<i>Phoeniconaias Minor</i>	NT	W	Non f	Am
Curlew Sandpiper	Scolopacidae	<i>Calidris Ferruginea</i>	VU	W	Non f	PM
Eurasian Curlew	Scolopacidae	<i>Numenius Arquata</i>	NT	W	Non f	PM

4.1.2 Migration status

Of the bird species recorded in and around Lake Solai, 163 species were residents indicating year-round occurrence within the area. Twenty-nine species were Afrotropical migrants (AM) that move within the African continent, while 26 species were Palearctic migrants (PM) that arrive seasonally from the northern hemisphere. One species was both AM and PM migrant, suggesting flexible or overlapping migratory behavior, and one species was identified as nomadic (n) (Table 4).

Table 4: Migration status of birds in Lake Solai

MIGRATION STATUS	NUMBER OF SPECIES
Afrotropical Migrants occurring with residents or other migrants - am	23
Palearctic Migrants – PM	17
Palearctic Migrants occurring with residents or other migrants- pm	6
Afrotropical Migrants- AM	5
Occasional Palearctic Migrants- (pm)	3
Occasional Afrotropic Migrants- (am)	1
Mixed Afrotropical and Palearctic Migrant am(pm)	1
Nomadic/ wandering bird(n)	1
Residents	163

4.1.3 Forest dependency of bird species

Among the 212 bird species recorded, four were identified as forest specialists (FF), 20 as forest generalists (F), and 42 as forest visitors (f). The majority, 146 species, were classified as non-forest-dependent (Non f), predominantly occupying open or non-forested habitats, demonstrating their adaptability to a wide range of environmental conditions. (Figure 7).

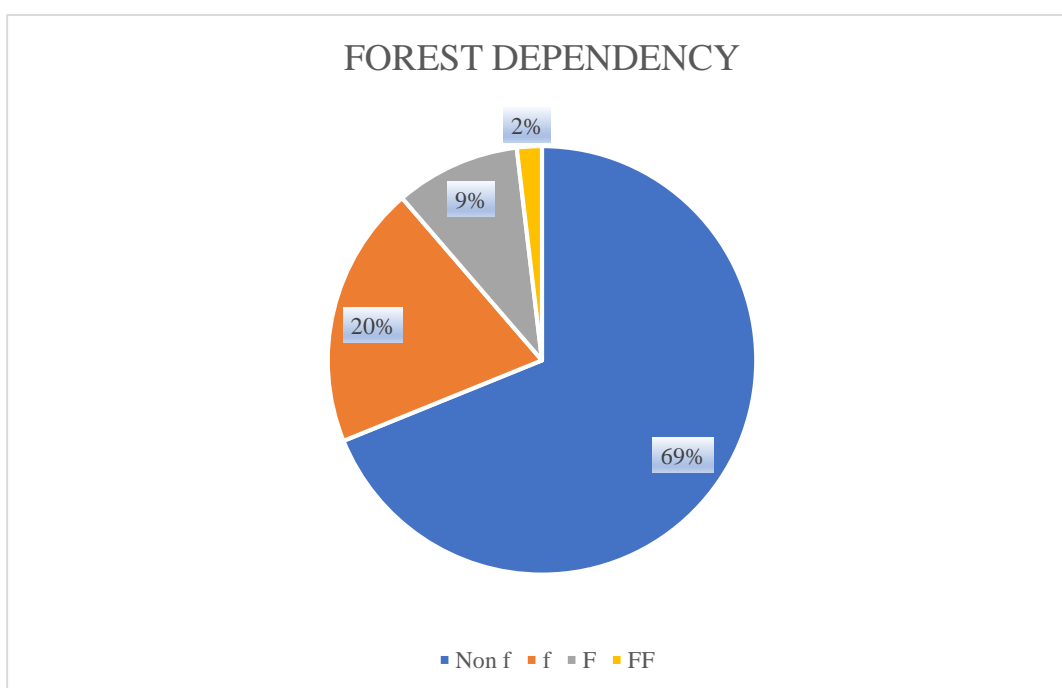


Figure 7: Birds Forest dependency categories in Lake solai

4.1.4 Feeding guilds of birds

Insectivores were the most dominant feeding guild, with 41 species recorded in grasslands and 40 in wetlands. Granivores were also well represented, with 25 species in farmlands, 24 in grasslands, and 23 in settlements. Omnivores ranged from 13 species in forests to 32 in wetlands, while carnivores were more frequent in wetlands (16 species) and grasslands

(10 species). Frugivores occurred mainly in forests (10 species) and farmlands (5 species), whereas nectarivores were relatively few, with up to four species in forests and grasslands. Piscivores were concentrated in wetlands (10 species) (Figure8).

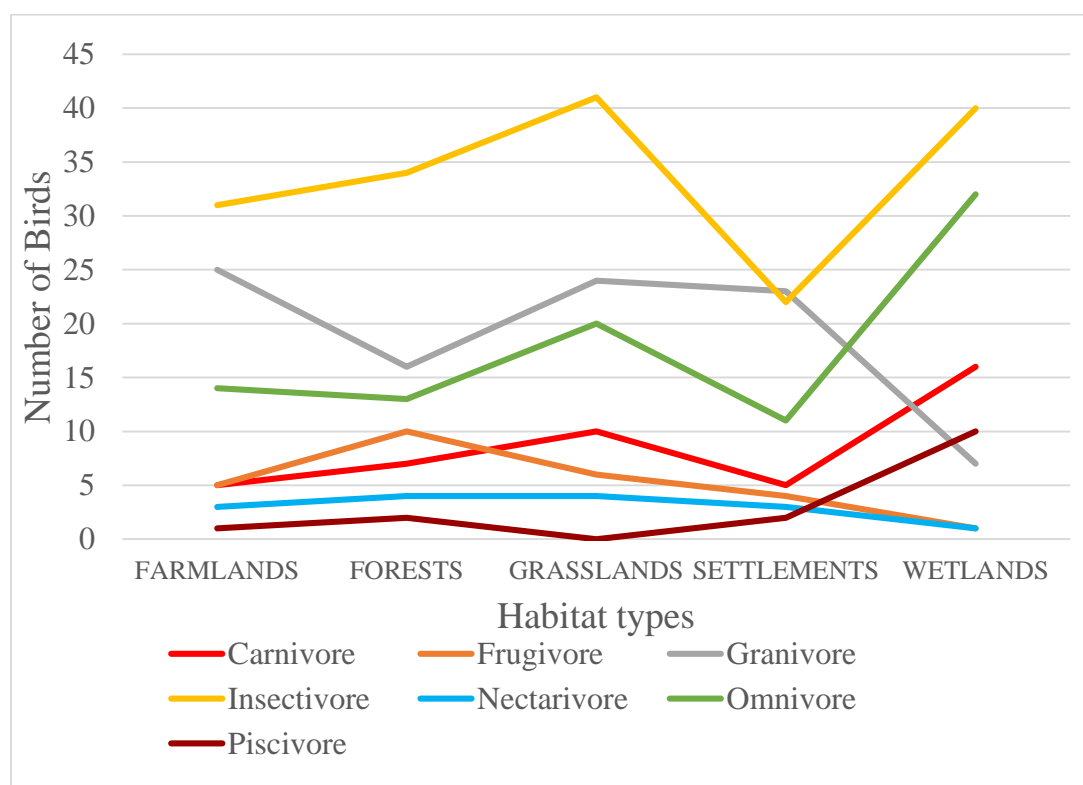


Figure 8: Birds feeding guilds across habitats around Lake Solai

The Shannon Diversity Index (H') was calculated to assess habitat diversity within each bird feeding guild. The results (Figure 9) show variation in diversity across guilds, with Insectivores having the highest diversity ($H' = 2.8$), indicating that insectivorous species

were more widely distributed across different habitats. Granivores followed closely with high diversity ($H' = 2.6$), suggesting a broad habitat use as well.

Moderate diversity was observed in Carnivores and Omnivores (both $H' = 1.9$), while Frugivores and Nectarivores exhibited lower diversity indices ($H' = 1.4$ and 1.3 respectively), implying more restricted habitat associations. Piscivores had the lowest Shannon diversity ($H' \approx 1.2$), potentially reflecting their dependency on fewer habitat types.

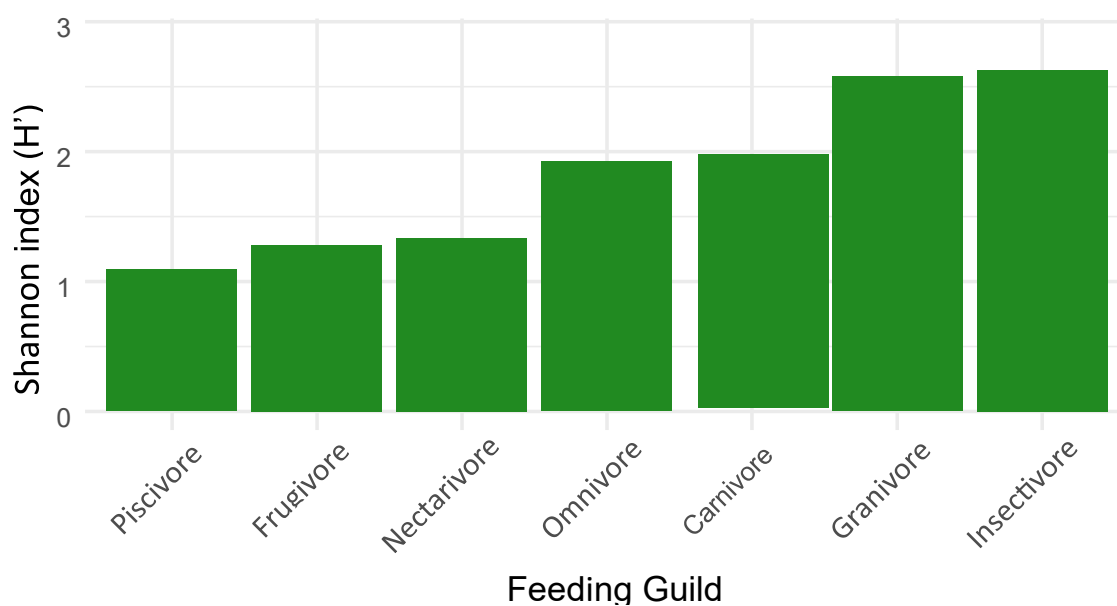


Figure 9: Shannon diversity index across feeding guilds

Results of the Hutcheson's t-test given in figure 10 below revealed significant differences in Shannon diversity among several bird feeding guilds. Insectivores and Granivores has significantly higher diversity than all the other guilds. No significant differences were observed among the remaining 5 feeding guilds but insectivores had significantly higher diversity than Granivores.

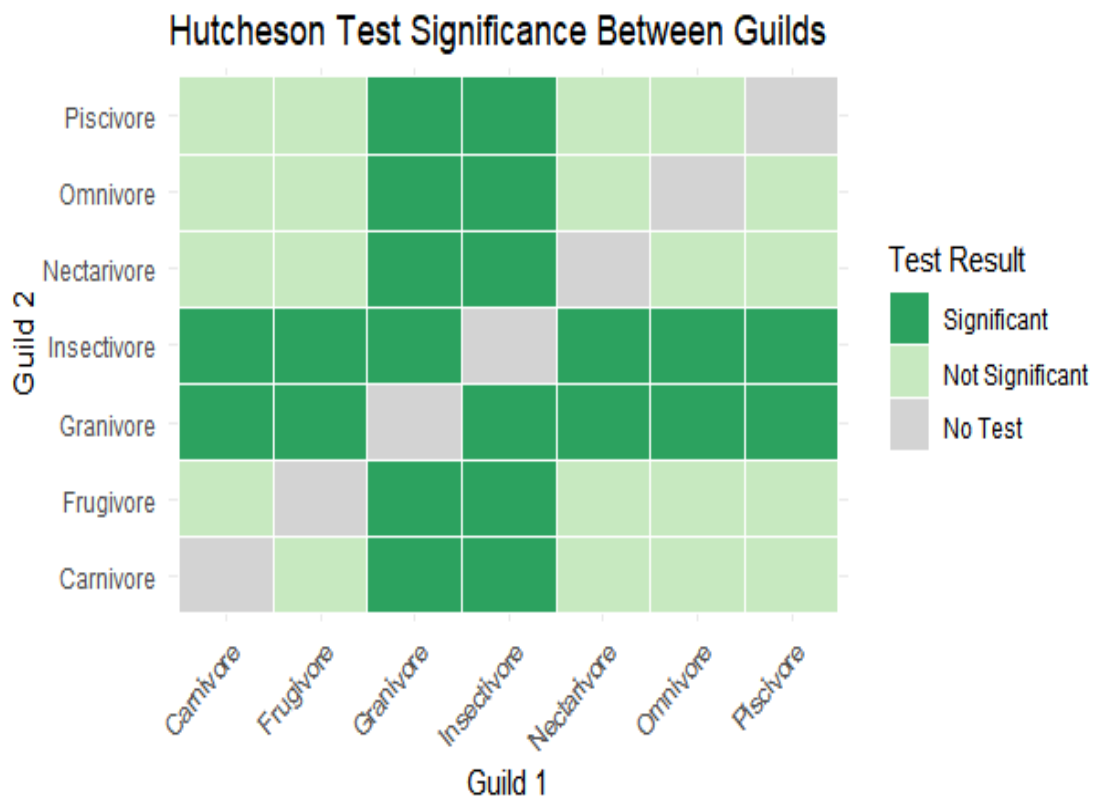


Figure 10: Hutcheson's t-test among feeding guilds

4.2 Species richness and diversity of birds around Lake Solai

4.2.1 Richness of birds

A total of 212 bird species were recorded across the five habitats. Grasslands supported the highest richness with 107 species, closely followed by Wetlands (105 species). Forests harboured 90 species, while Farmlands contained 86 species. Settlements had the lowest diversity, with 70 species observed (Figure11).

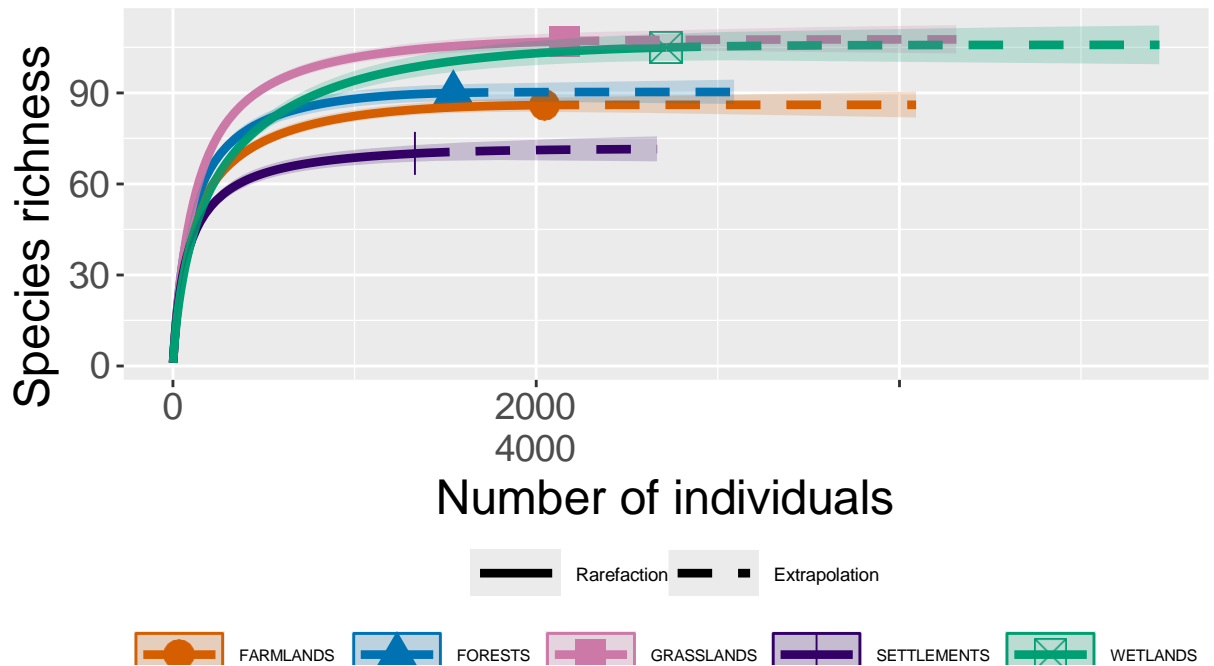


Figure 11: Chao rarefaction curves for avian species richness across habitats

4.2.2 Birds diversity indices

4.2.2.1 Shannon-Wiener diversity index of bird species across habitats

The Shannon-Wiener diversity index (H') values indicate a gradient in bird species diversity across habitats, increased progressively from wetlands ($H' = 3.723$) and settlements ($H' = 3.774$) to farmlands ($H' = 3.938$), forests ($H' = 4.087$), and was highest in grasslands ($H' = 4.151$) (Figure 12).

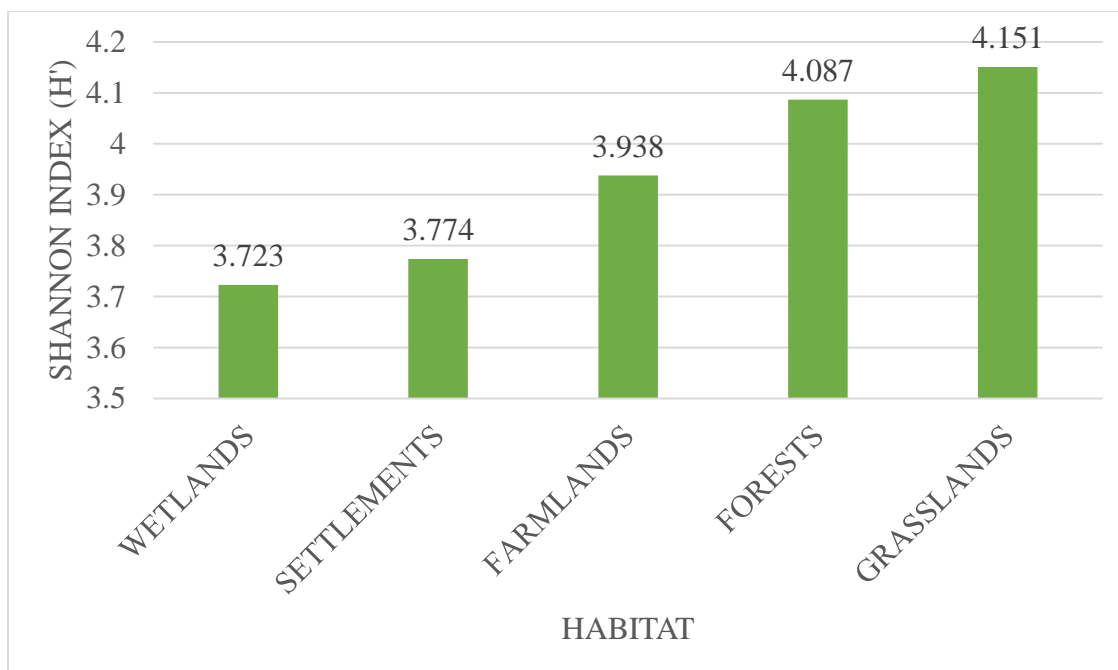


Figure 12 Shannon Wiener diversity index across habitats

4.2.2.2 Hutcheson's t-test

Pairwise comparisons of Shannon diversity indices were conducted among the five habitat types using Hutcheson's t-tests. Shannon diversity significantly differed between all habitat pairs, except between forests vs. grasslands ($t = -2.111$, $df = 3627$, $p = 0.348$) and settlements vs. wetlands, ($t = 1.476$, $df = 3693$, $p = 1.000$). Hence Wetlands and Settlements had the lowest species diversity followed by Farmlands with Forests and Grasslands having the highest. (Table 5).

Table 5: Pairwise comparisons of Shannon diversity indices between habitats using Hutchenson’s t-test with Bonferroni correction.

Habitat 1	Habitat 2	t-value	df	p-value
Farmlands	Forests	-5.144	3455	<0.001
Farmlands	Grasslands	-7.241	4188	<0.001
Farmlands	Settlements	5.274	2916	<0.001
Farmlands	Wetlands	6.709	4725	<0.001
Forests	Grasslands	-2.111	3627	0.348
Forests	Settlements	9.84	2768	<0.001
Forests	Wetlands	11.116	4212	<0.001
Grasslands	Settlements	11.707	3120	<0.001
Grasslands	Wetlands	12.92	4866	<0.001
Settlements	Wetlands	1.476	3693	1.000

4.2.2.3 Sorenson’s similarity index

Pairwise Sorenson’s Similarity Indices (SSI) were calculated to assess the similarity in bird species among habitat types. The index ranges from 0 (no similarity) to 1 (complete similarity).

Pairwise Sorenson’s similarity ranged from 0.195 to 0.570 (Table 6), with wetlands exhibiting the most distinct and lowest similarity across all habitats. Moderate affinity was found between settlements and forests (SSI= 0.425) and between forests and grasslands

(SSI=0.467), while the closest community resemblance occurred among settlements and grasslands (SSI=0.520) and farmlands (SSI= 0.526), followed by forests and farmlands (SSI= 0.545), peaking between grasslands and farmlands (SSI= 0.570).

Table 6: Pairwise Sorenson's similarity index (SSI) values for bird species between habitats

Habitat 1	Habitat 2	Sorenson's Index
Grasslands	Farmlands	0.570
Forests	Farmlands	0.545
Farmlands	Settlements	0.526
Grasslands	Settlements	0.520
Forests	Grasslands	0.467
Settlements	Forests	0.425
Farmlands	Wetlands	0.230
Settlements	Wetlands	0.229
Grasslands	Wetlands	0.217
Forests	Wetlands	0.195

4.3 Relative density of birds

The median relative density of bird species varied across habitats, with the highest recorded in wetlands (0.0100) reflecting their ecological productivity and structural complexity, followed by grasslands (0.0097), forest had (0.0096) but displayed the greatest variability, as indicated by the wide interquartile range. Settlements recorded a density of 0.0095 and farmlands had the least density of 0.0094 (Figure 13).

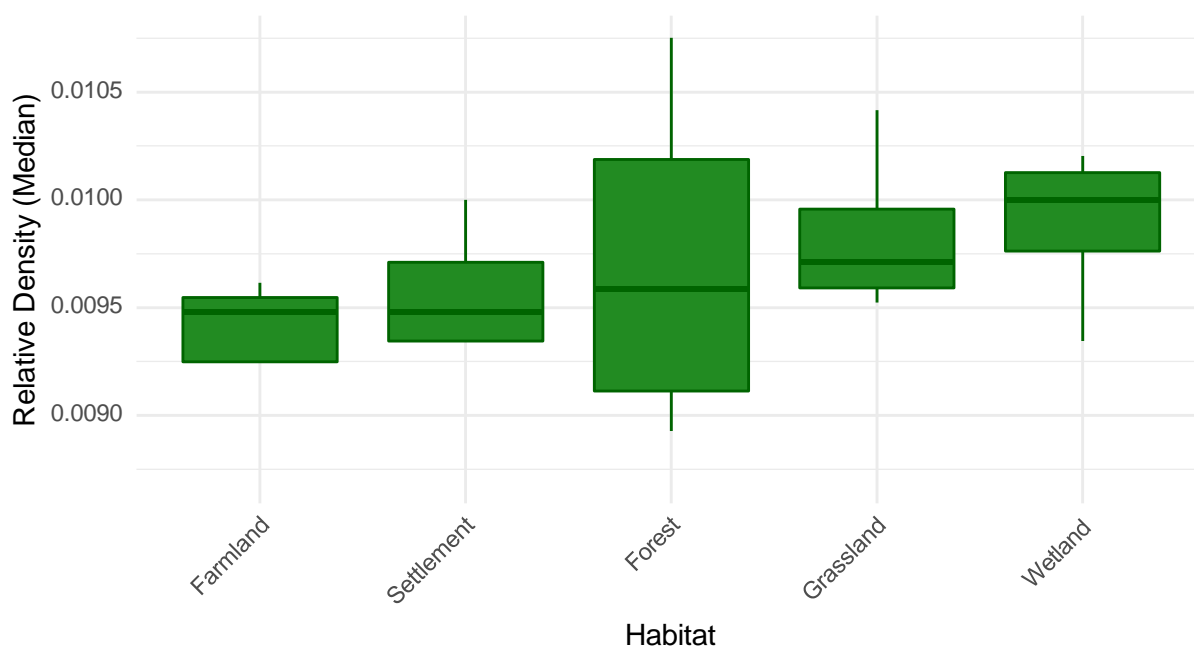


Figure 13: Box plot analysis for relative density across habitats

4.3.1 Shapiro-Wilk test

This was conducted to test whether there was normal distribution of the relative density data in habitats. All habitats (Farmlands, Forests, Grasslands, Settlements, Wetlands) showed p-values > 0.05 , indicating that the data for each habitat were not significantly different from a normal distribution (Table 7). However, given the ecological nature of the data and sample sizes, further tests were conducted to confirm variance assumptions. Results are given on next page.

Table 7: Shapiro-Wilk test for normality of relative density data across different habitat types

Habitat	W Statistic	p-value
Farmland	0.91	0.0818
Settlement	0.942	0.229
Forest	0.964	0.626
Grassland	0.95	0.257
Wetland	0.955	0.354

4.3.2 Levene's test

Levene's test result showed non-significant difference ($F = 1.50$, $df=4$, $p= 0.252$), satisfying the assumption of homogeneity of variance for ANOVA.

4.3.3 One-Way Analysis of Variance

ANOVA revealed no statistically significant difference in density across habitats ($F= 0.832$, $df= 4$, $p= 0.525$).

4.4 Threats to birds and their habitats

4.4.1 Socio-demographic characteristics of respondents

The respondent's distribution by village was 28 % from Majitamu, 22 % from Kapndege, 20 % from Kasururei, 16 % from Tuiyotich, and 14 % from Machine. Slightly more than half of the respondents (51%) were aged between 20 and 40 years, while 38% were above

40 years, and only 11% were aged between 18 and 20 years. In terms of gender, 64% of the participants were male, and 36% were female. Most of the respondents engaged in farming activities (38%), cattle rearing (28%) and fishing (24%) while eco-tourism (7%) and local trade (3%) were the least. (Table 8).

Table 8: Socio-demographic characteristics of respondents

VARIABLE	FREQUENCY	PERCENTAGE
VILLAGE		
Kapndege	22	22
Kasururei	20	20
Tuiyotich	16	16
Machine	14	14
Maji tamu	28	28
Total	100	100
AGE		
18-20 years	11	11
20-40 years	51	51
Above 40 years	38	38
Total	100	100
GENDER		
Male	64	64
Female	36	36
Total	100	100
ECONOMIC ACTIVITY		
Fishing	57	24
Farming	89	38
Cattle rearing	67	28
Eco-tourism	17	7
Local trade	7	3
Total	237	100

Note: Respondents chose more than one economic activity.

4.4.2 Community perception of species diversity levels

The Survey results showed that 39% of respondents rated bird species diversity as moderate, 36% as high and 22% as very high, indicating a generally positive perception about diversity. Only 3% of respondents perceived it as low (Table 9). These findings suggest that most community members view the area as having a robust variety of bird species, potentially reflecting diverse habitats.

Table 9: Perceived diversity level of bird species

Diversity level	Frequency	Percent
Very high	22	22
High	36	36
Moderate	39	39
Low	3	3
Total	100	100

4.4.3 Perceived threats to birds and their habitats around Lake Solai

Questionnaire results revealed that habitat loss/degradation was the most frequently cited threat, identified by 28% of the respondents, highlighting its prominence as a perceived environmental challenge. Climate change was the second (26%), reflecting widespread concern about impacts such as altered weather patterns. Human disturbance was reported by 22% of respondents, likely encompassing activities like tourism or infrastructure development that disrupt local ecosystems. Pollution was identified by 16% of respondents, indicating significant concern about contaminants (such as plastics, chemicals) affecting environmental quality.

Less frequently cited threats included avian disease outbreak (3%), suggesting moderate concern about pathogens affecting wildlife or plant populations, possibly linked to environmental changes. Illegal hunting/poaching (3%) were less commonly mentioned, indicating these are perceived as less immediate threats in Lake Solai. Overfishing (2%), cutting of trees (1%), and increased livestock (1%) received minimal mentions. Limited financial resources for conservation were cited by only 1% of respondents, indicating that systemic issues are less prominent than direct environmental threats in community perceptions (Table 10).

These findings indicate that respondents are generally aware of a wide range of pressures affecting bird populations, with a particular emphasis on habitat-related and climate-associated threats showing their priority for conservation efforts.

Table 10: Perceived threats to birds and their environment

THREAT	FREQUENCY	PERCENTAGE
Degradation	70	28
Extreme weather changes	65	26
Human disturbance	55	22
Pollution	40	16
Illegal hunting/poaching	7	3
Overfishing	4	2
Cutting trees	3	1
Increased livestock	2	1
Limited financial resources for conservation	1	1
Total	247	100

Chi-square test of results revealed a significant difference between the threats ($\chi^2=296.796$, $df=10$, $p<0.001$) indicating that some threats reported were more or less and often than others.

4.4.4 Relationship between socio-demographic characteristics and perceived threats

A chi-square test of independence performed to determine the relationship between village, age, gender and economic activities and respondent's perceived threats to birds and their environment revealed that there was a significant association between economic activities and perceived threats ($\chi^2 = 219.906$, $df= 40$, $p < 0.001$). This suggests that individuals' engagement in different economic activities influences how they perceive various threats. There was however no significant association between perceived threats and village, age and gender (Table 11). This implies that these have no influence on how the respondents perceive threats to birds and their habitats.

Table 11: Chi-square test of independence results showing the relationship between demographic characteristics and perceived threats to birds and their habitats

Variables	Chi-square values	df	p-values
Village	31.289	10	0.502
Age	16.640	16	0.409
Gender	7.572	8	0.476
Economic Activities	219.906	40	<0.001

Following the significant chi-square test results, a contingency table was used to systematically display the distribution of perceived threats across economic activities, enabling a detailed analysis of their association. Degradation was most frequently reported by fishers (38%), whereas farmers identified climate change and pollution (each 24%) as major threats. Cattle rearers highlighted climate change (24%) and human disturbance (16%) as significant concerns. Eco-tourism related respondents noted human disturbance (9%), while local traders reported minimal perceived threats, with limited financial resources for conservation being the only notable issue (1%). These results indicate differential threat perceptions in relation to livelihood types (Figure 14).

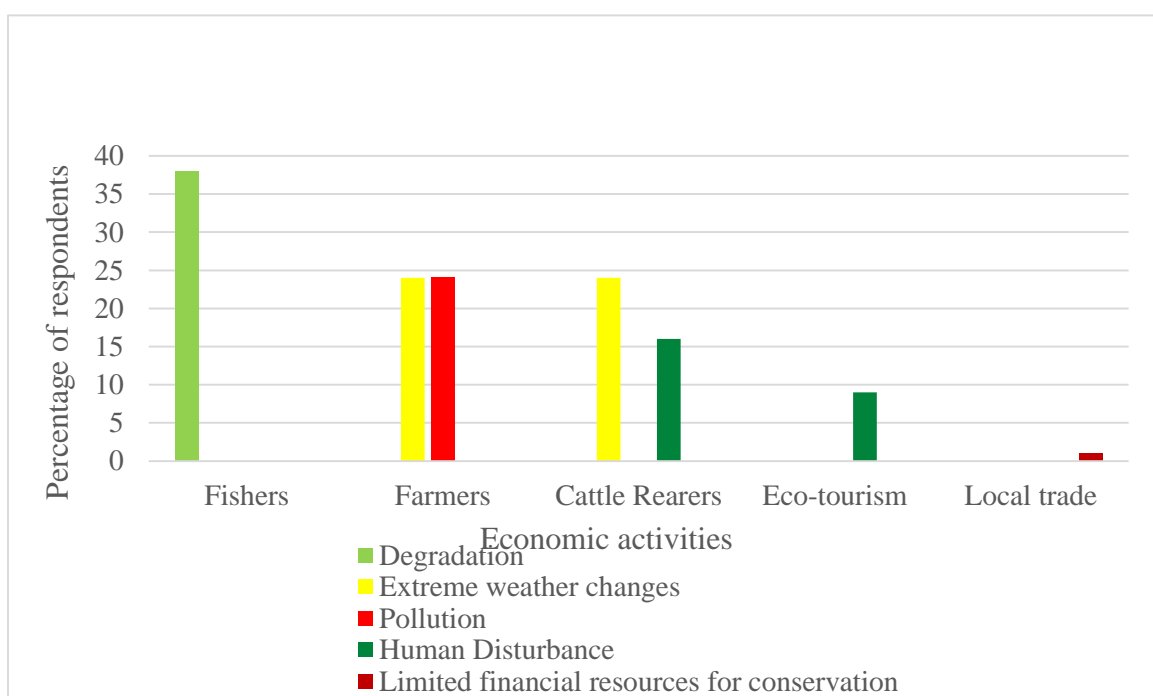


Figure 14: Distribution of perceived threats across economic activities

4.4.5 Perceived mitigation measures to threats to birds and habitats

Thematic analysis was conducted to systematically identify and categorize community perceptions of effective mitigation measures. This approach was chosen to uncover recurring themes and specific strategies valued by the community, providing a structured understanding of their priorities for conservation efforts. The results, summarized in Table 12 revealed four key thematic categories: Education, environmental governance, Protection, and Environment.

Support and funding theme was the most frequently cited, 39% emphasizing measures Education specifically creating awareness, was highlighted by 38% of respondents indicating a near-equal priority on educational initiatives to foster community engagement in conservation. Protection accounted for 13% of responses and environmental was noted by 10% of respondents.

Table 12: Perceived mitigation measures to threats on birds and their habitats

Thematic category	Mitigation measure	Frequency	Percentage
Education	Creating awareness	38	38%
Sub total		38	38%
Support and Funding	Conservation support	26	26%
	Govt cooperation,	2	2%
	Financing	11	11%
Sub total		39	39%
Protection	Protection of endangered species,	12	12%
	Create sanctuary	1	1%
Sub total		13	13%
Environment	Regulate water flow,	1	1%
	Tree planting	5	5%
	Ban charcoal burning	4	4%
Sub total		10	10%
Total		100	100%

4.4.6 Relationship between demographic characteristics with mitigation measures

To examine whether demographic and socioeconomic factors influenced these perceptions, chi-square tests were performed (Table 13). The results revealed a significant association between village and perceived mitigation measures ($\chi^2 = 31.448$, $df = 12$, $p < 0.001$). Age, gender and economic activities showed no significant association with perceived mitigation measures preferences.

Table 13: Chi-square test of independence results showing the influence of demographic characteristics on respondent's views on mitigation measures

Variables	Chi-square values	df	p-values
Village	31.448	12	<0.001
Age	7.782	6	0.254
Gender	3.482	3	0.323
Economic Activities	2.508	6	0.868

Due to the significant results between villages and mitigation measure, a contingency table was constructed to show the perceptions to mitigation measures (Table 14) Education was mostly prioritized by Tuiyotich village respondents (13%) and Machine (7%), followed by Kapndege (6%) and Kasururei and, Majitamu (6%). While support and funding were most prioritized by Kapndege (14%) and Majitamu residents (11%), followed by Kasururei (10%), machine 3% and Tuiyotich at (1%). Respondents from Majitamu prioritized protection at 7% followed by Machine (3%), Tuiyotich (2%), Kasururei 1% while no one considered it in Kapndege. Environment was also seen as a priority in Majitamu (4%) followed by Kasururei (3%), Kapndege (2%), Machine (1%) while it was not considered in Tuiyotich.

Table 14: Contingency table showing the influence of villages on mitigation measures

	Kapndege		Kasururei		Tuiyotich		Machine		Majitamu		Total
	F	%	F	%	F	%	F	%	F	%	
Education	6	6	6	6	13	13	7	7	6	6	38
Support and funding	14	14	10	10	1	1	3	3	11	11	39
Protection	0	0	1	1	2	2	3	3	7	7	13
Environment	2	2	3	3	0	0	1	1	4	4	10
Total	22		20		16		14		28		100

4.4.7 Perceived effectiveness of conservation efforts

From the survey, 30% of the respondents were aware of ongoing conservation efforts while the rest (70%) were not aware of any ongoing conservation efforts. This finding indicates that conservation efforts around Lake Solai are limited and largely informal. The most frequently reported actions were community volunteering (13%) and awareness creation (10%), reflecting modest levels of local engagement. However, structured interventions such as the establishment of a registered wetland conservancy (2%), tree planting by locals (4%), and regulation of fishing activities (1%) were rarely mentioned. Overall, only 30% of responses referenced any conservation activity, suggesting that active and organized efforts remain sparse, with most initiatives relying on individual or community-driven actions rather than formal management structures (Table 15).

Table 15: Community perceived conservation efforts

	Frequency	Percent
Awareness creation	10	10
Volunteering individuals	13	13
Presence of registered wetland conservancy	2	2
Tree planting by locals	4	4
Regulation of fishing	1	1
Total	30	30

Chi-square test of goodness of fit results on whether community perceptions of effective conservation efforts for bird species diversity followed a uniform distribution across five categories revealed a significant difference in mitigation measures ($\chi^2 = 18.333$, $df = 4$, $p = 0.001$).

Association of demographic activities with perceived conservation efforts

Chi-square test of independence results on whether demographic activities influenced perceived conservation efforts revealed that none of these variables showed a statistically significant association (Table 16).

Table 16: Chi-square test of independence results on the influence of demographic characteristics on perceived conservation efforts

Variables	Chi-square values	Df	p-values
Village	20.43	16	0.202
Age	5.96	8	0.663
Gender	2.40	4	0.662
Economic Activities	0.93	4	0.920

CHAPTER FIVE

DISCUSSION

5.1 Distribution of bird species and feeding guilds in Lake Solai

5.1.1 Distribution of birds

The distribution of bird species across wetlands, forests, grasslands, farmlands, and settlements highlighted distinct ecological patterns and habitat preferences. The presence of generalist species across all habitats suggests their adaptability to varied environmental conditions, likely due to flexible foraging and nesting behaviors (Norris & Martin, 2025). This adaptability enables generalists to thrive in heterogeneous landscapes, enhancing their resilience to habitat alterations (Besson et al. 2022).

Wetlands supported the highest number of specialist species, reflecting their resource-rich environments that sustain diverse ecological niches such as those for water-dependent birds (Smith, 2023). Forests and grasslands also hosted notable specialist diversity, likely due to their structural complexity and abundant food resources, which cater to specific dietary guilds (Dri et al. 2024). Farmlands supported fewer specialists, possibly due to agricultural practices that create patchy habitats, though these can still provide unique foraging opportunities (Estrada-Carmona et al. 2022). The absence of specialists in settlements indicates that urban environments, with their high disturbance and habitat homogenization, are less suitable for niche-specific species (Baek & Kim, 2024).

Family richness was highest in grasslands, followed closely by forests, suggesting these habitats support broad taxonomic diversity due to their structural and resource diversity (Pérez-Giraldo et al. 2025). Wetlands and farmlands showed moderate family richness,

while settlements had the lowest, likely reflecting the impact of anthropogenic disturbance on taxonomic diversity (Shaw et al. 2024). These patterns align with global trends, where natural habitats sustain greater biodiversity than human-modified ones (Muposhi, 2024).

The occurrence of seven bird species of conservation concern as listed on the IUCN Red List, across wetlands, forests, grasslands, and farmlands highlights the ecological significance of these habitats for threatened avian taxa. Wetlands supported the highest number of conservation-concern species, and this pattern underscores role of wetlands as critical refugia, providing specialized foraging and breeding resources for water-dependent and migratory species (Ramírez-Albores, 2025). The high productivity and habitat heterogeneity of wetlands likely facilitate niche partitioning, supporting these species' ecological requirements (Qiu et al. 2024).

Farmlands supported only Grey-Crowned crane (*Balearica regulorum*), reflecting the constraints of agricultural intensification, which often reduces habitat suitability through monoculture and chemical inputs (Katuwal et al. 2025). The absence of conservation-concern species in settlements indicates that urban environments, with their high anthropogenic disturbance and habitat homogenization, are suboptimal for these species, though targeted urban greening could enhance their viability (Callaghan et al. 2024).

The presence of Afrotropical migrants (AM) and Palearctic migrants (PM) underscores Lake Solai's role as a critical stopover and wintering site for intra-African and Eurasian migratory species, likely driven by its wetland resources and strategic location along migration flyways (Ramírez-Albores, 2025). The single species with both AM and PM codes suggests adaptive flexibility in migration behavior, potentially responding to environmental cues across regions (Alerstam et al. 2025). These patterns emphasize Lake

Solai's ecological significance for diverse migratory strategies, necessitating conservation efforts to protect wetland habitats from degradation and ensure connectivity for migratory and nomadic species.

The forest dependency classification of bird species at Lake Solai reveals distinct ecological guilds, with few forest specialists, a moderate proportion of forest generalists, some forest visitors, and a predominance of non-forest-dependent species adapted to open habitats. This pattern suggests limited dependence on forested ecosystems, reflecting the region's diverse, non-forested landscapes (Şekercioğlu et al. 2023). The rarity of forest specialists indicates their high vulnerability to forest degradation, necessitating prioritized conservation of forest patches to safeguard these specialized taxa (Tobias et al. 2022). In contrast, the abundance of non-forest-dependent species highlights their adaptability to varied environmental conditions, contributing to ecosystem resilience in open landscapes (Renner et al. 2024). Based on the foregoing there is need for integrated conservation strategies that protect both forest habitats for specialists and open habitats for versatile species to maintain avian biodiversity in the study area.

5.1.2 Feeding guilds of birds

The distribution of bird species across feeding guilds in the habitats surrounding Lake Solai reflects habitat-specific resource availability and ecological constraints, emphasizing the role of habitat diversity in supporting avian functional diversity. Insectivores were most prevalent in grasslands and wetlands, likely due to high insect abundance in these productive, heterogeneous ecosystems (Mariyappan et al. 2023). Granivores dominated in farmlands, grasslands, and settlements, where seeds were abundant due to agricultural activities and open landscapes (Ahmed & Khan, 2022). Omnivores showed greatest

representation in wetlands, leveraging the diverse food resources in aquatic environments (Cuthbert et al. 2022) . Carnivores are more common in wetlands and grasslands, where small vertebrates and invertebrates provide ample prey for predatory species (Karjee et al. 2022). Frugivores were primarily associated with forests, where fruit-bearing vegetation is abundant, and to a lesser extent in farmlands, likely due to cultivated fruit sources (Rabeau et al. 2025). Nectarivores, though scarce, occurred in forests and grasslands, linked to flowering plants in these habitats (Yilangai et al. 2023). Piscivores were predominantly found in wetlands, reflecting the availability of fish and aquatic organisms (Cliquet, 2025). The Shannon Diversity Index analysis results of bird feeding guilds at Lake Solai revealed distinct habitat associations driven by resource availability and ecological specialization. Insectivores exhibited the highest habitat diversity, reflecting their widespread distribution across wetlands and grasslands, where abundant insect prey supports varied foraging strategies (Tscharntke et al. 2024). Granivores also showed high habitat diversity, indicating adaptability to seed-rich open landscapes like farmlands and grasslands, consistent with their flexibility in anthropogenically altered environments (Panda et al. 2023). Carnivores and omnivores displayed moderate habitat diversity, leveraging diverse prey in resource-rich wetlands, though with less breadth than insectivores (Barbaro et al. 2022). Frugivores and nectarivores were more habitat-specific, primarily associated with forests due to concentrated fruit and nectar resources (Leveau et al. 2025). Piscivores showed the most restricted habitat use, predominantly tied to wetlands where aquatic prey is abundant (Qiu et al. 2024). These patterns highlight the critical role of habitat-specific resources in shaping feeding guild distributions at Lake Solai.

Hutcheson's t-test revealed significant differences in Shannon diversity between insectivores and granivores compared to other feeding guilds at Lake Solai, reflecting their broader habitat use due to abundant insect and seed resources, while the lack of differences among other guilds suggests similar habitat specificity driven by restricted resources (Husna et al. 2024)

These guild-specific patterns highlight the linkage between habitat characteristics and resource availability, shaping avian community structure. The prominence of insectivores and piscivores in wetlands and granivores in farmlands underscores the need to conserve resource-rich habitats to maintain functional diversity. Protecting wetlands for piscivores and omnivores, forests for frugivores, and grasslands for insectivores is critical to sustaining these ecological roles.

The distribution of bird species around Lake Solai reflects the habitat heterogeneity and varying degrees of anthropogenic disturbance across the landscape. Habitat degradation, especially in wetlands and forests, could disproportionately affect biodiversity and specialized guilds such as insectivores and frugivores, potentially disrupting ecological processes such as pest control and seed dispersal (Whelan et al. 2008). These findings align well with previous studies that highlight habitat complexity and resource availability as key drivers of the structures of bird communities.

5.2 Bird species richness, diversity and similarity

5.2.1 Bird species richness

Habitats with greater structural complexity and ecological heterogeneity such as grasslands and wetlands, tend to support higher bird species richness and diversity as demonstrated by steeper and extended rarefaction curves. In contrast, simplified habitats like farmlands and settlements often show early plateaus, indicating fewer ecological niches and lower richness. This pattern is consistent with studies showing that habitat heterogeneity is a key determinant of avian diversity across ecosystems (Hua et al. 2024). Structurally complex wetlands and agroecosystems provide a variety of foraging and nesting opportunities thereby supporting more diverse bird communities (Qiu et al. 2024).

5.2.2 Bird species diversity and similarity

The Shannon-Wiener diversity index (H') results demonstrated a clear gradient of avian diversity among habitats, with grasslands and forests supporting the highest diversity values. This pattern aligns with the ecological theory that structurally complex and less disturbed habitats provide a greater variety of niches and resources, facilitating coexistence of diverse bird species (Lu et al. 2024). Grasslands typically offer heterogeneous vegetation structure and diverse food availability, promoting higher species evenness and richness (Oliveira et al. 2022). Forest habitats, with their vertical stratification and diverse microhabitats support both specialist and generalist species contributing to increased diversity (Bitani et al. 2023).

Farmlands showed moderate diversity, likely influenced by agricultural heterogeneity and the presence of remnant natural patches, which can provide supplementary habitat

resources despite ongoing anthropogenic disturbance (Štěpán et al. 2025). Wetlands, though vital for many waterbirds, often experience fluctuating environmental conditions and limited terrestrial cover, which can restrict overall bird diversity (Teng et al. 2025). Settlements exhibited the lowest diversity, consistent with studies showing that urbanization and habitat fragmentation reduce habitat quality and resource availability thereby limiting bird species richness and evenness (Martínez-Núñez et al. 2023). These findings emphasize the importance of maintaining habitat heterogeneity and minimizing anthropogenic impacts to preserve avian biodiversity across landscape mosaics.

The significant differences in Shannon diversity indices across most habitat pairs highlight the pivotal role of habitat type in structuring bird communities around Lake Solai. The similarity in diversity between forests and grasslands suggests that both habitats provide comparable levels of structural complexity and resource availability, enabling them to sustain diverse avian assemblages as similarly reported by Concha et al. (2023), who found structurally complex habitats support higher species richness and evenness. The lack of significant difference between settlements and wetlands indicate that these habitats face similar limitations such as habitat fragmentation, anthropogenic disturbances, or fluctuating environmental conditions, which constrain their capacity to support diverse bird populations (Newton et al. 2020). The significant diversity differences observed among the other habitat pairs underscore how variations in vegetation structure, disturbance regimes, and resource heterogeneity drive spatial patterns in avian diversity (Anderle et al. 2023). These findings reinforce the ecological principle that habitat heterogeneity enhances biodiversity by providing a range of niches and resources (Thomsen et al. 2022).

Sørensen's Similarity Indices revealed varying degrees of species overlap among habitats, with wetlands showing the lowest similarity, likely due to their unique hydrology and specialist bird species (Özgencil et al. 2025). The highest similarity between grasslands and farmlands suggests shared vegetation structure supporting generalist species (Tripathi et al. 2021). Moderate similarity between forests, grasslands, and settlements may reflect edge effects and habitat transitions (Curipaco Quinto et al. 2024). These patterns highlight the importance of preserving distinct habitats like wetlands to maintain overall bird diversity.

This underscores the need for targeted management strategies that preserve and restore structurally complex habitats such as grasslands and forests which serve as biodiversity reservoirs. Improving habitat quality in wetlands and settlements by reducing fragmentation and mitigating human disturbance could enhance their capacity to support more diverse bird communities. Maintaining a mosaic of diverse and interconnected habitats is critical to sustaining avian biodiversity in Lake Solai landscape, thus aligning with landscape ecology principles that emphasize connectivity and heterogeneity for biodiversity conservation.

5.3 Relative density of bird species

Wetlands characterized by high productivity and structural complexity, support diverse bird communities, which is consistent with observations of (McKinney et al. 2011) that seasonally flooded wetlands exhibited high species richness and abundance. Similarly, forests, despite showing variability provide critical habitats for avian species, as

demonstrated by Mulwa et al. (2021) where near-natural forests supported a diverse bird assemblage compared to degraded habitats.

Grasslands and settlements, while offering moderate bird densities are increasingly influenced by anthropogenic activities. John et al. (2025). Farmland habitats exhibited lower bird densities reflecting the negative impacts of intensive agriculture on habitat complexity and bird populations which aligns with findings of Busch et al. (2020). There is need on emphasis on conservation strategies that maintain habitat complexity and mitigate anthropogenic disturbances to support avian biodiversity.

These foregoing align with the broader literature emphasizing the importance of habitat structural diversity and the impacts of anthropogenic disturbance on avian communities reinforcing the need to preserve habitat complexity, particularly in agricultural landscapes (Sekercioglu et al. 2020).

The one-way ANOVA revealed no statistically significant differences suggesting that categorical habitat distinctions alone do not drive density variation in the Lake Solai landscape. This lack of significant difference indicated that microhabitat features such as ground-layer vegetation and localized cover can override broad habitat classifications in determining avian density (Coddington, 2023). Density patterns can be influenced by factors beyond habitat classification, hence need for the inclusion of additional ecological variables (Santini et al. 2023).

Ecologically, these results imply that birds around Lake Solai exploit a mosaic of food resources, nesting sites, and shelter that are distributed more uniformly across land uses than expected. This pattern echoes observations by (Silva, 2024) where properly connected sites achieved densities comparable to remnant habitats. Consequently, conservation and

management efforts should prioritize enhancing landscape connectivity and fine-scale structural heterogeneity (such as retaining remnant trees in fields, establishing mixed-vegetation buffers in settlements, and conserving wetland microhabitats).

5.4 Threats to birds and their habitats

Survey results indicated a predominantly positive community perception of bird species diversity. This positive outlook may reflect a healthy local ecosystem, effective conservation efforts, or heightened community awareness of bird species, which could be driven by visible species richness or engagement with environmental initiatives (Obradović et al. 2023). The high proportion of favorable responses as high or very high aligns with research indicating that communities often associate biodiversity with ecological health and the presence of charismatic species like birds (Kuras et al. 2020).

The percentage of respondents rating diversity as moderate may indicate a cautious perspective, possibly due to uneven distribution of bird populations across the study area or limited exposure to certain species. This aligns with findings that perceptions of biodiversity can vary based on access to natural habitats or personal experience with wildlife (Bele & Chakradeo, 2021). For instance, urban residents may perceive lower diversity if they primarily encounter common species, while those near protected areas might report higher diversity due to greater species richness (Belaire et al. 2022). The moderate rating could also reflect a nuanced understanding of biodiversity, where respondents recognize sufficient but not exceptional variety, potentially warranting further investigation into specific habitat conditions or species distributions.

The small fraction of respondents perceiving low diversity may point to localized environmental challenges such as habitat fragmentation or degradation which can reduce bird populations and visibility (Cassola et al. 2025). This group might also include individuals with limited ecological knowledge or those in areas with reduced access to green spaces, as community perceptions are often shaped by both environmental exposure and education (Schell et al. 2020). The high level of optimism suggests a receptive audience for initiatives like habitat restoration or citizen science programs, which can further enhance engagement (Ferretti et al. 2023).

Degradation was the most commonly perceived threat particularly by fishermen, reflects the acute vulnerability of Lake Solai's wetland ecosystems to anthropogenic pressures. Activities such as fishing, shoreline agriculture, and infrastructure development likely contribute to vegetation loss and soil erosion, disrupting nesting and foraging habitats for waterbirds (Flitcroft et al. 2023). This finding aligns with global trends where wetland degradation threatens avian biodiversity, particularly for migratory species reliant on stable ecosystems (Wang et al. 2024). Restoration strategies, including shoreline revegetation, wetland rehabilitation, and establishing protected buffer zones, are critical to restore habitat integrity (Braun, 2023). Community-based monitoring could ensure sustainable land use, especially in fishing areas where degradation is most perceived.

Climate change, perceived particularly by farmers and cattle rearers highlights concern about altered precipitation, temperature shifts, and extreme weather events impacting Lake Solai's ecosystems. These changes can reduce water availability, alter wetland hydrology, and disrupt bird breeding cycles as observed in East African wetlands (Karanja, 2022).

Prolonged droughts may shrink foraging grounds for wading birds, while erratic rainfall could affect agricultural productivity, indirectly putting pressure on habitats through intensified land use (Dunee et al. 2025). Climate change also disrupts migration patterns of birds and other ecological processes (Kumar et al. 2024). Implementing climate-smart agriculture such as drought-resistant crops, agroforestry, and rainwater harvesting, is essential to enhance ecosystem resilience and support livelihoods (Hussein, 2024).

Human disturbance, as reported notably by cattle rearers and eco-tourism respondents, likely arises from grazing, trampling, and tourism activities disrupting sensitive bird habitats. Grazing can degrade vegetation critical for nesting, while tourism-related infrastructure or visitor traffic may cause behavioral changes in birds reducing breeding success (Page & Connell, 2020). Shorebirds are particularly sensitive to human presence near breeding sites, leading to nest abandonment (Martínez-Curci et al. 2021). Zoning grazing areas, promoting rotational grazing, and developing proper eco-tourism guidelines (for instance restricted access zones or low-impact trails) are vital to minimize disturbance while supporting local economies.

Pollution which was cited especially by farmers points to agricultural runoff including pesticides and fertilizers which degrade the water quality essential for aquatic birds. Nutrient enrichment can lead to eutrophication, reducing oxygen levels and altering food webs as seen in similar wetland systems (Dubey & Dutta, 2020). Plastic waste and chemical pollutants may also directly harm birds through ingestion or habitat contamination (Wang et al. 2021). Integrated pest management, buffer strips along water bodies, and community waste management programs are necessary to reduce pollution

impacts and hence optimize ecosystem services (Cole et al. 2020). Engaging farmers in these practices could align conservation with agricultural productivity.

Although invasive species, illegal hunting/poaching, overfishing, cutting of trees, increased livestock and limited financial resources for conservation were perceived as less prominent threats by the community, their ecological impacts are far from negligible and may be underestimated by local communities due to lack of awareness or limited visibility or long-term, indirect effects. Invasive species can alter ecosystems by outcompeting native flora, reducing habitat quality as reported by Mayfield et al. (2021), while poaching directly threatens bird populations, particularly for high-value species (Ashokumar, 2023). Awareness campaigns could elevate community vigilance for these risks.

The association between economic activities and threat perceptions reflects livelihood driven environmental concerns. Fishermen focus on habitat degradation aligns with their lake dependency, while farmers' emphasis on climate change and pollution corresponds to agriculture's environmental sensitivities. Cattle rearers' concern for human disturbance highlights grazing impacts, and tourism respondents' focus on disturbance suggests visitor-related pressures. Business community respondents' minimal input (citing limited financial capacity for conservation) indicates limited environmental engagement. The lack of age or gender influence simplifies outreach, which must integrate with dominant livelihoods farming, cattle rearing, and fishing to ensure adoption. The findings reflect a clear understanding among local communities of the pressing threats to birds and their habitats, particularly habitat degradation and climate change, which are globally recognized as leading drivers of biodiversity loss (Katuwal et al. 2021).

Thematic analysis of community perceptions of effective mitigation measures for bird species conservation, identified four key themes: Support and funding, Education, Protection, and Environment. The prominence of support and funding as the most frequently cited theme underscores the community's trust in regulatory frameworks to drive conservation outcomes. This aligns with findings that strong policy measures, such as habitat protection laws or wildlife management regulations, are often perceived as critical for biodiversity conservation (Brockett et al. 2023).

Education emerged as a nearly equally valued theme, highlighting the community's recognition of awareness campaigns and educational initiatives as vital for fostering engagement. This supports research indicating that environmental education enhances public support for conservation by increasing knowledge and emotional connection to local ecosystems (Ardoin et al. 2020). The near-equal prioritization of policy and education suggests a community that values both top-down governance and grassroots awareness to sustain conservation efforts.

The Environment themes, though less frequently cited, indicate additional community priorities, such as direct species protection (like sanctuaries or anti-poaching measures) and habitat restoration through reforestation or wetland management. These align with studies showing that communities often support tangible, localized actions that visibly enhance biodiversity (Kukkonen et al. 2025).

The significant association between village and perceived mitigation measures indicates geographic variation in conservation preferences. Age, gender, and economic activities had no significant influence suggesting local context outweighs individual factors (Thapa et al. 2025). Tuiyotich and Machine prioritized Education, likely due to exposure to awareness

programs (Jacobson et al. 2015). Policy was favored in Kapndege and Majitamu reflecting trust in regulatory measures (Gibbon, 2021). Protection was emphasized in Majitamu and Environment in Majitamu and Kasururei indicating localized concerns about species safety or habitat restoration (Carlen et al. 2024). Conservation efforts should tailor strategies to village-specific priorities to align with community values.

The predominance of informal actions such as volunteering and awareness creation aligns with research indicating that community-led initiatives often emerge in areas with limited formal conservation infrastructure (Luz & Ruiz-Mallén, 2020). Similarly, awareness creation is critical for building public support but requires consistent, well-funded programs to translate knowledge into actionable conservation outcomes (Dorris et al. 2025).

The low recognition of structured interventions such as wetland conservancies or fishing regulations points to a gap in institutional conservation strategies. The low mention of tree planting and fishing regulation further suggests that tangible, ecosystem-focused interventions are either underdeveloped or poorly communicated to the community. This lack of visibility may erode community trust in conservation efforts as perceptions of effectiveness are closely tied to observable outcomes (Thapa et al. 2025).

The significant chi-square results underscore that community perceptions are not uniformly distributed across conservation measures, reflecting diverse local priorities or varying exposure to initiatives. The chi-square test of independence revealed no statistically significant association between demographic variables and the perceived effectiveness of conservation efforts around Lake Solai. Notably, this pattern likely reflects a general lack of awareness about the existence or implementation of any formal conservation initiatives

in the region. Similar findings have been documented in regions with limited conservation outreach. Where conservation efforts are absent, poorly communicated, or disconnected from local communities, respondents tend to express a uniformly neutral or uninformed stance regarding conservation outcomes (Obradović et al. 2023). In the case of Lake Solai area, most residents were unaware of any ongoing conservation interventions, which is likely why there were no significant variations in perception regardless of age, gender, or livelihood.

The foregoing highlights a key gap in conservation communication and stakeholder engagement. Successful conservation relies not only on ecological outcomes but also on local awareness, participation, and ownership (Schell et al. 2023). When communities are unaware of conservation measures, it undermines both local support and the sustainability of such efforts. Where no clear efforts are recognized by the public, perceptions of effectiveness remain uniformly low or uncertain across all groups. Hence to strengthen conservation around Lake Solai, stakeholders should prioritize institutional support for formal interventions, such as establishing and promoting wetland conservancies, alongside sustained outreach to elevate awareness. Additionally, partnerships with local organizations and integration of traditional ecological knowledge could align conservation strategies with community values, ensuring both ecological and social sustainability (Davis et al. 2019).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

- i. Wetlands and forests serve as vital refuges for conservation priority and habitat-specialized species. There is predominance of species adapted to open habitats reflecting the area's diverse landscape.
- ii. The study concludes that bird species diversity in and around Lake Solai is significantly influenced by habitat type.
- iii. Bird species density in and around Lake Solai varies with habitat structure and resource availability.
- iv. Habitat degradation, climate change, human disturbance, and pollution were identified as the primary anthropogenic pressures affecting avian communities and habitats in and around Lake Solai. These threats are closely associated with livelihood activities such as agriculture, fishing, and grazing

This pioneering checklist and ecological assessment provide an essential foundation for informing conservation policy and management in Lake Solai, ensuring the long-term protection of its avifaunal communities and regional ecosystem stability.

6.2 Recommendations

6.2.1 Policy and management recommendations

- i. Protection and restoration of wetlands and forests in and around Lake Solai should be prioritized through formal designation as conservation areas. These habitats are critical for specialist and conservation-priority bird species and require

management interventions such as riparian vegetation recovery, buffer zone establishment, and integration into environmental policies to maintain ecological integrity.

- ii. Habitat-based conservation planning should be adopted to safeguard bird diversity across the different habitat types around Lake Solai. Land-use zoning that preserves habitat heterogeneity, coupled with stringent environmental impact assessments for development projects, will ensure that ecological considerations are embedded within regional land management frameworks.
- iii. Promoting reforestation, catchment protection, and pollution control, alongside community-led habitat monitoring, will help preserve ecosystem balance and ensure the continued provisioning of ecological resources.
- iv. Integrating climate-smart agriculture, environmental education, and participatory management within local livelihoods will enhance community ownership of conservation initiatives and foster long-term ecological resilience in the Lake Solai ecosystem.

6.2.2 Recommendations for further research

- i. Long-term monitoring of avian population dynamics should be conducted to evaluate the impacts of environmental changes on biodiversity.
- ii. The effectiveness of current conservation interventions in sustaining avian diversity should be evaluated.
- iii. Studies should be conducted to investigate the effects of land-use changes on wetland ecosystem services to provide valuable insights on habitat functions and resilience.

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APPENDICES

APPENDIX I: LAKE SOLAI BIRDS AND HABITAT THREATS ASSESSMENT

QUESTIONNAIRE

A. SOCIO-DEMOGRAPHIC INFORMATION ON RESPONDENTS

Date of visit..... Sub-location..... Village.....

1. Age:(1) 18-20years (2) 20-40years (3) 40 and above years
2. Gender: Male () Female ()
3. What are the primary activities undertaken by the community living near Lake Solai? (Tick all undertaken)

- 1) Fishing
- 2) Farming
- 3) Cattle rearing
- 4) Eco tourism
- 5) Local trade

B. BIRDS AND THEIR HABITAT

4. (a) Are you aware of the bird species present in Solai? (Yes) (No)

(b) If yes, name any bird species observed here

.....

5. How would you describe the current diversity of bird species in Lake Solai and its surroundings?

- 1) Very High
- 2) High
- 3) Moderate
- 4) Low
- 5) Very Low

6. Which bird species do you think have declined in numbers over the years? Please list them from the most affected to the least affected:

.....

7. How would you describe the habitat in Solai area where birds are commonly found?

- 1) Human settlements
- 2) Agricultural areas
- 3) Forested areas
- 4) Wetland areas
- 5) Riparian land

8. Which common species of birds do you rarely see again? Please list:

.....

9. Which bird species are now very common than before? Please list them:

.....

10. In your opinion, what reasons may have caused the disappearance of these bird species?.....

C. IDENTIFICATION OF THREATS

11.(a) Have you noticed any changes in bird habitats in Solai over the past few years? (Yes) (No)

(b) If yes which changes have you noticed

.....

12. In your opinion, what are the most significant threats to bird populations in Lake Solai? (Tick where appropriate)

- 1) Degradation
- 2) Pollution
- 3) Extreme weather changes
- 4) Overfishing
- 5) Human disturbance
- 6) Illegal hunting/poaching
- 7) Other (please specify.....)

13. How do the community activities potentially impact bird habitats in the Lake Solai area?

.....

APPENDIX II: CHECKLIST OF BIRD SPECIES ACROSS FIVE HABITAT TYPES IN AND AROUND LAKE

SOLAI

	FAMILY AND COMMON NAMES	SCIENTIFIC NAME	IUCN REDLIST STATUS	HABITATS	FEEDING GUILDS	MIGRATION STATUS	FOREST DEPENDENCY
	Accipitridae						
1	African Fish Eagle	<i>Haliaeetus vocifer</i>	LC	W, S	Piscivore	R	Non f
2	African Goshawk	<i>Aerospiza tachiro</i>	LC	F	Carnivore	R	F
3	African Harrier Hawk	<i>Polyboroides typus</i>	LC	W, F	Carnivore	R	f
4	Augur Buzzard	<i>Buteo augur</i>	LC	W, F, G, FA, S	Carnivore	R	f
5	Banded Snake Eagle	<i>Circaetus cinerascens</i>	LC	F	Carnivore	R	F
6	Black Kite	<i>Milvus migrans</i>	LC	G, FA	Carnivore	Pm	Non f
7	Brown Snake Eagle	<i>Circaetus cinereus</i>	LC	G, FA	Carnivore	R	Non f
8	Long Crested Eagle	<i>Lophaetus occipitalis</i>	LC	W, G, FA	Carnivore	R	f
9	Marsh Harrier	<i>Circus ranivorus</i>	LC	W	Carnivore	R	Non f
	Acrocephalidae					R	
10	Common Reed Warbler	<i>Acrocephalus scirpaceus</i>	LC	W	Insectivore	PM	Non f
	Alcedinidae						

11	African Pygmy Kingfisher	<i>Ispidina picta</i>	LC	F	Insectivore	Am	f
12	Grey-headed Kingfisher	<i>Halcyon leucocephala</i>	LC	W, F	Insectivore	Am	f
13	Malachite Kingfisher	<i>Corythornis cristatus</i>	LC	W, F	Piscivore	R	Non f
14	Pied Kingfisher	<i>Ceryle rudis</i>	LC	W, F, FA	Piscivore	R	Non f
15	Striped Kingfisher	<i>Halcyon chelicuti</i>	LC	W	Insectivore	R	Non f
16	Woodland Kingfisher	<i>Halcyon senegalensis</i>	LC	W	Insectivore	Am	Non f
	Anatidae						
17	Cape Teal	<i>Anas capensis</i>	LC	W	Omnivore	R	Non f
18	Egyptian Goose	<i>Alopochen aegyptiaca</i>	LC	W	Herbivore	R	Non f
19	Hottentot Teal	<i>Spatula hottentota</i>	LC	W	Omnivore	R	Non f
20	Red-billed Teal	<i>Anas erythrorhyncha</i>	LC	W	Omnivore	R	Non f
21	White-backed Duck	<i>Thalassornis leuconotus</i>	LC	W	Omnivore	R	Non f
22	White-faced Whistling Duck	<i>Dendrocygna viduata</i>	LC	W	Omnivore	R	Non f
23	Yellow-billed Duck	<i>Anas undulata</i>	LC	W	Omnivore	Am	Non f
	Anhingidae						
24	African Darter	<i>Anhinga rufa</i>	LC	W	Piscivore	R	Non f
	Apodidae						
25	African Black Swift	<i>Apus barbatus</i>	LC	G, FA	Insectivore	R	Non f
26	Common Swift	<i>Apus apus</i>	LC	W	Insectivore	PM	Non f
27	Nyanza Swift	<i>Apus niansae</i>	LC	W, G, FA	Insectivore	R	Non f

	Ardeidae						
28	Black-headed Heron	<i>Ardea melanocephala</i>	LC	W, G, S	Carnivore	R	Non f
29	Cattle Egret	<i>Bubulcus ibis</i>	LC	W, G, S	Insectivore	Am	Non f
30	Goliath Heron	<i>Ardea goliath</i>	LC	W	Carnivore	R	Non f
31	Great White Egret	<i>Ardea alba</i>	LC	W	Carnivore	R	Non f
32	Grey Heron	<i>Ardea cinerea</i>	LC	W, G, FA, S	Carnivore	am, pm	Non f
33	Little Egret	<i>Egretta garzetta</i>	LC	W, G	Insectivore	R	Non f
34	Purple Heron	<i>Ardea purpurea</i>	LC	W	Carnivore	(pm)	Non f
35	Squackoo Heron	<i>Ardeola ralloides</i>	LC	W	Insectivore	am, pm	Non f
	Bucerotidae						
36	African Grey Hornbill	<i>Tockus nasutus</i>	LC	FA	Omnivore	R	Non f
37	Jackson's Hornbill	<i>Tockus jacksoni</i>	LC	F, G	Omnivore	R	Non f
38	Red-billed Hornbill	<i>Tockus erythrorhynchus</i>	LC	G	Omnivore	R	FF
39	Von der Decken's Hornbill	<i>Tockus deckeni</i>	LC	FA	Omnivore	R	Non f
	Bucorvidae						
40	Southern Ground Hornbill	<i>Bucorvus leadbeateri</i>	VU	F, FA	Omnivore	R	Non f
	Buphagidae						
41	Red Billed Oxpecker	<i>Buphagus erythrorhynchus</i>	LC	W, G, S	Insectivore	R	Non f
42	Yellow Billed Oxpecker	<i>Buphagus africanus</i>	LC	W, G	Insectivore	R	Non f
	Burhinidae						

43	Water Thick-knee	<i>Burhinus vermiculatus</i>	LC	W	Insectivore	R	Non f
	Campephagidae						
44	Black Cuckooshrike	<i>Campephaga flava</i>	LC	G	Insectivore	Am	f
	Capitonidae						
45	Red And Yellow Barbet	<i>Trachyphonus erythrocephalus</i>	LC	F, G, FA	Omnivore	R	Non f
46	White Headed Barbet	<i>Lybius leucocephalus</i>	LC	F	Frugivore	R	f
	Caprimulgidae						
47	Montane Nightjar	<i>Veles binotatus</i>	LC	F	Insectivore	R	F
48	Plain Nightjar	<i>Caprimulgus inornatus</i>	LC	G	Insectivore	AM	Non f
	Charadriidae						
49	Black-headed Plover	<i>Vanellus tectus</i>	LC	FA	Insectivore	R	Non f
50	Blacksmith Plover	<i>Vanellus armatus</i>	LC	W, G, FA	Insectivore	R	Non f
51	Crowned Plover	<i>Vanellus coronatus</i>	LC	W, G, FA, S	Insectivore	R	Non f
52	Kittlitz's Plover	<i>Charadrius pecuarius</i>	LC	W	Insectivore	Am	Non f
53	Long-toed Plover	<i>Vanellus crassirostris</i>	LC	W	Insectivore	R	Non f
54	Spur-winged Plover	<i>Vanellus spinosus</i>	LC	W, FA	Insectivore	R	Non f
55	Three-banded Plover	<i>Charadrius tricollaris</i>	LC	W	Insectivore	R	Non f
	Ciconiidae						

56	Abdim's Stork	<i>Ciconia abdimii</i>	LC	W	Insectivore	AM	Non f
57	Marabou Stork	<i>Leptoptilos crumenifer</i>	LC	W	Carnivore	(am, n)	Non f
58	Saddle-billed Stork	<i>Ephippiorhynchus senegalensis</i>	LC	W	Carnivore	R	Non f
59	Yellow-billed Stork	<i>Mycteria ibis</i>	LC	W	Carnivore	Am	Non f
	Cisticolidae						
60	Grey-backed Camaroptera	<i>Camaroptera brevicaudata</i>	LC	F	Insectivore	R	f
61	Pale Prinia	<i>Prinia somalica</i>	LC	F, FA	Insectivore	R	Non f
62	Rattling Cisticola	<i>Cisticola chiniana</i>	LC	F, G, FA, S	Insectivore	R	Non f
63	Yellow-Breasted Apalis	<i>Apalis flavida</i>	LC	F	Insectivore	R	f
64	Zitting Cisticola	<i>Cisticola juncidis</i>	LC	F, G, FA, S	Insectivore	R	Non f
	Coliidae						
65	Blue Naped Mousebird	<i>Urocolius macrourus</i>	LC	F, G, FA, S	Frugivore	R	f
66	Speckled Mousebird	<i>Colius striatus</i>	LC	F, G, FA, S	Frugivore	R	f
	Columbidae						
67	African Green Pigeon	<i>Treron calvus</i>	LC	F, G, FA	Frugivore	R	F
68	African Mourning Dove	<i>Streptopelia decipiens</i>	LC	W, F, G, S	Granivore	R	f
69	Dusky Turtle Dove	<i>Streptopelia lugens</i>	LC	G	Granivore	R	f
70	Emerald-spotted Wood Dove	<i>Turtur chalcospilos</i>	LC	W, F, G, FA, S	Granivore	R	f

71	Laughing Dove	<i>Spilopelia senegalensis</i>	LC	W, F, G, FA, S	Granivore	R	Non f
72	Namaqua Dove	<i>Oena capensis</i>	LC	F, G, FA, S	Granivore	R	Non f
73	Red-eyed Dove	<i>Streptopelia semitorquata</i>	LC	F, FA, S	Granivore	R	f
74	Ring-necked Dove	<i>Streptopelia capicola</i>	LC	F, G, FA, S	Granivore	R	f
75	Speckled Pigeon	<i>Columba guinea</i>	LC	F, G, FA, S	Granivore	R	f
76	Tambourine Dove	<i>Turtur tympanistris</i>	LC	F	Granivore	R	F
	Coraciidae						
77	Lilac-breasted Roller	<i>Coracias caudatus</i>	LC	W, F, G, S	Carnivore	Am	Non f
	Corvidae						
78	Pied Crow	<i>Corvus albus</i>	LC	G, FA, S	Omnivore	R	Non f
	Cuculidae						
79	African Emerald Cuckoo	<i>Chrysococcyx cupreus</i>	LC	F	Insectivore	R	F
80	Great Spotted Cuckoo	<i>Clamator glandarius</i>	LC	G	Insectivore	am (pm)	Non f
81	Red-chested Cuckoo	<i>Cuculus solitarius</i>	LC	F, G, FA, S	Insectivore	Am	F
	Cuculidae						
82	Black Coucal	<i>Centropus grillii</i>	LC	G, S	Insectivore	R	Non f
83	White-browed Coucal	<i>Centropus superciliosus</i>	LC	G, S	Omnivore	R	Non f
	Dicruridae						

84	Common Drongo	<i>Dicrurus adsimilis</i>	LC	W, F, G, FA, S	Insectivore	R	f
	Estrildidae						
85	African Firefinch	<i>Lagonosticta rubricata</i>	LC	G, FA, S	Granivore	R	Non f
86	Blue-cheeked Cordon-bleu	<i>Uraeginthus bengalus</i>	LC	FA, S	Granivore	R	Non f
87	Bronze Mannikin	<i>Spermophaga haematina</i>	LC	FA, S	Granivore	R	Non f
88	Purple Grenadier	<i>Uraeginthus ianthinogaster</i>	LC	G, FA, S	Granivore	R	Non f
89	Red-billed Firefinch	<i>Lagonosticta senegala</i>	LC	G, FA, S	Granivore	R	Non f
90	Red-cheeked Cordon-bleu	<i>Uraeginthus bengalus</i>	LC	G, S	Granivore	R	Non f
	Ploceidae						
91	Red-billed Quelea	<i>Quelea quelea</i>	LC	G, FA, S	Granivore	Am	Non f
	Falconidae						
92	Pygmy Falcon	<i>Polihierax semitorquatus</i>	LC	G	Carnivore	R	Non f
	Fringillidae						
93	Streaky Seed Eater	<i>Crithagra striolata</i>	LC	F, G, FA	Granivore	R	f
94	Yellow-fronted Canary	<i>Crithagra mozambica</i>	LC	F, G, FA, S	Granivore	R	Non f
	Glareolidae						
95	Three-banded Courser	<i>Rhinoptilus cinctus</i>	LC	W	Insectivore	R	Non f

	Gruidae						
96	Grey-crowned Crane	<i>Balearica regulorum</i>	EN	W, F, G, FA, S	Omnivore	R	F
	Hirundinidae						
97	Barn Swallow	<i>Hirundo rustica</i>	LC	W, F, G, FA	Insectivore	PM	Non f
98	Mosque Swallow	<i>Cecropis senegalensis</i>	LC	W, G, S	Insectivore	R	Non f
99	Plain Mattin	<i>Riparia paludicola</i>	LC	W	Insectivore	Am	Non f
100	Wire-Tailed Swallow	<i>Hirundo smithii</i>	LC	W, F, G	Insectivore	R	Non f
	Indicatoridae						
101	Green-backed Honeybird	<i>Prodotiscus zambesiae</i>	LC	F	Nectarivore	R	F
	Jacanidae						
102	African Jacana	<i>Actophilornis africanus</i>	LC	W	Omnivore	R	Non f
103	Lesser Jacana	<i>Microparra capensis</i>	LC	W	Omnivore	R	Non f
	Laniidae						
104	Common Fiscal	<i>Lanius humeralis</i>	LC	W, G, FA	Insectivore	R	Non f
105	Grey-backed Fiscal	<i>Lanius excubitoroides</i>	LC	W, F, G, FA, S	Insectivore	R	f
106	Long-tailed Fiscal	<i>Lanius cabanisi</i>	LC	F, FA	Insectivore	R	F
	Laridae						

107	Common Tern	<i>Sterna hirundo</i>	LC	W	Piscivore	PM	Non f
108	Grey-headed Gull	<i>Chroicocephalus cirrocephalus</i>	LC	W	Insectivore	R	Non f
109	Gull-billed Tern	<i>Gelochelidon nilotica</i>	LC	W	Insectivore	PM	Non f
110	Whiskered Tern	<i>Chlidonias hybrida</i>	LC	W	Piscivore	(pm)	Non f
	Leiothrichidae						
111	Arrow-marked Babbler	<i>Turdoides jardineii</i>	LC	FA	Insectivore	R	Non f
112	Rufous Chatterer	<i>Turdoides rufus</i>	LC	W	Insectivore	R	Non f
	Lybiidae						
113	Red-fronted Tinkerbird	<i>Pogoniulus uropygialis</i>	LC	F, G, FA	Frugivore	R	F
114	D'Arnaud's Barbet	<i>Trachyphonus darnaudii</i>	LC	F, G, S	Omnivore	R	Non f
115	Yellow-rumped Tinkerbird	<i>Pogoniulus bilineatus</i>	LC	F	Frugivore	R	F
	Macrosphenidae						
116	Red-faced Crombec	<i>Sylvietta whytii</i>	LC	F, G	Insectivore	R	Non f
	Malaconotidae						
117	Brown-crowned Tchagra	<i>Tchagra australis</i>	LC	F, S	Insectivore	R	Non f
118	Nothern Puffback	<i>Dryoscopus gambensis</i>	LC	F	Insectivore	R	F
119	Slate-coloured Boubou	<i>Laniarius funebris</i>	LC	G	Insectivore	R	Non f

120	Tropical Boubou	<i>Laniarius major</i>	LC	F, G, FA, S	Insectivore	R	f
	Meropidae						
121	Olive Bee-eater	<i>Merops superciliosus</i>	LC	W	Insectivore	am,	Non f
122	Carmines Bee-eater	<i>Merops nubicus</i>	LC	F, G, FA	Insectivore	AM	Non f
123	Cinnamon-chested Bee-eater	<i>Merops oreobates</i>	LC	W, FA	Insectivore	R	F
124	Little Bee-eater	<i>Merops pusillus</i>	LC	W, F, G, FA, S	Insectivore	R	Non f
125	White-fronted Bee-eater	<i>Merops bullockoides</i>	LC	G	Insectivore	R	Non f
126	White-throated Bee-eater	<i>Merops albicollis</i>	LC	W, F, G, FA, S	Insectivore	AM	f
	Monarchidae						
127	African Paradise Flycatcher	<i>Terpsichore viridis</i>	LC	F, G, FA, S	Insectivore	Am	f
	Motacillidae						
128	African Pied Wagtail	<i>Motacilla aguimp</i>	LC	W, FA, S	Insectivore	R	Non f
129	Grassland Pipit	<i>Anthus cinnamomeus</i>	LC	W, G	Insectivore	R	Non f
130	Yellow-throated Longclaw	<i>Macronyx croceus</i>	LC	W, G, FA	Insectivore	R	Non f
131	Yellow Wagtail	<i>Motacilla flava</i>	LC	G, FA	Insectivore	PM	Non f
	Muscicapidae						

13 2	African Dusky Flycatcher	<i>Muscicapa adusta</i>	LC	W, F	Insectivore	R	F
13 3	Cape Robinchat	<i>Cossypha caffra</i>	LC	F, G, FA, S	Insectivore	R	f
13 4	Mocking Cliff Chat	<i>Thamnolaea cinnamomeiventris</i>	LC	G, S, F	Insectivore	R	f
13 5	Northern Ant Eater Chat	<i>Myrmecocichla aethiops</i>	LC	W, FA	Insectivore	R	Non f
13 6	Rueppell's Robin Chat	<i>Cossypha semirufa</i>	LC	F, G	Insectivore	R	F
13 7	Sooty Chat	<i>Myrmecocichla nigra</i>	LC	G, FA	Insectivore	R	Non f
13 8	Spotted Flycatcher	<i>Muscicapa striata</i>	LC	G, S	Insectivore	PM	Non f
13 9	White-eyed Slaty Flycatcher	<i>Melaenornis fischeri</i>	LC	W, F, G	Insectivore	R	F
	Musophagidae						
14 0	Hartlaub's Turaco	<i>Tauraco hartlaubi</i>	LC	F	Frugivore	R	FF
	Nectariniidae						
14 1	Beautiful Sunbird	<i>Cinnyris pulchellus</i>	LC	G	Nectarivore	R	Non f
14 2	Bronze Sunbird	<i>Nectarinia kilimensis</i>	LC	F, G, FA, S	Nectarivore	R	f
14 3	Scarlet-chested Sunbird	<i>Nectarinia senegalensis</i>	LC	W, F, G, FA, S	Nectarivore	R	FF

14 4	Variable Sunbird	<i>Cinnyris venustus</i>	LC	F, G, FA, S	Nectarivore	R	f
	Numididae						
14 5	Helmeted Guineafowl	<i>Numida meleagris</i>	LC	G, FA	Omnivore	R	Non f
14 6	Vulturine Guineafowl	<i>Acryllium vulturinum</i>	LC	G, S	Omnivore	R	Non f
	Oriolidae						
14 7	Black-headed Oriole	<i>Oriolus larvatus</i>	LC	F	Omnivore	R	f
	Otididae						
14 8	Black-bellied Bustard	<i>Lissotis melanogaster</i>	LC	G	Omnivore	R	Non f
	Passeridae						
14 9	Grey-headed Sparrow	<i>Passer griseus</i>	LC	G, FA, S	Granivore	R	Non f
15 0	House Sparrow	<i>Passer domesticus</i>	LC	G, S	Granivore	R	Non f
15 1	Kenya Rufous Sparrow	<i>Passer rufocinctus</i>	LC	G	Granivore	R	Non f
15 2	Yellow-spotted Petronia	<i>Gymnoris pyrgita</i>	LC	W	Granivore	R	Non f
	Pelecanidae						
15 3	Great White Pelican	<i>Pelecanus onocrotalus</i>	LC	W	Piscivore	Am	Non f
	Phasianidae						
15 4	Crested Francolin	<i>Ortygonis sephaena</i>	LC	G	Omnivore	R	Non f

	Phoenicopteridae						
15 5	Greater Flamingo	<i>Phoenicopterus roseus</i>	LC	W	Omnivore	am, pm	Non f
15 6	Lesser Flamingo	<i>Phoeniconaias minor</i>	NT	W	Omnivore	am	Non f
	Phoeniculidae						
15 7	Green Wood-hoopoe	<i>Phoeniculus purpureus</i>	LC	F, FA	Insectivore	R	f
15 8	Common Scimitarbill	<i>Rhinopomastus cyanomelas</i>	LC	F	Insectivore	R	Non f
	Picidae						
15 9	Nubian Woodpecker	<i>Campethera nubica</i>	LC	F, G, S	Insectivore	R	Non f
	Platysteiridae						
16 0	Chin-spot Batis	<i>Batis molitor</i>	LC	F	Insectivore	R	f
	Ploceidae						
16 1	Baglafecht weaver	<i>Ploceus baglafecht</i>	LC	F, FA	Granivore	R	f
16 2	Yellow-backed Weaver	<i>Ploceus melanocephalus</i>	LC	FA	Granivore	R	Non f
16 3	Golden-backed Weaver	<i>Ploceus jacksoni</i>	LC	F, FA	Granivore	R	f
16 4	Jackson's Widowbird	<i>Euplectes jacksoni</i>	LC	FA	Granivore	R	Non f
16 5	Lesser Masked Weaver	<i>Ploceus intermedius</i>	LC	G	Granivore	R	Non f

16 6	Spectacled Weaver	<i>Ploceus ocularis</i>	LC	FA, F	Granivore	R	f
16 7	Speke's Weaver	<i>Ploceus spekei</i>	LC	W, G, FA, S	Granivore	R	Non f
16 8	Village Weaver	<i>Ploceus cucullatus</i>	LC	F, G, FA, S	Granivore	R	f
16 9	White-browed Sparrow Weaver	<i>Plocepasser mahali</i>	LC	W, F, G, FA, S	Granivore	R	Non f
17 0	White-headed Buffalo Weaver	<i>Dinemellia dinemelli</i>	LC	W, G, FA, S	Granivore	R	Non f
17 1	Yellow Bishop	<i>Euplectes capensis</i>	LC	G, FA, S	Granivore	R	Non f
	Podicipedidae						
17 2	Little Grebe	<i>Tachybaptus ruficollis</i>	LC	W	Piscivore	R	Non f
	Psitaculidae						
17 3	Fischer's Lovebird	<i>Agapornis fischeri</i>	NT	W, F, G, S	Frugivore	R	f
	Pycnonotidae						
17 4	Common Bulbul	<i>Pycnonotus barbatus</i>	LC	F, G, FA, S	Omnivore	R	f
	Rallidae						
17 5	African Water Rail	<i>Rallus caerulescens</i>	LC	W	Omnivore	R	Non f
17 6	Black Crake	<i>Zapornia flavirostra</i>	LC	W	Omnivore	R	Non f
17 7	Common Moorhen	<i>Gallinula chloropus</i>	LC	W	Omnivore	R	Non f

178	Eurasian Coot	<i>Fulica atra</i>	LC	W	Omnivore	R	Non f
179	Lesser Moorhen	<i>Gallinula angulata</i>	LC	W	Omnivore	AM	Non f
180	Red-knobbed Coot	<i>Fulica cristata</i>	LC	W	Omnivore	Am	Non f
181	Purple Swamphen	<i>Porphyrio</i>	LC	W	Omnivore	R	Non f
	Recurvirostridae						
182	Pied avocet	<i>Recurvirostra avosetta</i>	LC	W	Carnivore	am ,pm	Non f
183	Black-winged Stilt	<i>Himantopus himantopus</i>	LC	W	Carnivore	am, (pm)	Non f
	Sagittariidae						
184	Secretary Bird	<i>Sagittarius serpentarius</i>	EN	G	Carnivore	R	Non f
	Scolopacidae						
185	Common Sandpiper	<i>Actitis hypoleucos</i>	LC	W	Omnivore	PM	Non f
186	Common Snipe	<i>Gallinago gallinago</i>	LC	W	Omnivore	PM	Non f
187	Curlew Sandpiper	<i>Calidris ferruginea</i>	VU	W	Omnivore	PM	Non f
188	Eurasian Curlew	<i>Numenius arquata</i>	NT	W	Omnivore	PM	Non f
189	Green Sandpiper	<i>Tringa ochropus</i>	LC	W	Omnivore	PM	Non f

190	Common Greenshank	<i>Tringa nebularia</i>	LC	W	Omnivore	PM	Non f
191	Little Stint	<i>Calidris minuta</i>	LC	W	Omnivore	PM	Non f
192	Marsh Sandpiper	<i>Tringa stagnatilis</i>	LC	W	Omnivore	PM	Non f
193	Ruff	<i>Calidris pugnax</i>	LC	W	Omnivore	PM	Non f
194	Wood Sandpiper	<i>Tringa glareola</i>	LC	W	Omnivore	PM	Non f
	Scopidae						
195	Hamerkop	<i>Scopus umbretta</i>	LC	W, F, G, S	Carnivore	R	F
	Stenostiridae						
196	African Blue Flycatcher	<i>Elminia longicauda</i>	LC	F, G, FA, S	Insectivore	R	f
	Strigidae						
197	African Wood Owl	<i>Strix woodfordii</i>	LC	F	Carnivore	R	F
	Sturnidae						
198	Greater Blue Eared-starling	<i>Lamprotornis chalybaeus</i>	LC	F, G, FA, S	Omnivore	R	f
199	Hildebrandt's Starling	<i>Lamprotornis hildebrandti</i>	LC	G,F	Omnivore	R	Non f
200	Red -winged Starling	<i>Onychognathus morio</i>	LC	W, G, FA, S, F	Omnivore	R	f
201	Rüppell's Starling	<i>Lamprotornis purpuroptera</i>	LC	G	Omnivore	R	Non f

20 2	Superb Starling	<i>Spreo superbus</i>	LC	F, G, FA, S	Omnivore	R	Non f
20 3	Violet-backed Starling	<i>Cinnyricinclus leucogaster</i>	LC	F, FA	Omnivore	R	f
	Musophagidae						
20 4	White-bellied Go-away-bird	<i>Criniferoides leucogaster</i>	LC	F, G, FA, S	Frugivore	R	Non f
	Threskiornithidae						
20 5	African Spoonbill	<i>Platalea alba</i>	LC	W	Piscivore	R	Non f
20 6	Glossy Ibis	<i>Plegadis falcinellus</i>	LC	W, S	Piscivore	am,pm	Non f
20 7	Hadada Ibis	<i>Bostrychia hagedash</i>	LC	W, G, FA, S	Omnivore	R	Non f
20 8	Sacred Ibis	<i>Threskiornis aethiopicus</i>	LC	W, G	Omnivore	R	Non f
	Trogonidae						
20 9	Narina Trogon	<i>Apaloderma narina</i>	LC	F	Frugivore	R	F
	Turdidae						
21 0	African Thrush	<i>Turdus pelios</i>	LC	F, G, FA, S	Omnivore	R	f
	Upupidae						
211	African Hoopoe	<i>Upupa africana</i>	LC	F, G, FA, S	Insectivore	R	FF
	Viduidae						
21 2	Pin Tailed Whydah	<i>Vidua macroura</i>	LC	F, G, S	Granivore	R	f

Legend

VU-Vulnerable	AM- Afrotropical Migrants	FF- Forest Specialists
EN- Endangered	am- Afrotropical Migrants occurring with residents or other migrants	F- Forest generalists
NT-Near Threatened	PM- Palearctic Migrants	f- Forest visitors
LC- Least Concern	pm- Palearctic Migrants occurring with residents or other migrants	Non f- non-forest dependent
F-Forests	(am)- Occasional Afrotropic Migrants	
FA- Farmlands	(pm)- Occasional Palearctic Migrants	
G-Grasslands	am(pm)- Mixed Afrotropical and Palearctic Migrant	
S- Settlements	(n)- Nomadic/ wandering bird	
W- Wetlands	R- Residents	

APPENDIX III: NACOSTI RESEARCH PERMIT



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