DIVERSITY AND DISTRIBUTION OF AVIFAUNA RESOURCE: A CASE OF LAKE BURIGI WETLAND, NORTH WESTERN TANZANIA

BY

SEVERINUS JUSTINIAN MUTAGWABA

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ABSTRACT

Lake Burigi wetland forms part of Burigi Game Reserve (GR) hence an important water source for wildlife. Besides, it is connected to trans-boundary ecosystems in northern Tanzania and constitutes the Burigi-Biharamulo Important Bird Area. This area is important for fishing activities, agriculture, provision of protein and tourist hunting. The area has received minimal attention, hence poor information on its conservation status. This study was carried out to determine species richness, assess abundance and spatial distribution of birds and compare bird diversity and spatial distribution between protected and non-protected parts of the wetland. A point count method was employed to count birds within 200m in water and 100m on land. Eleven locations were randomly sampled and surveyed between September and December 2008. Analysis of variance was used to test the difference in abundance of birds in different habitat covers and locations. T-test was carried out to test the difference between the protection status and substrate for both abundance and diversity. ArcView GIS was used to map the surveyed area whereas LCCS software was used to develop the habitat classes. Distance program was used to estimate population and population density of birds. A total of 2 935 birds in 101 species were counted. Number of birds varied significantly with locations, habitat cover and radial distances. Number of birds was significantly high in the non-protected part of the wetland. Diversity index varied significantly with locations. Results revealed that birds were unequally distributed on locations, habitat covers and protection status. The area had 23 migratory species and 27 IUCN Red List species. Further studies during dry season, on limnology and socioeconomic importance of the area are recommended.

DECLARATION

I, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work and has not been submitted to any other university for a degree.

_____ _____

SEVERINUS JUSTINIAN MUTAGWABA Date

(MSc Candidate)

The above declaration is confirmed

_____ _____

Dr. SHOMBE N. HASSAN Date

(Supervisor)

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DEDICATION

Dedicated to my family and the people I love.

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ABBREVIATIONS

BI	-	Birdlife International
FAO	-	Food and Agriculture Organization of the United Nations
GIS	-	Geographical Information System
GR	-	Game Reserve
GPS	-	Global Positioning System
IBA	-	Important Bird Area
IUCN	-	International Union for Conservation of Nature and Natural Resources
LCCS	-	Land Cover Classification System
SPSS	-	Statistical Product Services and Solutions
ANOVA	-	Analysis of Variance
UTM	-	Universal Transverse Mercator

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Biodiversity on which human life is dependent encompasses every living thing that exists on our planet and the environment in which they live (CI, 2005). Life supporting benefits from biodiversity include food, medicines, industrial products, recreation and tourism (Chivian, 2003; Cohn and Lerner, 2005; Lundberg *et al.*, 2008). However, there has been alarming loss of biodiversity resources within recent years (Brooks *et al.*, 2001; Chivian, 2003), a situation which seems to threaten the human race (Shumway, 1999; Chivian, 2003; Lundberg *et al.*, 2008). This has caused concerns for best and harmonious ways to conserve biodiversity. Conservation of biodiversity requires enormous efforts and resource. The prime concern has been the need to set up priorities to conserve the biodiversity in biodiversity "hot spots" and ecosystems, threatened species and other species in order of usefulness to humans (Brooks *et al.*, 2001; GEF, 2002; Lundberg *et al.*, 2008). These biodiversity "hot spots" areas include both terrestrial and wetlands ecosystems (Daniels and Cumming, 2008).

Wetlands harbour diverse communities and are specifically known for their high diversity in birdlife (Shumway, 1999; Weller, 1999). High diversity in wetlands is due to the microhabitats that exist as a result of fluctuation of water regimes and geo-physical set up of these areas (Hails, 1997; Timmermans and Crewe, 2005). Despite of great importance, wetlands face many threats (Daniels and Cumming, 2008; Ehrenfeld, 2008). Activities that threaten aquatic ecosystems are conversion

of wetland to agriculture, aquaculture, conversion of water regimes and illegal fishing. Other factors are poor land use planning, inappropriate policies, introduction of exotic species and climate change (Davis and Froend, 1999; Shumway, 1999).

Birds have different spatial and temporal distribution in any wetland (Weller, 1999; Fletcher and Hutto, 2008). The diversity and distribution pattern depend on birds' mobility, food availability, habitat suitability, geo-physiological structure of a wetland and size of the wetland (Weller, 1999; Akosim *et al.,* 2008). Moreover, there is distribution of wetland birds according to adaptation caused by food allocation, nesting, roosting and behaviour set up (Weller, 1999).

Assessment of diversity and distribution of ecosystem resources provide information on the resource that is contained in an ecosystem, resource relationships and the environmental factors that influence their distribution and diversity (Bibby *et al*., 2000; Thiollay, 2007). Shumway, (1999) insists that many sites face multiple threats due to incomplete knowledge about the ecology of most aquatic species and limited taxonomic knowledge and incomplete information on species distribution.

Lake Burigi wetland is an inland wetland in Tanzania that supports the Burigi-Biharamulo ecosystem. The north western part of it is protected under Burigi and Biharamulo Game Reserves (GR). Due to a good number of avifauna the wetland is within Burigi-Biharamulo Important Bird Area (IBA) (BI, 2007).

1.2 Problem statement and justification

Wetland biodiversity has been neglected in different studies (Shumway, 1999; Chivian, 2003). Consequently biodiversity is lost in these areas unnoticed (Chivian, 2003). Apparently, Lake Burigi experiences activities that threaten her biodiversity which include illegal fishing in the portion under protection status, and uncontrolled fishing, settlements, agriculture, poaching and grazing in the non-protected environs of the lake (TWCM, 2000; Baker and Baker, 2002, BI, 2007). All these cause substantial deterioration of wetland habitat and hence affect richness, distribution and abundance of birds in the area. According to Baker (2004), previous bird counts at Lake Burigi were partial in terms of coverage of the wetland, causing knowledge gaps in key information leave alone not being update. From such studies, only about 60 species of birds were known (BI, 2007; MS, 2007) before this study. The list includes few migrant bird species like Shoebill (*Balaeniceps rex)*, Red-faced Barbet (*Lybius rubrifacies*),Concrake (*Crex crex)* and Great Snipe *(Gallinago media*) (Baker and Baker 2002; BI, 2007). Since avifauna diversity serves as an indicator of environmental sustainability (Weller, 1999; Bibby *et al.,* 2000; Timmermans and Crewe, 2005), this study supplements existing information on the health status of the ecosystem through bird diversity data, whereas comparative information between protected and unprotected parts of Lake Burigi provides guidance on management interventions and policy issues related to natural resources management.

1.3 Objectives

1.3.1 General objective

The general objective was to assess the diversity and distribution of avifauna resource at Lake Burigi wetland ecosystem.

1.3.2 Specific objectives

- To determine species richness and assess abundance of bird resource.
- To assess spatial distribution of birds by species and numbers.
- To compare bird diversity and spatial distribution between protected and non-protected parts of the wetland.

1.3.3 Research questions

i. How rich is the wetland in terms of avifauna resource?

ii. How is avifauna resource distributed spatially in the wetland both in terms of species and number of individuals?

iii. How do species richness and abundance compare between the protected and non-protected parts of the wetland?

CHAPTER TWO

2.0 LITERATURE REVIEW

2. 1 Biodiversity

Biodiversity is the natural stock of genetic material within an ecosystem (Riclefs, 2001; CI, 2005). The usual unit of analysis in biodiversity studies is the number of existing species (Ricklefs, 2001). Biologists have estimated that the number of species animal and plant ranges from 10 million to 30 million of which 43 850 are vertebrates and 9 000 are birds (Ricklefs, 2001). Lundberg *et al.* (2008) and CI (2005) show that species diversity influences ecosystem stability and enhances essential ecological services. Furthermore, genetic diversity determines agro ecosystem's productivity, resistance to diseases and pests and ultimately food security. It is also fundamental to human health for both pharmaceutical and traditional medicines (Chivian, 2003; CI, 2005).

Studies have shown that the current rates of extinction of species are at least 1 000 times greater than those of the earth's history (Brooks *et al.,* 20001; CI, 2005). This is due to the fact that many biodiversity threats are concentrated in centres of endemism where many species with small ranges occur (Brooks *et al.,* 2001; Colen *et al.,* 2008; Daniels and Cumming, 2008). This occurs in tropics where important data on biodiversity is insignificant (Colen *et al.,* 2008). It is important therefore to prioritise conservation of areas with species of interest and considering the extent of threats to these areas (Brooks *et al.,* 2001; Collen *et al.,* 2008; Lundberg *et al.,* 2008). An approach which considers numbers in an area, identity of species relative to those in other areas and processes promoting persistence processes like migration

(Brooks *et al.*, 2001; Collen *et al.*, 2008; Lundberg *et al.*, 2008) is critically important. Study of biodiversity also needs to prioritise conservation of indicator taxa (Books *et al.*, 2001). Different studies show the relationship between one taxa and the other. For example the study of forest birds and mammals showed that areas for conservation priority of birds captured 77% of mammals and areas for conservation priority of mammals captured 94% of birds (Books *et al.*, 2001). This justifies why the study of diversity is mostly on birds and mammals as indicator taxa.

IBAs are sites of high significance for birds and contain globally threatened species, contain restricted range of species. They are biome-restricted assemblage sites i.e. areas containing species endemic to a particular biome contain particular congregations of individual birds (Brooks *et al.*, 2001). At least 228 IBAs have been identified in East Africa of which 76 are in Tanzania, and most of them wetlands (Brooks *et al.*, 2001; BI, 2007). Lake Burigi is located in Burigi-Biharamulo IBA (BI, 2007).

2.2 Wetlands

Wetlands are defined as " areas of marsh, fen, peatlands or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty including areas of marine water, the depth of which does not exceed six meters during low-tide" and "may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands" (RCS, 2004; Yhogo, 2005). Wetlands

cover about 750 000 million hectares of the earth land surface (Drisdelle, 2007). In Tanzania they cover about 10% of the total land in the form of lakes, swamps, riverine floodplains, intertidal swamps and manmade wetlands (Kihwele, 2005). Lake Burigi is one of the wetlands in Tanzania classified as inland wetland under Burigi-Ikimba basins (Hughes and Hughes, 1992).

Wetlands serve several purposes for human livelihood including food production, reducing the natural calamities like floods, acting as a sink tank for different hazardous materials, supply of water for domestic and agricultural activities, supporting economies of local people in their areas and in transport issues (Shumway, 1999; Chivian, 2003; Daniels and Cumming, 2008). Generally, wetlands are important ecosystems that support ecological processes of adjacent areas and serve as refuge for distant ecosystems (Daniels and Cumming, 2008).

2.3 Wetland bird diversity, distribution and adaptation

A combination of the number of species and their relative abundance defines species diversity. The relative abundance of species is the most fundamental aspect of community structure. Species diversity is higher in complex environment (Molles, 2008). Hassan *et al.* (2004) insist on the importance of determination of diversity of an area as a means of assessing the conservation importance of area or relative values of different habitats or areas.

The lake shores, muddy bays and surrounding marshes support 80% of the fisheries (Hails, 1997). Many bird species also depend on littoral zones the lake and shallow

waters (Shumway, 1999; Stewart, undated). The best known function of wetlands is to provide a habitat for birds (RCS, 2004) and birds use them for breeding, nesting and rearing the young, source of drinking water and for feeding, resting, shelter and social interactions (Stewart, undated; Brooks *et al.,* 2001). Varieties of wetland and variability within the wetland (Stewart, undated; Hails, 1997) influence bird's adaptation to and use of wetland environments (Weller, 1999). Weller (1999) described bird distribution based on geographical perspective (zoogeography) but more specific to vegetation zonation and climate of a given wetland.

There are several approaches for classification of wetland birds that have implication on wetland birds distribution. One approach is on the natural classification of wetland birds according to birds phylogenetic make up. Another approach is classifying birds on the basis of their dependence on water environment. Some birds depend on wetlands almost entirely for nesting and breeding, feeding and shelter during their breeding cycles. These are termed as wetland obligate birds (waterfowl, rails, storks and cranes) (Stewart, undated; Weller, 1999). Others use the wetlands only for some of their needs and they spend most of time on upland habitats (Stewart, undated) and are termed as facultative wetland birds. Many birds use forested wetland as well as upland habitats equally feeding on the abundant forest insects and are termed as opportunistic birds (warblers) (Stewart, undated).

Another approach is by classifying wetland birds based on adaptation to wetland conditions. In this approach wetland birds are grouped as divers; grebes, pelicans,

shags and cormorants and darters, frigate birds; waterfowl, flamingos, herons and egrets, hawks and eagles, rails, crakes, coots and cranes, charadriiformes, cuckoos, owls, kingfishers and songbirds (Weller, 1999).

A study of riparian birds in Morogoro shows a difference in birds' distribution, with a slight similarity of diversity between three rivers (Hassan *et al.*, 2004). The results suggest that habitats may be determinant of bird species assemblage types, which signifies the importance of studying different ecological habitats.

The value of a wetland to a specific bird species is affected by the presence of surface water, duration and timing of flooding, depth, availability and quality of water (Stewart, undated; Weller, 1999; Lagos *et al.*, 2008). Wetlands form an important buffer or barrier to land based-predators and reduce the risk of predation to nesting or young birds. Wetland birds are highly adapted to feeding in the wetland environment and have genetic adaptations that lower their risk of becoming prey (Stewart, undated; Weller, 1999).

Geographic locations of wetlands determine how and when birds will use it or adjacent habitat (Stewart, undated; Weller, 1999). In the northern altitudes, some wetlands are covered with ice in the winter and are out of service for birds adapted to a water environment (Stewart, undated). Some wetlands are on migration path of the waterfowl while others provide stopover locations for travelling birds. Tanzania contains 42 sites known to hold internationally important numbers of bird population (Boere *et al.*, 2006).

Important water bird counts in the country include the 1995 and 2005 (Boere *et al.*, 2006; BI, 2007). Estimated number birds by 2006 in the birds atlas is 772 000 of which 11 600 (15.8%) are water birds (Boere *et al.,* 2006). The exact or near approximation of water birds in Tanzania is by far not known. This implies also that the knowledge on diversity and distribution is insignificant. Boere *et al.* (2006), insists on the need to shorten the knowledge gap by studying more wetlands and birds as accurately as possible.

2.4 Effects of wetland loss and degradation on birds

Wetlands of the world are at great threat such that over the 20th century some 10 million square kilometres have been lost globally (Chivian, 2003; Daniels and Cumming, 2008) due to conversion of these areas to different uses that exceed the acceptable limit (Davis and Froend, 1999; Shumway, 1999; Armstrong *et al.*, 2008). These uses are conversion of wetland to agriculture, aquaculture and overgrazing (Shumway, 1999; Drisdelle, 2007). Other undesirable activities in the wetlands include pollution by industrial disposals and pesticides (BSC, 2005; Timmermans and Crewe, 2005; Pendleton and Baldwin, 2007; Bischoff and Schulz, 2008), indiscriminate felling of trees, burning of forests and clearing vegetation around the wetlands, illegal fishing and overfishing (Stewart, undated; GEF, 2002; Kihwele, 2005; Adeney *et al.,* 2006; Ehrenfeld, 2008). Wide spread draining and alteration of wetlands worldwide greatly affect the bird population (Stewart, undated; Kingsford and Auld, 2005; Ehrenfeld, 2008). Wetland loss due to draining, filling or altering of the surface-water and ground water-flow has a substantial effect on bird

population (Stewart, undated; Shumway, 1999; Adeney *et al.*, 2006; Ehrenfeld, 2008; Uzarski *et al.*, 2009). Similarly habitat fragmentation be it wetland or forest may have negative impact on ecosystems and species (Armstrong *et al.*, 2008; Uzarski *et al.*, 2009). Due to impaired dispersal there is obvious change in habitat quality and population dynamics due to loss of connectivity (Armstrong *et al.*, 2008). Loss of wetland plant communities leads to loss of plant diversity, reduction in primary production and consequently loss of fauna diversity due to loss of habitat, food, decreased aeration of sediments and increased nutrient levels (Epaphras *et al.*, 2007; Armstrong *et al.*, 2008).

International wetland conservation efforts are through international agreements that either impact directly or indirectly on the ecological balances of conservation of wetlands e.g. the Ramsar Convention on Wetlands (RSC, 2004; Drisdelle, 2007), the Migratory Bird Treaty and the Convention on Biological Diversity. In Tanzania, the approach is through declaring different sites as Ramsar sites, creating policies and laws that protect wetlands. Several factors that hinder wetlands conservation include poverty, inadequate resources, expertise and accessibility to these areas (Davis and Froend, 1999; Borere *et al.*, 2006). However, efforts are still low and there is a call for efforts to conserve the wetlands through resource assessment studies (Davis and Froend, 1999).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

Lake Burigi is situated between latitudes 20°01' and 2°12'S, and between longitudes 31°14' and 31°20'E north western Tanzania (Kiss, 1977; Hughes and Hughes, 1992). The lake is shared mainly by Karagwe and Muleba administrative districts (Fig.1). It is approximated to be 30km long and 4km wide (BI, 2007) making approximately 7 000 ha (Hughes and Hughes, 1992). The area is inhabited by the fishermen community on an unprotected part of the wetland.

The vegetation is typical of western equatorial districts (Hughes and Hughes, 1992). The lake is characterized by swampy papyrus, phragmite spp, typha, bulrushes and some patches of ground water forest. There is relict sclerophyl forest on some hill-slopes suggestive of more extensive forest cover (BI, 2007). Wildlife in the lake include hippopotamus (*Hippopotamus amphibious*) and crocodile (*Crocodylus niloticus*) (Hughes and Hughes 1992; MS, 2007). The area surrounding the lake has wildlife such as sable antelopes (*Hippotragus equinus*), roan antelopes (*Hippotragus niger)* and many species of water birds (Hughes and Hughes 1992; MS, 2007). Some fish species in this lake include *Protopterus aethiopicus, Clarias mossambicus* and *Haplochromis nubilus* (Kiss, 1977).

Landscape is dominated by rolling hills, valleys, cliffs and rocky outcrops (MS, 2007). The lake has the maximum depth of 7.8 m, maximum width of 7 km, maximum length of

42 km and shoreline of 227 km (Kiss, 1977). The lake is on average about 1600 m above sea level (asl). It is separated from Lakes Ikimba and Victoria by hill ridges that rise 1300-1710m asl (Hughes and Hughes, 1992). The soil of this area is of the Karagwe-Ankolean System that has the parent rock consisting of sequences of clay stones and fine-grained quartizic sandstones (Mitti and Rweyemamu, 2001). The lake is fed by river Ruiza (Hughes and Hughes, 1992) and is drained into Kagera River by Mwisa River (Kiss, 1977).

The climate of this area is of Bukoba type with bimodal rainfall consisting of short and long rains. January and February consist of the short dry season followed by short but intense rainy season from March through May. June to September is a long dry season followed by long but moderate rainy season from September to December (Mitti and Rweyemamu, 2001).

3.1.1 Lake Burigi Wetland description

a) Lake Burigi Wetland characteristics

Based on visual observations the study area was classified in different parts according to topography and landscape structure as follows:

i. Upper part

This part of a wetland is found in all three districts i.e. Muleba, Biharamulo and Karagwe and is also found in the protected part and the unprotected part. It has shallow extension of the wetland dimensions including permanently or temporally inundated areas (Plate 1). In this study it included sample locations of Karubambo,

Kashwa, Masheli, Mkwajuni, Mkwajuni P and Ngoma. In most cases open water is immediate to the land associated with bare rocks, sands and gravels, hard ground and immediate rise of the land surface. The vegetation cover for this part is characterised by acacia woodlands, bulrushes and a bit of phragmite species.

Plate 1: A view of Lake Burigi characteristic of an upper part

ii. Intermediate part

This is a part that has medium wetland characteristics. This means that the wetland vegetation extends from the littoral zone of the lake and extends to over 10 metres on land. These areas are associated with constant inundation that cause water logged conditions, emergent vegetations and extensive muddy flats characterised shore parts. The dominant vegetation is the typha with traces of papyrus reeds, few perennial trees and traces of forest covers. In this study areas sampled with this characteristic include Mutoma, Nkonje and Biharamulo-Lukili.

iii. Flood plain

The area covering Nyakagugu and Nyarushojo are typically extensive flat wetland. The vegetation is mainly grasses including phragmite species, bulrushes and papyrus reeds. It is continuously flooded with water ponds. Flooding extent fluctuates with elevation creating continuous inundation of the area. Immediate to it is the acacia woodland. Nyarushojo is specifically where this lake stems though now covered with vegetation.

iv. Open water

This lake has water with approximately maximum of 4km, wide 27 km length and at least 8m deep. The water is saline as one approaches the shore and becomes fresh as one moves interior the lake (Kulekana, 2004). The pH for water in this lake ranges between 8.5-8.3 (Kiss, 1977; Kulekana, 2004)

b) Land uses

Land uses of this area are a result of the set up explained above. In the upper part fisheries activities dominate both in protected and unprotected part. This activity entails fishing in the lake using canoes, fish processing and transportation. There is a lot of pressure from this activity in the lake that is due to fish curing associated with tree felling and bush clearing.

Agriculture is mainly practised in areas that are flat and main crops include rice on flat plain areas and maize close to the lake not in flooded areas. Extensive grazing is done at some points by illegal emigrants from the neighbouring countries like

Rwanda, Burundi and Uganda. These also favour plain areas for good pasture and drinking water for the livestock. The above activities involve humans who need places to rest. There are thus temporal settlements that are associated with vegetation clearing and construction of settlement.

3.1.2 Map projection

A reconnaissance survey was done throughout Lake Burigi wetland, to ascertain the study design and workability. Movement around was either on foot along the shore line where accessibility was possible or by canoe. During this reconnaissance survey, the positions coordinate grids for the whole study area were recorded in UTM (Universal Transverse Mercator) with Garmin hand held GPS. Grid coordinates were then executed into an ArcView GIS 3.3 to map the surveyed area (Fig. 1).

3.1.3 Land cover classification

Land cover classes (LCCs) were developed in Land Cover Classification System (LCCS) software developed by FAO (FAO, 2005). Growth and life forms of habitat cover on the ground were the base characteristics that LCCS applied. Both stages of the LCCS i.e. the modular and dichotomous phases were considered when developing the land cover classes (FAO, 2005).

Following the FAO LCCS (2005) eight habitat cover classes were developed. These were 1Consolidated Bare Areas, 1Forest, 5Grasslands, 5Grasslands 2, 1Natural Water bodies, 4Shrublands, 1Unconsolidated Bare Areas and 2Woodland. However some habitat cover classes were modified hence adopted in this study (Table 1).

Table 1: Habitat cover classification of Lake Burigi Wetland

Habitat Classes (FAO 2005)	Habitat Classes adopted in this dissertation	Description
1Consolidated Bare Areas	Consolidated bare Areas	Bare Rock and/or Coarse Fragments - Gravels. Major Land class: Level Land, Valley Floor, Slope Class: Gently Undulating to Undulating
5Grasslands	Grasslands	Perennial Closed tall Grassland On Waterlogged Soil. Waterlogged phragmite species
5Grasslands	Grasslands 2	Open Short Grassland with Shrubs flooded at some instances
1Natural Water bodies	Natural Open Water Bodies	Open Water and ponds
2Unconsolidated Bare Areas	Unconsolidated Bare Areas	Stony Bare Soil And/or Other Unconsolidated Material(s)
1Forest	Forest	Aphyllous Medium High Trees with Closed Medium High Shrubs and High Emergents
4Shrubland	Shrubland	(40 - (20-10) %) Medium High Shrubland with Open Medium to Tall Herbaceous
2Woodland	Woodland	Acacia woodlands mixed fragmented (cellular) woodland and trees. Aphyllous Woodland with Open Medium to Tall Herbaceous Layer and Sparse Medium High Shrubs

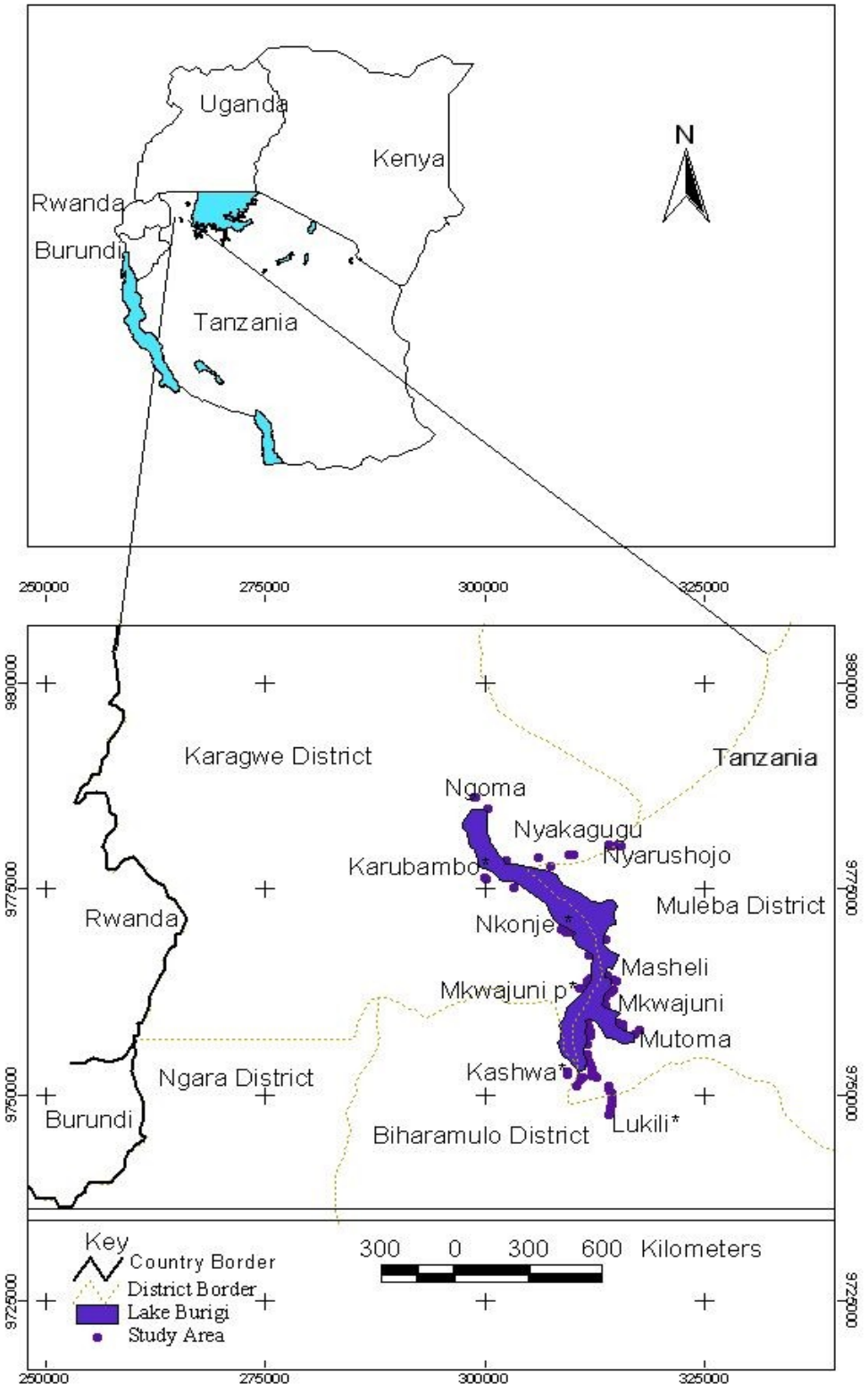

Figure 1: Location map of study site at Lake Burigi Wetland

3.2 Study design and data collection techniques

Point count method was applied at 11 grid sampling points randomly located at an interval of at least 200 m along the shoreline with repetition to make 70 counts. This makes the sampled area to be over 1 906 ha while the study area is approximately 7 000 ha. Five points were located in the protected part of the wetland (i.e. on the side of Burigi-Biharamuro GR), and the remaining 6 in the open area of the wetland. Therefore Masheli, Ngoma, Nyakagugu, Nyarushojo, Mutoma and Mkwajuni were located in an unprotected area of the wetland, and Mkwajuni P, Karubambo, Kashwa, Biharamulo-Lukili and Nkonje in the protected area of the wetland.

With the aid of Leica Rangemater (7X), birds were clearly identified, counted and distances from observer to bird or centre of group of birds precisely measured. At each point birds were scanned up to 200 m from the shore inside the lake and up to 100 m towards the land. The predetermined maximum radial distance were based on trial exercise which proved low and poor detection and identification of birds beyond 200 m and 100 m in water and on land respectively, specifically for smaller sized birds. Counting took ten minutes in open habitat and 20 minutes in a thick habitat (Bibby *et al.*, 2000). At each sampling point and during each counting bout, a species heard without being seen was recorded once to avoid overestimation of population due to repeated singing by the same individual. Species, number of birds, radial distance (distance from observer to bird), habitat cover class, locality, substrate and protection status of the locality at the wetland (protected or open wetland) were recorded. Stevenson and Fanshawe (2002) and Zimmerman (1999) field guides were used for birds' identification and classification. Habitat cover for

each count point was scored according to the Land Cover Classification System (LCCS) developed by FAO (FAO, 2005). Birds were also recorded either being found in water or in land (substrate type). This aimed at exploring the distribution of wetland with respect to substrate type.

The observer started counting at least five minutes since arrival to allow birds to settle following disturbance caused by the observer on arriving at the sampling points (Pomeroy, 1992). Counting at each sampling location was run between 0600 hrs and 0900 hrs and between 1600 hrs and 1800 hrs. Each counting point was sampled at a minimum of four days from September to December 2008.

3.3 Data analysis

3.3.1 Species richness and abundance

The species list (Appendix 1) was prepared by listing all species encountered where as relative abundance (Appendix 4) was computed in Excel spreadsheet. Classification and nomenclature followed Zimmerman (1999), Fanshawe (2002), and Perlo (1995). Additionally, birds were classified according to migration pattern and geographical range of the species as per Perlo (1995) and Flegg and Hosking (1993). IUCN categorizes organisms in the Red List on the basis of risk of extinction into six categories namely, Extinct (EX), Extinct in the wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (IUCN, 2008) (Appendix II). This categorisation is important in assessing the Conservation status of organisms and therefore was applied in this.

3.3.2 Statistical analyses

Statistical Product Services and Solutions (SPSS) Version 12 software was used to do the statistical analysis. Before inferential statistics were performed, number of birds and radial distances were transformed to $\log_{10}$ to improve homogeneity and normality (Quinn and Keough, 2002; Skinner and Clark, 2008; Gunaratne *et al.*, 2008). Since transformation makes no alteration of the data (Quinn and Keough, 2002; Fletcher and Koford, 2004), the results are presented without the $\log_{10}$ notation.

Analysis of Variance (ANOVA) was used to test the difference in number of birds between the habitat cover classes and localities. Number of birds was treated as a response variable while habitat cover classes and location as predictor variables. ANOVA was also applied to test the difference in diversity and species evenness on different localities.

t- Tests were applied to test the difference in means in number of birds between the two protection status and substrate types. The same was applied for testing the difference in means for species diversity indices and species evenness between two protection status types. Pearson correlation was applied to examine the relationship between the radial distance and the number of birds.

3.3.3 Diversity index

Species diversity in terms of richness and evenness were analysed by the use of Shannon Weiner diversity indices (equation 1) calculated for different locations and protection status conditions

$$H' = -\sum_{i=1}^{S} (pilnpi) \quad \text{……..(1)}$$

Where: Where H'=the value of Shannon Wiener diversity index for the diversity in a sample of S species or kinds

S - the number of species in the sample

pi – relative abundance of i^{th} species or kinds measures i.e. = ni/N

N – total number of individuals of all kind

ni - number of individuals of i^{th} species

ln – natural log .

Species Evenness (E) information was calculated as in equation 2 following Soini (2006). $E = H/\log(S)$ ……(2)

3.3.4 Distribution, population estimates and density

Distribution of avifauna was expressed in respect of number (abundance) of birds counted in different habitat cover classes, different locations, substrate type and protection status. Substrate type was categorised as either land or water. Both total number of birds for all species, and total number of birds for each species were summed arithmetically. The latter was divided by the former and the result was multiplied by 100 to obtain relative abundance for each species. Number of birds of each species was derived from frequency at which the species was encountered.

The program DISTANCE version 5.1 (Thomas *et al.*, 2006) was applied to do the population and density estimates. This program employs formula

$D = n/kw^2Pa$ ..... (3)

Where w= Detection distances, k=points for the design and D= object density, pa=Probability of detecting an object in an area (Thomas *et al.*, 2002; Fletcher and Koford, 2004; Alldredge *et al.*, 2007).

Since the population is based on samples, statistical procedures are performed in software employing all the parameters above in a statistical model. In this study the Half-normal key model was selected by the program as shown (Equation 4).

Model: Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))……(4)

Cosine adjustments of order(s) : 2, 3, 4, 5

Data items:

x(i) - distance to i-th observation

chi-p - probability for chi-square goodness-of-fit test

Parameters or functions of parameters:

A(I) - i-th parameter in the estimated probability density function(pdf)

N - estimate of number of birds in specified area

Areas were calculated in Excel Spread sheets from the recorded radial distances.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Avifauna resource at Lake Burigi Wetland

A total of 2 935 birds were counted during this survey. These consisted of 101 bird species in 14 orders and 47 families (Appendix 1). Of the 101 bird species, 23 species were categorized as migratory whereas other 27 species were recognized to constitute the IUCN Red List species. The classes encountered with respect to migration included Palaearctic Migrant (PAM), Uncommon Migrant (UM), Migrant (M), Common Migrant (CM), Wide spread (W), Local (L) and Ubiquitous (U) (Flegg and Hosking, 1993; Perlo, 1995) (Appendix 1). About 27 species (26.7%) of the 101 surveyed species are characterized as species of Least Concern category (LC), and only one species as Near Threatened (NT) (Appendix 1 & 2). The overall density was 2.72 birds/ha (SE ± 0.134), and the estimated population was 3 633 birds (SE ± 178.250).

Birds at Lake Burigi were found to consist of several categories with respect to feeding mechanisms. These categories as applied by Dugger *et al.*, (2005) were wading terrestrial foragers e.g. *Bubulcus ibis*, sediment probers e.g. ibises, large-prey tactile feeders e.g. storks, great egret, large-prey visual feeders e.g. Great Heron, Goliath Heron (*Ardea goliath*) and small-prey visual feeders e.g. other herons. These were encountered in the study areas either in water, in muddy shores, vegetations, bare soils and rocks.

Cattle Egret (*Bubulcus ibis*) had the highest relative abundance, 26 % whereas about 76 % of other species recorded showed relative abundance below 1 % (Appendix 4). Pied Kingfisher (*Ceryle rudis)*, African Fish Eagle (*Haliaeetus vocifer*) and Hamerkop (*Scopus umbretta)* were the most sighted (23-31 sightings) (Appendix 4). However, the average frequency of encounter was found to be 10, whereas detection probability of birds was 90 (Fig.2).

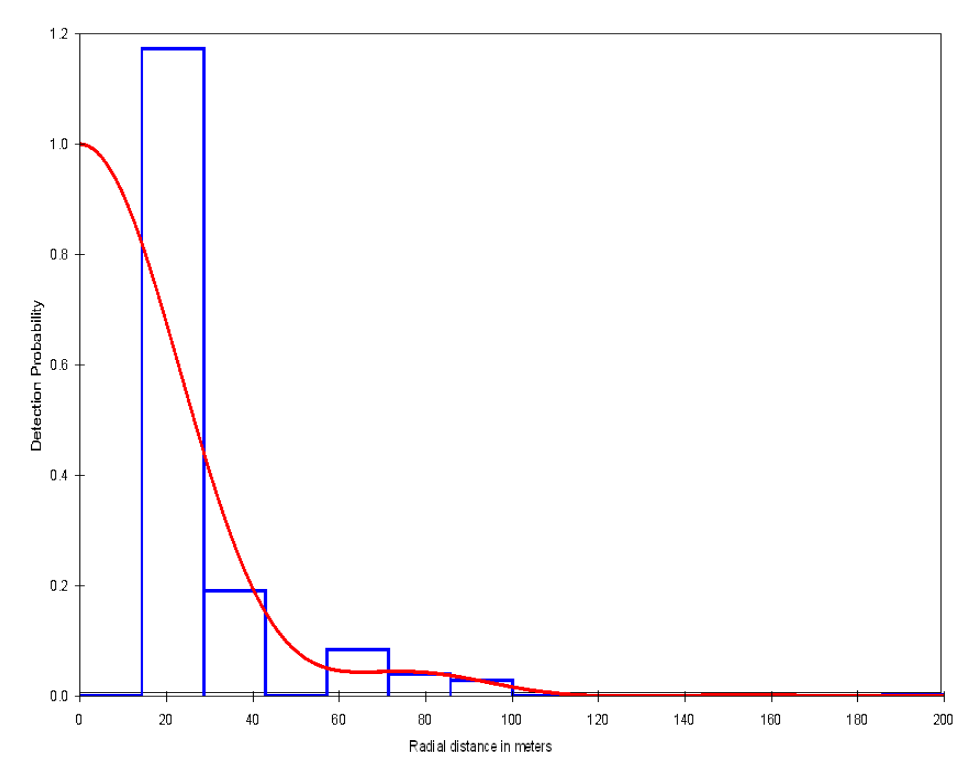

Figure 2: Detection probability of birds along radial distances of Lake Burigi Wetland

4.1.2 Distribution of birds with respect to habitat cover

The number of birds varied significantly with habitat cover classes ($p < 0.001$, $F= 4.699$, $df = 7$). Similarly, there was significant difference in number of birds

between pairs of habitat cover classes with forest contrasting with five of eight habitat cover classes (Appendix 3). Apparently, Graslands 2 had the highest mean number of birds (Mean ± SE, 13 ± 4.15 n=472) in 44 species while Forest had the lowest (2 ± 0.202 n=472) in 5 species (Appendix 3; Fig. 3).

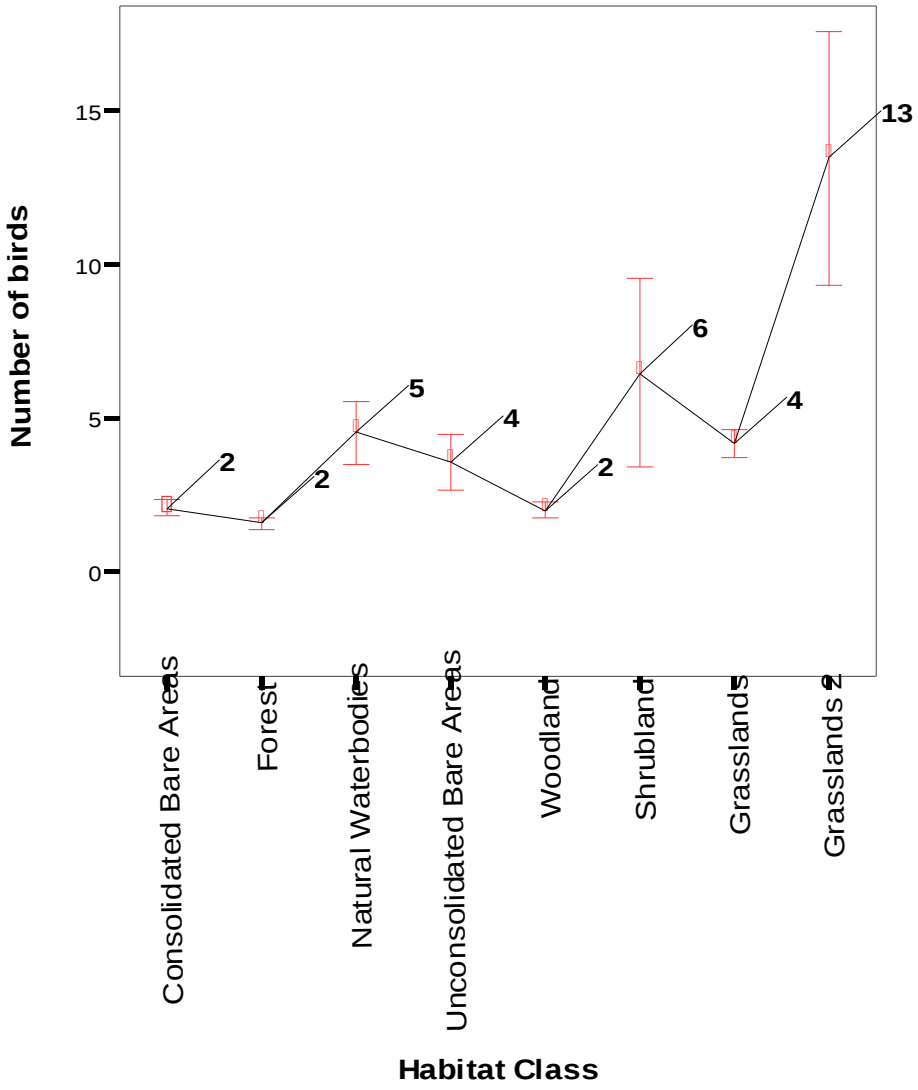

Figure 3: Mean number of birds per habitat class of Lake Burigi Wetland

On the other hand, shrubland with 33 species ranked second (6.46 ±3.073 birds n=472**)** followed by natural water bodies (4.53 ± 1.01 birds n=472) with 28 species (Appendix 3 & 5, Fig. 3). Other habitat cover classes had fair influence on bird distribution.

Some species observed were associated with water closely though they are not water dependant species. These were found on shoreline in most cases associated with rocks and bare unconsolidated areas e.g. some members of Burhinidae family (Water Thick-knee (*Burhinus vermiculatus*), Eurasian Thick-knee (*Burhinus oedicnemus*) and Senegal Thick-knee (*Burhinus senegalensis inornatus*), Charadriidae family (Common sandpiper (*Actitis hypoleucos*), and Ardeidae family (Dwarf Bittern (*Ixobrychus sturmii*).

The distance (radial distance) at which birds were sighted differed between habitat cover classes but generally ranged from 1 – 200 m (Table 2). Although the number of birds sighted varied significantly with radial distances ($p = 0.006$, $F = 7.504$, $df = 1$), there was a positive correlation (Pearson's correlation) between number of birds and radial distances ($r = 0.242$, $p < 0.001$). However, no Forest birds were sighted either below 11 m or beyond 175 m. The highest distance recorded in water was 192 m which corresponded with the Great White Pelican (*Pelecanus onocrotalus*).

Table 2: Sighting distance and species richness in different habitat classes

Habitat class	Sighting distance (m)	Species Richness per habitat class
Consolidated Bare Areas	1 – 47	12
Forest	11 – 175	5
Natural Water bodies	1 – 192	28
Unconsolidated Bare Areas	1 – 98	20
Woodland	1 – 107	20
Shrubland	1 – 96	32
Grasslands	1 – 200	48
Grasslands 2	1 – 189	44

Type of substrate (land and water) did not make significant influence on number of birds that utilised the substrates (Table 3).

Table 3: Bird distribution on land and water substrates at Lake Burigi Wetland

Substrate	**Number o. of Birds**	**Mean number of birds**	**Frequency**
Land	2055	6.65	309
Water	880	5.40	163
Total	**2935**	**6.22**	**472**

4.1.3 Distribution of birds with respect to locations

The number of birds varied significantly between locations ($p = 0.000$, $F = 5.323$, $df = 10$) with Nyarushojo (outside protected parts of the wetland) differing from nine of eleven locations (Appendix 5). Subsequently, Nyarushojo registered the highest number of birds all sites put together while Masheli had the lowest number of birds (Appendix 6, Table 4). However, MkwajuniP which seems to have relatively higher number of birds compared to Masheli registered lowest mean number of birds (Table 4). Other areas both inside (Kashwa and Karubambo) and out side Burigi

Game Reserve (Mutoma and Ngoma (outside protected parts of the wetland) also recorded fewer birds (Table 4).

Table 4: Distribution of birds per locality around Lake Burigi Wetland

Location	Number of birds	Observations (N)	Mean number of birds	S E M	% of Total Number of birds	% of Total Observations
Biharamulo-Lukili*	210	52	4.04	0.947	7.2	11.0
Karubambo*	122	39	3.13	0.654	4.2	8.3
Kashwa*	153	47	3.26	0.432	5.2	10.0
Masheli	55	21	2.62	0.653	1.9	4.4
Mkwajuni	169	45	3.76	1.047	5.8	9.5
Mkwajuni P*	81	36	2.25	0.307	2.8	7.6
Mutoma	195	35	5.57	1.927	6.6	7.4
Ngoma	261	32	8.16	5.410	8.9	6.8
Nkonje*	272	56	4.86	1.316	9.3	11.9
Nyakagugu	186	33	5.64	2.131	6.3	7.0
Nyarushojo	1231	76	16.20	5.559	41.9	16.1
Total	**2935**	**472**	**6.22**	**1.029**	**100.0**	**100.0**

* ***Sample study localities in the Protected part of Lake Burigi Wetland i.e. an area in Burigi Game Reserve***

4.1.4 Distribution, species diversity index and evenness of birds with respect to protection status of Lake Burigi Wetland

The number of birds was significantly high in an unprotected part of the wetland ($t = 2.509$, $p = 0.013$, $df = 262.526$). Observations in the Game Reserve showed a mean of about 4 ± 0.414 birds per 472 observations compared to a mean of about 9 ± 1.958 birds per 472 observations recorded outside the Game Reserve (Table 5). However, specific localities such as Nkonje and Biharamulo-Lukili had high mean number of birds, 5 ± 1.316, and 4 ± 0.947; n=472 respectively (Table 4).

Table 5: Distribution of birds between protected and open parts of Lake Burigi Wetland

Protection Status	No. of Birds	Mean number of birds	Frequency
Protected	838	3.64	230
Unprotected	2097	8.67	242
Total	**2935**	**6.22**	**472**

Both diversity index and species evenness did not vary significantly between protected and open portions of Lake Burigi wetland (Table 6). However, disregarding this, protection status revealed significant difference in species diversity between some localities, with diversity index for Masheli varying from those of five localities (Appendix 7). Karubambo and Mkwajuni P located inside the Game Reserve demonstrated relatively higher diversity index (Figure 4). Contrary, Nyarushojo and Masheli located outside the Game Reserve had the highest and lowest diversity indices, respectively (Fig. 4). Similarly, irrespective of protection status species evenness was different between Masheli and other six localities (Appendix 7) with highest value for Masheli and lowest for Nyarushojo (Fig. 5).

Table 6: Shannon indices of diversity and species evenness for the bird communities in protected and open parts of Lake Burigi Wetland

Protection Status	Diversity Index	p value	F	df	T	Species Evenness	p value	F	df	t
Protected	51.69 (1.48± 0.08)	0.08	1.10	65.16	1.78	69.67 (1.99 ± 0.09)	0.87	4.73	53.20	1.71
Open	44.08 (1.26 ± 0.10)					70.72 (2.02 ± 0.15)				

Note: Statistically significant at p≤0.05, n=70 counts

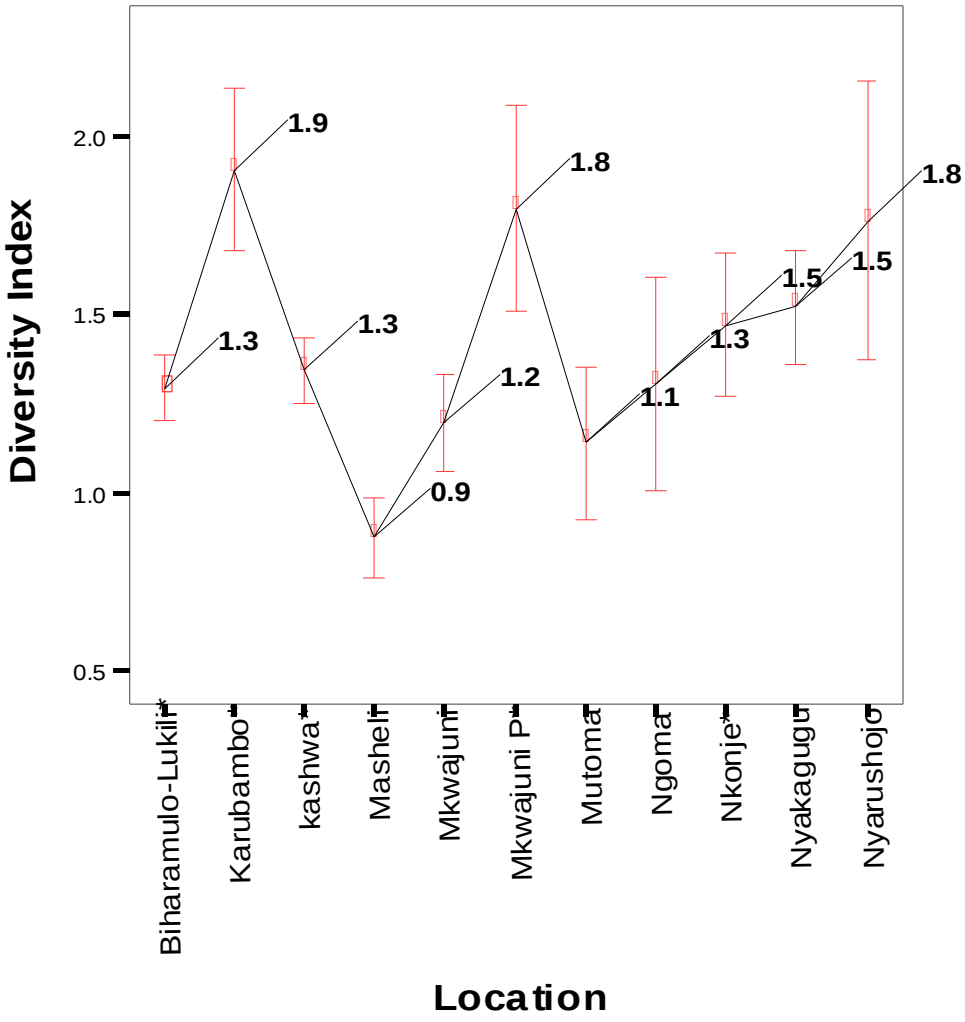

Figure 4: Mean index (Shannon-Weiner) of diversity for the bird communities per locality around Lake Burigi Wetland

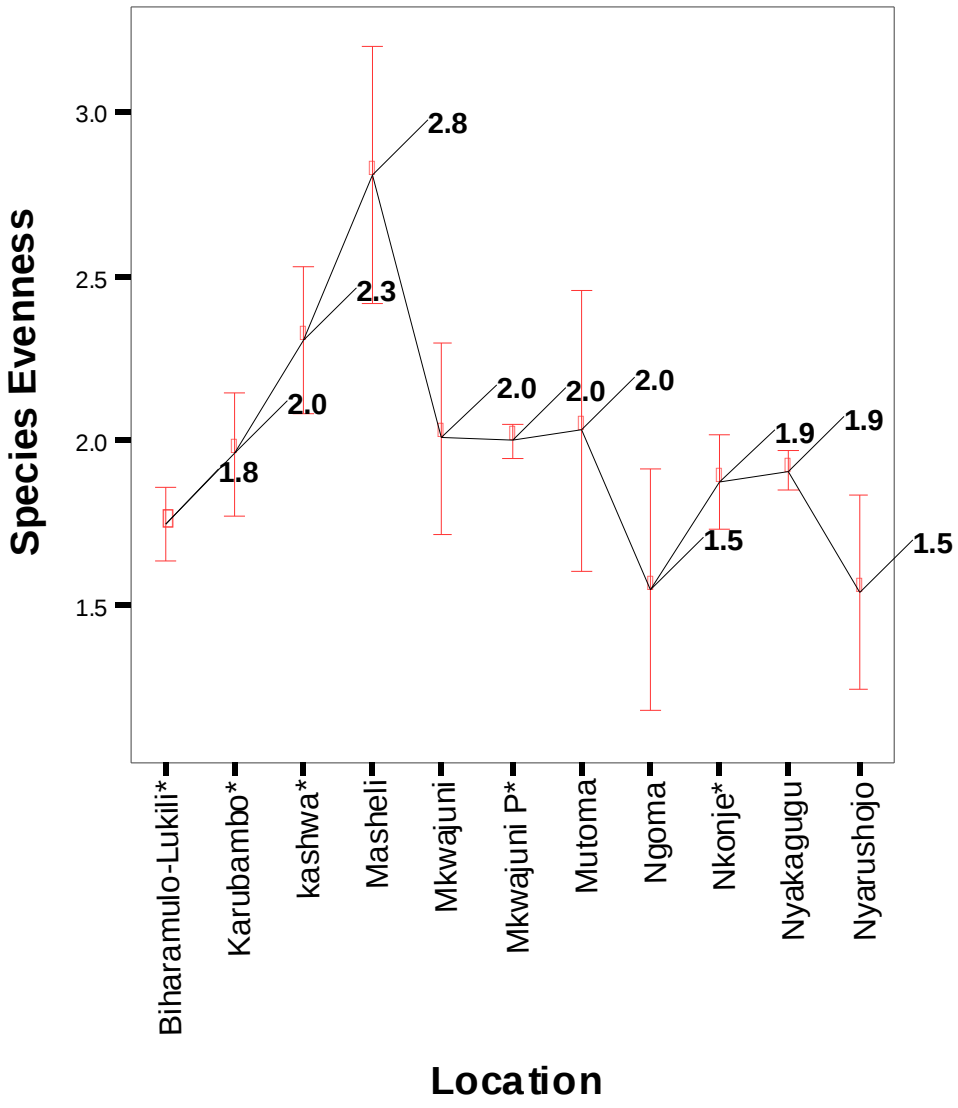

Figure 5: Mean birds' species evenness per locality at Lake Burigi Wetland

4.2 DISCUSSION

4.2.1 Avifauna Resource at Lake Burigi Wetland

Bird species richness of 101 for this area in 14 orders and 47 families is attributable to a combination of factors. These include: 1) nature of the landscape, 2) human influence, 3) ecological processes and 4) risk of extinction. Being a wetland landscape, this area is considered as a complex environment (Dugger *et al.*, 2005; Akosim *et al.*, 2008) in terms of extent of flooding, dampness in the area and deposition of organic matter.

The entire Game Reserve, which includes portion of the wetland experiences high human disturbances such as livestock grazing (Plate 2, 5 and 6), heavy harvesting of woody material including timber, building poles and rope, fuel wood for drying fish (Plate 3, 4 and 7), and honey hunting and harvesting with the aid of fire. Such anthropological activities may lead to change in habitat structures (TWCM, 2000), which tends to shape the population size and diversity (Dugger *et al.*, 2005; White *et al.*, 2007) as result of local bird movements to newly created habitats (new forest edges, forest gaps and patches and transitional vegetations (ecotones).

Large scale migration is another important ecological process for wild birds (Lundberg *et al.*, 2008) that contributes greatly to the diversity and distribution of species (Brooks *et al.*, 2001; Urfi, 2002) as it serves these birds from contaminated environments in developed countries (BSC, 2005; Timmermans and Crewe, 2005). According to Pomeroy, (1992) and Boere *et al.* (2006), the northern western part of Tanzania lies along the major migration route of birds especially during August-

December. This corresponds to the time that this study was carried out. Different migratory species were encountered as explained above such as PAMs from Europe and Asia, Intra Africa migrants and local migrants. As Urfi (2002) noted, most of the waders are migrants. Most of the migrant species Urfi (2002) found on Byet Dwarka Island were observed during this survey. Urfi (2002) recons that these species favour saline environment. As Lake Burigi wetland water is somehow alkaline (Kulekana, 2004) observations in this study are in line with Urfi's (2002) supposition. Although Reiynaud (1995) recognises no potential threat on migrant species as human population increases, but we are certain of some threats. On the other hand, climate change might exacerbate impact on these species (Reif *et al.*, 2008).

Birds' diversity structure and distribution is also a function of the number of birds in the risk of extinction. Results show that Lake Burigi wetland is a home to species with a risk of extinction. Two categories of birds in risk of extinction namely LC and NT categories were identified (Appendix 1). Furthermore, Baker and Baker (2002) and BI (2007) indicate the presence of the VU category represented by *Balaeniceps rex* and NT category represented by several species such as *Lybius rubrifacies*, *Crex crex* and *Gallinago media*. This signifies conservation importance of the area not only to common bird species but also to birds of international concern. Such bird categories together with other aforementioned criteria put the conservation status of this area under the IBA status. According to IUCN (2008), the LC category of organisms indicates either decline in number of bird of a group in a population or suggests insufficient data on

population trends to justify the species not being included in T, VU and NT categories (Appendix 2). Only the *Charadrius pallidus veustus*, a Near Threatened species (IUCN, 2008) was encountered. The bird's habitats are said to be globally threatened hence limited in Tanzania and elsewhere (IUCN, 2008). According to Pomeroy *et al.* (2003), areas with intermediate alkalinity like that of Lake Burigi (pH 8.3-8.5) (Kulekana, 2004) tend to have high species richness compared to freshwater areas. Salinity of water for this lake increases towards the shore and dry season (Kulekana, 2004). This matches with observations on birds along the shoreline and muddy areas in the range of 1- 47 m for Consolidated Bare Areas and 1-98 m for Unconsolidated Bare areas (Table 2).

Bird species did occur in varying numbers, and *Bubulcus ibis*is was the most abundant (Appendix 4). The species occurred in single species flocks of 100 to 400 birds either at water points for livestock or in foraging flocks in association with grazing livestock (Plate 2). Such big flocks put the species on top of all species recorded during this study. Pomeroy *et al.* (2003) and Dugger *et al.* (2005) made similar observation and found strong association between size of flocks of *Bulbus ibis* and size of herd of cattle, the flock being large where a herd of cattle was also larger.

Plate 2: A flock of *Bubulcus ibis* at a cattle water point at Lake Burigi Wetland

Relative abundance of Black Crake (*Amaurornis flavirostris*), *Ceryle rudis* and Common Squacco Heron (*Ardeola ralloides*) were in the range of 1 % to 3 % ranked moderate in abundance. *Ardeola ralloides, Vanellus armatus* and others ranked lowest (Appendix 4). This is due to their low population not only in this ecosystem, but also in other areas (IUCN, 2008). However, *Ceryle rudis*, *Haliaeetus vocifer* and *Scopus umbretta* were the most sighted (Appendix 2). This is perhaps because they are of conspicuous size, colour and shape (Takeishi, 1983; Hassan *et al.*, 2004; Thiollay, 2007).

Most species were detected at the distance between 1 and 20 meters (Fig. 2). The species in this case included *Bubulcus ibis*, *Haliaeetus vocifer*, *Ceryle rudis* and Common Sandpiper (*Actitis hypoleucos*). In open water, birds were detected easily compared to areas with high vegetation cover, which causes low visibility. Therefore, detection probability was high for species detected within short radial

distances. This is in agreement with Forcey and Anderson (2002), McCallum (2005) and Skinner and Clark (2008). There is argument that activity/behaviour and coloration of certain species, i.e. cryptic or brilliant enhance easy detection of bird species even where visibility is impaired (McCallum, 2005; Skinner and Clark, 2008). With point count technique of data collection, which allows the counter to settle for sometimes before counting, all factors, i.e. visibility, behaviour and colouration were important in detecting birds.

Haliaeetus vocifer was the only raptor found during this survey. As Thiollay (2007) explains, most raptor species prefer forest, forest edges and woodland habitats. Availability of *Haliaeetus vocifer* and *Ceryle rudis* are associated with the availability of fish stock in the lake. During this study *Haliaeetus vocifer* was seen fishing or perching on vantage points for precision fishing for over 80 % of number of times it was seen. Another category of birds with lowest relative abundance is that of wetland opportunistic birds like Grey-headed Sparrow (*Passer griseus*), Yellow White-eye (*Zostterops senegalensis*), Southern Cordon Bleu (*Lagonosticta rubricata hildebrandti*) and Yellow-vented Bulbul (*Pycnonotus barbatus*). These appeared in wetland ecosystem by chance. Also are those birds whose habitats occur as traces in the overall community e.g. the Narina Trogon (*Apaloderma narina*), *Lanius mackinnoni* and Laughing Dove (*Streptopelia senegalensis*). By and large, these are forests dependants and forests are very minimal in this environment. Equivalent results were made in the study of grassland bird community of the Serengeti Grasslands (Gottschalk *et al.,* 2007).

4.2.2 Distribution of birds with respect to habitat cover classes

Habitat covers with high number of bird species and individuals as per results above include Grassland2, Shrublands and Natural Water Bodies (Fig.3, Appendix 3). These habitats lie contiguous to Lake Burigi wetland and were predominant in the Nyarushojo area. The three habitats either are flooded or permanently hold water at ponds. The three habitats also appeared to have more deposits of wetland organic sediment materials; dampness and experienced moderate disturbance particularly fires. These attributes may favour survival of birds in terms of breeding success, food availability and predation avoidance (Dugger *et al.,* 2005; Gottschalk *et al.,* 2007; Thiollay, 2007; White *et al.,* 2007; Gunaratne *et al.,* 2008) and hence their high utilisation. Consequently, Natural Water Bodies supported quite reasonable number of water birds (Appendix 3). As of L˜ohmus (2005), the importance of structural diversity of forest stands and well managed forest will allow reproduction success not only of raptors but of the forest bird community. Contrary, the low number of birds observed in the Forest vegetation cover class may be attributed to poor visibility of birds in forests and few instances of forest in the entire area, which is the result of forest degradation. On the other hand, consolidated Bare Areas are preferred by humans for settlement and fish processing. As these activities are currently being carried out, they cause habitat degradation and fragmentation. Therefore, low abundance of birds in Consolidated Bare Areas is associated with human accessibility and disturbances (Reynaud, 1995; O'Reilly *et al.,* 2006; Daniels and Cumming, 2008; Gillings, 2008; Gunaratne *et al.,* 2008). A previous study in Burigi Game Reserve and adjacent areas (Masalu, 2008) revealed disturbances caused by refugees. According to Jambiya *et al.* (2007) around 600

000 refugees were located in camps around the Reserve and the entrance to this reserve was not controlled. The influx caused stunning deterioration of the environment including many bird habitats.

In general, the numbers of birds detected in various habitats/vegetation types decreased as sighting distance increased (Fig. 2). Most of the wading birds were observed along the shore line where vegetation is relatively short to give visibility within short distance range (Table 2). Findings of this study with respect to sighting distance and habitat/vegetation type agrees with Forcey and Anderson (2002), who also found that size of an individual bird and overall species size coupled with visibility of different habitats/vegetation type and structure, bird activity, weather condition and observer's acuity were important.

Number of birds did not vary significantly between land and water substrates despite greater number of birds on land compared to water, which suggests that even terrestrial birds very much depend on wetland environment. Nevertheless, water obligate birds and waders were many at the lake compared to other groups of birds. These were found feeding in areas where water had re ceded after flooding. BSC (2005) and Timmermans and Crewe (2005) ascertain that water availability for water birds caused by flooding tends to lead to high number of water birds in the wetland. Lack of significant difference in numbers of birds between the two substrates could be attributable to periodic and nearly permanent inundation of some land habitats due to heavy rains and flooding. Water availability in areas other

than the lake itself may obscure the environmental difference between water and land substrates.

4.2.3 Distribution of birds with respect to locations

Nyarushojo, Ngoma, Nyakagugu, Mutoma and Nkonje recorded a high number of birds. High abundance for the first four localities is probably due to geomorphology of the landscape surrounding Lake Burigi and human induced activities. The landscape consists of flat plains with grass mosaics and shrubs that attract birds for food acquisition, escape from predators and provide environment conducive for breeding. Equally, rice and maize farming caused flocking of birds to rice fields whereas cattle grazing caused some birds to flock to where cattle were driven. Birds that were attracted to rice and maize field included *Bubulcus ibis*, Spur-winged Goose (*Plectropterus gambensis*), White-faced Whistling Duck (*Dendrocygna viduata*) and some members of order Charadriiformes. Waterfowls were seen feeding in rice and maize farms, a situation which exposed them to killing by farmers either for protein or in defense of crops. The birds are also potentially exposed to effects of pesticides and chemical fertilizers. Influence of anthropogenic activities on birds' distribution has also been reported elsewhere. Cases reported include tolerance of modified environment by White-tailed Swallow (*Hirundo megaensis*) in places where settlement patterns were changing (Mellanby *et al.*, 2008), increase in number of ground feeding species by fire incidences and fields with paddy rice (Etoori and Abe, 1992; Tréca, 1992).

Favourable landscape features coupled with being located in protected part of this wetland probably contributed to the highest bird abundance in Nkonje area. Experience shows that protection of wildlife areas against uncontrolled human utilization result to overall high diversity of animals and birds (Dugger *et al.*, 2005; O'Reilly *et al.*, 2006; Gbogbo, 2007; Gottschalk *et al.*, 2007; Akosim *et al.*, 2008; Daniels and Cumming, 2008; Gunaratne *et al.*, 2008). Therefore, findings of this study matches with comparative studies on water bird distribution between managed and unmanaged coastal wetlands in Ghana (Gbogbo, 2007). In such studies, population density for unmanaged wetlands was found to be lower than that of managed wetland.

Few birds were recorded at MkwajuniP, Kashwa and Masheli (in open part of the wetland). This condition may be ascribed to the landscape and anthropogenic activities. The landscape at these areas is raised (Upper part) with small area of a wetland, minimal extent of flooding, little availability of organic matter and small amount of hydric soils. Being located in the unprotected part of Lake Burigi wetland, Masheli is subjected to legal settlements and activities associated with human occupancy such as clearing land for establishment of settlements and clearing forest stands for fuel wood to dry fish (Plate 3). Such human disturbances were observed even in localities in the protected part though were less severe.

Plate 3: Fish processing at Mkwajuni area associated with vegetation clearing and fuel wood collection

4.2.4 Distribution, species diversity index and evenness of birds with respect to protection status of Lake Burigi Wetland

Generally, the number of birds was high in an unprotected part of Lake Burigi wetland, contrary to the common tendency of high occurrence of birds in protected than open areas (Gbogbo, 2007), which is indicative of effective management. Actually, bird occurrence in the GR was highly inconsistent, with some locations showing very low numbers compared to locations outside the reserve. For example, at Kashwa and Biharamulo-Lukili, human activities like fishing, land clearing for settlements and fuel wood for fish processing as well as grazing were prominent, probably accounting for the trend (O'Reilly *et al.*, 2006; Gbogbo, 2007). While fishing activity may attract fish-eating birds, grazing and clearance of vegetation (L˜ohmus (2005) may attract birds that occupy edges of forest patches and forest

gaps and overall modified habitats. An alternative thinking to explain high bird occurrence in open areas could be one that associates the event with regeneration of vegetation cover following negative impact of refugees on environ (Dugger *et al.*, 2005; O'Reilly *et al.*, 2006; Jambiya *et al.*, 2007). Masalu (2008) and Jambiya *et al.* (2007) noted vegetation recovery in areas that were already deserted by refugees, suggesting possibility for this factor to contribute to the imbalanced bird occupancy between protected and open areas.

However, during this survey, some species such as Knob-billed Ducks (*Sarkidiornis melanotos*), Chestnut-banded Plover (*Charadrius pallidus veustus*), *Lanius mackinnoni*, and Black-napped Tern (*Sterna sumatrana*) were encountered only in Burigi GR. According to Riffell *et al.*, (2001) certain species require habitats that are specific for their survival. It seems these species are intolerant to human disturbances. *Sterna sumatrana* was observed to remain perfectly in water and in most cases in flight. This species is said to have restricted appearance on certain areas (Fanshawe, 2002).

The study area in Burigi GR had generally higher diversity than the study area outside the reserve. This is could be due to differences in status of landscape habitats and vegetation composition and structure as a result of human influenced disturbances. According to Reynaud (1995), diversity decreases with increase in human population through different activities. All areas both outside the reserve and inside the reserve with severe level of interferences had low diversity indices. A similar situation is portrayed by species evenness such that areas e.g. Masheli with

human activities demonstrate high species evenness (Fig.5). Severe level of human activities dates back to the time refugees exuded into the areas from 1994 onwards exposing these areas to settlement and intensified fishing and hunting activities (Jambiya *et al.,* 2007; Masalu, 2008) (Plate 4 and 7). Rwandese, Burundians and Ankole pastoralists also located these areas for grazing (Masalu, 2008, Personal observation) (Plate 5 and 6).

As discussed earlier, Lake Burigi Wetland contains grasslands mosaics that support high diversity of birds in plain and flooded areas of Nyarushojo and Nyakagugu. Similarly, grazing and rice farming may promote temporarily high bird diversity as they attract birds.

Plate 4: Fish products processed on Lake Burigi shore being transported to market

Plate 5: Heavily grazed plain of Lake Burigi Wetland by Ankole and Rwandese cattle

Plate 6: Ankole cattle introduced by illegal immigrants exposed by refugees influx at Lake Burigi Wetland

Plate 7: Settlement along Lake Burigi with fish processing

In future, over fishing may lead do decrease in fish dependant birds like *Amaurornis flavirostris*, *Ceryle rudis* and *Haliaeetus vocifer*. Only sustainable extraction of the fish stock will sustain fish stock in the lake for human consumption as well as for the water birds. This also will ensure clean and safe water for the wildlife in Burigi GR and the overall IBA.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The study was successful by obtaining results that portray the existing situation on the diversity and distribution of avifauna resource along Lake Burigi wetland which is key to wildlife in Burigi-Biharamulo GR, and hydrology of Burigi-Biharamulo ecosystem. Abundance of avifauna differed significantly between different habitat cover classes, locations and protection status. This condition was attributed to the effect of refugees' influx in 1994; landscape set up and increased human activities due to easy accessibility. The diversity of this area is mainly contributed by habitat differentiation, the presence of migratory species and presence of birds at risk of extinction. Diversity indices of birds also varied significantly with locations a situation related to habitat covers of this area. According to IUCN Red List records, some species were in the category of Least Concern and *Charadrius pallidus veustus* was the only species in the Near Threatened group found in this area.

Generally this area is diverse and has sufficient bird diversity. However, interferences with this system were observed. The main concern is tree felling for firewood and fish processing, overgrazing, poaching, illegal beach seining, dynamite fishing and settlements.

5.2 RECOMMENDATIONS

i. There is a need to have a study that covers both dry and wet seasons so as to have a full understanding of the avifauna resource in the area.

ii. Improve conservation measures on the lake for healthy of the wildlife populations in Burigi GR.

iii. International effort is also needed to conserve international important species in the red list like the *Charadrius pallidus veustus* and migratory species that were identified and others not identified by this study.

iv. It is important to note that this area is connected to neighbouring ecosystems e.g. the Akagera National Park in Rwanda and the Kagera Swamps in Tanzania. Species encountered in this area have been identified in most of the East and Central Africa Region. Therefore cross border attention is important as this area is on the border of Burundi, Rwanda and Uganda countries. This will address the migration, livestock pressure and conservation cooperation of the resource in this system.

v. More studies that need emphasis on this area include Limnological changes and fisheries activities in this area.

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APPENDICES

Appendix 1: Birds species list of Lake Burigi Wetland

Order	Family	Common name	Scientific Name	Movement Pattern	IUCN Conservation Status
Anserformes	Anatidae	Egyptian Goose	*Alopochen aegyptiacus*	U	LC
	Anatidae	Eurasian Wigeon	*Anas penelope*	PAM	LC
	Anatidae	Knob-billed Ducks	*Sarkidiornis m.melanotos*	PAM	
	Anatidae	Spur-winged Goose	*Plectropterus g.gambensis*	L	
	Anatidae	White-faced Whistling Duck	*Dendrocygna viduata*	W	
Apodiformes	Apodidae	Alpine Swift	*Apus melba africanus*	L	
Charadriiformes	Laridae	Black-napped Tern	*Sterna sumatrana*		LC
	Charadriidae	Black-winged Plover	*Vanellus melanopterus minor*	L	
	Charadriidae	Blacksmith Plover	*Vanellus armatus*	L	
	Charadriidae	Chestnut-banded Plover	*Charadrius pallidus veustus*	L	NT
	Charadriidae	Crowned Plover	*Vanellus c. coronatus*	W	
	Charadriidae	Long-toed Plover	*Vanellus c. crassirostris*	L	
	Charadriidae	Spur-winged Plover	*Vanellus spinosus*	L	
	Charadriidae	Wattled Plover	*Vanellus senegallus lateralis*	L	
	Charadriidae	Kittlitz's Plover	*Charadrius pecuarius*	L	
	Charadriidae	Lesser Sandplover	*Charadrius mongolus pamirensis*	PAM	
	Haematopodidae	Eurasian Oystercatcher	*Haematopus ostralegus longipes*	PAM	
	Jacanidae	African Jacana	*Actophilornis africanus*	W	LC
	Recurvirostridae	Black-winged Stilt	*Himantopus h.himantopus*	W	
	Scolopacidae	Temminck's Stint	*Calidris temminckii*	PAM	LC
	Scolopacidae	Terek Sandpiper	*Xenus cinereus*	CM	
	Scolopacidae	Common Greenshank	*Tringa nebularia*	PAM/CM	
	Scolopacidae	Marsh Sandpiper	*Tringa stagnatilis*	PAM	
	Scolopacidae	Broad-billed Sandpiper	*Limicola falcinellus*	UM	

	Scolopacidae	Common Sandpiper	*Actitis hypoleucos*	PAM	LC
	Scolopacidae	Sanderling	*Calidris alba*	CM	LC
	Burhinidae	Eurasian Thick-knee	*Burhinus o. oedicnemus*	PAM	LC
	Burhinidae	Senegal Thick-knee	*Burhinus senegalensis inornatus*	L	LC
	Burhinidae	Water Thick-knee	*Burhinus v. vermiculatus*	L	LC
	Scolopacidae	Common Redshank	*Tringa totanus ussuriensis*	UM	
	Scolopacidae	Common Snipe	*Gallinago g. gallinago*	PAM	LC
Ciconiiformes	Ardeidae	Cattle Egret	*Bubulcus i.ibis*	W	
	Ardeidae	Little Egret	*Egretta g.garzetta*	W	
	Ardeidae	Great Egret	*Casmerodius albus melanorhynchos*	W/AM	
	Ardeidae	Intermediate Egret	*Mesophoyx intermedia*	W	
	Ardeidae	Black-headed Heron	*Ardea melanocephala*	W	LC
	Ardeidae	Common Squacco Heron	*Ardeola ralloides*	W	LC
	Ardeidae	Dwarf Bittern	*Ixobrychus sturmii*	INAM	
	Ardeidae	Goliath Heron	*Ardea goliath*	L/PAM	LC
	Ardeidae	Green-backed Heron	*Butorides striatus atricapillus*	W	
	Ardeidae	Grey Heron	*Ardea c. cinerea*	W	LC
	Ardeidae	Rufous-bellied Heron	*Ardeola rufiventris*	L	LC
	Ciconiidae	Open-billed Stork	*Anastomus I.lamelligerus*	R/INAM	
	Ciconiidae	Marabou Stork	*Leptoptilos crumeniferus*	W	
	Scopidae	Hamerkop	*Scopus u. umbretta*	W	
	Threskiornithidae	Hadada Ibis	*Bostrychia hagedash brevirostris*	W	LC
	Threskiornithidae	Glossy Ibis	*Plegadis f. falcinellus*	W	
	Threskiornithidae	Sacred Ibis	*Threskiornis aethiopica*	W	
Coliiformes	Coliidae	Speckled Mousebird	*Colius striatus*	L	
Columbiformes	Columbidae	Laughing Dove	*Streptopelia s.senegalensis*	L	
	Columbidae	Ring-necked Dove	*Streptopelia capicola*	W	
Coraciiformes	Alcedinidae	African Pygmy Kingfisher	*Ispidina p. picta*	L	
	Alcedinidae	Pied Kingfisher	*Ceryle r. rudis*	L	LC
	Alcedinidae	Woodland Kingfisher	*Halcyon s.senegalensis*	L	
	Phoeniculidae	Black Billed Wood-Hoopoe	*Phoeniculus s.somaliensis*	L	

	Bucerotidae	Southern Ground Hornbill	*Bucorvus leadbeateri*	L	
	Meropidae	Blue-cheeked Bee-eater	*Merops p.persicus*	PAM	
	Meropidae	Eurasian Bee-eater	*Merops apiaster*	PAM	
Cuculiformes	Cuculidae	White-Browed Coucal	*Centropus s.superciliosus*	R	
	Musophagidae	Bare- faced Go- away- bird	*Corythaixoides leucogaster*	L	
Falconiformes	Accipitridae	African Fish Eagle	*Haliaeetus vocifer*	W	
Galliforms	Phasianidae	Red-necked Spurfowl	*Francolinus afer*	L	
	Numinidae	Helmeted Guineafowl	*Numida meleagris*	W	
Gruiformes	Rallidae	Black Crake	*Amaurornis flavirostris*	W	LC
	Gruidae	Grey-crowned Crane	*Balearica regulorum gibbericeps*	W	LC
Passeriformes	Dicruridae	Common Drongo	*Dicrurus a. adsimilis*	L	
	Muscapidae	Northern Black-flycatcher	*Melaenornis edolioides*	L	
	Pycnonotidae	Yellow-vented Bulbul	*Pycnonotus barbatus*	U	
	Sturnidae	Bronze-tailed Starling	*Lamprotornis chalybaeus*	L	
	Sturnidae	Greater Blue-eared Starling	*Lamprotornis c. chloropterus*	L	
	Alaudidae	Flappet Lark	*Mirafra rufocinnamomea*	R	V
	Hirundinidae	Barn Swallow	*Hirundo r. rustica*	PAM	
	Hirundinidae	Red-rumped Swallow	*Hirundo daurica emini*	L	
	Hirundinidae	Angola Swallow	*Hirundo angolensis*	L	
	Motacillidae	African Pied Wagtail	*Motacilla aguimp vidua*	W	
	Motacillidae	Yellow Wagtail	*Motacilla flava*	PAM/W	
	Laniidae	Grey-Backed Fiscal	*Lanius e. excubitoroides*	L	
	Laniidae	Mackinnon's Fiscal	*Lanius mackinnoni*	L	
	Timaliidae	Arrow-Marked Babbler	*Turdoides jardineii emini*	L	
	Malaconotidae	Black-Headed Gonolek	*Laniarius erythrogaster*	L	
	Malaconotidae	Brubru	*Nilaus afer minor*	W	
	Malaconotidae	Rosy-patched Bush-shrike	*Rhodophoneus cruentus*	L	
	Ploceidae	Black-headed Waver	*P. cucullatus*	L	
	Ploceidae	Jackson's Golden-backed Weaver	*Ploceus jacksoni*	L	
	Ploceidae	Juba Weaver	*P. dichrocephalus*	L	
	Ploceidae	Northern Masked	*P. t. velatus taeniopterus*	L	

		Weaver			
	Ploceidae	Yellow-backed Weaver	*P. melanocephalus fischeri*	L	
	Euplectes	Fan-tailed Widowbird	*Euplectes axillaris*	L	
	Passeridae	Grey-headed Sparrow	*Passer griseus*	L	
	Estrildidae	Common Waxbill	*Estrilda astrild*	W	
	Estrildidae	Southern Cordon-bleu	*Uraeginthus angolensis niasensis*	L	
	Estrildidae	African Firefinch	*Lagonosticta rubricata hildebrandti*	L	
	Sylviidae	Great Reed Warbler	*Acrocephalus a. arundinaceus*	PAM	LC
	Nectariniidae	Purple-banded Sunbird	*Nectarinia bifasciata*	L	
	Zosteropidae	Yellow White-eye	*Zostterops senegalensis*	L	
Pelecaniformes	Anhingidae	African Darter	*Anhinga rufa*	W	LC
	Phalacrocoracidae	Little Cormorant	*Phalacrocorax niger*	V	LC
	Phalacrocoracidae	Long-tailed Cormorant	*Phalacrocorax a. africanus*	W	
	Phalacrocoracidae	Great Cormorant	*Phalacrocorax carbo lucidus*	W	
	Pelecanidae	Great White Pelican	*Pelecanus onocrotalus*	W	
Trogoniformes	Trogonidae	Narina Trogon	*Apaloderma n. narina*		LC

Description-

i) Movement: PAM=Palaearctic Migrant, UM=Uncommon Migrant, M=Migrant, CM=Common Migrant, INAM=Intra-African Migrant

ii) IUCN Conservation Status: NT=Near Threatened, LC=Least Concern

iii) Distribution Range: W=Wide spread, L=Local, U=Ubiquitous

Appendix 2: The IUCN Red List of Threatened Species 2001 Categories & Criteria (version 3.1)

Citing of the Red List Categories and Criteria may be written out in full or abbreviated as shown in the headings.

EXTINCT (EX)

A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

EXTINCT IN THE WILD (EW)

A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

CRITICALLY ENDANGERED (CR)

A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered (see Section V), and it is therefore considered to be facing an extremely high risk of extinction in the wild.

ENDANGERED (EN)

A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered (see Section V), and it is therefore considered to be facing a very high risk of extinction in the wild.

VULNERABLE (VU)

A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable (see Section V), and it is therefore considered to be facing a high risk of extinction in the wild.

NEAR THREATENED (NT)

A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

LEAST CONCERN (LC)

A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

DATA DEFICIENT (DD)

A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well

known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data are available. In many cases great care should be exercised in choosing between DD and a threatened status. If the range of a taxon is suspected to be relatively circumscribed, and a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified.

NOT EVALUATED (NE)

A taxon is Not Evaluated when it is has not yet been evaluated against the criteria.

Note: As in previous IUCN categories, the abbreviation of each category (in parenthesis) follows the English denominations when translated into other languages (see Annex 2).

Citation of the IUCN Red List Categories and Criteria

Source: IUCN, 2008

Appendix 3: Species and number of birds per habitat class of Lake Burigi Wetland

Habitat Class	Species Name	Frequency of sighting	Number of Birds	Mean
Consolidated Bare Areas	African Fish Eagle	1	1	1.00
	Black-winged Stilt	1	1	1.00
	Black Crake	2	6	3.00
	Common Greenshank	1	2	2.00
	Common Sandpiper	5	12	2.40
	Crowned Plover	1	1	1.00
	Egyptian Goose	1	1	1.00
	Eurasian Thick-knee	1	2	2.00
	Little Cormorant	1	1	1.00
	Little Egret	1	1	1.00
	Long-toed Plover	1	2	2.00
	Spur-winged Plover	2	7	3.50
	Sub Total	**18**	**37**	**2.06**
Forest	African Fish Eagle	3	4	1.33
	Hadada Ibis	1	2	2.00
	Juba Weaver	1	1	1.00
	Laughing Dove	1	2	2.00
	Southern Ground Hornbill	1	2	2.00
	Sub Total	**7**	**11**	**1.57**
Natural open Water bodies	African Darter	1	1	1.00
	African Fish Eagle	6	9	1.50
	African Pygmy Kingfisher	2	2	1.00
	African Wagtail	4	6	1.50
	Black-napped Tern	6	26	4.33
	Black-winged Plover	1	7	7.00
	Black-winged Stilt	6	14	2.33

	Cattle Egret	2	3	1.50
	Common Greenshank	3	8	2.67
	Common Redshank	1	2	2.00
	Common Sandpiper	5	10	2.00
	Egyptian Goose	5	18	3.60
	Great Cormorant	8	23	2.88
	Great Egret	2	2	1.00
	Great White Pelican	4	123	30.75
	Grey Heron	1	4	4.00
	Hamerkop	7	18	2.57
	Intermediate Egret	3	65	21.67
	Knob-billed Ducks	2	24	12.00
	Little Egret	8	27	3.38
	Long-tailed Cormorant	2	3	1.50
	Marabou Stork	1	1	1.00
	Marsh Sandpiper	1	3	3.00
	Pied Kingfisher	11	30	2.73
	Sanderling	1	2	2.00
	Spur-winged Goose	1	2	2.00
	Water Thick-knee	1	1	1.00
	Wattled Plover	1	1	1.00
	Sub Total	**96**	**435**	**4.53**
Unconsolidated Bare Areas	African Fish Eagle	1	1	1.00
	African Wagtail	1	1	1.00
	Angola Swallow	1	10	10.00
	Black Crake	2	7	3.50
	Cattle Egret	1	3	3.00
	Chestnut-banded Plover	1	5	5.00
	Common Sandpiper	10	17	1.70

	Eurasian Oystercatcher	1	1	1.00
	Hadada Ibis	1	6	6.00
	Hamerkop	8	23	2.88
	Kittlitz's Plover	1	1	1.00
	Lesser Sandplover	1	5	5.00
	Little Egret	2	43	21.50
	Marabou Stork	2	6	3.00
	Pied Kingfisher	1	1	1.00
	Sanderling	2	4	2.00
	Spur-winged Plover	4	11	2.75
	Terek Sandpiper	1	4	4.00
	Wattled Plover	2	6	3.00
	Yellow Wagtail	1	1	1.00
	Sub Total	**44**	**156**	**3.55**
Woodland	African Fish Eagle	12	18	1.50
	Bare-faced-go-away Bird	1	4	4.00
	Black-billed Wood-hoopoe	1	1	1.00
	Black-headed Gonolek	1	1	1.00
	Blue-eared Starling	1	2	2.00
	Bronze-tailed Starling	1	2	2.00
	Common Drongo	1	2	2.00
	Grey-backed Fiscal	4	14	3.50
	Hadada Ibis	1	1	1.00
	Juba Weaver	1	7	7.00
	Laughing Dove	1	2	2.00
	Marabou Stork	1	1	1.00
	Narina Trogon	1	2	2.00
	Pied Kingfisher	1	1	1.00
	Purple-banded Sunbird	1	1	1.00

	Ring-necked Dove	1	4	4.00
	Rosy-patched Bush-shrike	1	2	2.00
	Senegal Thick-knee	2	3	1.50
	Speckled Mousebird	1	3	3.00
	Woodland Kingfisher	4	4	1.00
	Sub Total	**38**	**75**	**1.97**
Shrubland	African Fish Eagle	1	1	1.00
	Alpine Swift	1	2	2.00
	Angola Swallow	3	43	14.33
	Arrow-marked Babbler	1	2	2.00
	Black-headed Gonolek	4	9	2.25
	Black-headed Weaver	1	1	1.00
	Black Crake	3	9	3.00
	Northern Black-flycatcher	1	1	1.00
	Blue-eared Starling	1	1	1.00
	Bronze-tailed Starling	1	4	4.00
	Cattle Egret	1	175	175.00
	Common Squacco Heron	3	4	1.33
	Dwarf Bittern	1	2	2.00
	Eurasian Thick-knee	2	6	3.00
	Great Cormorant	1	1	1.00
	Green-backed Heron	1	1	1.00
	Grey-backed Fiscal	1	2	2.00
	Hamerkop	1	2	2.00
	Jackson's Golden-backed Weaver	1	2	2.00
	Marabou Stork	2	3	1.50
	Northern Masked Weaver	2	10	5.00
	Pied Kingfisher	7	30	4.29
	Red-rumped Swallow	1	20	20.00

	Ring-necked Dove	1	2	2.00
	Speckled Mousebird	4	17	4.25
	Spur-winged Plover	2	3	1.50
	Water Thick-knee	2	5	2.50
	Wattled Plover	1	1	1.00
	White-browed Coucal	2	3	1.50
	Woodland Kingfisher	1	1	1.00
	Yellow-vented Bulbul	2	3	1.50
	Yellow White-eye	1	2	2.00
	Sub Total	**57**	**368**	**6.46**
Grasslands	African Firefinch	1	4	4.00
	African Fish Eagle	6	12	2.00
	African Jacana	2	5	2.50
	African pygmy Kingfisher	1	1	1.00
	Black-headed Weaver	1	2	2.00
	Black Crake	17	68	4.00
	Blue-cheeked Bee-eater	1	2	2.00
	Brubru	1	1	1.00
	Cattle Egret	1	1	1.00
	Common Greenshank	1	1	1.00
	Common Sandpiper	1	2	2.00
	Common Squacco Heron	11	36	3.27
	Common Waxbill	2	38	19.00
	Eurasian bee-eater	1	7	7.00
	Glossy Ibis	1	2	2.00
	Goliath Heron	1	3	3.00
	Great Reed Warbler	2	5	2.50
	Green-backed Heron	1	4	4.00
	Grey-backed Fiscal	2	8	4.00

Grey-headed Sparrow	1	2	2.00
Grey Heron	1	1	1.00
Hadada Ibis	1	6	6.00
Hamerkop	5	19	3.80
Helmeted-guinea Fowl	1	3	3.00
Jackson's golden-backed Weaver	4	42	10.50
Little Cormorant	1	1	1.00
Little Egret	2	3	1.50
Long-tailed Cormorant	1	8	8.00
Long-toed Plover	2	13	6.50
Mackinnon’s Fiscal	1	1	1.00
Marabou Stork	1	3	3.00
Marsh Sandpiper	1	20	20.00
Northern Masked Weaver	2	5	2.50
Pied Kingfisher	10	47	4.70
Red-rumped Swallow	2	17	8.50
Ring-necked Dove	1	2	2.00
Rufous-bellied Heron	3	7	2.33
Sacred Ibis	1	19	19.00
Southern Cordon-bleu	1	2	2.00
Speckled Mousebird	1	3	3.00
Spur-winged Goose	2	7	3.50
Spur-winged Plover	2	3	1.50
Temminck's Stint	1	1	1.00
Wattled Plover	1	2	2.00
White-browed Coucal	2	6	3.00
Yellow-vented Bulbul	1	2	2.00
Yellow-backed Weaver	1	3	3.00
Yellow Wagtail	1	1	1.00

	Sub Total	**108**	**451**	**4.18**
Grasslands 2	African Fish Eagle	1	2	2.00
	African Jacana	2	19	9.50
	African Wagtail	2	3	1.50
	Bare-faced-go-away Bird	1	3	3.00
	Barn Swallow	1	65	65.00
	Black-headed Heron	1	1	1.00
	Black-winged Plover	1	10	10.00
	Black-winged Stilt	1	2	2.00
	Black Crake	1	4	4.00
	Blacksmith Plover	1	2	2.00
	Broad-billed Sandpiper	1	9	9.00
	Bronze-tailed Starling	1	4	4.00
	Cattle Egret	9	582	64.67
	Common Greenshank	4	38	9.50
	Common Sandpiper	3	34	11.33
	Common Snipe	2	7	3.50
	Common Squacco Heron	1	22	22.00
	Crowned Plover	2	5	2.50
	Egyptian Goose	3	27	9.00
	Eurasian Wigeon	6	12	2.00
	Fan-tailed Widowbird	2	10	5.00
	Flappet Lark	3	5	1.67
	Goliath Heron	1	8	8.00
	Grey-crowned Crane	2	6	3.00
	Grey Heron	1	2	2.00
	Hadada Ibis	3	50	16.67
	Hamerkop	2	7	3.50
	Intermediate Egret	2	11	5.50

Little Egret	2	16	8.00
Long-tailed Cormorant	1	1	1.00
Long-toed Plover	5	85	17.00
Marabou Stork	5	92	18.40
Marsh Sandpiper	4	62	15.50
Open-billed Stork	2	8	4.00
Pied Kingfisher	1	2	2.00
Red-necked Spurfowl	1	4	4.00
Rufous-bellied Heron	2	17	8.50
Southern Ground Hornbill	1	4	4.00
Spur-winged Goose	2	17	8.50
Spur-winged Plover	9	43	4.78
Water Thick-knee	1	1	1.00
Wattled Plover	5	24	4.80
White-faced Whistling Duck	2	75	37.50
Woodland Kingfisher	1	1	1.00
Sub Total	**104**	**1402**	**13.48**
Grand Total	**472**	**2935**	**6.22**

Appendix 4: Relative abundance of species of birds at Lake Burigi Wetland

Species Name	Number of birds	Relative abundance (%)	Frequency
African Darter	1	0.034	1
African Firefinch	4	0.136	1
African Fish eagle	48	1.635	31
African Jacana	24	0.818	4
African Pygmy Kingfisher	3	0.102	3
African Wagtail	10	0.341	7
Alpine Swift	2	0.068	1
Angola Swallow	53	1.806	4
Arrow-marked Babbler	2	0.068	1
Bare-faced-go-away Bird	7	0.239	2
Barn Swallow	65	2.215	1
Black-billed Wood-hoopoe	1	0.034	1
Black-headed Gonolek	10	0.341	5
Black-headed Heron	1	0.034	1
Black-headed Weaver	3	0.102	2
Black-napped Tern	26	0.886	6
Black-winged Plover	17	0.579	2
Black-winged Stilt	17	0.579	8
Black Crake	94	3.203	25
Blacksmith Plover	2	0.068	1
Blue-cheecked Bee-eater	2	0.068	1
Blue-eared Starling	3	0.102	2
Broad-billed Sandpiper	9	0.307	1
Bronze-tailed Starling	10	0.341	3
Brubru	1	0.034	1
Cattle Egret	764	26.031	14
Chestnut-banded Plover	5	0.170	1
Common Drongo	2	0.068	1
Common Greenshank	49	1.670	9
Common Redshank	2	0.068	1
Common Sandpiper	75	2.555	24
Common Snipe	7	0.239	2
Common Squacco Heron	62	2.112	15
Common Waxbill	38	1.295	2
Crowned Plover	6	0.204	3
Dwarf Bittern	2	0.068	1
Egyptian Goose	46	1.567	9
Eurasian Bee-eater	7	0.239	1
Eurasian Oystercatcher	1	0.034	1
Eurasian Thick-knee	8	0.273	3
Eurasian Wigeon	12	0.409	6
Fan-tailed Widowbird	10	0.341	2
Flappet Lark	5	0.170	3
Glossy Ibis	2	0.068	1
Goliath Heron	11	0.375	2
Great Cormorant	24	0.818	9
Great Egret	2	0.068	2
Great Reed Warbler	5	0.170	2
Great White Pelican	123	4.191	4
Green-backed Heron	5	0.170	2
Grey-backed Fiscal	24	0.818	7
Grey-crowned Crane	6	0.204	2
Grey-headed Sparrow	2	0.068	1
Grey Heron	7	0.239	3
Hadada Ibis	65	2.215	7
Hamerkop	69	2.351	23
Helmeted-guinea fowl	3	0.102	1
Intermediate Egret	76	2.589	5
Jackson's Golden-backed Weaver	44	1.499	5
Juba Weaver	8	0.273	2
Kittlitz's Plover	1	0.034	1
Knob-billed Ducks	24	0.818	2

Laughing Dove	4	0.136	2
Lesser Sandplover	5	0.170	1
Little cormorant	2	0.068	2
Little Egret	90	3.066	15
Long-tailed Cormorant	12	0.409	4
Long-toed Plover	100	3.407	8
Mackinnon's Fiscal	1	0.034	1
Marabou Stork	106	3.612	12
Marsh Sandpiper	85	2.896	6
Narina Trogon	2	0.068	1
Northern Black-flycatcher	1	0.034	1
Northern Masked Weaver	15	0.511	4
Open-billed Stork	8	0.273	2
Pied Kingfisher	111	3.782	31
Purple-banded Sunbird	1	0.034	1
Red-necked Spurfowl	4	0.136	1
Red-rumped Swallow	37	1.261	3
Ring-necked Dove	8	0.273	3
Rosy-patched Bush-shrike	2	0.068	1
Rufous-bellied Heron	24	0.818	5
Sacred Ibis	19	0.647	1
Sanderling	6	0.204	3
Senegal Thick-knee	3	0.102	2
Southern Cordon Bleu	2	0.068	1
Southern Ground Hornbill	6	0.204	2
Speckled Mousebird	23	0.784	6
Spur-winged Goose	26	0.886	5
Spur-winged Plover	67	2.283	19
Temminck's Stint	1	0.034	1
Tereck Sandpiper	4	0.136	1
Water Thick-knee	7	0.239	4
Wattled Plover	34	1.158	10
White-browed Coucal	9	0.307	4
White-faced Whistling Duck	75	2.555	2
Woodland Kingfisher	6	0.204	6
Yellow-vented Bulbul	5	0.170	3
Yellow-backed Weaver	3	0.102	1
Yellow Wagtail	2	0.068	2
Yellow White-eye	2	0.068	1
Total	**2935**	**100**	**472**

Appendix 5: UNOVA Pair-wise comparisons of mean difference in number of birds on habitat cover classes

Habitat Class	Habitat Class	S E	p
Forest	1Natural Water bodies	0.157	0.012
	Unconsolidated Bare Areas	0.165	0.009
	Shrubland	0.159	0.019
	Grasslands	0.158	0.012
	Grasslands 2	0.157	0.001
Natural Water bodies	Woodland	0.078	0.001
	Grasslands 2	0.063	0.043
Unconsolidated Bare Areas	Woodland	0.091	0.001
Woodland	Shrubland	0.084	0.005
	Grasslands	0.076	0.001
	Grasslands 2	0.077	0.000
Shrubland	Grasslands 2	0.070	0.036
Grasslands	Grasslands 2	0.057	0.032

* The mean difference is significant at the 0.05 level.

Appendix 6: UNOVA Pair-wise comparisons of mean difference in number of birds on locations

Location	Location	S E	p
Masheli	Nkonje	0.102	0.045
Mkwajuni P	Nkonje	0.084	0.037
Nyarushojo	Biharamulo-Lukili	0.076	0.000
	Karubambo	0.082	0.000
	Kashwa	0.077	0.000
	Masheli	0.098	0.000
	Mkwajuni	0.080	0.000
	Mkwajuni P	0.089	0.000
	Mutoma	0.086	0.001
	Ngoma	0.088	0.000
	Nkonje	0.079	0.000
	Nyakagugu	0.084	0.000

* The mean difference is significant at the 0.05 level.

Appendix 7: ANOVA Post Hoc multiple comparisons tests (LSD) showing mean differences in diversity index and species evenness

Dependent Variable	Location	Location	S E	p
Diversity Index	Biharamulo-Lukili	Karubambo	0.287	0.037
	Masheli	Karubambo	0.309	0.001
		Mkwajuni P	0.309	0.004
		Nkonje	0.258	0.024
		Nyakagugu	0.309	0.040
		Nyarushojo	0.290	0.003
	Mkwajuni	Karubambo	0.287	0.016
		Mkwajuni P	0.287	0.040
		Nyarushojo	0.267	0.037
	Mutoma	Karubambo	0.300	0.013
		Mkwajuni P	0.300	0.032
		Nyarushojo	0.280	0.029
Species Evenness	Biharamulo-Lukili	Masheli	0.367	0.005
	Kashwa	Nyarushojo	0.382	0.049
	Masheli	Mkwajuni	0.367	0.033
		Mutoma	0.388	0.050
		Ngoma	0.445	0.007
		Nkonje	0.376	0.016
		Nyakagugu	0.450	0.050
		Nyarushojo	0.422	0.004

* The mean difference is significant at the 0 .05 level.