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Avifauna Community in a Threatened Conservation Landscape, Western Tanzania: A Baseline

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ABSTRACT

Conservation of avian biodiversity in landscapes under immense anthropogenic pressures is dependent on sound population data that could guide informed conservation strategies. Using point count surveys, field observations and interviews, we assessed bird communities in Lake Rukwa, an anthropogenically threatened ecosystem in western Tanzania, to establish some vital parameters on this taxon. A total of 5840 bird individuals belonging to 85 species, 17 orders and 39 families were recorded. Of these, five were globally threatened and 19 were migrant species. Avian Shannon's (H') and Simpson's (D) diversity indices were 2.936 and 0.8655, respectively. Bird species richness was different across foraging and habitat guilds (both $p = 0.0001$). Insectivores were the most species-rich foraging guild, while nectarivores were the least; similarly, non-forest birds were the most species-rich habitat guild, while forest generalists were the least. Grazing, bushfires, tree cutting, unsustainable fishing and bird harvesting are the major anthropogenic threats to bird biodiversity in the area. Regular provision of conservation-related education programs to local residents is a highly recommended conservation measure. This study serves as a baseline for avifaunal monitoring in Lake Rukwa and provides useful insights into the avifauna conservation planning in anthropogenically disturbed landscapes.

Keywords: avian community parameters - anthropogenic-related pressures - conservation measures - disturbed landscapes - Lake Rukwa.

INTRODUCTION

A cornerstone of conservation strategies globally has been to establish and manage protected areas (PAs), including nature reserves, national parks and other categories of protected landscapes. The PAs currently cover 15% and 7% of Earth's land and oceans, respectively (Bai *et al.* 2021). The goal as stated in Aichi Biodiversity Target 11 in 2010 is to further expand the global PA network in the future (CBD 2010). The main intention of establishing PAs is to maintain conditions within them that will enable their existing biological communities to thrive and flourish over time. Evidence shows that PAs make significant contributions to the maintenance of natural habitats and their biodiversity (Lu *et al.* 2022). Nevertheless, recent expansion of the scale of anthropogenic activities (e.g., land clearing, logging, grazing, hunting and fire) within and around the PAs is increasingly attracting considerable conservation and research concerns. This is due to the fact that most of the threats affecting biodiversity of different taxa, including birds, are related to these activities. For example, illegal hunting was among the primary anthropogenic drivers of the decline or local extinction of bird populations in some PAs (Thiollay 2006, Shafiee *et al.* 2015). Moreover, a recent study has also found that the global PAs seem to be insufficient to safeguard about half of the world's mammals from anthropogenic-induced extinction (Williams *et al.* 2022). Taken together, these studies reinforce the need for urgent actions to halt global biodiversity decline.

Birds play many important ecological roles in different ecosystems, including as pest and scavengers, seed predators and dispersers, pollinators and ecosystem engineers (Whelan *et al.* 2008). Therefore, on-going decline in bird biodiversity in PAs may have considerable detrimental effects on the provision of these ecosystem services, with cascading effects on diverse flora and fauna species. Tanzania is one of the richest countries in bird biodiversity worldwide. It harbours 1,074 species (BirdLife International 2022a) out of the 10,928 extant bird species of the world (Gill *et al.* 2022). Of the 1,074 bird species, 47 are globally threatened and 33 are country endemics. Currently, Tanzania has a total of 80 Important Bird & Biodiversity Areas (IBAs) and 9 Endemic Bird Areas (EBAs) (BirdLife International 2022a) located in both protected and unprotected areas. This is to acknowledge the importance of these areas as refuge for diverse avifauna communities of conservation concern. The criteria used to designate IBAs worldwide are the presence of globally threatened, restricted-range, biome-restricted and congregatory species (Fishpool and Evans 2001, Baker and Baker 2002, BirdLife International 2013). The Tanzania's IBAs are also not immune to anthropogenic activities that are threatening many of the world's protected ecosystems.

Lake Rukwa is one of the 80 IBAs of the country based on IBAs criteria A2, A4i and A4iii (BirdLife International 2022b). Its valley represents the southernmost point of the Somali-Masai biome and the southern limit for the ranges of distribution of the several species (e.g. Common ostrich/*Struthio camelus* L.) found in the East Africa (Baker and Baker 2002). However, most of the bird species information for Lake Rukwa are out-dated as they are based on surveys carried out over many decades ago (e.g. Vesey-FitzGerald and Beesley 1960). In recent years, villages adjacent to the northern shore of the lake have been experiencing rapid human population growth (URT 2006, 2013a). This has led to the enhancement in anthropogenic activities and their associated disturbances within and around the lake (Paradzavi 2003, Pers. Obser). Considering that birds are highly sensitive to habitat disturbances due to their specificity in habitat requirements, it is important to understand the current status of bird communities in this hitherto anthropogenically disturbed landscape. Therefore, the objectives of this study were to: (i) assess species richness and diversity, and relative abundance of various avifauna; (ii) determine the guild richness and abundance of the avifauna based on their foraging and habitat preference; (iii) assess the conservation and migratory status of avifauna; (iv) identify the anthropogenic activities that threaten avifaunal species; and (v) highlight important conservation and mitigation measures.

MATERIALS AND METHODS

Study area

Lake Rukwa, located in the south-western corner of Tanzania at latitude 8°11.00' S, longitude 32°52.00' E and 800 m.a.s.l. (BirdLife International 2016), belongs to the western rift of the Great Rift Valley. It lies to the southeast of the wildlife protected area complex (URT 2013b) and is shared by three regions: Katavi, Rukwa and Mbeya. The complex is composed of Rukwa Game Reserve, which covers most of the northern section of the lake, Lukwati Game Reserve on the north-eastern shore, and Uwanda Game Reserve on the south-west, occupying almost 50% of the lake ecosystem. The lake is connected on the northwest to Katavi National Park via Lake Rukwa Basin. Most rain in the area falls between November and April. The driest period is between June and September, getting almost no rain. Mean annual rainfall ranges from 650 to 2500 mm (Seegers 1996, URT 2013b). The temperature varies from 12 °C in highland areas to 30 °C in lowland areas (URT 2013b). Extensive permanent swamps and temporary floodplains cover the northern and western shores of the lake. The northern shore also consists of grassland and woodland habitats (Pers. Obser).

Sampling design and data collection techniques

Avifauna surveys were conducted in 2016 using the fixed-radius point count method (Bibby *et al.* 2000). This is the most effective, efficient and information-rich method and has been widely used for the determination of avian species composition and abundance, particularly in tropical forest ecosystems. A total of 50 points were established from a total of 10 transect lines, each measuring 1.5 km long. Thus, five-point counts were designed and surveyed per transect line, and each had a radius of 50 m. The first point count station for each transect line was located 100 m away from the lake shore towards the mainland along the established transects. Point count stations were separated from one another by a minimum distance of 250 m and transect lines were spaced 4 km apart. Point count stations were surveyed only in the mornings (between 6:30-11:30) during favourable weather conditions (Rueda-Hernandez *et al.* 2015), particularly on sunny days when bird activities were most prominent. A total of 5 minutes were used to walk between point counts. Then, observers waited for 5 minutes to allow birds to settle down before the survey began. All birds seen or heard within 15 minutes in a 50 m radius were identified to species level and their numbers recorded. However, overflying birds were recorded only when detected taking off from the visited point count and correctly identified by the observers. For avian species not identified in the field, photographs and note taking on colour/colour pattern and shape of various body parts were performed to aid later identification. During the entire study period, each point count station was visited only once. Avifauna observations and identification were aided by binoculars (10 × 50) and bird field guide books. The data on the present anthropogenic activities, their threats to avifauna community and the potential conservation measures were obtained using both direct observation and questionnaire methods. During direct observation, indicators of habitat disturbance such as nests destruction, tree cutting, bushfires, livestock grazing, presence of bird nets and carcasses were all noted. Questionnaires were administered to a total of 90 fishermen and 10 staff of Rukwa/Lukwati Game Reserve. Only respondents who had resided in the area longer than a year and could provide the required information were requested to fill out questionnaires with informed consent.

Data analysis

Species richness was calculated as the total number of species encountered in a community. In order to determine the overall avifauna species diversity, Shannon's and Simpson's Diversity Indices were computed using the PAST software (Version 3.06). The

Relative Abundance/RA (%) of each avifauna species was calculated to examine the dominance of the recorded birds. Chi-square (χ^2) and Kruskal-Wallis (H) tests were performed to assess the avifaunal community differences among foraging and habitat guilds. Data were tested for normality using the Kolmogorov-Smirnov test to check if transformations were necessary. Statistical significance is reported as $P < 0.05$ unless otherwise stated. In addition, interview data were analysed using descriptive analysis.

RESULTS

Avifauna species richness, diversity and relative abundance

We recorded a total of 5840 bird individuals, distributed in 85 species, 17 orders and 39 families (Table 1). The overall bird species diversity was 2.936 (Shannon's Diversity Index) and 0.8655 (Simpson's Diversity Index). The highest number of families was recorded in the order Passeriformes (14 families), equivalent to 35.90% of all recorded bird families. Thirteen out of 17 orders represented one family each (2.56%) (Table 1). Among the observed families, Ardeidae was the most species-rich bird family (7 species; 8.24%), followed by Accipitridae, Anatidae and Ciconiidae (6 species each; 7.06%).

Family Ardeidae and Ploceidae were the most dominant families in terms of the number of individuals, comprising 2363 (40.46%) and 1212 (20.75%), respectively, of the total number of recorded birds. Cattle Egret/*Bubulcus ibis* had the highest number of individuals (1958 individuals), equivalent to 33.53% of all counted birds (Table 1). Whereas three raptors i.e., Martial Eagle/*Polemaetus bellicosus*, African Marsh-harrier/*Circus ranivorus* and Augur Buzzard/*Buteo augur* were the rarest avian species (one individual each; RA = 0.02%) (Table 1).

Bird guild richness and abundance and conservation and migratory status

All identified birds were grouped into seven main foraging guilds; Frugivore (Fr), Granivore (Gr), Insectivore (In), Nectarivore (Ne), Omnivore (Om), Piscivore (Pi) and Raptors (Ra). Insectivore was the most species-rich foraging guild, with 28 species; equivalent to 32.94% of all species. Nectarivore had the smallest number of bird species of any of the foraging guilds (1.18% of the total number of species) (Table 2). Piscivore was the most dominant foraging guild in terms of the number of individuals/detections (2768 individuals; RA = 47.40%), while Nectarivore was the least (10 individuals; RA = 0.17%). There were significant differences between foraging guilds in terms of their species richness (Chi-square test, $\chi^2 = 38.118$; D.F. 6; $P = 0.0001$) and relative abundance (Kruskal-Wallis test, H = 17.326; D.F. 6; $P = 0.008$).

Furthermore, the recorded birds were grouped into three habitat guilds; forest generalists (F), forest visitors (f) and non-forest species (non-f). There was significant difference in species richness between habitat guilds (Kruskal-Wallis test, H = 24.069; D.F. 2; $P = 0.0001$). Of the 85 recorded species, only one was forest generalist (F; 1.18%), 13 forest visitors (f; 15.29%) and 71 were non-forest species (non-f; 83.53%). No forest specialists (FF) were encountered during the entire study.

The study recorded five globally threatened species, including two endangered (EN): Lappet-faced Vulture/*Torgos tracheliotos* and Grey Crowned Crane/*Balearica regulorum*), two vulnerable (VU): Martial Eagle/*Polemaetus bellicosus* and Woolly-necked Stork/*Ciconia episcopus*), and one near threatened (NT): Bateleur/*Terathopius ecaudatus* (Table 2). Raptor had three of the threatened bird species, whereas Omnivore and Piscivore guilds contained one threatened species each.

**Table 1. Checklist of avifauna spe
cies recorded in the northern shore of Lake Rukwa**

Order	Family	Scientific Name (Author)$^{IUCN\ CONSERV.\ STATUS}$	Common Name	FG^{MS}	HG	RA (%)
Accipitriformes	Accipitridae	*Haliaeetus vocifer* (Daudin, 1800)^{LC}	African Fish Eagle	Ra	non-f	0.19
Accipitriformes	Accipitridae	*Polemaetus bellicosus* (Daudin, 1800)^{VU}	Martial Eagle	Ra	non-f	0.02
Accipitriformes	Accipitridae	*Torgos tracheliotos* (Forster, 1791)^{EN}	Lappet-faced Vulture	Ra	non-f	0.26
Accipitriformes	Accipitridae	*Terathopius ecaudatus* (Daudin, 1800)^{NT}	Bateleur	Ra	f	0.09
Accipitriformes	Accipitridae	*Circus ranivorus* (Daudin, 1800)^{LC}	African Marsh-harrier	Ra	non-f	0.02
Accipitriformes	Accipitridae	*Buteo augur* (Rüppell, 1836)^{LC}	Augur Buzzard	Ra	f	0.02
Anseriformes	Anatidae	*Dendrocygna viduata* (Linnaeus, 1766)^{LC}	White-faced Whistling Duck	Om	non-f	0.65
Anseriformes	Anatidae	*Alopochen aegyptiacus* (Linnaeus, 1766)^{LC}	Egyptian Goose	Om	non-f	0.96
Anseriformes	Anatidae	*Sarkidiornis melanotos* (Pennant, 1769)^{LC}	Knob-billed Duck	Om^{AM}	non-f	0.38
Anseriformes	Anatidae	*Anas hottentota* (Eyton, 1838)^{LC}	Hottentot Teal	Om	non-f	0.07
Anseriformes	Anatidae	*Plectropterus gambensis* (Linnaeus, 1766)^{LC}	Spur-winged Goose	Om	non-f	0.38
Anseriformes	Anatidae	*Nettapus auritus* (Boddaert, 1783)^{LC}	African Pygmy Goose	Om	non-f	0.07
Bucerotiformes	Bucerotidae	*Tockus nasutus* (Linnaeus, 1766)^{LC}	African Grey Hornbill	Fr	non-f	0.1
Charadriiformes	Charadriidae	*Charadrius tricollaris* (Vieillot, 1818)^{LC}	Three-banded Plover	In	non-f	0.1
Charadriiformes	Charadriidae	*Vanellus armatus* (Burchell, 1822)^{LC}	Blacksmith Plover	In	non-f	0.51
Charadriiformes	Charadriidae	*Vanellus spinosus* (Linnaeus, 1758)^{LC}	Spur-winged Plover	In	non-f	0.5
Charadriiformes	Charadriidae	*Vanellus crassirostris* (Hartlaub, 1855)^{LC}	Long-toed Lapwing	In	non-f	0.03
Charadriiformes	Jacanidae	*Actophilornis africanus* (Gmelin, 1789)^{LC}	African Jacana	In	non-f	0.21
Charadriiformes	Laridae	*Chroicocephalus cirrocephalus* (Vieillot, 1818)^{LC}	Grey-headed Gull	Pi	non-f	4.83
Charadriiformes	Recurvirostridae	*Himantopus himantopus* (Linnaeus, 1758)^{LC}	Black-winged Stilt	In	non-f	0.07
Charadriiformes	Rostratulidae	*Rostratula benghalensis* (Linnaeus, 1758)^{LC}	Greater Painted-snipe	Om	non-f	5.14
Charadriiformes	Scolopacidae	*Actitis hypoleucos* (Linnaeus, 1758)^{LC}	Common Sandpiper	In^{PM}	non-f	0.22
Charadriiformes	Scolopacidae	*Calidris minuta* (Leisler, 1812)^{LC}	Little Stint	In^{PM}	non-f	0.34
Ciconiiformes	Ciconiidae	*Leptoptilos crumenifer* (Lesson, 1831)^{LC}	Marabou Stork	Pi	non-f	0.07
Ciconiiformes	Ciconiidae	*Ciconia ciconia* (Linnaeus, 1758)^{LC}	White Stork	Pi^{PM}	non-f	0.6
Ciconiiformes	Ciconiidae	*Mycteria ibis* (Linnaeus, 1766)^{LC}	Yellow-billed Stork	Pi^{AM}	non-f	0.5
Ciconiiformes	Ciconiidae	*Ephippiorhynchus senegalensis* (Shaw, 1800)^{LC}	Saddle-billed Stork	Pi	non-f	0.12
Ciconiiformes	Ciconiidae	*Ciconia episcopus* (Boddaert, 1783)^{VU}	Woolly-necked Stork	Pi	non-f	0.34
Ciconiiformes	Ciconiidae	*Ciconia nigra* (Linnaeus, 1758)^{LC}	Black Stork	Om^{PM}	non-f	0.51
Coliiformes	Coliidae	*Urocolius indicus* (Latham, 1790)^{LC}	Red-faced Mousebird	Fr	non-f	0.17
Columbiformes	Columbidae	*Streptopelia capicola* (Sundevall, 1857)^{LC}	Ring-necked Dove	Fr	f	0.09
Columbiformes	Columbidae	*Turtur chalcospilos* (Wagler, 1827)^{LC}	Emerald-spotted Wood Dove	Fr	f	0.17
Columbiformes	Columbidae	*Oena capensis* (Linnaeus, 1766)^{LC}	Namaqua Dove	Fr	f	0.07
Coraciiformes	Cerylidae	*Ceryle rudis* (Linnaeus, 1758)^{LC}	Pied Kingfisher	Pi	non-f	0.21

Coraciiformes	Coraciidae	*Eurystomus glaucurus* (Statius Muller, 1776)^{LC}	Broad-billed Roller	In$^{AM, PM}$	f	0.14
Coraciiformes	Meropidae	*Merops persicus* (Pallas, 1773)^{LC}	Blue-cheeked Bee-eater	In^{PM}	f	1.93
Cuculiformes	Cuculidae	*Centropus superciliosus* (Hemprich & Ehrenberg, 1833)^{LC}	White-browed Coucal	In	non-f	0.46
Cuculiformes	Cuculidae	*Centropus grillii* (Hartlaub, 1861)^{LC}	Black Coucal	In	non-f	0.45
Cuculiformes	Cuculidae	*Centropus cupreicaudus* (Reichenow, 1896)^{LC}	Coppery-tailed Coucal	In	non-f	0.14
Galliformes	Numididae	*Numida meleagris* (Linnaeus, 1758)^{LC}	Helmeted Guineafowl	Om	f	1.03
Gruiformes	Gruidae	*Balearica regulorum* (Bennett, 1834)^{EN}	Grey Crowned Crane	Om	non-f	1.04
Passeriformes	Laniidae	*Lanius excubitoroides* (Prévost & Des Murs, 1847)^{LC}	Grey-backed Fiscal	In	non-f	0.62
Passeriformes	Laniidae	*Lanius souzae* (Barboza du Bocage, 1878)^{LC}	Souza's Shrike	In	non-f	0.03
Passeriformes	Alaudidae	*Eremopterix leucopareia* (Fischer & Reichenow, 1884)^{LC}	Fischer's Sparrow-lark	Gr	non-f	0.34
Passeriformes	Estrildidae	*Estrilda paludicola* (Heuglin, 1863)^{LC}	Fawn-breasted Waxbill	Gr	non-f	0.07
Passeriformes	Estrildidae	*Lagonosticta rubricata* (Lichtenstein, 1823)^{LC}	African Firefinch	Gr	f	0.03
Passeriformes	Estrildidae	*Uraeginthus bengalus* (Linnaeus, 1766)^{LC}	Red-cheeked Cordon-bleu	Gr	non-f	0.14
Passeriformes	Estrildidae	*Lonchura cucullata* (Swainson, 1837)^{LC}	Bronze Mannikin	Gr	f	0.17
Passeriformes	Hirundinidae	*Hirundo rustica* (Linnaeus, 1758)^{LC}	Barn Swallow	In^{PM}	non-f	6.15
Passeriformes	Hirundinidae	*Riparia cincta* (Boddaert, 1783)^{LC}	Banded Martin	In^{AM}	non-f	0.03
Passeriformes	Malaconotidae	*Tchagra minutus* (Hartlaub, 1858)^{LC}	Marsh Tchagra	In	non-f	0.21
Passeriformes	Malaconotidae	*Tchagra senegala* (Linnaeus, 1766)^{LC}	Black-crowned Tchagra	In	non-f	0.1
Passeriformes	Motacillidae	*Motacilla aguimp* (Dumont, 1821)^{LC}	African Pied Wagtail	In	non-f	0.21
Passeriformes	Motacillidae	*Motacilla flava* (Linnaeus, 1758)^{LC}	Western Yellow Wagtail	In^{PM}	non-f	1.1
Passeriformes	Motacillidae	*Anthus cinnamomeus* (Rüppell, 1840)^{LC}	African Pipit	In	non-f	0.17
Passeriformes	Nectariniidae	*Cinnyris manoensis* (Reichenow, 1907)^{LC}	Miombo Double-collared Sunbird	Ne	non-f	0.17
Passeriformes	Passeridae	*Passer domesticus* (Linnaeus, 1758)^{LC}	House Sparrow	Gr	non-f	0.07
Passeriformes	Ploceidae	*Ploceus baglafecht* (Daudin, 1802)^{LC}	Baglafecht Weaver	Gr	f	0.68
Passeriformes	Ploceidae	*Euplectes axillaris* (Smith, 1838)^{LC}	Fan-tailed Widowbird	Gr	non-f	1.49
Passeriformes	Ploceidae	*Ploceus melanocephalus* (Linnaeus, 1758)^{LC}	Black-headed Weaver	Gr	non-f	4.28
Passeriformes	Viduidae	*Vidua macroura* (Pallas, 1764)^{LC}	Pin-tailed Whydah	Gr	non-f	0.34
Passeriformes	Ploceidae	*Quelea quelea* (Linnaeus, 1758)^{LC}	Red-billed Quelea	Gr^{AM}	non-f	5.99
Passeriformes	Ploceidae	*Quelea cardinalis* (Hartlaub, 1880)^{LC}	Cardinal Quelea	Gr	non-f	5.14
Passeriformes	Ploceidae	*Euplectes orix* (Linnaeus, 1758)^{LC}	Southern Red Bishop	Gr	non-f	0.74
Passeriformes	Viduidae	*Anomalospiza imberbis* (Cabanis, 1868)^{LC}	Parasitic Weaver	Gr	non-f	0.7
Passeriformes	Ploceidae	*Euplectes hordeaceus* (Linnaeus, 1758)^{LC}	Black-winged Red Bishop	Gr	non-f	2.43
Passeriformes	Pycnonotidae	*Pycnonotus goiavier* (Scopoli, 1786)^{LC}	Yellow-vented Bulbul	In	f	0.14
Passeriformes	Cisticolidae	*Cisticola juncidis* (Rafinesque, 1810)^{LC}	Zitting Cisticola	In	f	0.46
Passeriformes	Cisticolidae	*Cisticola brachypterus* (Sharpe, 1870)^{LC}	Short-winged Cisticola	In	non-f	0.03
Passeriformes	Macrosphenidae	*Melocichla mentalis* (Fraser, 1843)^{LC}	Moustached Grass Warbler	In	non-f	0.77
Passeriformes	Sylvioidea	*Acrocephalus schoenobaenus* (Linnaeus, 1758)^{LC}	Sedge Warbler	In^{PM}	non-f	0.17
Pelecaniformes	Ardeidae	*Ardeola ralloides* (Scopoli, 1769)^{LC}	Squacco Heron	Pi$^{AM, PM}$	non-f	0.29

Pelecaniformes	Ardeidae	*Ardea cinerea* (Linnaeus, 1758)[LC]	Grey Heron	Pi[AM, PM]	non-f	0.15
Pelecaniformes	Ardeidae	*Egretta ardesiaca* (Wagler, 1827)[LC]	Black Heron	Pi	non-f	0.55
Pelecaniformes	Ardeidae	*Bubulcus ibis* (Linnaeus, 1758)[LC]	Cattle Egret	Pi[AM]	non-f	33.53
Pelecaniformes	Ardeidae	*Ardea alba* (Linnaeus, 1758)[LC]	Great White Egret	Pi[PM]	non-f	1.4
Pelecaniformes	Ardeidae	*Ardea goliath* (Cretzschmar, 1827)[LC]	Goliath Heron	Pi	non-f	0.09
Pelecaniformes	Ardeidae	*Ardea intermedia* (Wagler, 1829)[LC]	Intermediate Egret	Pi	non-f	4.45
Pelecaniformes	Pelecanidae	*Pelecanus rufescens* (Gmelin, 1789)[LC]	Pink-backed Pelican	Pi	non-f	0.19
Pelecaniformes	Threskiornithidae	*Plegadis falcinellus* (Linnaeus, 1766)[LC]	Glossy Ibis	Om[AM, PM]	non-f	2.81
Pelecaniformes	Threskiornithidae	*Bostrychia hagedash* (Latham, 1790)[LC]	Hadada Ibis	In	non-f	0.03
Phoenicopteriformes	Phoenicopteridae	*Phoenicopterus roseus* (Pallas, 1811)[LC]	Greater Flamingo	Om[AM, PM]	non-f	0.15
Strigiformes	Strigidae	*Asio capensis* (Smith, 1834)[LC]	Marsh Owl	Ra	non-f	0.09
Suliformes	Phalacrocoracidae	*Microcarbo africanus* (Gmelin, 1789)[LC]	Long-tailed Cormorant	Pi	non-f	0.09
Trogoniformes	Trogonidae	*Apaloderma narina* (Stephens, 1815)[LC]	Narina Trogon	Fr	F	0.03

FG: Feeding Guilds; HG: Habitat Guilds; RA: Relative Abundance; EN: Endangered species; VU: Vulnerable species; NT: Near Threatened species; LC: Least Concern species; Fr: Frugivore; Gr: Granivore: In: Insectivore; Ne: Nectarivore; Om: Omnivore; Pi: Piscivore; Ra: Raptor; AM: Afro-tropical Migrant; PM: Palearctic Migrant; AM, PM: Afro-Palearctic Migrant; F: Forest generalists; f: Forest visitors; non-f: Non forest species**. Note**: Information from various literatures (e.g. Hassan *et al.* 2013, Rija *et al.* 2014, 2015) was used to classify birds according to their feeding and habitat guilds. Similarly, available literatures were used to group birds to their conservation status (based on the IUCN Red List) and migratory status.

Table 2. Summary of avifauna species according to their habitat guilds, IUCN conservation status and foraging/feeding guilds in the study area

Variables	Bird Species (Total: 85 species) Number of spp	Proportion (%)	Bird Abundance (Total: 5840 individuals) Number of Detections	Proportion (%)
Habitat Guilds				
FF-species	0	0	0	0
F-species	1	1.18	2	0.03
f-species	13	15.29	266	4.55
non-f species	71	83.53	5545	94.95
IUCN Conser. Status				
EN-species	2	2.35	76	1.30
VU-species	2	2.35	21	0.36
NT-species	1	1.18	5	0.09
LC-species	80	94.12	5738	98.25
Foraging Guilds				
Fr-species	6	7.06	37	0.63
Gr-species	15	17.65	1321	22.62
In-species	28	32.94	895	15.33
Ne-species	1	1.18	10	0.17
Om-species	12	14.12	770	13.18
Pi-species	16	18.82	2768	47.40
Ra-species	7	8.24	39	0.67

FF: Forest specialists; F: Forest generalists; f: Forest visitors; non-f: non-Forest species; EN: Endangered species; VU: Vulnerable species; NT: Near Threatened species; LC: Least Concern species; Fr: Frugivore; Gr: Granivore: In: Insectivore; Ne: Nectarivore; Om: Omnivore; Pi: Piscivore; Ra: Raptor.

Table 3. Ranking of avifauna species according to their migratory status in the northern shore of Lake Rukwa

Scientific Name	Feeding Guild (FG)	Migration Status (MS)	Relative Abundance (RA: %)
Bubulcus ibis	Piscivore	Afro-tropical	33.53
Hirundo rustica	Insectivore	Palearctic	6.15
Quelea quelea	Granivore	Afro-tropical	5.99
Plegadis falcinellus	Omnivore	Afro-Palearctic	2.81
Merops persicus	Insectivore	Palearctic	1.93
Ardea alba	Piscivore	Palearctic	1.40
Motacilla flava	Insectivore	Palearctic	1.10
Ciconia ciconia	Piscivore	Palearctic	0.60
Ciconia nigra	Omnivore	Palearctic	0.51
Mycteria ibis	Piscivore	Afro-tropical	0.50
Sarkidiornis melanotos	Omnivore	Afro-tropical	0.38
Calidris minuta	Insectivore	Palearctic	0.34
Ardeola ralloides	Piscivore	Afro-Palearctic	0.29
Actitis hypoleucos	Insectivore	Palearctic	0.22
Acrocephalus schoenobaenus	Insectivore	Palearctic	0.17
Ardea cinerea	Piscivore	Afro-Palearctic	0.15
Phoenicopterus roseus	Omnivore	Afro-Palearctic	0.15
Eurystomus glaucurus	Insectivore	Afro-Palearctic	0.14
Riparia cincta	Insectivore	Afro-tropical	0.03

A total of 19 migrant birds were recorded, including Palearctic, Afro-tropical and Afro-Palearctic migrants (Table 3). Among the migrant avifauna species, Cattle Egret (*Bubulcus ibis*) which is an Afro-tropical was the most dominant species (RA = 33.53%), whereas Banded Martin (*Riparia cincta)* which is also an Afro-tropical was the rarest species (RA = 0.03%). Regarding feeding guilds, the Insectivore community had the highest number of migrant bird species (8 species; 42.11%), followed by Piscivore (6 species; 31.58%), Omnivore (4 species; 21.05%) and lastly Granivore (1 species; 5.26%) (Table 3). There were no Frugivore, Nectarivore and Raptor among the observed migrant birds (Table 1).

Current anthropogenic activities, their threats to birds and potential conservation measures

Different anthropogenic activities that are considered as the main threats to the survival of birds were recorded, including livestock grazing, bushfires, tree cutting, unsustainable fishing and bird harvesting (Plate 1; Table 4). Respondents perceived livestock grazing as a more serious threat (Table 4). Respondents also believe that these activities can cause destruction of avifauna breeding and habitat sites, bird death and emigration and reduction in avifauna richness (Table 5).

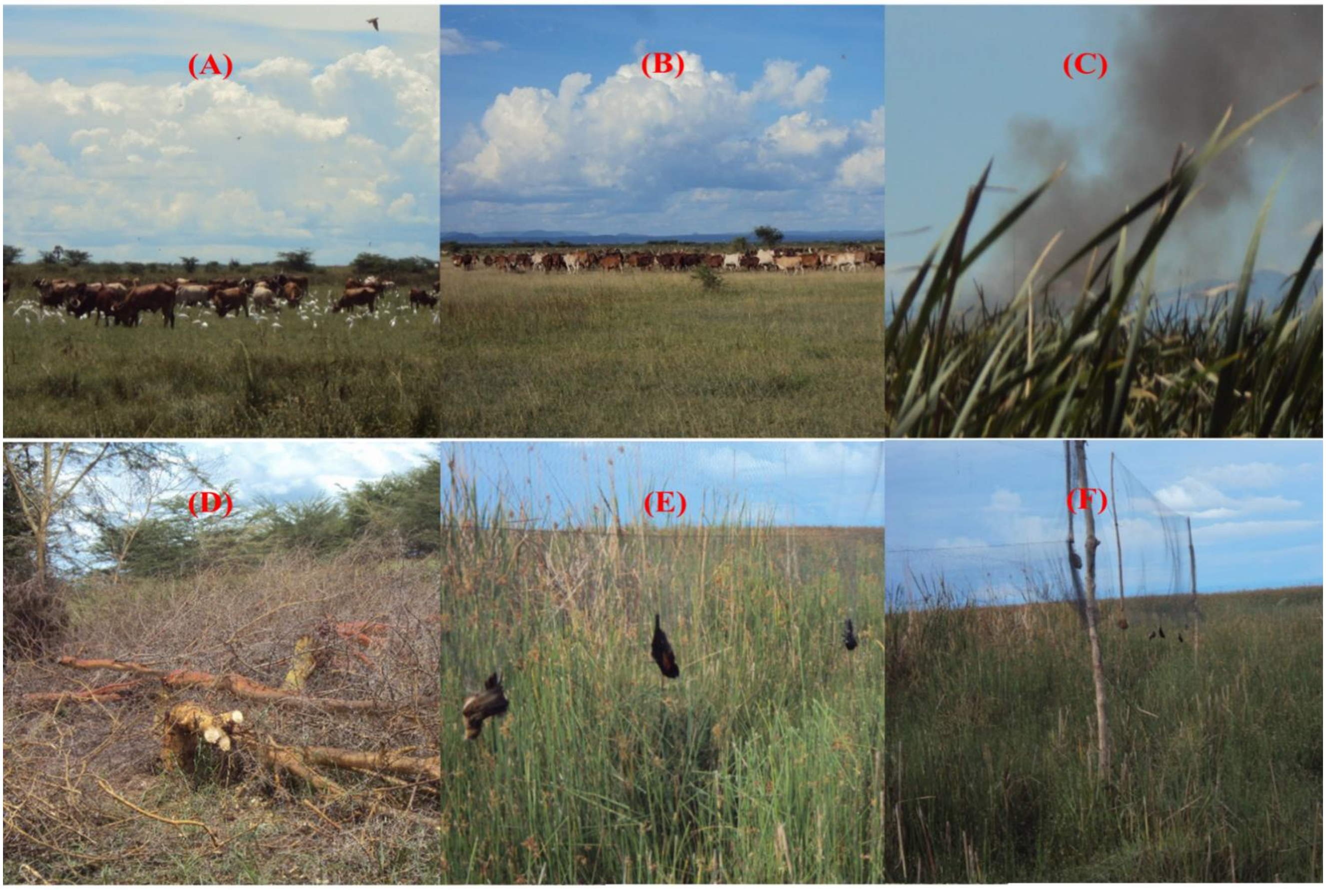

Plate 1. Identified anthropogenic activities in the study area: A & B) Livestock grazing, C) Bushfires, D) Tree cutting, and E & F) Bird harvesting.

Table 4. Various anthropogenic threats to bird biodiversity in Lake Rukwa

Activity	Number of respondents	Proportion (%)
Bird harvesting	19	7.82
Bushfire	58	23.87
Livestock grazing	90	37.03
Tree cutting	57	23.46
Unsustainable fishing	19	7.82

Table 5. Effects of the identified anthropogenic threats in the study area

Effects	Number of respondents	Proportion (%)
Bird death	48	24.00
Bird emigration	12	6.00
Breeding site destruction	85	42.50
Habitat destruction	45	22.50
Richness reduction	10	5.00

The respondents mentioned lack of environmental conservation awareness as a major cause of the existing threats (Table 6). They also listed other causes to be poor management of the area by the relevant conservation authority, activities conducted outside the protected area of the lake (non-point activities) and lack of participation of fishermen in the management of Lake Rukwa (Table 6). To effectively and efficiently protect avifauna communities from the aforementioned anthropogenic threats, respondents recommended the following measures; regular provision of conservation education to the local people, removal of livestock from the area, strengthening protection of the studied area, improvement of local people's participation in conservation activities, as well as controlling rapid human immigration into the surrounding villages to prevent further encroachment (Table 7).

Table 6. Major causes of the existing threats in the northern shore of Lake Rukwa

Cause	Number of respondents	Proportion (%)
Lack of environmental conservation awareness	86	45.01
Lack of participatory management	8	4.23
Non-point activities	29	15.20
Poor management of the area	68	35.56

Table 7. Suggested measures for controlling the existing threats in the study area

Measure	Number of respondents	Proportion (%)
Controlling rapid human immigration	1	0.48
Enhance participatory management	5	2.38
Livestock removal	63	30.00
Provision of conservation education	87	41.43
Strengthen the protection of the area	54	25.71

DISCUSSION

Avifauna species richness, diversity and relative abundance

The present study shows that the northern shore of Lake Rukwa has a rich community of bird species. This high avifauna richness and diversity could be attributed to the high heterogeneity of both aquatic and terrestrial habitats. Aquatic habitats include the lake itself, rivers that feed the lake (from big perennial to small seasonal rivers) and the extensive network of wetland ecosystems (e.g. permanent swamps and temporary floodplains). Terrestrial habitats consist mainly of grasslands, woodlands as well as the existing man-made habitats, especially agricultural fields and home gardens in the nearby villages. These habitats may have led to the diversification of food resources (e.g. insects, reptiles, fish, fruits, grains, nectar and small mammals) across the study area. Landscape heterogeneity is a key determinant of biological diversity (Fahrig *et al.* 2011) and has been associated with increased wildlife diversity in tropical habitats (Surasinghe and De Alwis 2010). This is mainly due to the fact that habitat heterogeneity enhances niche availability, thereby increasing the availability of diverse food resources for wildlife species, including birds. A previous study has observed greater avifauna diversity in habitats with greater structural complexity (Honkanen *et al.* 2010). Similar observations have been reported in other taxonomic groups e.g. ungulates (Cromsigt *et al.* 2009) and small mammals (Ricketts and Sandercock 2016). Therefore, conservation actions aiming at maximizing and maintaining habitat complexity and heterogeneity are recommended to sustain diverse avifauna communities.

Apart from fish as the primary food, the ability of Cattle Egret (*Bubulcus ibis*) to forage on other available food resources (Kopij 2003) and their group living behaviour (Hassan *et al*. 2004) may have contributed greatly to the increase in their relative abundance compared to other species. On the other hand, the high relative abundance of Barn Swallow (*Hirundo rustica*) could be due to its feeding behaviour and close association with humans. The species is an aerial insectivore with high manoeuvrability hence avoids competition for food resources with other insectivores. Barn Swallow can also use the opportunity of the available man-made structures in the nearby villages for breeding. Thus, the relative abundance of this species is likely to continue to increase in the future considering the on-going growth of human habitations. Red-billed Quelea (*Quelea quelea*), which is known to be a nomadic pest of cereal crops that feeds in huge flocks, was the third most abundant species. The availability of sufficient grains in the area, which was perhaps supplemented by grains obtained from farmlands in the neighbouring villages, could account for its abundance. However, Martial Eagle (*Polemaetus bellicosus*), African Marsh-harrier (*Circus ranivorus*) and Augur Buzzard (*Buteo augur*) are raptors that prey on small mammals, birds and reptiles. The stenophagous feeding behaviour was associated with their lower relative abundance, probably imposed by limited availability of food resources.

Bird guild richness and abundance and conservation and migratory status

The area harbours significant diversity of bird functional guilds (both ecological and foraging guilds) attributable to the presence of a mosaic of aquatic and terrestrial habitats. However, the absence of forest specialists (FF), which are good indicators of undisturbed forests (Bennun and Howell 2002), and the greater richness and abundance for non-forest (non-f) avifauna species, which prefer to colonize open landscapes, provide a warning of land cover (or habitat) change. Given the nature of the landscape in view of main vegetation/habitat types (woodlands, grasslands, aquatic habitats and the nearby agricultural fields), it was not astonishing to find non-forest avian species in very high abundance and richness as the habitat conditions were ideal for them. For the purpose of this study, non-forest bird species constitute water specialists and savannah species (i.e. woodland and grassland lovers). Since insectivore is the most sensitive feeding guild to various forms of habitat disturbance (Sekercioglu *et al.* 2002), such as selective logging, forest degradation and fragmentation, among others, their observed high species richness might point out the presence of remaining tiny patches of undisturbed habitats across the surveyed landscape. The dominance of piscivores in terms of number of individuals can be attributed to the availability of high number of aquatic habitats that offer significant amount of their main food source i.e., fish. On the other hand, nectar feeders (nectarivore) were the least abundant foraging guild, suggesting that nectar supply as their primary food, which is mediated by seasonality, can greatly influence their abundance.

This study also revealed the presence of five globally threatened species hence signifying the importance of the northern shore of Lake Rukwa as a refuge for threatened avifauna species, which have adapted to open landscapes i.e. woodlands and grasslands (Mulwa *et al.* 2012). Their current conservation status might have been caused by the global common anthropogenic threats, such as habitat loss and degradation, and poisoning by the farmers (either accidentally or intentionally). Furthermore, migratory birds (i.e. Palearctic, Afro-tropical and Afro-Palearctic migrants) were also recorded during the study period. Their high richness might be due to availability of their basic requirements, especially food resources (Lakshmi 2006), which may have been supplied by the aquatic and terrestrial habitats, as well as the neighbouring agricultural fields.

Current anthropogenic activities, their threats to birds and potential conservation measures

As for other flora and fauna taxa, avifauna communities are facing a number of threats owing to adverse anthropogenic activities resulting from rapid human population growth (Biamonte *et al.* 2011). This condition can be potentially aggravated by the on-going climate change. The present study identified various anthropogenic activities (i.e., livestock grazing, bushfires, tree cutting, unsustainable fishing practices and bird harvesting) in the northern shore of Lake Rukwa and the neighbouring villages (Plate 1; Table 4). A study conducted in India by Mistry (2015) recorded deforestation, livestock grazing, hunting and unsustainable fishing among the major threats to avian biodiversity. Similar results have been reported elsewhere (e.g., Soka *et al.* 2013, Joshi and Krishna 2014). The multiple harmful anthropogenic activities observed in the area were attributed not only to habitat loss and destruction, but also to death and emigration of birds. This might contribute to the decline of bird biodiversity, thus hampering future growth of avian-based tourism. To provide solution to the reported causes of the existing threats, participatory management programmes must be implemented. Furthermore, a number of conservation measures as proposed by respondents are very essential to the management authority. These measures were to: ensure regular provision of conservation education to boost local community awareness on natural resources related issues, implement the available conservation laws that require evacuation of livestock within the area and strengthen security of the area through adequate and continuous patrols. Improvement on participation of local inhabitants in conservation related activities and control against rapid human population growth in the surrounding villages to prevent further encroachment were also proposed.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Despite the greater richness, diversity and abundance of birds in the northern shore of Lake Rukwa, there is an urgent need for taking conservation actions to effectively and sustainably reduce, mitigate, or otherwise manage the observed adverse anthropogenic activities. The move is expected to result to protection and preservation of the complex habitat and vegetation heterogeneity in the entire ecosystem for preservation of the present bird populations and re-establishment of forest specialists, which were not observed, but might have been an integral part of Lake Rukwa IBA. The move will additionally require incorporating different conservation measures that were proposed by respondents in order to curb the mentioned causes of the existing threats. To sustain their livelihoods, local inhabitants depend highly on the resources that are available in the study area, and therefore a need for participatory management programmes is critical. On the whole, we are of opinion that the observed anthropogenic activities will persist unless all relevant stakeholders act together to implement the measures and recommendations as suggested by the respondents and authors.

Recommendations

i) Even though bird surveys during this study were conducted only in the mornings (from 6:30 hrs to 11:30 hrs), the standard procedure to better understand fauna assemblage of a given area requires counting both in the morning and evening (16:00 hrs to 18:00 hrs) to even out potential variances in bird richness, diversity and abundance (in the same habitat) between the two time periods.

ii) It is strongly recommended that the next survey be carried out both in wet and dry seasons to detect the likely influence of seasonality on the bird community.

iii) A study that covers the entire Lake Rukwa ecosystem is essential to have updated information about Lake Rukwa IBA, and that might require use of a combination of methods that will suit the different key habitat/vegetation types in the ecosystem.

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