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A Comparison of Avian Diversity in Aquatic Environs of Kariba and the Zambezi River, Zimbabwe

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Abstract

Avifauna communities in three sections of the Zambezi Valley were compared using species richness, Czekanowski Coeffient, Simpson's Index and evenness. The study covered three sections of the Zambezi Valley namely: (i) Zambezi River upstream of Lake Kariba whose flow regime and habitats were presumed not altered by construction of Lake Kariba; (ii) section of Lake Kariba situated within the hinterlands of Kariba Town which was characterised by human settlements and high anthropogenic activities; and (iii) Zambezi River downstream of Lake Kariba whose flow regime and habitats were altered by construction of Lake Kariba. Surveys involved distance sampling point count method to establish avian composition, and species relative abundances in habitats. Czekanowski Coefficient showed low similarity (Czekanowski Coefficient < 45%) in avian community composition between sections of the Zambezi Valley. Aquatic avian species diversity was highest within the hinterlands of Kariba Town than in lotic habitats of the Zambezi River. Results showed significant differences ($p<0.05$; One way ANOVA) in species richness, species diversity and evenness among the three sections of the Zambezi Valley. Tukey's pairwise comparisons showed significant differences ($p<0.05$) in species richness between sections of the Zambezi Valley. Tukey's pairwise comparison tests also showed significant difference ($p<0.05$) in species diversity and evenness between lentic environs of Lake Kariba and lotic environs of the Zambezi River both upstream and downstream of the lake. However, Tukey's pairwise comparison showed no significant difference ($p>0.05$) in species diversity and evenness between habitats upstream of the lake and habitats downstream of the lake.

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Results corroborated with the research hypothesis that avian communities within the three sections of the Zambezi Valley were significantly different from each other. These results could be a reflection of varying responses of avifauna to different habitat conditions in the different sections of the Zambezi Valley.

Keywords: avian diversity; Zambezi Valley; aquatic environs.

1. Introduction

In the present era, threat to biodiversity lies in the continuing depletion of suitable habitats in response to changes in the physical environment [1, 2, 3]. These depletions increase with increase in human activities. Construction of Lake Kariba on the Zambezi River channel in the 1960s was associated with apparent ecological and biodiversity changes in the submerged areas of Kariba and sections downstream of the lake [4]. These alterations were mainly a result of controlled water volume flowing past the dam wall, as well as the periodic opening and closing of flood gates [5, 6, 7]. While creation of Lake Kariba resulted in submerging of specialised riverine habitats in some sections of the Zambezi Valley, it also led to creation of new specialised habitats that were associated with the lentic environment [4, 8]. In addition to construction of the inland reservoir, shifting in land use from subsistence farming to commercial fishing, eco-tourism and the subsequent establishment and expansion of human settlements, further augmented ecosystem alterations in the Zambezi Valley. Thus, the current pattern of species composition within the Zambezi Valley is a product of historical processes that took place in the area over many years [4].

Historically, the Zambezi Valley has been known for its high diversity of avian species [9, 10, 11]. However, considering impacts of river obstruction on ecosystems, it is most likely that construction of Lake Kariba on the Zambezi River channel and the subsequent shifting in land use practices in the Zambezi Valley imposed significant effects on diversity and distribution of avifauna in different sections of the Zambezi Valley. Following river impoundment, understanding of community assemblages and how species composition and numbers vary in space and time is of paramount importance to conservationists. In this study, we compared contemporary aquatic avifauna assemblages in three distinct aquatic environs of the Zambezi Valley, in Zimbabwe more than fifty years after construction of Lake Kariba on the Zambezi River channel. The study compared aquatic avian community of Lake Kariba within the hinterlands of Kariba Town, with the aquatic avian communities of the Zambezi River channel upstream and downstream of Lake Kariba. The study hypothesised that contemporary aquatic avian communities of the Zambezi River upstream and downstream of Lake Kariba were significantly different from each other since the two sections of the river had distinct flow regimes following construction of Lake Kariba. These differences were mainly a result of controlled water volume flowing past the dam wall, as well as periodic opening and closing of flood gates that altered the Zambezi River flow rate and flood regime downstream of Lake Kariba [6]. The study also hypothesised that contemporary aquatic avian communities of the Zambezi River upstream and downstream of Lake Kariba were significantly different from the aquatic avian community in the lentic habitats of Lake Kariba within the hinterlands of Kariba Town, which was a section of the Zambezi Valley with pronounced human settlements and high anthropogenic activities.

2. Study Area

The Zambezi Valley in Zimbabwe is part of a large zoogeographical landscape that is associated with the perennial Zambezi River which flows from its source in northern Zambia to the Indian Ocean in Mozambique. The valley consists of special terrestrial and aquatic habitats associated with large rivers and lake environs and harbours a large biodiversity of flora and fauna.

This study covered three aquatic sections of the Zambezi Valley situated in Zimbabwe namely: (i) a section of the Zambezi River upstream of Lake Kariba whose flow regime and habitats were presumed not altered by construction of Lake Kariba; (ii) a section of Lake Kariba situated within the hinterlands of Kariba Town which was characterised by human settlements and high anthropogenic activities; and (iii) a section of the Zambezi River downstream of Lake Kariba whose flow regime and habitats were altered by construction of Lake Kariba. Upstream of Lake Kariba, sampling to establish avian composition and diversity was conducted along the Zambezi River channel on the Zimbabwean side on a section stretching from Kazungula Boarder Post to Victoria Falls which was situated between geographical locations 17˚48'14.82"S 025˚16'6.99"E and 17˚ 55'29.60"S 025˚ 51'1.85"E. Downstream of the lake, sampling was conducted along the Zambezi River on a section situated between Vundu and Nyamatutsi, lying within geographical locations 15˚73.487'S 029˚ 34.965'E and 15˚ 70.327'S 029˚ 41.666'E. In Lake Kariba, sampling was conducted along Kariba Town Shoreline from the dam wall (16˚ 32.199'S 28˚ 45.459'E) to Charara River mouth (16˚33.583'S 28˚ 57.047'E).

Human population and activities were high within the hinterlands of Kariba Town with eco-tourism, fisheries, aquaculture and commercial farming being the major activities. The other two sections of the Zambezi Valley sampled in this study were lotic habitats situated along the Zambezi River channel upstream and downstream of Lake Kariba and were characterised low human population.

3. Materials and Methods

This study focused on avian species that utilised the aquatic habitats and the associated riparian environs for habitat, food acquisition and/or to reproduce within the Zambezi Valley. Surveys in the three sections of the Zambezi Valley were conducted in July, August, October and November of 2014 and 2015 to capture species seasonal variations.

July and August represented the cold season while October and November represented the hot season. Surveys involved the distance sampling point count method to establish avian composition, and species relative abundances in the aquatic environs. Point count locations were a minimum of one kilometre apart to minimise multiple counting of birds. Sampling points were accessed by road in all the three sections of the Zambezi Valley.

Counting lasted fifteen minutes per station counting all birds at a station and noting their habitats. Surveys were conducted in July, August and October of 2014 and 2015. In each section of the Zambezi Valley, a single point count survey was conducted within a single day per sampling month. Surveys commenced at dawn and continued for six hours, ending around 1100hrs in October and November and around 1200hrs in July and

August. Focal observations were conducted using binoculars (Dialyt 8X30B) and a stop watch was used to time duration of observations at sampling points.

3.1 Statistical Analyses

Data were organised in Excel and analysed using PAST Statistical Package Version 3. Species Richness (S) was used to describe avian community composition in each section of the Zambezi Valley. S was based on presence/ absence data and was the total number of species recorded in a section in the Zambezi Valley during sampling. S was denoted by formula 1 as follows:

$$S = \text{total number of species recorded in a section of the Zambezi Valley} \qquad (1)$$

Proportional abundances (*B*) of species were used to depict relative species reporting rates in different sections of the Zambezi Valley. *B* had values ranging between 0 and 1.

The higher the value of *B*, the more abundant the species was in the community. *B* was based on abundances of individual species in a community relative to the total number of individuals belonging to all species in the community and was calculated using formula 2 as follows:

$$B = m_i/M \qquad (2)$$

Where m_i = the number of individuals belonging to species *i* counted in a section of the Zambezi Valley; and M = total number of individuals belonging to all species counted in the section.

Czekanowski Coefficient or Percent Similarity (PS) was used to compare similarities in avian species composition and relative species abundances between the different sections of the Zambezi Valley. PS was based on presence/absence data as well as the relative abundances of individual species in the two communities being compared and was measured as a percentage. PS was calculated using formula 3 as follows:

$$PS = \Sigma^i_1 (R_i) \qquad (3)$$

Where R_i = the lower percentage value of the i^{th} species between the two sections of the Zambezi Valley being compared. If a species was present in one community and absent in the other a lower percent value of 0 was assigned. High PS values indicated more biodiversity similarity with respect to species composition and relative species abundances between the two sections of the Zambezi Valley being compared.

Simpson's Index (D_s) was used to describe avian diversity in each section of the Zambezi Valley. D_s was based on species relative abundances and measured the probability that two birds picked from a community belonged to the same species. D_s was calculated using formula 4 as follows:

$$D_s = 1\text{-} \Sigma^i_1 [n_i*(n_i\text{-}1)]/ [N*(N\text{-}1)] \qquad (4)$$

Where n_i = number of individuals belonging the i^{th} species and N = total number of birds belonging to all species counted in a section of the Zambezi Valley. D_s had values ranging from 0 to 1 with 1 representing no diversity and values approaching 0 representing infinity diversity.

Evenness (E) was used as a measure of equality or heterogeneity in relative abundances of different species present in each section of the Zambezi Valley. E was also based on species relative abundances and had values ranging between 0 and 1. A value of 0 signified no evenness in species abundances and 1 denoted complete evenness. E was calculated using formula 5 as follows:

$$E = H/ln(S) \qquad (5)$$

Where $H = - \Sigma^{i}_{1} [P_i * \ln(P_i)]$ and P_i = the proportion of each species in a section of the Zambezi Valley; and ln(S) = the natural logarithm of the species richness (S) in a section of the Zambezi Valley.

One way ANOVA was used to test for significant differences in species richness, species diversity, and evenness among the three section of the Zambezi Valley.

Tukey's pair-wise comparisons were used to test for significant difference in species richness, species diversity, and species evenness between different sections of the Zambezi Valley. Communities often vary between seasons in response to changes in the physical environment. Wilcoxon signed rank test was therefore used to test for seasonal differences in mean species abundances, species richness and species diversity in each section of the Zambezi Valley.

4. Results

Results corroborated with our hypothesis that avian communities within the three sections of the Zambezi Valley were significantly different from each other. One way ANOVA results showed significant difference ($p<0.05$) in species richness, species diversity and species evenness among the three sections of the Zambezi Valley. Tukey's pairwise comparisons showed significant difference ($p<0.05$) in species richness between sections of the Zambezi Valley.

Tukey's pairwise comparison tests also showed significant difference ($p<0.05$) in species diversity and evenness between the lentic environs of Lake Kariba and lotic environs of the Zambezi River both upstream and downstream of the lake. However, Tukey's pairwise comparison showed no significant difference ($p>0.05$) in species diversity and species evenness between habitats upstream of the lake and habitats downstream of the lake on the Zambezi River channel.

Highest number of avian species was recorded in lotic habitats of the Zambezi River downstream of Lake Kariba in all sampling months (Table 1; Table 2).

In general, more avian species were observed in Lake Kariba than on the Zambezi River upstream of the lake. Except in August 2015, more avian species were recorded in the lentic environs surrounding Kariba Town than on the Zambezi River, upstream of Lake Kariba (Table 1).

Table 1: Cold season avian species composition and their proportional abundances (*B*) in the three sections of the Zambezi Valley, in Zimbabwe (K = aquatic environs of Lake Kariba within the hinterlands of Kariba Town; V= the Zambezi River upstream of Lake Kariba; and M = the Zambezi River downstream of Lake Kariba).

	July 2014			July 2015			August 2014			August 2015		
	K	V	M	K	V	M	K	V	M	K	V	M
Haliaeetus vocifer	0.02	0	0.02	0.02	0.04	0.04	0.01	0	0.03	0.02	0.05	0.01
Actophilornis africanus	0.02	0	0.01	0.04	0.06	0	0.02	0.06	0	0.03	0.02	0.02
Motacilla aguimp	0	0.03	0	0	0.07	0	0	0.06	0	0	0.01	0
Rynchops flavirostris	0	0.07	0.03	0.03	0.05	0.05	0.02	0.12	0.04	0.02	0.04	0.01
Platalea alba	0	0	0.03	0	0	0.04	0	0	0.05	0	0	0.01
Vanellus armatus	0.03	0	0.06	0.03	0	0.05	0.01	0	0.04	0.02	0.07	0.03
Himantopus himantopus	0	0.05	0.04	0	0.04	0.05	0	0.08	0.04	0	0.03	0.01
Ardea melanocephala	0	0	0.05	0	0	0.02	0	0	0.02	0	0	0.03
Neafrapus boehmi	0	0	0.02	0	0	0.04	0	0	0.03	0	0	0.02
Bubulcus ibis	0.04	0.22	0.05	0.06	0.11	0.05	0.02	0.10	0.05	0.03	0.10	0.07
Glareola pratincola	0	0.08	0	0	0.06	0	0	0.06	0	0	0.06	0
Actitis hypoleucos	0	0	0	0	0	0	0.01	0	0.04	0.01	0.01	0.07
Anhinga melanogaster	0	0.04	0	0	0.02	0	0	0.02	0	0	0	0
Alopochen aegyptiacus	0.02	0.13	0.13	0.04	0	0.05	0.03	0	0.03	0.04	0.07	0.02
Plegadis falcinellus	0.04	0	0.12	0.06	0	0.08	0.04	0.06	0	0.05	0.02	0.16
Ardea goliath	0.02	0	0	0.03	0	0	0.01	0	0	0.02	0	0
Egretta alba	0	0	0.03	0	0	0.02	0	0	0.04	0	0	0.02
Butorides striatus	0	0.05	0	0	0.18	0	0	0.05	0	0	0.07	0
Ardea cinerea	0.04	0	0.01	0.04	0	0.03	0.02	0	0.01	0.01	0	0.03
Larus cirrocephalus	0.07	0	0.02	0.06	0	0.05	0.09	0	0.03	0.13	0	0.07
Bostrychia hagedash	0	0	0.08	0	0.09	0.05	0	0.06	0.11	0	0.02	0.05
Scopus umbretta	0	0.08	0.01	0	0	0.05	0.01	0	0.01	0.02	0.02	0.01
Sarkidiornis melanotos	0.01	0.11	0	0	0.05	0	0	0.1	0	0	0.09	0
Egretta garzetta	0	0	0.04	0	0.02	0.04	0	0	0.04	0	0.01	0.02
Vanellus crassirostris	0	0	0.04	0	0	0	0	0	0.02	0	0	0.03
Leptoptilos crumeniferus	0.51	0	0	0.3	0	0	0.47	0	0	0.36	0.05	0.05
Ceryle rudis	0.01	0.03	0.03	0.01	0	0.04	0.01	0.04	0.03	0.003	0.03	0.02
Phalacrocorax africanus	0.02	0.05	0	0.02	0.03	0.04	0.02	0.1	0	0.03	0.08	0
Ceryle rudis	0.07	0	0.01	0.12	0	0.04	0.11	0	0.05	0.08	0	0.04
Phalacrocorax africanus	0.002	0	0.02	0.01	0	0.01	0	0	0.02	0	0	0.06
Ceryle rudis	0	0	0.02	0	0.09	0.02	0	0	0.03	0	0.03	0
Phalacrocorax africanus	0	0	0.01	0	0	0.02	0	0	0.01	0	0	0
Ceryle rudis	0.03	0.04	0.01	0.07	0.09	0	0.06	0.12	0	0.08	0.12	0.06
Vanellus albiceps	0.01	0	0.07	0.01	0	0.04	0.03	0	0.10	0.04	0	0.02
Charadrius marginatus	0.04	0	0	0.06	0	0	0.02	0	0	0.03	0	0
Ciconia episcopus	0	0	0.03	0	0	0.06	0	0	0.05	0	0	0.07
Mycteria ibis	0.01	0	0.01	0	0	0.01	0.01	0	0.02	0	0	0.01
TOTAL SPECIES (S)	19	13	27	18	15	25	20	14	25	19	21	27

In Lake Kariba, most species were recorded within the edges of the shallow waters. On the contrary, sandbanks and midstream rocks were the most utilised habitats by bird parties on the Zambezi River, upstream of the lake. Downstream of Lake Kariba, highest avian species richness and abundances occurred on pools and sandbanks. In Lake Kariba, sandbanks were mostly used for perching by plovers, ibises and storks. Fringing vegetation and floating weeds were mostly used as foraging grounds by the African Jacana (*Actophilornis africanus*) in Lake Kariba and on the Zambezi River. Fringing vegetation and floating weeds were also the most frequently used habitats by the Longtoed Plover (*Vanellus crassirostris*) on the Zambezi River downstream of the lake.

Table 2: Hot season avian species composition and their proportional abundances (*B*) in the three sections of the Zambezi Valley, in Zimbabwe (K = aquatic environs of Lake Kariba within the hinterlands of Kariba Town; V= the Zambezi River upstream of Lake Kariba; and M = the Zambezi River downstream of Lake Kariba).

	October 2014			October 2015			November 2014			November 2015		
	K	V	M	K	V	M	K	V	M	K	V	M
Haliaeetus vocifer	0.01	0.04	0.03	0.01	0	0.02	0.01	0.10	0.02	0.01	0.10	0.005
Actophilornis africanus	0.02	0.06	0.03	0.02	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.01
Motacilla aguimp	0	0.01	0	0	0.01	0	0	0.02	0	0	0.02	0
Rynchops flavirostris	0.01	0.09	0.05	0.01	0.07	0.04	0.003	0	0.02	0.003	0	0.01
Platalea alba	0	0	0.01	0	0	0.02	0	0	0	0	0	0.01
Vanellus armatus	0.02	0.09	0.03	0.02	0	0.03	0.02	0.06	0.03	0.02	0.06	0.02
Himantopus himantopus	0	0.03	0.02	0	0.05	0.02	0	0.03	0.03	0	0.03	0.01
Ardea melanocephala	0	0	0.01	0	0	0.02	0	0	0.01	0	0	0.02
Neafrapus boehmi	0	0	0.03	0	0	0.02	0	0	0	0	0	0.005
Bubulcus ibis	0.03	0	0.02	0.02	0.06	0.01	0.03	0	0.04	0.03	0	0.005
Glareola pratincola	0	0.03	0	0	0.01	0	0	0.06	0	0	0.06	0
Actitis hypoleucos	0.01	0	0.01	0.01	0	0.03	0.004	0	0.02	0.004	0	0.01
Anhinga melanogaster	0	0.01	0	0	0.01	0	0	0.03	0	0	0.03	0
Alopochen aegyptiacus	0.04	0.09	0.06	0.03	0.11	0.06	0.01	0.05	0.06	0.01	0.05	0.09
Plegadis falcinellus	0.05	0.09	0.09	0.03	0.09	0.03	0.03	0.13	0.07	0.03	0.13	0.13
Ardea goliath	0.01	0	0	0.01	0	0	0.01	0	0	0.01	0	0
Egretta alba	0	0	0.02	0	0	0.03	0	0	0.02	0	0	0.01
Tringa nebularia	0	0	0	0	0	0	0	0	0	0	0	0.002
Butorides striatus	0	0.07	0	0	0.04	0	0	0.07	0	0	0.07	0
Ardea cinerea	0.01	0	0.01	0.01	0	0.01	0.004	0	0.01	0.004	0	0.02
Larus cirrocephalus	0.07	0	0	0.09	0	0	0.08	0	0	0.08	0	0
Bostrychia hagedash	0	0	0.10	0	0.11	0.11	0	0	0.02	0	0	0.03
Scopus umbretta	0.02	0	0.03	0.02	0	0.02	0.01	0	0.02	0.01	0	0.04
Sarkidiornis melanotos	0	0.12	0.02	0	0.04	0.01	0	0.06	0	0	0.06	0.02
Egretta garzetta	0	0.04	0.05	0	0.03	0.03	0	0.02	0.01	0	0.02	0.01
Vanellus crassirostris	0	0	0.01	0	0	0.01	0	0	0.01	0	0	0.02
Leptoptilos crumeniferus	0.49	0	0	0.57	0	0	0.49	0	0	0.49	0	0
Anastomus lamelligerus	0.02	0	0.07	0.01	0.11	0.05	0.02	0	0.05	0.02	0	0.01
Ceryle rudis	0.005	0.07	0.02	0.01	0	0.01	0.01	0.06	0.02	0.01	0.06	0.04
Phalacrocorax africanus	0.03	0.05	0.01	0.02	0.08	0.02	0.02	0.09	0.02	0.02	0.09	0.02
Glareola nuchalis	0	0.03	0.03	0	0	0.01	0	0.04	0.01	0	0.04	0.02
Ceryle rudis	0.08	0	0.1	0.06	0	0.14	0.15	0	0.21	0.15	0	0.18
Phalacrocorax africanus	0.01	0	0.01	0.002	0	0.01	0.01	0	0.01	0.01	0	0.02
Ceryle rudis	0	0.03	0	0	0.04	0.01	0	0.04	0	0	0.04	0.01
Phalacrocorax africanus	0	0	0.01	0	0	0.01	0	0	0.002	0	0	0.01
Ceryle rudis	0.01	0.04	0.05	0.03	0.10	0.03	0.03	0.14	0.14	0.03	0.14	0.05
Ciconia ciconia	0.005	0	0	0.01	0	0	0.001	0	0	0.001	0	0
Vanellus albiceps	0.01	0	0.03	0.005	0	0.02	0.03	0	0.03	0.03	0	0.005
Charadrius marginatus	0.02	0	0	0.01	0	0	0.01	0	0	0.01	0	0

Ciconia episcopus	0	0	0.06	0	0	0.16	0	0	0.09	0	0	0.14
Mycteria ibis	0.01	0	0.01	0.005	0	0.01	0.01	0	0.02	0.01	0	0.01
TOTAL SPECIES (S)	23	18	30	23	17	31	23	17	27	23	17	32

Shoreline grassland and marshes were common along the edges of Lake Kariba and were used as foraging grounds by the Cattle Egret (*Bubulcus ibis*), Blacksmith Plover (*Vanellus armatus*), Marabou Stork (*Leptoptilos crumeniferus*) and the Sacred Ibis (*Threskiornis aethiopicus*). *Leptoptilos crumeniferus* also used the riparian vegetation for perching in Lake Kariba. The ducks and the geese mostly preferred edges of the inland waters with vegetation fringes for foraging within the lake and on the Zambezi River. The Blackwinged Stilt (*Himantopus himantopus*) was only recorded on the Zambezi River where it occupied marshes along the river channel. The riparian vegetation was a common habitat along the Zambezi River channel and was mostly utilised by the African Fish Eagle (*Haliaeetus vocifer*), Hammerkop (*Scopus umbretta*) and the Böhm's Spinetail (*Neafrapus boehmi*). In Lake Kariba, *H. vocifer* also preferred perching on dry mopane stumps that projected above the water surface.

Results of pairwise community comparisons using Czekanowski Coefficient also corroborated with our hypothesis that avian communities within the three sections of the Zambezi Valley were dissimilar. Czekanowski Coefficient showed low similarity (PS < 45%) in avian community composition between sections of the Zambezi Valley in all sampling months (Table 3). In general, avian species diversity was higher within the lentic habitats of Lake Kariba than in lotic habitats of the Zambezi River both upstream and downstream of Lake Kariba (Table 4). Simpson's Index ranged between 0.91 and 0.96 in the lotic habitat downstream of Lake Kariba. Upstream of the lake, D_s ranged between 0.89 and 0.94 across all the sampling months (Table 4). Higher D_s values on the Zambezi River indicated less avian species diversity on lotic habitats of the Zambezi River compared to aquatic habitats of Kariba Town. Lake Kariba scored the least D_s values in all sampling months, indicating highest avian species diversity within the hinterlands of Kariba Town than in lotic habitats of the Zambezi River. The least D_s (0.65) was recorded in Lake Kariba in October 2015 (Table 4).

Table 3: Czekanowski Coefficient (PS) for the three different avian communities in the Zambezi Valley

Sampling Month	Section of the Zambezi Valley being compared	Czekanowski Coefficient (PS) %	
		2014	**2015**
	Kariba & Upstream	12.69	24.39
July	Kariba & Downstream	24.46	41.21
	Upstream & Downstream	31.76	32.21
	Kariba & Upstream	20.45	34.24
August	Kariba & Downstream	32.27	42.83
	Upstream & Downstream	29.55	37.32
	Kariba & Upstream	20.63	17.26
October	Kariba & Downstream	41.75	29.32
	Upstream & Downstream	44.26	44.58
November	Kariba & Upstream	15.66	10.7
	Kariba & Downstream	41.01	33.74
	Upstream & Downstream	40.91	40.98

Table 4: Simpson's Index (D_s) and Species Evenness (E) in the hinterlands of Kariba Town, the Zambezi River channel upstream of Lake Kariba and the Zambezi River channel downstream of Lake Kariba.

Section	Sampling Month	Simpson's Index (D_s)		Evenness (E)	
		2014	2015	2014	2015
Kariba	July	0.72	0.87	0.68	0.85
	August	0.74	0.83	0.67	0.78
	October	0.74	0.65	0.68	0.58
	November	0.73	0.72	0.63	0.57
Zambezi River Upstream of Kariba	July	0.89	0.91	0.93	0.94
	August	0.92	0.94	0.97	0.92
	October	0.94	0.92	0.95	0.93
	November	0.93	0.91	0.94	0.90
Zambezi River Downstream of Kariba	July	0.94	0.96	0.91	0.98
	August	0.95	0.94	0.95	0.90
	October	0.94	0.93	0.90	0.85
	November	0.91	0.92	0.85	0.83

Although species diversity was highest in aquatic environs of Kariba than in lotic habitats of the Zambezi River, evenness results showed that species abundances were more homogenous in the lotic habitats of the Zambezi River than in Lake Kariba. Evenness ranged between 0.90 and 0.97 upstream of Lake Kariba on the Zambezi River and between 0.83 and 0.98 downstream of the lake across the sampling months (Table 4). In general, species evenness was lower in Lake Kariba (ranged between 0.57 and 0.85) compared to lotic habitats of the Zambezi Valley. Except for July 2015, species evenness was below 0.8 in all the sampling months in Lake Kariba (Table 4). The avian community of Lake Kariba was dominated with respect to bird abundance by *L. crumeniferus*. Proportional abundance of *L. crumeniferus* ranged between 0.3 and 0.57 across sampling months in Lake Kariba (Table 1 and Table 2), indicating the species population size dominance in the lentic habitat. Although avian communities were significantly different in the three sections of the Zambezi Valley, the individual avian communities did not vary significantly in different seasons. Wilcoxon signed rank test showed no significant differences ($p>0.05$) in mean seasonal species abundances, species richness, species diversity and species evenness in Lake Kariba as well as in lotic habitats of the Zambezi River both upstream and downstream of the lake. These results showed insignificant changes in avian community assemblages in species composition and species proportional abundances in different seasons.

5. Discussion

Aquatic avian assemblages are often influenced by the hydrology of wetland ecosystems [12]. Hydrology and limnology cycles determine spatial and temporal distribution of resources for birds in aquatic environments. In this study, Czekanowski Coefficient and one-way ANOVA results revealed distinct differences in bird assemblages in different sections of the Zambezi Valley. These results could be a reflection of varying responses of avifauna to different habitat conditions within the Zambezi Valley. Distribution of birds often relates directly to food availability, foraging habitat and presence of breeding grounds [13, 14]. Variations in spatial distribution of these factors most likely contributed to the observed patterns of avian species composition and diversity in different sections of the Zambezi Valley. Creation of Lake Kariba on the Zambezi River channel led to establishment of diverse habitats for avifauna within the lentic environment of Kariba, which were evidently distinct from habitats previously available on the lotic environment [4, 8]. Sandbanks, flood channels, river-cut cliffs, pans and the riparian vegetation, which were specialised habitats for avian species on the Zambezi River channel disappeared in areas surrounding Kariba after inundation and in their places large expanses of open water characterised by marginal strips of emergent vegetation, sandbars and marshes were created [8, 10]. In addition to these habitat modifications, establishment of Kariba Town within the shoreline of Lake Kariba further imposed ecosystem transformations in this section of the lake.

Results of this study revealed that avian community assemblage within the hinterlands of Kariba Town was significantly different from the avian community assemblages in the lotic habitats of the Zambezi River. Effects of anthropogenic activities cannot be ruled out on the observed diversity and distribution of avifauna in the lentic environs of Kariba Town. However, besides effects of nutrient enrichment emanating from anthropogenic activities that often promote high avian species diversity in lakes, lentic ecosystems also offer a diverse range of habitats for waterbirds [15]. These habitats vary in suitability for different avian species. Highest avian species richness and abundance were observed in the shallow waters and marshy habitats of Lake Kariba. Zones of shallow waters and marshy substrate in lentic environs often attract large numbers of waterbirds, as they are rich sources of food like bulbs, roots, stems of hygrophilous plants, crustaceans, worms, frogs, fish and molluscs [15]. In this study, plovers, ibises, storks, herons and egrets were observed to favor shallow waters and marshy substrates as these habitats were most likely offering efficient foraging patches in the lacustrine environment.

Effects of lake level fluctuations on avian assemblages in Lake Kariba can also not be underestimated. Studies have revealed that lake level fluctuations influence habitat quality in lentic ecosystems [14, 16]. Water level fluctuations in lentic ecosystems shape the spatial and temporal diversity and distribution of waterbirds as they influence temporal availability of critical resources such as foraging and breeding grounds and the rate of their replenishment [15, 16, 17]. While receding waters often expose suitable foraging patches for some avian guilds like ibises, storks, herons and egrets, periodic rising of water levels may be detrimental to other species [10]. This is usually the case with species that breed on sandbanks in lentic ecosystems [5]. Emergent sandbanks are important habitats for sandbank nesters like the African Skimmer (*Rynchops flavirostris*), Whitefronted Plover (*Charadrius marginatus*) and Whitecrowned Plover (*Vanellus albiceps*), as these species totally depend on sandbanks for breeding [5, 10, 18, 19, 20]. However, *R. flavirostris*, *C. marginatus* and *V. albiceps* were recorded in Lake Kariba during our surveys suggesting that the species could have managed to adapt to the lentic environment, albeit in low densities as reflected by the species proportional densities observed in this study. On the contrary, *L. crumeniferus* a carrion feeder and shoreline dweller, was observed to be doing well in Lake Kariba within the hinterlands of Kariba Town. This was reflected by the species conspicuously high proportional abundances across all sampling months. Communities dominated by one or a few species often exhibit skewed proportional species abundances. Larger proportional abundances of *L. crumeniferus* during all sampling months within the hinterlands of Kariba Town explained lower species evenness observed in the lentic environment compared to the lotic habitats. In the lotic habitats, abundances of all species were relatively homogenous, explaining the high species evenness observed in avian communities of the Zambezi River, both upstream and downstream of Lake Kariba. No species dominated the lotic communities of the Zambezi River in terms of population size upstream and downstream of Lake Kariba. Although *L. crumeniferus* was a carrion feeder, the lake shoreline most likely provided readily available alternative food sources for the avian species. Besides carrion, *L. crumeniferus* also feeds on fish, young crocodiles, and frogs [21] which are often easily available within shorelines of lentic habitats.

Alterations of the Zambezi River flow regime can be used to explain the observed pattern of bird assemblages on the Zambezi River upstream and downstream of Lake Kariba. Avian species richness was significantly higher in lotic habitats downstream of Lake Kariba than upstream of the lake. Construction of Lake Kariba on the Zambezi River channel was reported to have caused significant changes on the Zambezi River flow regime downstream of Lake Kariba [4, 5, 8]. Alterations of the Zambezi River flow downstream of Lake Kariba were reflected in two basic characteristics of the river namely; the daily flow and the seasonal flow of the river. These two hydrology features were reported to have fallen below average downstream of Lake Kariba following construction of the lake on the Zambezi River channel in the 1960s [5, 10]. Consequently, the alluvial structure of the riverbed downstream of the lake was heavily altered by the reduced daily and seasonal flows, leading to evolution of ecosystems currently associated with the Zambezi River [5, 6, 7, 10]. Contrary, the Zambezi River flow regime upstream of Lake Kariba did not experience these hydrology alterations, leading to establishment of distinct lotic ecosystems upstream and downstream of the lake. Existence of pools attracted large numbers of waterbirds on the lotic habitat downstream of Lake Kariba. Slow moving water is often associated with formation of pools on large rivers. These pools were characterised by muddy edges, making them suitable foraging habitats for plovers, ibises, storks, herons and ducks, downstream of the lake. Pools were not common on the Zambezi River upstream of Lake Kariba, and this most likely accounted for the lower species richness and lower species abundances observed in the upstream section of the Zambezi Valley. However, a lot of hydrology and limnology factors influence distribution of birds in aquatic habitats, therefore further studies on habitat conditions are necessary to be able to fully account for the observed spatial distribution of avifauna in different sections of the Zambezi Valley.

This study revealed that avian communities did not vary significantly in different seasons. Results suggested insignificant changes in avian community assemblages in species composition and species proportional abundances in different seasons. This suggestion could be true considering that most waterbirds recorded in different sections of the Zambezi Valley have been indicated to be resident species, with the exception of four species that have been reported to be seasonal migrants and present in the Zambezi Valley during the hot and wet season [20, 21]. The Openbilled Stork (*Anastomus lamelligerus*) was observed in all the three sections of the Zambezi Valley in October and November where it preferred marshes in Lake Kariba, and river shallows on the banks of the Zambezi River. The Greenshank (*Tringa nebularia*) was only observed in pans in the lotic habitat of the Zambezi River downstream of Lake Kariba in November 2015. The Rock Pratincole (*Glareola* *nuchalis*) was observed on midstream rocks and boulders on the Zambezi River both upstream and downstream of the lake in October and November and was not recorded in Lake Kariba during our surveys. The White Stork was only recorded in Lake Kariba in October and November where it used grasslands and marshes as foraging grounds.

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