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Comparison of Shannon-Weinner's and Simpson's indices for estimating birds species diversity in Bodel forest of Gashaka Gumti national park, Nigeria

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Abstract

The decline in bird's species population and their diversity posed a great challenge to the conservators and the ornithologist. Shannon-Weinner's and Simpson Indices were used to evaluate the bird's species diversity in Bodel forest reserve of Gashaka Gumti National Park. A systematic sampling method was adopted, in which three (3) transects of 1 km in length were laid at an interval of 200 m apart in the study site. Species of birds sighted along the transect were observed and recorded. The species evenness was determined using the evenness equation $E = H'/\ln(S)$. The results on bird's species distribution revealed a total of 788 birds, belonging to 73 species and 26 families in the study area. *Lunchura cucullata* has the highest frequency of 82 birds (10.4%), this was followed by *Ploceus cucullatus* with a frequency of 50 birds (6.3%), while the least frequency of 1(0.1%) was recorded for *Eliminilongi cauda*. The two diversity indices revealed that bird species in the Bodel forest reserve of Gashaka Gumti National park are highly diverse. Simpson's index gave a value of 0.97, while Shannon-Weinner's index gave a value of 3.79 of species diversity in the Bode forest reserve. T-test conducted shows that the two indices are significant in measuring bird's species diversity, but, Shannon-Weinner's index is mostly preferred due to its lower mean standard error (0.005). The study has shown that the Bodel Forest reserve of Gashaka Gumti National Park is capable of sustaining a large population of bird species, if human interference is curtailed. Since bird's are an integral part of the ecosystem that occupy many tropic levels in a food chain ranging from producers to consumers, their occurrence should be protected and conserved as they are of helpful in environmental health indicator, pollinators, seed dispersal and as an agent of pest control.

Keywords: Species diversity, population, occurrence, protected, tropic level

1. Introduction

Understanding the processes that contribute to the distribution and diversity of birds species is still a challenge in ecological studies. Since there are many mechanisms and factors that may affect biological diversity [1]. This diversity is inserted in a dynamic and complex ecosystem, where factors such as predation, intra and interspecific interactions, competition for food and environmental and spatial factors may affect its distribution and permanence.

The rapid increase in the human population has adversely affected diversity around the globe [2]. The negative effects of this increase include pollution, climate change, deforestation, habitat loss, and invasion of exotic species [3, 4, 5].

The birds are good environment indicators and help to identify priority areas for conservation [6]. Metrics such as species currently inhabiting any specific area, their historic distribution records, and the levels of threat to the species aid in protection efforts [7, 8]. These threats are leading species toward extinction [9]. So we have designed a project to know the diversity and distribution of birds in different habitats.

Birds are organisms with high dispersal ability, that participate in many biological interactions and are usually highly faithful to specific habitats [10, 11]. In addition, birds make up the most diverse group of terrestrial vertebrates, comprising species that are excellent environmental indicators that respond quickly to subtle changes in the environment [12]. Thus, understanding the biotic and abiotic mechanisms that affect the distribution of bird species may play a key role in the discussion of the processes that contribute to the establishment and diversity of species. The Climate, particularly the dry and rainy seasons clearly affects the abundance of food resources, where rainy seasons have greater environmental complexity and higher supply

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and availability of resources [13, 14]. Climate is a key environmental variable for the occurrence and abundance of birds in the landscape, in both time and/or space [10, 11]. Also, variables such as humidity, solar radiation and air temperature affect the metabolic rate of avian species, producing different levels of physiological responses [15], thus influencing the egg hatching rates in birds, where high temperatures associated with low humidity ranges can lead to reduced reproductive success [16]. Birds help in the stability of an ecosystem by dispersing seeds and pollination of plants.

The change in climatic conditions, also puts many bird species at risk of extinction, even those currently considered safe [17]. With a global mean surface temperature increase of 1-2 °C above pre-industrial levels, many unique and threatened ecological systems will be at risk and numerous species will face extinction [18, 19].

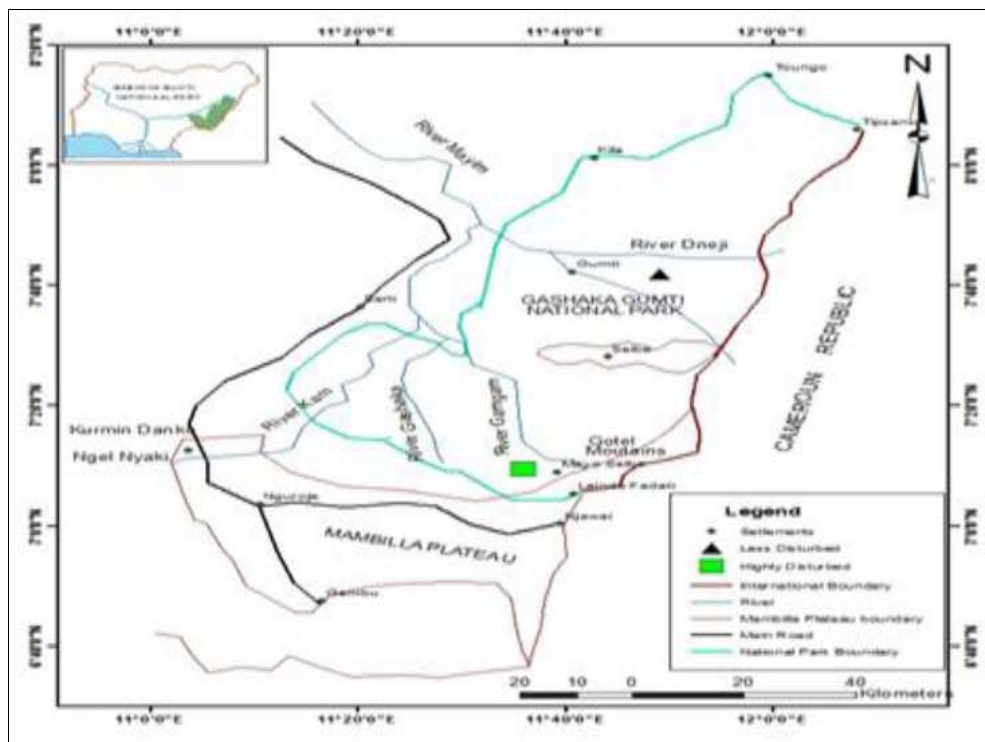
Precipitation, along with temperature, is also especially likely to influence the behaviour of migratory birds. It is expected to affect their decision to depart for migration indirectly by acting on food availability and birds' consequent ability to build up energy reserves. Drought in critical stopover areas for migratory birds affects their ability to refuel on water and prey before crossing barriers such as deserts [20]. The focus of this study is to compare the two most commonly used diversity indices with the aim of chosen the best that can be used to describe bird's species diversity in Bodel Forest Reserve of Gashaka Gumti National Park.

2. Materials and Methods

2.1 Study Area

Gashaka Gumti National Park is the largest and most diverse

park in Nigeria, covering an area of approximately 6,671sq. Km, and is split between Adamawa and Taraba States. It's located in the Northeast of Nigeria between latitudes 6° 55' and 8° 05'N, and between longitudes 11°11' and 12°13'E, with the Federal Republic of Cameroon on the eastern border (Figure 1). The park's name was derived from two of the region's oldest and most historic settlements: Gashaka village in Taraba State, and Gumti village in Adamawa State. Gashaka Gumti National Park was created (along with other seven national parks) by Decree No. 36 of August, 1991, and repealed by Decree NO. 46 of 1999 (now Act) by the merging of Gashaka Game reserve with Gumti Game Reserve [21]. The pattern of climatic zones in the study area is distorted by the influence exerted by highland areas that are located throughout the region and beyond [22]. This results in increased rainfall on the crests and western flanks of these mountain ranges and low rain shadow to the east. Annual rainfall within the park ranges from 1200mm in the north to 3000mm in the southern region. The wet season is normally experienced from April to November, and the dry season is from December to March. In the December period, there is always a low temperature at night, and ranges from 10-15 °C, while, in March and April, the temperature is as high as 40° per daytime. Temperature can be much cooler at higher altitudes and during the harmattan period that occurs from November to March [22]. The region can be divided into two major physiographic provinces. The plains of the Benue valley, which lie to and north of the region, predominantly 300m above sea level and the Adamawa Highlands are situated to the south and East of the park.



Source: [23]

Fig 1: Map of Gashaka Gumti National Park Showing the Study Area

2.2 Method of data collection

The data for this study were collected from September to December 2021. Systematic sampling technique was adopted for data collection. Three (3) lines of transect T1, T2 and T3 of one (1) km in length were laid at an interval of 200 m

across the study site. All species of bird sighted along each transect with the aid of binoculars and naked eyes were identified and recorded. Two to three minutes of keen observation was usually done on a line transects, which allowed the birds to acclimate to human presence. Also,

physical features like the colour of the head, colour of the neck, the colour of the wings and colour of the tail were also observed. The counts were done as early as 6.00 am, because birds are warm blooded and are active almost all the time. Each line transects was visited for five (5) times during the study period. Information on climatic factors of the study area was collected, and this was used for predicting the population of the bird species in the study area.

2.3 Data Analysis

The data obtained was presented in the form of a table, frequencies and percentages. Shannon diversity index was used to estimate bird's species diversity in the study.

2.4 Estimation of Diversity Indices and Equitability

The diversity Index was estimated using Shannon diversity index (H') (Equation 1) and Simpson's diversity index (Equation 2), while, species equitability (evenness) (Equation 3) was estimated using Pielou's measure of species evenness.

$$1. H' = -\sum P_i \ln P_i \quad \text{Equation (1)}$$

$$2. D = 1 - \left(D = 1 - \frac{n(n-1)}{N(N-1)} \right) \quad \text{Equation (2)}$$

$$3. E = H' / \ln(S) \quad \text{Equation (3)}$$

2.5 Comparison of the Species Diversity Indices

Student t-test was used to compare the significant effect of the

two diversity indices on the bird's population, and is of the form:

$$t = \frac{\overline{Sh} - \overline{Sm}}{\sqrt{Sp_{h,m} \left(\frac{1}{nsh} + \frac{1}{nsm} \right)}}$$

Where

t = student t-test

\overline{Sh} = mean of number of Shannon

\overline{Sm} = mean of number of Simpson's

$Sp_{h,m}$ = pooled variance

nsm, nsh = number of observation

3. Results and Discussion

3.1 Birds Species Distribution in Bodel Forest of Gashaka Gumti National Park

A total of 788 birds, belonging to 73 species and 26 families were identified in the study area. *Lunchura cucullata* has the highest frequency of 82 birds (10.41%), this was followed by *Ploceus cuculatus* with a frequency of 50 birds (6.35%), while the least frequency of 1(0.13%) was recorded for *Eliminilongi cauda* (Table 1).

Table 1: Distribution of Birds Species in Bodel Forest, Gashaka Gumti National Park

S/No.	Species	Frequency	Percentage (%)
1	<i>Acrocephalus rufescens</i>	3	0.380711
2	<i>Agapornis pullarius</i>	11	1.395939
3	<i>Antichromus minutes</i>	5	0.634518
4	<i>Apalis nigriceps</i>	7	0.888325
5	<i>Apus horus</i>	20	2.538071
6	<i>Arthreptes rectirostris</i>	14	1.77665
7	<i>Ati capilla</i>	8	1.015228
8	<i>Baeopogon indicator</i>	2	0.253807
9	<i>Bubulus ibis</i>	3	0.380711
10	<i>Buteo buteo</i>	2	0.253807
11	<i>Centropus senegalensis</i>	3	0.380711
12	<i>Chalcomitra rubessers</i>	23	2.918782
13	<i>Cinnyris cupreus</i>	11	1.395939
14	<i>Cinnyris minullus</i>	17	2.15736
15	<i>Cinnyris venustus</i>	14	1.77665
16	<i>Circus cyaneus</i>	3	0.380711
17	<i>Coccyzus abyssinicus</i>	7	0.888325
18	<i>Corvinella corvina</i>	5	0.634518
19	<i>Crinifer zonurus</i>	21	2.664975
20	<i>Cypsiurus parvus</i>	2	0.253807
21	<i>Delichon urbica</i>	3	0.380711
22	<i>Dicrurus adsimilis</i>	5	0.634518
23	<i>Egrets ardesiaca</i>	2	0.253807
24	<i>Egretta alba</i>	40	5.076142
25	<i>Elanus caeruleus</i>	11	1.395939
26	<i>Eliminilongi cauda</i>	1	0.126904
27	<i>Elminia albiventris</i>	4	0.507614
28	<i>Estrilda melopoda</i>	12	1.522843
29	<i>Euplectes hartlaubi</i>	4	0.507614
30	<i>Euplectes macrourus</i>	11	1.395939
31	<i>Ficedula albiventris</i>	3	0.380711
32	<i>Francolinus squamatus</i>	2	0.253807
33	<i>Gypohierax angolensis</i>	11	1.395939
34	<i>Halcyon senegalensis</i>	4	0.507614
35	<i>Hedydipna platura</i>	11	1.395939
36	<i>Indicator indicator</i>	3	0.380711
37	<i>Kaupifalco monogrammicus</i>	5	0.634518

38	<i>Lagonosticta senegala</i>	5	0.634518
39	<i>Lamprotornis cholopterus</i>	4	0.507614
40	<i>Lamprotornis purpures</i>	2	0.253807
41	<i>Laniarius aethiopicus</i>	2	0.253807
42	<i>Laniarius poensis</i>	4	0.507614
43	<i>Lanius minor</i>	3	0.380711
44	<i>Logonisticta rufopicta</i>	7	0.888325
45	<i>Lunchura cucullata</i>	82	10.40609
46	<i>Malimbus erythrogaster</i>	3	0.380711
47	<i>Malimbus malimbicus</i>	8	1.015228
48	<i>Malimbus rubricollis</i>	3	0.380711
49	<i>Megacerlye maxima</i>	10	1.269036
50	<i>Melaenornis edolioides</i>	3	0.380711
51	<i>Milvus migrans</i>	8	1.015228
52	<i>Muscicapa adusta</i>	2	0.253807
53	<i>Musophaga rossae</i>	3	0.380711
54	<i>Numida melagris</i>	8	1.015228
55	<i>Oxylophus jacobinus</i>	25	3.172589
56	<i>Phoeniculus purpureus</i>	2	0.253807
57	<i>Phyllastreplus poenensis</i>	10	1.269036
58	<i>Ploceus cuculatus</i>	50	6.345178
59	<i>Ploceus luteolus</i>	20	2.538071
60	<i>Poicephalus senegalus</i>	5	0.634518
61	<i>Prodotiscus regulus</i>	11	1.395939
62	<i>Psaldiprocne nitens</i>	8	1.015228
63	<i>Pseudochelidon eurystomina</i>	40	5.076142
64	<i>Pycnonotus barbatus</i>	48	6.091371
65	<i>Sagittarius serpentarius</i>	3	0.380711
66	<i>Stephanoaetus coronatus</i>	2	0.253807
67	<i>Streptopelia decipens</i>	3	0.380711
68	<i>Streptopelia semitorquata</i>	17	2.15736
69	<i>Streptopelia senegulensis</i>	11	1.395939
70	<i>Streptopelia vinacea</i>	20	2.538071
71	<i>Sylvia borin</i>	11	1.395939
72	<i>Treron calva</i>	15	1.903553
73	<i>Uraeginthus bengalus</i>	17	2.15736
Total		788	100

3.2 Birds Species Richness, Diversity, and Evenness in Bodel Forest Reserve, GGNP

The high population distribution of bird's species recorded in the study area (Figure 2, Appendix I) indicates that the savannah woodlands of GGNP are very rich in plant species and a favourable climatic conditions, attracting diverse numbers of bird species types for conservation.

In terms of bird's species diversity in the study area, Shannon Weiner and Simpson indices (Figure 3) gave a value of 3.79 and 0.97 respectively, while, the value of the evenness of birds species (Figure 4) gave a value of 1.79. The Shannon Weiner index according to ^[24] bird's conspicuousness can vary with the observer, weather, and time of the day, Hence has the high diversity and abundance of bird species types as a result of good breeding sites, Factors that promoted the high diversity include a wide variety of resources, high productivity and moderate levels of predation ^[25].

One of the most important factors observed in Bodel forest was the moderate levels of disturbances from outside the community, and the presence of arboretum, which influenced the high population of members of some families of bird species like Estrildidae, Nectariniidae, and Ploceidae. This may be due to the different plant species precisely their fruits, seeds, leaves and grasses, some insects and maggots in the arboretum, which serves as a suitable feeding, nesting and breeding habitats for the birds. This result is in line with ^[26] who reported about 910 species of birds in 90 families in his study. Also, this study agrees with the findings of ^[27] in their study of the diversity of bird species and conservation carried out in two wetlands of Upper Benue River Basin (UBRB) State, Adamawa, Nigeria in which 53 and 55 bird families, 163 and 160 species were recorded in Kiri and Gyawana Lake respectively.

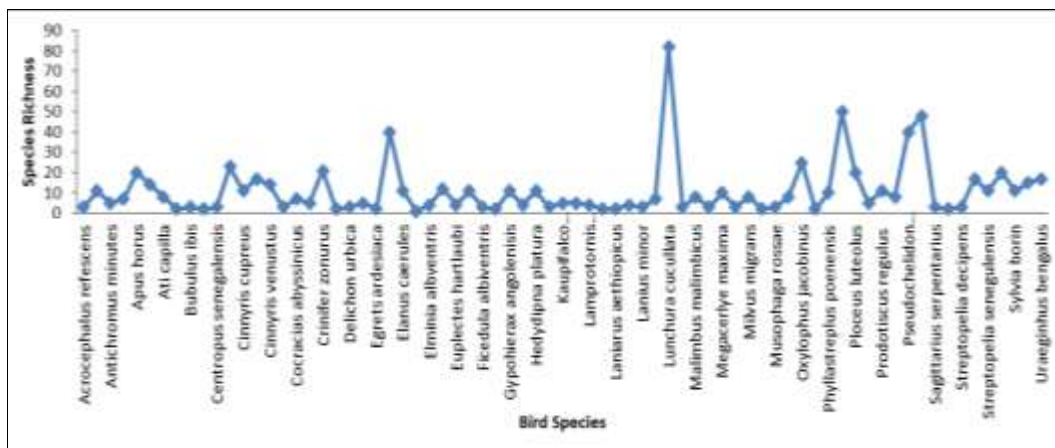


Fig 2: Bird's Species richness in Bodel Forest Reserve, GGNP

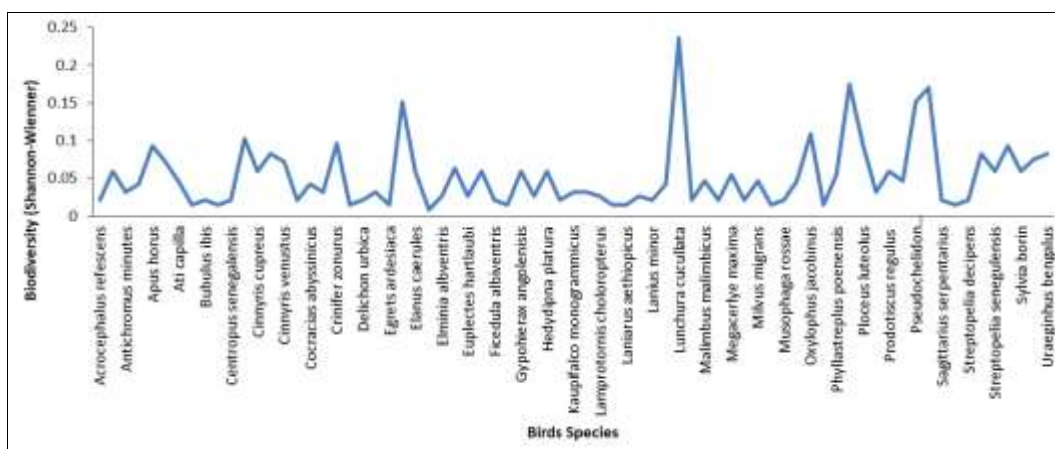
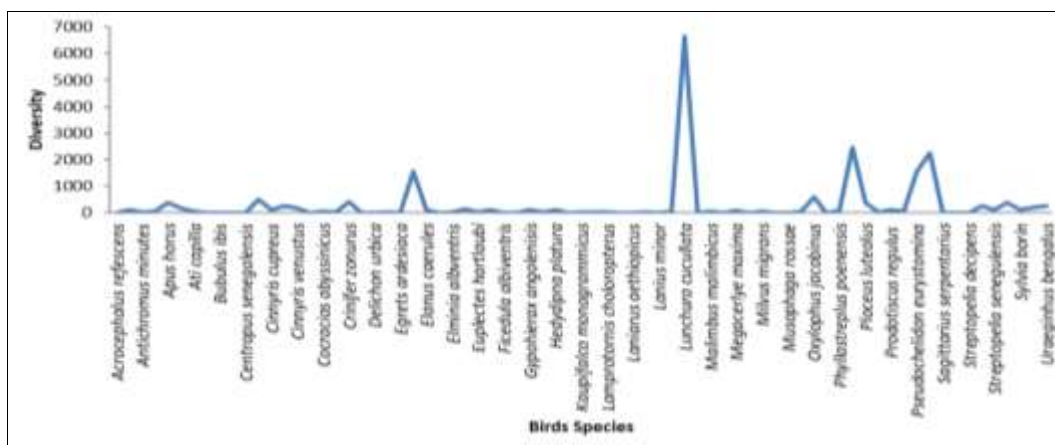


Fig 3: Bird's Species Diversity Indices (1 - Shannon-Weiner's; 2 - Index; Simpson's Index)

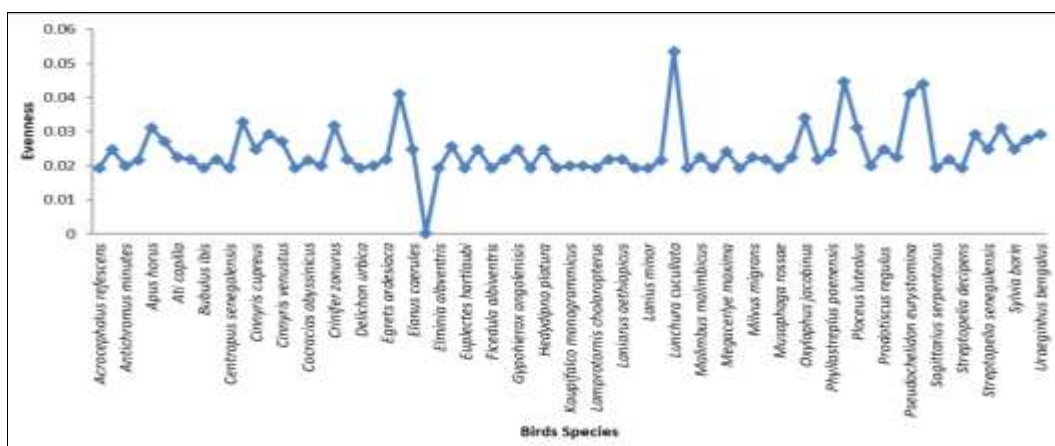


Fig 4: Birds Species Evenness in Bodel Forest Reserve, GGNP

3.3 Comparison of Shannon-Weinner's and Simpson Diversity Indices

Presented in Table 2 is the t-test result for comparing the Shannon-Weinner's and Simpson index as a measure of bird's species diversity in Bodel Forest Reserve of GGNP. The result revealed that the Shannon-Weinner index had a means

of 0.051 and a standard deviation of 0.043 respectively, while, Simpson's had a mean and standard of value 281.04 and 882.19 respectively. Also, the test further shows a high positive correlation coefficient (0.82) and a significant relationship ($p < 0.005$) between the two indices.

Table 2: T-test for comparing Birds Species Diversity

Diversity Indices	Mean	N	Std. Deviation	Std. Error Mean	Correlation	Sig.
Shannon-Weinner's	0.051	73	0.0433	0.0051	0.822	0.0003
Simpson	281.04	73	882.1899	103.252		

4. Conclusion

The study has shown that the Bodel Forest reserve of Gashaka Gumti National Park is capable of sustaining a large population of bird species, if human interference can be curtailed. The two indices compared for the assessment of bird's species diversity are good in measuring diversity in the study area, but the Shannon-Weinner index is most preferred due to lower value of mean standard error as compared to Simpson's index. Since birds are integral part of the ecosystem that occupy many trophic levels in a food chain ranging from producers to their consumers, their occurrence should be protected and conserved as they are helpful in environmental health indicator, pollinators, seed dispersal and an agent of pest control.

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Appendix I: Species Frequency, Simpson's and Shannon-Weiner's Diversity Indices

S/No.	Species	Frequency	Pi	Lnpi	Shannon-Weiner's [PiLnPi]	Simpson's [n(n-1)]
1	<i>Acrocephalus rufescens</i>	3	0.003807	-5.57089	0.021209	6
2	<i>Agapornis pullarius</i>	11	0.013959	-4.2716	0.059629	110
3	<i>Antichromus minutes</i>	5	0.006345	-5.06006	0.032107	20
4	<i>Apalis nigriceps</i>	7	0.008883	-4.72359	0.041961	42
5	<i>Apus horus</i>	20	0.025381	-3.67377	0.093243	380
6	<i>Arthropterus rectirostris</i>	14	0.017766	-4.03044	0.071607	182
7	<i>Ati capilla</i>	8	0.010152	-4.59006	0.0466	56
8	<i>Baeopogon indicator</i>	2	0.002538	-5.97635	0.015168	2
9	<i>Bubulus ibis</i>	3	0.003807	-5.57089	0.021209	6
10	<i>Buteo buteo</i>	2	0.002538	-5.97635	0.015168	2
11	<i>Centropus senegalensis</i>	3	0.003807	-5.57089	0.021209	6
12	<i>Chalcomitra rubessers</i>	23	0.029188	-3.534	0.10315	506
13	<i>Cinnyris cupreus</i>	11	0.013959	-4.2716	0.059629	110
14	<i>Cinnyris minullus</i>	17	0.021574	-3.83628	0.082762	272
15	<i>Cinnyris venustus</i>	14	0.017766	-4.03044	0.071607	182
16	<i>Circus cyaneus</i>	3	0.003807	-5.57089	0.021209	6
17	<i>Coccyzus abyssinicus</i>	7	0.008883	-4.72359	0.041961	42
18	<i>Corvinella corvina</i>	5	0.006345	-5.06006	0.032107	20
19	<i>Crinifer zonurus</i>	21	0.02665	-3.62498	0.096605	420
20	<i>Cypsiurus parvus</i>	2	0.002538	-5.97635	0.015168	2
21	<i>Delichon urbica</i>	3	0.003807	-5.57089	0.021209	6
22	<i>Dicrurus adsimilis</i>	5	0.006345	-5.06006	0.032107	20
23	<i>Egrets ardesiaca</i>	2	0.002538	-5.97635	0.015168	2
24	<i>Egretta alba</i>	40	0.050761	-2.98062	0.1513	1560
25	<i>Elanus caeruleus</i>	11	0.013959	-4.2716	0.059629	110
26	<i>Eliminilongi cauda</i>	1	0.001269	-6.6695	0.008464	0
27	<i>Elminia albiventris</i>	4	0.005076	-5.2832	0.026818	12
28	<i>Estrilda melopoda</i>	12	0.015228	-4.18459	0.063725	132
29	<i>Euplectes hartlaubi</i>	4	0.005076	-5.2832	0.026818	12
30	<i>Euplectes macrourus</i>	11	0.013959	-4.2716	0.059629	110
31	<i>Ficedula albiventris</i>	3	0.003807	-5.57089	0.021209	6
32	<i>Francolinus squamatus</i>	2	0.002538	-5.97635	0.015168	2
33	<i>Gypohierax angolensis</i>	11	0.013959	-4.2716	0.059629	110
34	<i>Halcyon senegalensis</i>	4	0.005076	-5.2832	0.026818	12
35	<i>Hedydipna platura</i>	11	0.013959	-4.2716	0.059629	110
36	<i>Indicator indicator</i>	3	0.003807	-5.57089	0.021209	6
37	<i>Kaupifalco monogrammicus</i>	5	0.006345	-5.06006	0.032107	20
38	<i>Lagonosticta senegala</i>	5	0.006345	-5.06006	0.032107	20
39	<i>Lamprotornis choleropterus</i>	4	0.005076	-5.2832	0.026818	12
40	<i>Lamprotornis purpureus</i>	2	0.002538	-5.97635	0.015168	2
41	<i>Laniarius aethiopicus</i>	2	0.002538	-5.97635	0.015168	2
42	<i>Laniarius poensis</i>	4	0.005076	-5.2832	0.026818	12
43	<i>Lanius minor</i>	3	0.003807	-5.57089	0.021209	6
44	<i>Logonosticta rufopicta</i>	7	0.008883	-4.72359	0.041961	42
45	<i>Lunchura cucullata</i>	82	0.104061	-2.26278	0.235467	6642
46	<i>Malimbus erythrogaster</i>	3	0.003807	-5.57089	0.021209	6
47	<i>Malimbus malimbicus</i>	8	0.010152	-4.59006	0.0466	56
48	<i>Malimbus rubricollis</i>	3	0.003807	-5.57089	0.021209	6
49	<i>Megacerlye maxima</i>	10	0.01269	-4.36691	0.055418	90
50	<i>Melaenornis edolioides</i>	3	0.003807	-5.57089	0.021209	6
51	<i>Milvus migrans</i>	8	0.010152	-4.59006	0.0466	56
52	<i>Muscicapa adusta</i>	2	0.002538	-5.97635	0.015168	2
53	<i>Musophaga rossae</i>	3	0.003807	-5.57089	0.021209	6
54	<i>Numida melagris</i>	8	0.010152	-4.59006	0.0466	56
55	<i>Oxylophus jacobinus</i>	25	0.031726	-3.45062	0.109474	600
56	<i>Phoeniculus purpureus</i>	2	0.002538	-5.97635	0.015168	2
57	<i>Phyllastreplus poenensis</i>	10	0.01269	-4.36691	0.055418	90
58	<i>Ploceus cucullatus</i>	50	0.063452	-2.75748	0.174967	2450
59	<i>Ploceus luteolus</i>	20	0.025381	-3.67377	0.093243	380
60	<i>Poicephalus senegalus</i>	5	0.006345	-5.06006	0.032107	20
61	<i>Prodotiscus regulus</i>	11	0.013959	-4.2716	0.059629	110

62	<i>Psalidoprocne nitens</i>	8	0.010152	-4.59006	0.0466	56
63	<i>Pseudochelidon eurystomina</i>	40	0.050761	-2.98062	0.1513	1560
64	<i>Pycnontus barbatus</i>	48	0.060914	-2.7983	0.170455	2256
65	<i>Sagittarius serpentarius</i>	3	0.003807	-5.57089	0.021209	6
66	<i>Stephanoaetus coronatus</i>	2	0.002538	-5.97635	0.015168	2
67	<i>Streptopelia decipens</i>	3	0.003807	-5.57089	0.021209	6
68	<i>Streptopelia semitorquata</i>	17	0.021574	-3.83628	0.082762	272
69	<i>Streptopelia senegalensis</i>	11	0.013959	-4.2716	0.059629	110
70	<i>Streptopelia vinacea</i>	20	0.025381	-3.67377	0.093243	380
71	<i>Sylvia borin</i>	11	0.013959	-4.2716	0.059629	110
72	<i>Treron calva</i>	15	0.019036	-3.96145	0.075408	210
73	<i>Uraeginthus bengalus</i>	17	0.021574	-3.83628	0.082762	272
Total		788			3.793263	20516