J Wet Eco 2011 (5): 48-58

Journal of Wetlands Ecology

Wetland Friends of Nepal (WFN)
http://www.nepjol.info/index.php/jowe
ISSN: 2091-0363

Research Article

Density and diversity of birds in the wetlands of Yankari Game Reserve, Bauchi, Nigeria

Taiwo Crossby Omotoriogun [1], **Joseph Daniel Onoja** [2], **Talatu Tende**[2], **Shiiwua Manu**[1] and **Ulf Ottosson**[1]

[1]*A.P Leventis Ornithological Research Institute, Biological Conservatory, Laminga, P.O, Box 13404, Jos, Nigeria*
[2] *APLORI Research Centre Yankari Game Reserve Bauchi, Nigeria*

***Received:* 2011-05-28** ***Accepted:* 2011-08-09** ***Published:*2011-12-30**

Abstract

The biological, chemical, and physical operations and attributes of wetlands are vital in facilitating food resources, water, and shelter, which many terrestrial bird and waterbird species rely on for their daily requirments. Wetlands in Yankari Game Reserve, Nigeria are key stone ecosystem that provides a stopover, breeding and/or foraging platform for migratory and resident birds. This study determined the density and diversity of birds in the wetlands of Yankari Game Reserve. Ten wetlands within the reserve were identified and surveyed. The sizes (kilometer square) and isolation distances (kilometer) of the wetlands were measured (using GPS and Map Source) to determine their effects on bird density and diversity. Point count survey method was used to count birds. One hundred and twenty three species of birds belonging to 51 families were recorded in the wetlands. Significant patterns in the densities of birds were observed across the wetlands (Kruskal-Wallis H, X^2=167.116, P=0.001) and also sizes of wetlands (Wilcoxon test: Z= -2.803, P=0.005). There was differences in mean number of birds in survey time (Kruskal-Wallis, X^2=15.784, P=0.045). Evenings were probably most preferred in bird-wetland utilization.

Key words:*Density, Diversity, Yankari ecosystem, Wetland utilization*

Corresponding Author: T.C. OMOTORIOGUN, e-mail: liberty_omos@yahoo.com, Phone: +2348169129747,

INTRODUCTION

Habitat requirements of all animals cut across similar resources (Weller 1999). Water is essential to maintain physical and biological processes, food for growth, shelter from potential predators and undisturbed space for meeting social and other life functions including nesting, foraging, loafing and moulting (Rajpar and Zakaria 2009). Seasonally changing climatic conditions such as rainfall, temperature and weather as often experienced in a tropical world, especially in semi-arid regions, usually pose constraint to continuous resource availability (Davies 1984; Dean 1997; Walker 1985). Under this condition, extensive nomadic movement and population shift is expected in search for available resource. Resource scarcity, unpredictability and patchy distribution usually initiate a corresponding change in home range size, habitat use, biotic and competitive interactions among and between individuals in a variety of animal species (Newton 1998; Krebs and Davies 1993; McIntyre and Wiens 1999; DeVault *et al.* 2004; Eide *et al.* 2004; Prange *et al.* 2004; Wauters *et al.* 2005; Molokwu *et al.* 2008). In a dynamic world, not only are resources scarce or patchily distributed but habitat quality is also questionable. The obviously increasing public concern regarding environmental contaminations has led to increase activities of researchers and specialists to monitor, evaluate, manage and mediate ecological damage (Marcos *et al.* 2007).

Wetland habitats and resources are currently being threatened by anthropogenic and biogeophysical factors such as population pressure and rapid urbanization, mining and pollution, logging and overgrazing, desertification and drought as well as invasion by alien flora and fauna species (Orimoogunje 2009). The degradation of and/or threats to wetlands through pollution as a result of the use of xenobiotic (Dike *et al.* 2004), generally diminish and incapacitate the vital ecosystem function and services they provide. The critical loss in wetland biodiversity at local and global levels due to anthropogenic influence, especially those linked to human induced and activities taking place within their catchments is a major concern, particularly in bird conservation (Wilen 1989; Duncan *et al.* 1999; and Mads *et al.* 2002). Threatened and non-threatened bird species depend on these habitats to fulfill their daily requirements (Reddy 2010). Wetlands are key habitats capable of supporting large populations of migratory and resident bird species. This disproportional habitat integrity is due to high nutritional values, outstanding productivity and widely diverse micro-habitats (Whittaker and Likens 1973; Gibbs 1993; Paracuellos 2006). It is recognized that freshwater holds more than 40% of bird species of the entire world and 12% of all animal species (Kirsten and Brander 2004; Rajpar and Zakaria 2009). In addition, the socio-economic, scientific and ecological significance of wetlands are overwhelming (Orimoogunje 2009); their roles in water storage, storm protection, river bank stabilization, ground water recharge and/or discharge and water purification as well as offering tremendous values such as water supply, fisheries, agriculture; and exceptional symbolic attributes of cultural heritage, wildlife sanctuaries to humanity (Ramsar Convention Bureau 2000) are important in the maintenance of the world ecosystems.

Water is a major component of wetlands and also a medium to transport pollutants. Its effect on wetland habitat variability due to fluctuations is recognized to impact wetland hydrology. Altering of timing in water inputs causes changes in water parameters such as depth, solute concentration and temperature (Wilson and Keddy 1986; Gaudet and keddy 1995; Weiher *et e al.*1996 and Euliss *et al.* 2004) and subsequently on the food availability, sizes, fauna and flora species (Castling et al 1986; Shay and Shay 1986; Chee and Vitt 1989; Engelhardt and Ritchie 2001; Lentz-Cipollini and Dunson 2006; Deshkar 2008). This influence directly or indirectly bird congregation (Paracuellos 2006; Jaksic 2004; Lagos *et al* 2008). A change in wetlands size and quality through short-term or long-term is capable of influencing species composition (Weller 1999; Reed 1988). Most studies on wetland productivity indicate that diversity and population of bird species are greatest in areas with unstable water regimes (Mitsch and Gosselink 1993). Though, the importance of habitat structure and complexity to avian ecology has been studied extensively (MacArthur 1961 and MacArthur *et al.* 1962) and positive correlations between habitat cover, habitat area, species richness and local abundance have been found (MacArthur 1961; Venier and Fahrig 1996), some habitat characteristics that are subject to change over time could influence birds selection criteria for breeding and non-breeding utilization.

When assessing environmental impact over time, it is not technically possible to measure the totality of both biotic and abiotic components that can modify the ecological status of a given ecosystem. Instead, suitable biological sentinels such as birds can service as reliable bioindicators of wider ecological conditions (Movalli 2000) and predictors of future environmental change (Moreno 2003; Rajpar and Zakaria 2009). Therefore, it's a priority to monitor the bio-physicochemical parameters of wetlands and its changes (Okaeme *et.al.* 1989) in order to develop rational strategies and monitoring for the stability, sustainable utilization and management of the available wetlands, to maintain the natural properties of the ecosystem (Davis 1993). This study determined the density, diversity and time of wetland-resource utilization by bird species in Yankari Game Reserve Nigeria.

MATERIAL AND METHODS

Study area

Yankari Game Reserve (YGR) is positioned on latitude 09°50' N and longitude 010°30' E at about 150-750m above sea level (Fig 1). Tourism wise, it is one of Nigeria's most famous and largest reserves in the Sudan–Guinea savanna vegetation belt. It approximately covers a total land mass of 2244.10sqkm and annually records rainfall and temperature ranges of 900-1000 mm and 12-36°C respectively. It is bisected by River Gaji- a main stream to which five springs plus River Yashi are tributaries. The riverine system in YGR is well developed; especially towards Wikki settlement. Approximately more than 10% of the total land area of the Reserve constitutes flood plains and swamps along the bank of River Gaji. For this study, ten wetland sections were surveyed along the bank of River Gaji, namely Mu'Azu Lamido, Mawulgo, Mawulgo Annex, Crocodile Zone, Magama, Baba Ilori, Tupper-Carry, Kan Giwa and Guruntu.

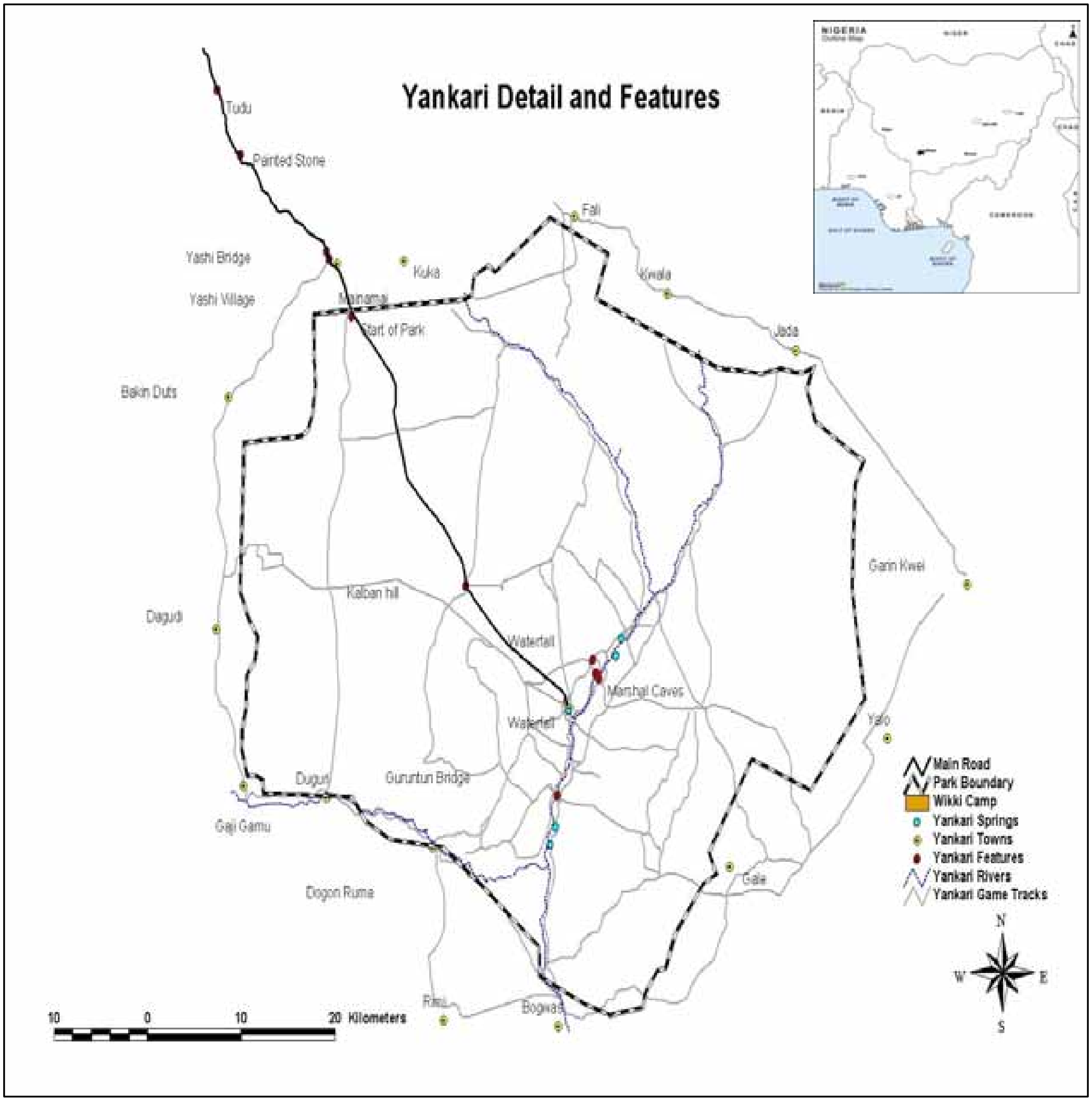


Figure 1 Location map of Yankari Game Reserve Bauchi State Nigeria.

Bird surveys

Bird surveys were carried out at Yankari wetlands using point count technique to determine density and diversity within ten wetlands. Twenty point-count stations at least 200 m apart from one another were established within wetlands. The use of spaced series of points for counting birds in an area provides a more representative data particularly in more fine-grained and opened habitat (Bibbey *et al.* 2000; Gregory and Jeffery 1998; Wasilco and Soulliere 1995). Birds were surveyed thirty consecutive times for each station to obtain reliable estimate and to reduce bias. The replication of point count stations increases precision and provides reliable result (Petit *et al* 1995; Smith *et al.* 1993).

Bird data such as number of birds seen, heard and flying including perpendicular distances between observer and patched birds were collected in the mornings (0600hr-1000hr GMT) and evenings (1500hr-1800hr GMT). Ten wetlands were visited in the order of five wetlands per morning and evening alternatively. The detection of birds within each point count station was done for ten-minutes. Ten-minutes should be fairly long enough to detect sufficient number of individuals with minimal effort and disturbance (Lee and Marsden 2008; Jimenez 2000; Lynch 1995; Gutzwiller 1991). Longer time at a point allows the detection of more species at such successive interval but time should be fixed to avoid multiple counts as this could contravene the assumption of distance sampling and also inflate density estimates. A novel approach to this study involved careful approach to wetlands to avoid displacement and scaring of birds until 75% of count made before observer's detection. This corrects the assumption that birds flushed from a point never return to point. Bird observations were made using a pair of binoculars (8X42) and a telescope. Field guide by Borrow and Demey (2001) aided identification of birds in difficult situations. Size and distances apart of wetlands were determined with the aid of a Global Positioning System (GPS), through marking positions while walking the edges of wetlands. Device was thereafter logged to Map Source to estimate area and distance by point linkage system.

Data analysis

The density of bird species was determined using Distance Version 4.1. Density estimates were only determined for bird species with large enough sample sizes, 60-80 encounters (Buckland *et al*. 1993). Species diversity was calculated for birds across wetlands and time of day using Shannon-Weiner's diversity index (H). Kruskal-Wallis test was used to determine the effect of time of day on the diversity and density of birds in wetlands. Wilcoxon test was also used to test variation in mean, density and diversity of birds with respect to size (km^2), isolation distance (km) of wetland.

RESULTS AND DISCUSSION

Point count method detected a total of 10,180 individual birds that belong to 123 species and 51 families in Yankari Game Reserve wetlands. Out of the total number of species, 32 bird species belong to water birds (4673 detections; 26.83%) and 91 bird species belong to terrestrial birds (5507 detections; 73.12%) (Appendix 1 and 2)

Bird means, density, diversity and wetland size

Mean of birds recorded showed a significant variation across wetlands (Wilcoxon test Z= -2.191, P=0.028). Highest mean were obtained in Mawulgo (12.64$\pm$0.89), Salt Lick B (12.34$\pm$0.49), Mu'Azu Lamido (11.92$\pm$1.06) and Baba Ilori (11.77$\pm$0.33). Alternatively, Guruntu and Tupper-Carry had lowest bird means of 6.00$\pm$0.81 and 6.58$\pm$0.74 respectively (Table 1). Mean of birds varied positively with size of wetlands (Wilcoxon test Z = -2.803, P=0.017) (Fig 2a).

Overall density estimate of birds ranged from 0.994 - 210.95 birdskm^{-2} with 96% confidence intervals (CI). Tafokere had the highest density of birds (210.95$\pm$215.08 birdskm^{-2}) while Mawulgo had lowest (0.99$\pm$1.20 birdskm^{-2}) (Table 1). Significant difference was detected in the density of birds across wetlands (Kruskal-Walli H, X^2= 167.116, P=0.001). There was also a negative relationship between density of birds and sizes of wetlands (Fig 2b). Five waterbird species recorded highest density in wetlands namely African Jacana *Actophilornis africana* (5.50$\pm$3.65 birdskm^{-2}), Spur-winged Lapwing *Vanellus spinosus* (2.71$\pm$2.49 birdskm^{-2}), Grey-headed Kingfisher *Halcyon leucocephala* (2.38$\pm$2.13 birdskm^{-2}), Senegal Thick-knee *Burhinus senegalensis* (1.17$\pm$1.07 birdskm^{-2}) and Green-backed Heron *Butroides striata* (1.00$\pm$0.72 birdskm^{-2}). Among terrestrial birds, highest density was recorded for Village Weaver *Ploceus cucullatus* (3.94$\pm$3.82 birdskm^{-2}), Red-throated Bee-eater *Merops bulocki* (1.60$\pm$1.10 birdskm^{-2}) and Vinaceous Dove *Streptopelia vinacae* (1.202$\pm$1.07 birdskm^{-2}).

Bird diversity in wetlands ranged from 0.02$\pm$0.00 - 0.30$\pm$0.02 (Table 1). A negative relationship was observed between diversity of birds and sizes of wetlands (Fig 2c).

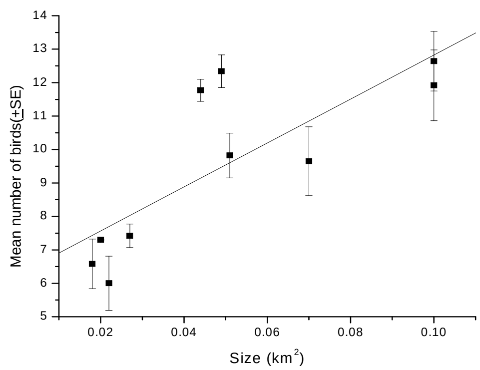
Time of day and wetland utilization

The mean of birds recorded by hours of the day in wetlands differ between surveys. Morning surveys showed significant difference in bird means (Kruskal-Wallis, X^2=10.186, P=0.017). The highest mean number of birds in wetlands was recorded in the evenings (10.03$\pm$1.1, N=60 observations) and lowest in the mornings (9.15$\pm$0.79, N=60 observations). No significant difference was obtained in bird means by hours of day during evening surveys

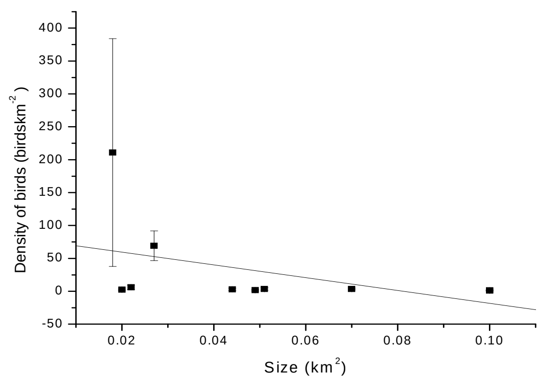
(Kruskal-Wallis, X^2=5.447, P=0.244). However, there was a significant difference in means of bird between mornings and evenings surveys (Kruskal-Wallis, X^2=15.784, P=0.045) (Fig 2d).

Wetlands	Means	Diversity	Density (birdskm^{-2})	Density at 96% CI (birdskm^{-2})
Mu'Azu Lamido	11.92±1.06	0.21±0.01	1.47±1.74	0.81 - 2.67
Mawulgo	12.64±0.89	0.20±0.01	0.99±1.20	0.53 - 1.86
Mawulgo Annex	7.30±0.01	0.27±0.00	2.349±3.04	1.11 - 4.96
Crocodile Zone	9.65±1.03	0.24±0.01	3.519±4.94	1.48 - 8.39
Magama	9.82±0.67	0.23±0.01	3.45±3.99	1.98 - 6.01
Baba Ilori	11.77±0.33	0.21±0.00	2.89±3.26	1.76 - 4.76
Salt Lick B	12.34±0.49	0.20±0.00	1.64±1.79	1.07 - 2.51
Tupper-Carry	6.58±0.74	0.29±0.02	210.95±215.08	173.13 - 257.03
Kan Giwa	7.42±0.35	0.27±0.01	69.152±116.72	22.69 - 210.74
Gurutun	6.00±0.81	0.30±0.02	6.007±6.90	3.51 - 10.28

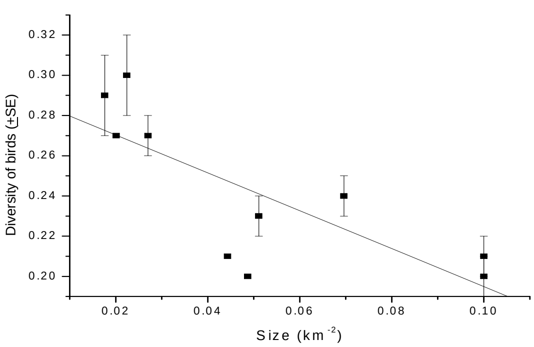
Table 1 Estimate of bird means, density and diversity in the wetlands of Yankari Game Reserve



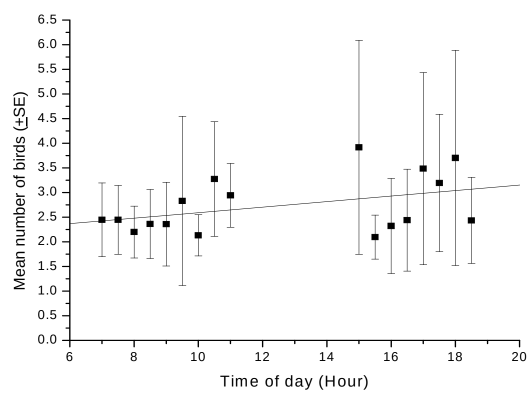
a) Bird means and wetlands size



b) Bird density and wetlands size



c) Bird diversity wetlands and size



d) Bird means per hour of the day

Figure 2 Relationship between means, density, diversity and wetlands size in Yankari Game Reserve.

The socio-economic implication of wetlands mismanagement is costly. Increasing pressure on wetland resource due to anthropogenic activities, climatic and edaphic factors has caused a serious decline to wetland fauna especially waterbirds throughout the world (Greenwood *et al.* 1995; Laurence 1999). Monitoring accurate population size and population changes of bird species in wetlands is an important factor in the understanding of bird population status, community structure and quality of wetlands existing in a given area (Thompson 2002; De Sanete *et al.* 2005; Kaminski *et al.* 2006).

The outcome of variation in the mean of birds with wetland sizes (Fig 2a) was consistent with other studies in a variety of environment (Nilsson 1986; Gali *et al.* 1976; Blake and Karr 1987; Robbins *et al.*1989). Increased habitat heterogeneity is associated with an increase in the number of species in a habitat (He and Legendre 1996; Elmberg *et al.* 1994) due to allowance for co-occurrence and habitat requirements of more species. In addition, species occur in areas of more diverse habitat because of spatial segregation that reduces competition (Roth 1976). An area of a habitat patch that is suitable for a particular species is dependent on the organism's sensitivity to resources, size, shape and location of the patch (Sisk *et al.* 1997). Furthermore, the generalist and specialist habits of some species also added to why they exist at low or high level in a given habitat.

With respect to density, a large number of bird species can be accommodated in an environment at two extremes: each species may have different habitat preference and feed throughout this habitat on all kinds of food, or all the species may share the entire habitat with each species feeding on a variety of food in a different situation within the habitat (Dami and Manu 2008). Differences among species in their abilities to exploit limiting resources affect their coexistence (Tilman 1982). Single wetlands often cannot provide all the necessary resources; therefore, it is important to have different wetlands in close juxtaposition to provide an adequate foraging, nesting and over wintering guilds. The size of the individual wetland basin may indeed be important for certain area-sensitive bird species and groups in marshes (Nudds 1992; Vanrees-Siewart and Dinsmore 1996). The increase in species richness with increasing wetland area was demonstrated in Brown and Dinsmore (1986). Species with highest density threshold, for example, the African Jacana, Village Weaver, Spur-winged Lapwing, Grey-headed Kingfisher, and Red-throated Bee-eater as recorded in this study, were dependent on wetlands for roosting, breeding and foraging. The Red-throated Bee-eaters in particular takes advantage of edges to maximize foraging, because wetland openness often provide clear opportunities for catching flying insects. It is therefore not surprising that some species occurred at high density in the wetlands. The low density of other species may be attributed to their occasional utilization such as for thermoregulation, depending on use type as situation warrants (Weller 1999). Some species that are difficult to detect due to their behavior and mode of life or whether partially migratory or erratic, for example, Sacred Ibis *Threskiornis aethiopica,* though mainly resident may also occur at low density (Borrow and Demey 2001).

The clear-cut in bird diversity was not observed in YGR wetlands, this may be an indication of equal availability of habitat requirements for food, cover, roosting and others across the wetlands. Diversity was negatively correlated with size of wetlands (Figure 2c). This is not consistent with other reports in which diversity increased with increased size of habitat (Brown and Dinsmore 1986). Size per se may not explain diversity in YGR wetlands at the time the survey was carried out because of the constriction of resource to certain location within the wetlands. Other factors such as habitat structure, weather (rainfall), social interactions and predators may also affect the distribution and habit selection of wetland by birds. (Zakaria *et al.* 2009)

To explain the time of wetland utilization, this study estimated highest mean of birds during 1500hr-1800hr GMT in wetlands. The occurrence is probably due to the influx of savanna and forest bird species to wetlands for resource exploitation. Some species that are sensitive to temperature changes also take cover in cooler thickets associated with wetlands (Burger *et al.* 1984). Similarly, the abundant outburst of insects, plus other routine of drinking, bathing and loafing in water pools may influence an increase in mean of birds encountered at this time of day (Eldrige and Krapu 1988; Weller 1999). In contrast, studies on woodland savanna habitat reported more bird counts in the early hours of the day (Dami and Manu 2008). However, this study only gave consideration to mornings (0600hr-1000hr GMT) and evenings (1500hrs-1800hr GMT).

CONCLUSION AND RECOMMENDATIONS

This study suggests that YGR wetlands are vital feeding ground to both terrestrial and waterbirds especially when resources become limiting on the uplands in the dry season. The wetland sizes, vegetation structure and composition and density of resources explain why they are key habitat in Yankari ecosystem. Though, the water parameters of the wetlands in this study were not considered, therefore, it is recommended that proper monitoring of the physico-chemical properties should be carried out to check pollutant influx that may be harmful to the ecosystem. Animals depend directly or indirectly on plants and plants in turn depend on water chemistry, animal distribution is expected to change with change in water chemistry.

Acknowledgements

Authors are grateful to Dr A.P Leventis, Sir Phil Hall and A.P Leventis Ornithological Research Institute, University of Jos. Special thanks to the management of Yankari Game Reserve and Bauchi State Government for permission to use the wetlands in this area for the study.

REFERENCES

Acuna R, Contras F, Kerekes J. 1994. Aquatic bird densities in two coastal lagoon system in Chiapas state Mexico, a preliminary assessment. *Hydrobiologia* 279/280:101-106.

Bibbey CJ, Burgess N, Hill DA. 2000. Bird Census Techniques. Academic Press, London.

Blake JG, Karr JR. 1987. Breeding birds of isolated woodlots: area and habitat relationships. *Ecology* 68:1724-1734.

Borrow N, Demey R. 2001. Field guide to the birds of Western Africa. London: Christopher Helm. Pp 1-512.

Brown M, Dinsmore JJ. 1986. Implication of marsh size and isolation for marsh bird management. *Journal of Wildlife Management* 50:392-397.

Buckland ST, Anderson DR, Burnham KP, Laake JL, Borchers DL, Thomas L. 2001. Introduction to distance sampling: estimating abundance of biological populations, Oxford University Press, Oxford.

Burger J, Trout JR, Wander W, Ritter GS. 1984. Jamaica bay studies VII: Factors affecting the distribution and abundance of ducks in a New York estuary. *Estuarine Coasta and Shelf Science* 18:673-89.

Catling PM, Freedman B, Stewart C, Kerekes JJ, Lefkovitch LP. 1986. Aquatic plants of acid lakes in Kejimkujik National Park, Nova Scotia; floristic composition and relation to water chemistry. *Canadian Journal of Botany* 64:724-729.

Chee WL, Vitt DH. 1989. The vegetation, surface water chemistry and peat chemistry of moderate-rich fens in central Alberat, Canada. *Wetlands* 9:227-261.

Crick HQP, Marshall PJ. 1981. The birds of Yankari Game Reserve, Nigeria: their abundance and seasonal occurrence. *Malimbus* 3:103-113.

Dami D, Manu SA. 2008. The Bird Species of Pandam Wildlife Park and the Surrounding Farmland. *Science World Journal* 3(1):7-11.

Davis TJ. 1993. Towards the wise use of wetlands, Wise Use Project. Ramsar Convention Bureau, Gland, Switzerland.

Davies S. 1984. Nomadism as a response to desert conditions in Australia. *J. Arid Environ* 7:183–195.

Dean WRJ. 1997. The distribution and biology of nomadic birds in the Karoo, South Africa. *J. Biogeog* 24:769–779.

De Sanete DF, Nott MP, Kaschube DR. 2005. Monitoring, Modeling and Management: Why Base Avian Monitoring on Vital Rates and How Should it be done. In: Birds Conservation Implementation and Integration in the Americas, Ralph, C.J. and T.D. Rich (Eds.). U.S. Forest Service, Albany, California, USA. pp: 295-308.

Deshkar SL. 2008. Avifaunal diversity and Ecology of wetlands in semi-Arid zone of Central Gujarat with reference to their conservation and categorization. Ph.D. Dissertation. The Maharaja Sayajirao University of Baroda, Vadodara India.

DeVault TL, Reinhart BD, Brisbin IL, Rhodes OE. 2004. Home ranges of sympatric Black and Turkey Vultures in South Carolina. *Condor* 106:706–711.

Dike NI, Ezealor AU, Oniye SJ. 2004. Concentrations of Pb, Cu, Fe and Cd during the dry season in River. Jakara, Kano, Nigeria. *Chemclass Journal* 1:78-81.

Duncan P, Hewison AJM, Houte S, Rosoux R, Tournebiz T, Dubs F, Burel F, Bretagnolle V. 1999. Long-term changes in agricultural practice and wildfowling in an internationally important wetland, and their effect on the guild of wintering ducks. *Journal of Applied Ecology* 36 (1):11-23.

Eide NE, Jepsen JU, Prestrud P. 2004. Spatial organization of reproductive Arctic foxes Alopex lagopus: responses to changes in spatial and temporal availability of prey. *J. Anim. Ecol* 73:1056–1068.

Eldridge JL, Krapu GL. 1988. The influence of diet quality on clutch size and laying pattern in mallard. *Auk* 105:102-93.

Elmberg, J, Nummi P, Poise H, Sjoberg K.1994. Relationship between species number, lake size and resource diversity in assemblages of breeding waterfowl. *Journal of Biogeography* 21:75-84.

Engelhardt K, Ritchie M. 2001. Effects of macrophyte species richness on wetland ecosystem functioning and services. *Nature* 411:687–89.

Euliss N, LaBaugh J, Fredrickson L, Mushet D, Laubhan M, Swanson G, Winter T, Rosenberry D, Nelson R. 2004. The wetland continuum: a conceptual framework for interpreting biological studies. *Wetlands* 24:448-58.

Gali A, Leck CF, Forman RTT. 1976. Avian distribution patterns in forested islands of different size in central New Jersey. *Auks* 93:356-364.

Gaudet CL, Keddy PA. 1995. Competition performance and species distribution in shorelines plant communities: a comparative approach. Ecology 76: 280-91.

Gibbs JP. 1993. The importance of small wetlands for the persistence of local populations of wetland-associated animals. *Wetlands* 13:25-31.

Gopal B, Sharma KP. 1990. Ecology of plant population I: Growth. In: Ecology and management of aquatic vegetation in India subcontinent (Gopal B. ed.). Kluver Academic Publisher, Netherland. pp. 79-106.

Greenwood JJD, Baillie SR, Gregory RD, Peach WJ, Fuller RJ. 1995. Some new approaches to conservation, monitoring of British breeding birds.*Ibis* 137:16-28.

Gregory JS, Jeffery MZ. 1998. Comparison of bird species richness and abundance and grassland and a grassland-wetland complex in Eastern Upper Michigan. *Wildlife Division Report* No 3277.

He F, Legendre P. 1996. On species-area relationship. *American Naturalist* 148:719-37.

Ishwara BP, Christopher SS, Hosetti BB. 2009. Avifaunal diversity of Anekere wetland, Karkala, Udupi district, Karnataka, India. *Journal of Environmental Biology* 30(6):1059-1062.

Kaminski MR, Baldassarre GA, Pearse AT. 2006. Waterbird responses to hydrologuical management of wetlands reserve habitats in New York. *Wildlife Society Bull* 34:921-926.

Kirsten S, Brander L. 2004. The Economic Values of the World's Wetlands. Living water. Amsterdam.

Krebs JR, Davies NB. 1993. An Introduction to Behavioural Ecology. Oxford: Blackwell Science Ltd.

Laurence WF. 1999. Reflection on the tropical deforestation crisis. *Biol. Conserv* 911: 109-117.

Lentz-Cipollini KA, Dunson WA. 2006. Abiotic features of Seasonal Pond habitat and Effects on Endangered Northeastern Bulrush, *Scirpus ancistrochaetus* Schuyler, in Central Pennsylvania. *Castanea* 71:272-281.

MacArthur R. 1964. Environmental factors affecting bird species diversity. *American Naturalist* 158:387-397.

MacArthur RH, MacArthur J, Preer J. 1962. On bird species diversity II. Prediction of bird census from measurements. American Naturalist 96:167-174.

Mads C, Forchhamemmer EP, Chris Nils. 2002. North Antlantic Oscillation timing of long-and short-distance migration. *Journal of Animal Ecology*: 71(6):1002-10114.

Marcos PL, de Mendoza MH, Beceiro AL, Rodriguez FS. 2008. Heavy metal (Cd, Pb, Zn) and metslloid (As) content in raptors species from Galicia (NW Spain). *Ecotoxicology and environmental safety* 70:154-162.

Movalli PA. 2000. Heavy metals and other residues in feather of laggar falcons Falco biamicus jugger from six districts of Parkistan. *Environ. Pollut* 109:267-275.

McIntyre NE, Wiens JA. 1999. Interactions between landscape structure and animal behavior: the roles of heterogeneously distributed resources and food deprivation on movement patterns. *Landsc. Ecol* 14:437–447.

Mitsch WJ, Gosselink JG, 1993. Wetlands, 2nd edn. New York: van Nostrand Reinhildt.

Molokwu MN, Olsson O, Nilsson JÅ, Ottosson U. 2008. Seasonal in patch use in a tropical African environment. *Oikos* 117:892-898.

Moreno MD. 2003. Toxicologia Ambiental. Evaluation de Riesgo parala Salud Humana. McGraw-Hill, Madrid.

Newton I. 1998. Population limitation in birds-Academic Press.

Nilsson SG. 1986. Are bird communities in small biotope patches random samples or from communities in large patches? *Biological Conservation* 38:1979-2004.

Nudds TD. 1992. Pattern in breeding waterfowl community. In Batt BDJ, Afton AD, Anderson MG, Ankney CD, Johnson DH, Kadlec JA, Krapu GL (Eds): Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis, MN, USA. P 540-567.

Okaeme AN, Haliru M, Wari M. 1989. Utilization of aquatic bird fishing communities of Lake Kainji. NIFFR Annual Report, pp. 40–45.

Orimoogunje OIO, Oyinloye OR, Momodou S. 2009. Geospatial Mapping of Wetlands Potential in Ilesa, Southwestern Nigeria FIG Working Week .

Paracuellos M. 2006. How can habitat selection affect the use of a wetland complex by waterbirds*? Biodiversity and Conservation* 15:4569-4582.

Petit DR, Petit LJ, Saab VA, Martin TE. 1995 Fixed Radius Point Counts in Forests: Factors Influencing Effectiveness and Efficiency. In: Monitoring Bird Populations by Point Counts, Ralph CJ, Sauer JR, Droege S, (Eds.). USDA For. Ser. Res. Southern For. Exp. Stn., Diane Publishing Co., New Orleans, Louisiana, ISBN: 0788143441, pp: 49-56.

Prange S, Gehrt SD, Wigger EP. 2004. Influences of anthropogenic resources on Raccoon (*Procyon lotor*) movements and spatial distribution. *J. Mammal* 85:483–490.

Rajpar MN, Zakaria M. 2010. Density and diversity of water birds and terrestrial birds at Paya Indah Wetland Reserve, Selangor Penisular Malaysia. Journal of *Biological Sciences* 10 (7):658-666.

Rajpar MN, Zakaria M. 2009. Assessment of waterbirds in paya indah wetland reserve, peninsular Malaysia. Proceedingsof the 8th internationalAnnual Symposium on Sustainability Science and Management, May 3-4, Terengganu, pp: 606-612.

Ramsar Convention Bureau. 2000. Background papers on Wetland values and Function. Gland, Switzerland: Ramsar convention Bureau, http://www.ramsar.org/info/values.

Reddy CS, Krishna PH, Swetha V, Shivakala T, Charan PD. 2010. Assessement and Monitoring of spatial-temporary changes in Keoladeo Ghana National Park, Rajasthan, Indian using Geoinformation

Reed PB. 1988. National List of Plant species that occur in Wetlands. Fish & Wildlife Service, U.S. Department of the Interior, Biological Report, 88.

Robbins CS, Dawson DK, Dowel BA. 1989. Habitat and Area requirement of breeding forest birds of the middle atlantics State. *Wildlife Monographs* 103:1-34.

Roth RR. 1976. Partial heterogeneity and bird species diversity. *Ecology* 57:773-782.

Shay JM, Shay CT. 1986. Prairie marshes in western Canada, with specific reference to the ecology of five emergent macrophytes. *Canadian. Journal of Botany* 64:443-454.

Sisk TD, Haddad NM, Ehrlich PR. 1997. Bird assemblages in pitching woodlands: Modeling the effect of edge and matrix habitat. *Ecology Application* 7:1170-1180.

Smith WP, Twedt DJ, Wiedenfeld DA, Hamel PB, Ford RP, Cooper RJ. 1993. Counts of Birds in Bottomland Hardwood Forests of the Mississippi Alluvial Valley: Duration, Mininum Sample Size and Point Versus Visits. USDA For. Ser Res. Southern For. Exp. Stn., Diane Publishing Co., Louisianna.

Thompson WL. 2002. Towards reliable bird surveys: Accounting for individual present but not detected. Auk, 119:18-25

Tilman D. 1982. Resource competition and community structure. Princeton University Press, Princeton, New Jersey, USA

Van Bodegom P, Bakker C, Van der Gon HD. 2004. Identifying key issues in environment wetland research using scaling and uncertainty analysis. Region *Environmental Changes* 4:100-106.

Vanrees-Siewart KL, Dinsmore JJ. 1996. Influence of wetland age on bird use of restored wetlands in Iowa. *Wetland* 16 (4):577-582.

Venier L, Fahrig L. 1996. Habitat variability causes the species-abundance-distribution relationship. *Oikos* 76:564-570.

Wasilco MR, Soulliere GJ. 1995. Initial waterbird use of created wetlands in Eastern Upper Michigan. Mich. Dept. Nat. Resour., Wildl. Div., Lansing. Rep. 322. 10pp.

Walker BH. 1985. Truncture and function of savannas: an overview.-In: Tothill JC, JJ Mott, (eds).Ecology and management of the world's savannas. Commonwealth Agric. Bureaux, pp. 83-91

Wauters LA, Bertolino S, Adamo M, Van Dongen S, Tosi G. 2005. Food shortage disrupts social organization: The case of red squirrels in conifer forests. *Evol. Ecol*. 19:375-404.

Weller MW. 1999. Wetland Birds: habitat resource and conservation implication. Pp 1-271.

Weller WM, Adams IC, Rose BJ. 1955. Winter roost of mash hawk and short-eared owls in central Missouri. Wilson Bulletin 67:189-993.

Wiegers J. 1990. Forested wetlands of Western Europe. Forested Wetlands. *Ecosystems of the World*, 15:407-436.

Wilen BO. 1989. Status and trend of inland wetlands and deepwater habitats in the conterminous United States. Freshwater Wetlands and wildlife. CONF-8603101. DOE symposium series no. 61 (R. R. Sharitz and J. W. Gibbons, Eds.). USDOE Office of Scientific and Technical information, Oak Ridge, Tennessee pp. 719-727.

Wilson SD, Keddy P. 1986. Species competition ability and position along a natural stress/disturbance gradient. *Ecology* 67:1236-1242.

Whittaker RH, Likens GE. 1973. Primary production: the biosphere and man. *Hum. Ecology* 1:357-369.

Salomonsen F. 1968. The moulting migration. *Waterfowls* 19:5-24.

Zakaria M, Rajpar MN, Sajap AS. 2009. Species diversity and feeding guilds of birds in paya indah wetland reserve, peninsular Malaysi. *Int. J.Zool. Res.*, 5:86-100

Supplements

Supplement 1 List of waterbird species recorded on wetlands at Yankari Game Reserve.

Family	Scientific names	Common names
Ardeidae	*Ardea cinerea*	Grey Heron
Ardeidae	*Ardea melanocephala*	Black-headed Heron
Ardeidae	*Ardea purpurea*	Purple Heron
Ardeidae	*Ardeola ralloides*	Squacco Heron
Ardeidae	*Bubulcus ibis*	Cattle Egret
Ardeidae	*Egretta garzetta*	Little Egret
Ardeidae	*Egretta alba*	Great Egret
Ardeidae	*Ixobrychus minutus*	Little Bittern
Ardeidae	*Butorides striata*	Green-backed Heron
Scopidae	*Scopus umbretta*	Hamerkop
Anatidae	*Dendrocygna viduata*	White-faced Whistling Duck
Anatidae	*Sarkidiornis melanotos*	Knot-billed Duck
Threskiornithidae	*Bostrychia hagedash*	Hadada Ibis
Threskiornithidae	*Threskiornis aethiopica*	Sacred Ibis
Ciconiidae	*Anastomus lamelligerus*	African Openbill Stork
Ciconiidae	*Ciconia episcopus*	Woolly-necked Stork
Ciconiidae	*Ciconia abdimii*	Abdim's Stork
Ciconiidae	*Ephippiorhynchus senegalensis*	Saddle-billed Stork
Rallidae	*Amaurornis flavirostra*	Black Crake
Rallidae	*Crex egregia*	African Crake
Rallidae	*Gallinula chloropus*	Common Moorhen
Jacanidae	*Actophilornis africana*	African Jacana
Heliornithidae	*Podica senegalensis*	African Finfoot
Burhinidae	*Burhinus senegalensis*	Senegal Thick-knee
Scolopacidae	*Tringa ochropus*	Green Sandpiper
Charadriidae	*Vanellus spinosus*	Spur-winged Lapwing
Charadriidae	*Vanellus senegallus*	African Wattled Lapwing
Alcedinidae	*Alcedo cristata*	Malachite Kingfisher
Alcedinidae	*Ceryle rudis*	Pied Kingfisher
Alcedinidae	*Halcyon malimbica*	Blue-breasted Kingfisher
Alcedinidae	*Halcyon leucocephala*	Grey-headed Kingfisher
Alcedinidae	*Megaceryle maxima*	Giant Kingfisher
Alcedinidae	*Halcyon senegalensis*	Woodland Kingfisher

Supplement 2 List of terrestrial bird species recorded on wetlands at Yankari Game Reserve.

Family name	*Scientific name*	Common name
Tytonidae	*Glaucidium perlatum*	Pearl-spotted Owlet
Cuculidae	*Cuculus gularis*	African Cuckoo
Cuculidae	*Chrysococcyx klass*	Klaas's Cuckoo
Cuculidae	*Chrysococcyx cuprius*	Didric Cuckoo

Cuculidae	*Chrysococcyx cupreus*	African Emerald Cuckoo
Cuculidae	*Clamator glandarius*	Great Spotted Cuckoo
Cuculidae	*Cuculus solitarius*	Red-chested Cuckoo
Cuculidae	*Ceuthmochares aerus*	Yellowbill
Cuculidae	*Centropus senegalensis*	Senegal Coucal
Cuculidae	*Oxylophus jacubinus*	Jacobin Cuckoo
Falconidae	*Falco ardosiaceus*	Grey Kestrel
Falconidae	*Falco chicquera*	Red-necked Falcon
Accipitridae	*Milvus migrans*	Black Kite
Accipitridae	*Gypohierax angolensis*	Palm-nut Vulture
Accipitridae	*Haliaeetus vocifer*	African Fish Eagle
Accipitridae	*Polyboroides Typus*	African Harrier Hawk
Accipitridae	*Terathopus ecaudatus*	Bateleur
Accipitridae	*Accipiter badius*	Shikra
Accipitridae	*Kaupifalco monogrammicus*	Lizard Buzzard
Accipitridae	*Polemaetus bellicosus*	Martial Eagle
Accipitridae	*Bustatur rufipennis*	Grasshopper Buzzard
Phasianidae	*Francolinus bicalcaratus*	Double-spurred Francolin
Phasianidae	*Ptilopachus petrosus*	Stone Partridge
Columbidae	*Streptopelia hypopyrrha*	Adamawa turtle Dove
Columbidae	*Streptopelia semitorquata*	Red-eyed Dove
Columbidae	*Treron waalia*	Bruce's Green Pigeon
Columbidae	*Streptopelia vinacae*	Vinaceous Dove
Columbidae	*Turtur abyssinicus*	Black-billed Wood Dove
Musophagidae	*Musophaga violacea*	Violet Turaco
Musophagidae	*Crinifer piscator*	Western Grey Plantain-eater
Apodidae	*Cypsiurus parvus*	African Palm Swift
Meropidae	*Merops pusillus*	Little Bee-eater
Meropidae	*Merops bulocki*	Red-throated Bee-eater
Bucerotidae	*Tockus nasutus*	African Grey Hornbill
Bucerotidae	*Bicorvus abyssinicus*	Abyssinian Ground Hornbill
Bucerotidae	*Tockus erythrorhynchus*	Red-billed Hornbill
Capitonidae	*Pogoniulus chrysoconus*	Yellow-fronted Tinkerbird
Capitonidae	*Lybius dubius*	Bearded Barbet
Capitonidae	*Lybius vieilloti*	Vieillot’s Barbet
Indicatoridae	*Indicator indicator*	Greater Honeyguide
Hirundinidae	*Hirundo daurica*	Red-rumped Swallow
Hirundinidae	*Hirundo leucosoma*	Pied-winged Swallow
Motacillidae	*Anthus leucophrys*	Plain-backed Pipit
Pyconotidae	*Pycnonotus barbatus*	Common Bulbul
Pyconotidae	*Chlorocichla flavicollis*	Yellow-throated Leaflove
Turdidae	*Turdus pelios*	African Thrush
Turdidae	*Cossypha albicapilla*	White-crowned Robin Chat
Turdidae	*Cossypha niveicapilla*	Snowy-crowned Robin Chat

Sylviidae	*Melocichla mentalis*	African Moustached Warbler
Sylviidae	*Camaroptera brachyura*	Grey-backed Camaroptera
Sylviidae	*Hypergerus atriceps*	Oriole Warbler
Sylviidae	*Prinia subflava*	Tawny-flanked Prinia
Sylviidae	*Cisticola galactotes*	Winding Cisticola
Muscicapidae	*Melaenornis edolioides*	Northern Black Flycatcher
Muscicapidae	*Muscicapa aquatica*	Swamp Flycatcher
Nectariniidae	*Chalcomitra senegalensis*	Scarlet-chested Sunbird
Nectariniidae	*Cyanomitra verticalis*	Green-headed Sunbird
Nectariniidae	*Cinnyris pulchellus*	Beautiful Sunbird
Nectariniidae	*Hedydipna platura*	Pygmy Sunbird
Nectariniidae	*Cinnyris venustus*	Variable Sunbird
Laniidae	*Corvinella corvine*	Yellow-billed Shrike
Malaconotidae	*Malaconotus sulfureopectus*	Sulphur-breasted Bush-shrike
Malaconotida	*Dryoscopus gambensis*	Northern Puffback
Malaconotida	*Laniarius barbarus*	Yellow-crowned Gonolek
Malaconotida	*Tchagra senegalus*	Black-crowned Tchagra
Sturnidae	*Lamprotornis chloropterus*	Lesser Blue-eared Starling
Sturnidae	*Cinnyricinclus leucogaster*	Violet-backed Starling
Sturnidae	*Lamprotornis purpureus*	Purple Glossy Starling
Passeridae	*Petronia dentata*	Bush Petronia
Ploceidae	*Ploceus cucullatus*	Village Weaver
Ploceidae	*Ploceus vitellinus*	Vitelline Masked Weaver
Ploceidae	*Euplectes franciscanus*	Northern Red Bishop
Estrilididae	*Uraeginthus bengalus*	Red-cheeked Cordon-bleu
Viduidae	*Vidua macroura*	Pin-tailed Whydah
Monarchidae	*Terpsiphone viridis*	African Paradise Flycatcher
Emberizidae	*Emberiza tahapisi*	Cinnamon-breasted Rock Bunting
Platysteiridae	*Platysteira cyanea*	Common Wattle-eye
Coraciidae	*Eurystomus glaucurus*	Broad-billed Roller
Oriolidae	*Oriolus auratus*	African Golden Oriole
Tamaliidae	*Turdoides plebejus*	Brown Babbler
Tamaliidae	*Turdoides reinwardtii*	Blackcap Babbler
Phoeniculidae	*Phoeniculus purpureus*	Green Wood-hoopoe
Phoeniculidae	*Rhinopomastus aterrimus*	Black Wood-hoopoe
Psittacidae	*Psittacula krameri*	Rose-ringed Parakeet
Psittacidae	*Poicephalus senegalus*	Senegal Parrot
Campephagidae	*Campephaga phoenicea*	Red-shouldered Cuckoo-shrike
Corvidae	*Ptilostomus afer*	Piac Piac
Paridae	*Parus (leucomelas) guineensis*	White-shouldered Black Tit
Numididae	*Numida meleagris*	Helmeted Guineafowl