THE EFFECTS OF SEASONALITY, LANDSCAPE VARIABLES AND ANTHROPOGENIC ACTIVITIES IN STRUCTURING BIRD COMMUNITY IN DUTSE, NIGERIA

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THE EFFECTS OF SEASONALITY, LANDSCAPE VARIABLES AND ANTHROPOGENIC ACTIVITIES IN STRUCTURING BIRD COMMUNITY IN DUTSE, NIGERIA

ABSTRACT

Seasonality and landscape transformations due to human activities are threatening global biodiversity, especially in Africa where most conservation effort seems feeble, coupled with paucity of data. Several studies on birds have been conducted in Nigeria but none had been conducted in Dutse, Northwestern Nigeria. This study aims to reveal the relationships between ecological parameters and diversity as well as abundance of birds in relation to seasonality, landscape variables and anthropogenic activities. The presence of birds in four sites (Warwade, Malamawa, Model and Wangara) was recorded via direct observation technique from August 2015 to February 2016. Data were collected over the period of wet and dry seasons and across woodland and shrubland habitats. All sites were dominated by woodland habitat except for Wangara (a shrubland habitat). Using the point transect method, 264 points on 48 km of transect were used to count birds between 0630 – 1100 hours. A total of 128 bird species (13,656 individuals) from 46 families were recorded, with Accipitridae having the highest bird species. The vulnerable Beaudouin's Snake Eagle (*Circaetus beaudouini*) and the near threatened Pallid Harrier (*Circus macrourus*) were also recorded. Highest bird species richness was recorded in Warwade, while highest abundance and diversity was recorded in Model. Dry season and woodland habitat showed higher bird species richness, abundance and diversity. Tree density was more important in increasing bird abundance than shrub density. The most abundant feeding guild was insectivores (48%), followed by granivores (16%) and frugivores (16%). Frugivore abundance was significantly higher in woodland habitat and the Model site. Majority of bird species in Dutse were residents (72%) while few species are non-breeding visitors (main range)

(10%), residents (partially migratory) (8%), non-breeding visitors (sparse occurrence) (6%), or breeding visitors (4%). The woodland and shrubland habitats had higher proportion of resident and migratory species. Similarly, Model and Wangara sites had higher proportion of resident and migrant birds respectively. Population trend assessments by the IUCN Red List of Threatened Species suggested that 57% of bird species in the study area showed stable population trend while 20% showed decreasing, 18% increasing and 5% uncertain trends. The dry season recorded higher abundance of insectivores, granivores and frugivores, residents and migrants, and birds with increasing, decreasing and stable population trends than the wet season. Both woodland and shrubland in Dutse are vital as bird habitats but migrant species utilized shrubland habitat more than woodland. Small-scale anthropogenic activities and habitat modification (such as farming, grazing, wood removal and human interference) did not appear to have affected the birds. However, loss of high tree density in woodland habitat may pose a major threat to the bird community in Dutse. High numbers of both resident and migrant bird species highlight the importance of Dutse as a key habitat and wintering ground in the region. Similarly, the presence of birds of concern in the area suggest the need for conservation efforts of avifauna and as well as the forested habitats in Dutse.

Keywords: abundance, diversity, habitat, season, site.

KESAN MUSIM, PERBEZAAN LANDSKAP DAN AKTIVITI ANTHROPOGENIK DALAM PENSTRUKTURAN KOMUNITI BURUNG DI DUTSE, NIGERIA

ABSTRAK

Perubahan musim dan lanskap akibat dari aktiviti manusia mengancam biokepelbagaian global, terutamanya di Afrika di mana kebanyakan usaha pemuliharaan agak lemah, ditambah dengan kekurangan data. Beberapa kajian terhadap burung telah dijalankan di Nigeria tetapi tiada kajian telah dijalankan kawasan barat laut Nigeria terutamanya di Dutse. Matlamat kajian ini adalah untuk mendedahkan perhubungan di antara parameter ekologi dengan kepelbagaian dan kelimpahan burung dari segi perubahan musim, perbezaan lanskap dan aktiviti antropogenik. Kehadiran burung di empat kawasan kajian (iaitu Warwade, Malamawa, Model and Wangara) telah direkodkan melalui teknik pemerhatian lansung dari Ogos 2015 hingga Februari 2016. Data telah dikumpul merangkumi musim basah dan kering serta merentasi habitat hutan dan pokok renek. Menggunakan kaedah transek titik, 264 titik di atas transek sepanjang 48 km digunakan untuk mengira burung di antara jam 0630 hingga 1100. Sejumlah 128 spesies burung (13,651 individu) daripada 46 keluarga telah direkodkan, dengan keluarga Accipitridae mempunyai bilangan spesies tertinggi. Spesies terancam, Helang Ular Beaudouin (*Circaetus beaudouini*) dan spesies hampir terancam, Pallid Harrier (*Circus macrourus*) juga berjaya direkodkan. Kekayaan spesies burung tertinggi dicatatkan di Warwade, kelimpahan tertinggi dan kepelbagaian tertinggi di Model. Musim kering dan habitat hutan menunjukkan nilai tertinggi bagi kekayaan spesies, kelimpahan dan kepelbagaian burung. Kepadatan pokok adalah lebih penting daripada kepadatan semak dalam peningkatan kelimpahan burung. Kaedah pemakanan yang paling kerap adalah insektivor (48%), diikuti oleh granivor (16%) dan frugivor (16%). Kelimpahan frugivor adalah lebih tinggi di habitat hutan dan di kawasan Model.

Majoriti spesies burung di Dutse adalah burung residen (72%), pelawat bukan pembiak (banjaran utama) (10%), residen (sebahagiannya bermigrasi) (8%), pelawat tidak membiak (jarang muncul) (6%) dan spesies migran (4%). Habitat hutan dan renek mempunyai kelimpahan tinggi burung residen dan migran. Begitu juga, kawasan Malamawa dan Wangara mempunyai nisbah burung residen dan migran yang tinggi. Penilaian corak populasi berdasarkan Senarai Merah Spesies Terancam IUCN mencadangkan bahawa 57% spesies burung di kawasan kajian adalah stabil, 20% berkurangan, 18% meningkat dan 5% tidak pasti. Musim kering mencatatkan kelimpahan tinggi insektivor, granivor dan frugivor, residen dan migran, dan spesies burung dengan kenaikan, penurunan dan corak populasi stabil berbanding musim lembap. Kedua-dua habitat hutan dan renek di Dutse adalah penting sebagai habitat burung tetapi spesies migran lebih gemar menggunakan habitat renek berbanding hutan. Kegiatan antropogenik berskala kecil dan pengubahsuaian habitat (seperti pertanian, ragutan, penebangan pokok dan gangguan manusia) tidak begitu mempengaruhi burung. Namun, kehilangan habitat hutan kayu boleh menyebabkan ancaman besar kepada komuniti burung di Dutse. Bilangan spesies residen dan migran yang tinggi menunjukkan Dutse merupakan habitat utama dan kawasan migrasi di kawasan ini. Begitu juga, kehadiran burung yang penting di kawasan kajian mencadangkan keperluan untuk usaha pemuliharaan avifauna dan juga habitat hutan di Dutse.

Kata kunci: kelimpahan, kepelbagaian, habitat, musim, tapak.

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ANOSIM	:	Analysis of Similarity
ANOVA	:	Analysis of Variance
APLORI	:	A.P. Leventis Ornithological Research Institute
EBAs	:	Endemic Bird Areas
GPS	:	Global Positioning System
IBAs	:	Important Bird Areas
ICBP	:	International Council for Bird Preservation
iNEXT	:	Interpolation and Extrapolation for Species Diversity
MANOVA	:	Multivariate Analysis of Variance
NBVMR	:	Non-breeding visitor with main range
NBVSO	:	Non-breeding visitor with sparse occurrence
NCF	:	Nigerian Conservation Foundation
NGOs	:	Non-Governmental Organisations
NMDS	:	Non-metric multidimensional scaling
PAST	:	Paleontological Statistics Software Package
PCA	:	Principal Component Analysis
R	:	Resident
RPM	:	Resident but partially migratory
SIMPER	:	Similarity Percentage
SSGs	:	Site Support Groups
WMBD	:	World Migratory Bird Day
WWD	:	World Wetlands Day

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CHAPTER 1: INTRODUCTION

The world biomes have been altered to an extent that they are now being referred to as anthropogenic biomes (Ellis & Ramankutty, 2008). Global biodiversity is fast changing and declining in response to these alterations (Sala *et al*., 2000). Since the last mass extinction event (dated 65 million years ago), habitat and species have been facing extinction and are currently disappearing faster than in any other times (Pimm *et al*., 1995; Pain *et al*., 2005). In many parts of the world, species and habitat loss have been connected to factors such as seasonality, landscape variables and anthropogenic activities (Gregory *et al*., 2005; Pain *et al*., 2005; Child *et al*., 2009). Similarly, in Nigeria, seasonal variability (wet and dry seasons), habitat loss and anthropogenic activities such as farming, wood removal, human interference, and grazing are among main threats faced by many bird species and other wildlife (Kelsey, 1992; Galushin *et al*., 2003; Thiollay, 2006a, 2006c; Cresswell *et al*., 2007; Stevens *et al*., 2010; Al-Amin, 2013; Adams *et al*., 2014; Birdlife International, 2016a).

Changes in the composition of habitat and species may alter the pattern of energy flow through ecosystem with a cascading effect (Fox & Hockey, 2007). Unfortunately, the negative impact of land transformation to agricultural and urban systems does not only stop at changing ecosystem processes, composition and resilience to environmental change but causes a cascading effect on human through the alteration of water supply and ecosystem services (Reyers, 2004), which will in turn affect biodiversity especially birds. Birds (especially migrants) have already been affected by climate change through changes in vegetations, increase temperature and extreme weather conditions, leading to significant changes to their habitats.

Therefore, there is a need to identify and conserve rich biodiversity areas to prevent further species extinction. However, this is often challenging because most species and their geographical distribution, as well as biodiversity areas have not been identified and formally described (Burgess *et al*., 2002). Notwithstanding, biologist and conservationist are striving hard in understanding and identifying biodiversity loss through human activities and to provide appropriate conservation solution (Soul *et al*., 1991; Margules & Pressey, 2000; Fairbanks *et al*., 2002).

1.1 Birds and ecosystem

Birds are widely distributed and comprised of ecologically and taxonomically diversified taxa (Furness *et al*., 1993; Palomino & Carrascal, 2006). Birds contribute to the resilience of an ecosystem (Folke, 2006; Pauw & Louw, 2012) and serve as biodiversity surrogate. Presence of indicator or surrogate bird species help in identifying priority areas for conservation, as many biodiversity areas are yet to be identified (Burgess *et al*., 2002; Fox & Hockey, 2007; Larsen *et al*., 2012). Birds directly and indirectly promote biodiversity (Neuschulz *et al*., 2011; Henriques *et al*., 2017). They play an important role in ecosystem functioning (Table 1.1 and 1.2, Figure 1.1) and may be more effective in nutrient cycling in a forest ecosystem than other vertebrate groups (Fox & Hockey, 2007; Holly *et al*., 2007).

Birds are indicators of environmental health (Fox & Hockey, 2007; Thiollay, 2007) and many conservationists used them as tools to monitor biodiversity (Coetzee & Chown, 2016), as well as to prioritise sites for biodiversity conservation (Elphick, 1997; Walther & Martin, 2001). This is possible because birds occupy different ecological niches and are variably susceptible to disturbance (Buechley *et al*., 2015). They are sensitive to environmental changes, likely due to their general visibility, high mobility and responsiveness to alterations at the landscape level (Balent & Courtiade, 1992; McIntyre, 1995; Gregory & van Strien, 2010).

Understanding how seasonality, landscape variables and anthropogenic (Farming, grazing, woodremoval and human interference) activities impact birdlife at spatial and temporal scales would be valuable to guide local conservation and to monitor efforts, especially when resources and manpower are lacking (Coetzee & Chown, 2016)

Table 1.1: Ecological and economical contributions of avian functional groups.

Functional group	**Ecological process**	**Ecosystem service and economical benefits**	**Negative consequences of loss of functional group**
Frugivores	Seed dispersal	Removal of seeds from parent tree; escape from seed predators; improved germination; increased economical yield; increased gene flow; recolonization and restoration of disturbed ecosystem	Disruption of dispersal mutualisms; reduced seed removal; clumping of seeds under parent tree; increased seed predation; reduced recruitment; reduced gene flow and germination; reduction or extinction of dependent species
Nectarivores	Pollination	Outbreeding of dependent and/or economically important species	Pollinator limitation; inbreeding and reduced fruit yield; evolutionary consequences; extinction
Scavengers	Consumption of carrion	Removal of carcasses; leading other scavengers to carcasses; nutrient recycling; sanitation	Slower decomposition; increase in carcasses; increases in undesirable species; diseases outbreaks; changes in cultural practices
Insectivores	Predation on invertebrates	Control of insect populations; reduced plant damages; alternative to pesticides	Loss of natural pest control; pest outbreaks; crop losses; trophic cascades
Piscivores	Predation on fishes and invertebrates and production of guano	Controlling unwanted species; nutrient deposition around rookeries; soil formation in polar environments; indicators of fish stocks; environmental monitors	Loss of guano and associated nutrients impoverishment of associated communities; loss of socioeconomic resources and environmental monitors trophic cascades
Raptors	Predation on vertebrates	Regulation of rodent populations; secondary dispersal	Rodent pest outbreaks; trophic cascades; indirect effects
All species	Miscellaneous	Environmental monitoring; indirect effects; birdwatching tourism; reduction of agricultural residue; cultural and economic uses	Losses of socioeconomic resources and environmental monitors; unpredictable consequences

Table 1.2: Major avian ecosystem services and ways to measure their efficiency.

Service Type	Service	Primary ecosystem services providers[a]	Efficiency measure(s)
Regulating	Seed dispersal	Frugivores (1350/1800)	Dispersal distance, recruitment rate, seed and seedling survival
	Pollination	Nectarivores (600/350)	Pollen deposition rate, flower ripening rate, seed/fruit set
	Pest control	Invertebrate (5700/1700) and vertebrate (300/1100) feeders	Invertebrate numbers, plant damage, primary productivity
	Carcass and Waste disposal	Scavengers (40/300)	Rate of disappearance of carcasses and waste
Supporting	Nutrient deposition	Aquatic birds (950)[b]	Soil, water, and plant nutrient levels; plant abundance
	Ecosystem engineering	Burrow and cavity diggers (1000)[c]	Number of nesting holes, nesting population of dependent species, process rate

[a]The approximate number of bird species providing each service is in parentheses. [b]An aquatic bird is a species whose primary habitat consists of wetlands, rivers or the sea. [c]Only species that actively dig burrows or cavities are included.

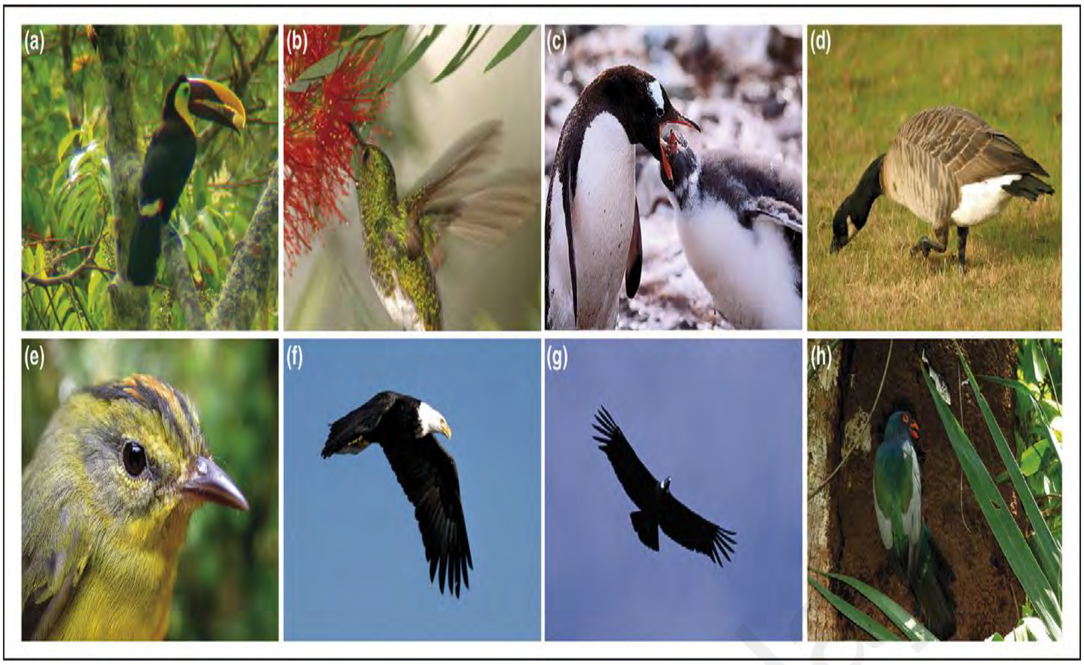

Figure 1.1: Example of the eight main types of avian ecosystem services providers. (a) Seed disperser: Black-mandible toucan *Ramphastos ambiguous* (Les Cruces, Costa Rica). (b) Pollinator: Snowy-bellied hummingbird *Amazilia edward* (Les Cruces, Costa Rica). (c) Nutrient depositor: Gentoo penguin *Pygoscelis papua* (Port Lockroy, Antarctica). (d) Grazer: Cackling goose *Branta hutchinsii* (California, USA). (e) Insectivore: Golden-crowned warbler *Basileuterus culicivorus* (Les Cruces, Costa Rica). (f) Raptor: Bald eagle *Haliaeetus leucocephalus* (Alaska, USA). (g) Scavenger: Andean condor *Vultur gryphus* (Patagonia, Chile). (h) Ecosystem engineer: Slaty-tailed trogon *Trogon massena* (Pipeline Road, Panama).

1.2 Bird species richness, abundance and diversity

Species richness (otherwise known as number of species) and evenness, and their relative abundance are the two basic component of species diversity. Gotelli and Chao (2013) define species diversity as ‘a measure of diversity that incorporates both the number of species in an assemblage and some measure of their relative abundances’ while species richness as ‘the total number of species in an assemblage or a sample’. They are combined in diversity indices such as Shannon’s and Simpson’s diversity (Dettmers, 2003; Wilsey & Stirling, 2007). These measures play an important role in ecology and conservation (Krebs, 1989; Fairbanks *et al*., 2002). Even though they differ in measuring rare species, but all provide an estimate of the effective number of species present (Hill, 1973). Patterns of species richness, abundance and diversity have been found to fluctuate where resources vary spatially and temporally (Cotton, 2007). Therefore, numerous studies globally attempted to investigate factors affecting bird abundance, diversity and their distribution both at spatial and temporal scales (MacArthur, 1964; Fretwell & Lucas, 1969; Roth, 1976; Brown, 1984; Paracuellos & Tellería, 2004; Thompson, 2007; Girma *et al*., 2017).

1.3 Factors affecting bird species richness, abundance and diversity

Bird species richness, abundance and diversity are governed by a number of factors including seasonality, landscape variables (tree and shrub abundance, habitat loss) and anthropogenic influence. Seasonality in weather patterns is a major factor in determining bird abundance, diversity and their distribution. Weather has been shown to affect the survival of bird species and can result in high bird mortality, especially during severe weather conditions (Clark, 2004). This could be indirect effects via the availability of food or direct effects through an increase in metabolic requirements in cold weather, and by hindering flight during strong wind (Clark, 2004; Johnston *et al*., 2016). Periods of severe weather condition have been reported to result in significant mortality in bird populations (Clark, 2004). Availability of cover, food, and water for many bird species is also affected by seasonality and consequently affectsbird survival and breeding success (Mengesha & Bekele, 2008; Girma *et al*., 2017). Therefore, changes in seasonal climate will affect both the bird community and vegetation structure, which in turn alters the cover, nest and food availability for birds (Mengesha *et al*., 2011).

Birds respond in different ways to habitat characteristics depending on the season. Increased bird diversity and richness was attributed to period of high amount of rainfall (van Heezik & Seddon, 1999). Species richness and functional diversity may increase with increasing rainfall (Schaefer *et al*., 2006; Seymour *et al*., 2015). In Britain and

Ireland, waterfowl mortality reached a peak during the winter period, especially in a severe cold season (Goss-Custard *et al*., 1977; Clark, 2004). In South America, seasonal availability of seed limits the abundance of granivorous emberizids (Schluter & Repasky, 1991; Gonnet, 2001). On the other hand, availability of food may have a carryover effect on non-breeding bird population (Brown & Sherry, 2006).

Local and landscape characteristics such as tree and shrub abundances influence bird assemblages (Savard *et al*., 2000), and have been found to have a positive effect on bird species richness, abundance and diversity. For example, abundance of Common Whitethroats (*Sylvia communis*) and Subalpine Warblers (*Sylvia cantillans*) was related to density of trees (Jones *et al*., 1996). Shade trees in cacao agroforestry have been shown to positively impact bird abundance and diversity (Clough *et al*., 2009). Vegetation structure is an important determinant of bird species richness, abundance and diversity especially in arid savannas (Sirami *et al*., 2009).

Bird distribution may vary spatially and temporally due to their habitat preferences and environmental conditions (Anderson & Cribble, 1998; Ballance *et al*., 2006; Amorim *et al*., 2009). Bird abundance and diversity have been reported to positively correlate with habitat quality, thus influencing their distribution (Skórka *et al*., 2016). This is true as heterogeneous habitat supports more bird species than homogeneous habitat due to more niches that are available to serve as habitat for different species (Lorenzón *et al*., 2016). Therefore, resource distribution and their availability in the environment influence habitat selection in birds, as adult birds occupy the best quality habitat (Schmid *et al*., 2016). Similarly, changes in resources (nesting sites, food and water) distribution and abundance will alter the distribution of birds in the landscape; these alterations may be beneficial to some bird species and detrimental to others (Fox & Hockey, 2007).

Bird species may also adapt to local characteristics in some regions because similar habitat with similar vegetation and composition in different regions may provide different resources (Salewski & Jones, 2006). For instance, Montagu's harrier (*Circus pygargus*) preferred crop-lands and some natural vegetation habitat in it wintering ground in the trans-Saharan Sahel (Liminana *et al*., 2012a). Other important factors such as plant diversity, tree height and density also influenced bird species richness, abundance and diversity (Sekercioglu, 2002; Harvey *et al*., 2006; Laube *et al*., 2008).

Changes in bird species richness, abundance, and diversity have been linked to changes in vegetation structure caused by anthropogenic activities in tropical arid Mexico (Arizmendi *et al*., 2008) and in South Africa (Neuschulz *et al*., 2011). Unfortunately, the increase in human population and their quest for forest resources keep changing the local vegetation structure leading to habitat loss for many bird species (Thiollay, 2007; Douglas *et al*., 2014). These alterations in vegetation structure will have a strong effect on birds (MacArthur & MacArthur, 1961; Chalmandrier *et al*., 2013).

In a natural habitat, bird species richness and diversity increase with an increase in the amount of woody vegetation and plant species (Pomeroy & Dranzoa, 1997). Peters *et al*. (2008) reported higher bird species richness and size of bird flocks in an undegraded than in a degraded habitat and decreasing size of forest fragments lowered these bird variables. Fox and Hockey (2007) found bird diversity and abundance to be higher in undisturbed (conservation areas) compared to adjacent disturbed habitats. In India, bird species diversity in the Sariska Tiger reserve was significantly lower in human disturbed sites (Shahabuddin & Kumar, 2006). Agricultural and urban areas were avoided by Golden Eagles *Aquila chrysaetos* (Domenech *et al*., 2015). Other examples of bird species richness and diversity being reduced in human disturbed sites can be found in Western Ghat, India (Raman & Sukumar, 2002), Ethiopia (Mengesha *et al*., 2011) and São Tomé and Príncipe, Africa (de Lima *et al*., 2013).

Since birds respond to changes in habitat structure and composition due to their sensitivity (Savard *et al*., 2000), ecological information, seasonality and habitat variation and loss, and anthropogenic influence in time and space are essential when planning conservation measures for declining bird species (Huber *et al*., 2016). However, bird conservation may be challenging especially in areas with paucity of data, because future planning requires the understanding of ecology and distribution of birds.

1.4 Justification

Many previous Nigerian bird studies were concentrated in south east Nigeria (Abalaka & Manu, 2007; Manu & Cresswell, 2007; Manu *et al*., 2010; Barshep & Manu, 2013; Dami *et al*., 2013), north central Nigeria (Molokwu *et al*., 2008; Brandt & Cresswell, 2008; Usieta *et al*., 2013; Yadok *et al*., 2014), and north east Nigeria (Jones *et al*., 1996; Vickery *et al*., 1999; Ezealor, 2002; Waldenström & Ottosson, 2002; Bell, 2007; Cresswell *et al*., 2007; Wilson *et al*., 2007; Stevens *et al*., 2010; Wilson & Cresswell, 2010; Atkinson *et al*., 2014). Some observed the relationships between birds and habitats (Cresswell *et al*., 2007; Ivande & Cresswell, 2016), effect of anthropogenic activities on bird population (Abalaka & Manu, 2007; Dami *et al*., 2013; Yadok *et al*., 2014), and documented bird species richness and diversity (Akinsola *et al*., 2000; Manu *et al*., 2010).

However, no bird study has been conducted in the Dutse area (northwestern Nigeria); presently not even a bird checklist exists for this capital state despite the rapid population growth, development and the corresponding demand for forest areas which may pose a significant threat to local bird population (Thiollay, 2006a, 2006c). Since no bird data exist in Dutse, spatiotemporal use of habitat by bird species (which is an important component of bird conservation) has yet to be investigated. Knowledge of residence status and population trend of bird species in Dutse is important in identifying bird species of conservation concern as well as to assign conservation priorities for target species where resources may be limited. This may however be impossible in places like Dutse where no comprehensive avian record or ecological information on feeding guild, residence status or population trend exist.

Understanding of the effects of seasonality (wet and dry), habitat (shrub and woodland) variation and loss and anthropogenic activities (farming, wood removal, grazing and human interference) on bird diversity and abundance at spatial and temporal scales will address gaps in avian scientific knowledge for Dutse. In addition, knowledge of foraging ecology (feeding guild) and spatiotemporal usage by birds of varying residency and population status will aid in informing appropriate conservation decisions in Dutse as well as the region.

1.5 Research aim, outline and objectives

The present study aimed at revealing the relationships between ecological parameters and diversity as well as abundance of birds in relation to seasonality, landscape variables and anthropogenic activities. The specific objectives are:

1. To record bird diversity and abundance in different seasons (wet and dry), habitats (woodland and shrubland) and sites (Wangara, Warwade, Malamawa and Model) in Dutse.

    1.1 To identify and record bird species of conservation concern

    1.2 To provide the first and comprehensive checklist of bird species of Dutse, Nigeria.

2. To study the effects of seasonality (wet and dry), landscape variables (trees and shrubs abundance), habitats (woodland and shrubland) and site (Wangara, Warwade, Malamawa and Model) variation on bird abundance and diversity in Dutse.

3. To examine the effect of anthropogenic activities (farming, grazing, wood removal and disturbance) on bird abundance and diversity in Dutse.

4. To investigate the utilization of habitat, space and season by bird according to their feeding guild, residence status and population trend.

5. To compare and examine the abundance of resident and migrant bird species with decreasing population trend across habitat and season in Dutse.

Avian and related data were collected using point count survey in different habitats, sites and seasons in Dutse to ascertain the effects of seasonality, landscape variables and anthropogenic activities on bird abundance and diversity. The current study has been summarized in six chapters. Roles of birds in the ecosystem and factors affecting their abundance and diversity were discussed in Chapter One. Chapter One further discusses the importance of environmental variables in structuring bird community and provides the aim and objectives of the study and reasons (justification) as to why the current study was worth conducting. Chapter Two discusses the current state of literature on how seasonality, landscape variables, anthropogenic activities affect bird abundance and diversity across the globe, and in Africa and Nigeria. Chapter Three introduces the study sites and metholodogy used in this study, including all statistical softwares used to analyse the data. Chapter Four reports the results and research findings with the use of figures and tables. Chapter Five discusses the results and implications of the research findings in relation to other relevant studies. Chapter Six provides conclusions from the findings of the current study as well as some useful recommendations for future research.

The current study hypothesizes significant roles of habitat, season and locality in influencing bird variables but the effects of anthropogenic variables on birds will be insignificant due to the long-standing presence of human impacts in the region. Utilization of habitats, seasons and sites by bird species according to feeding guilds, residence status and population trend will be significant across habitats, sites and seasons.

CHAPTER 2: LITERATURE REVIEW

2.1 Status of birds in Africa

Globally, bird populations are fast declining, and many bird species are at risk of extinction. Seasonality, habitat variation and anthropogenic activities at varying temporal and spatial scales continue to alter bird population and distribution (Parmesan & Yohe, 2003; Root *et al*., 2003; Hockey *et al*., 2011). These changes vary in different parts of the world; some regions experience more changes than others. In comparisons to other anthropogenic biomes (Ellis & Ramankutty, 2008), the effects of seasonality, landscape variables, habitat loss and anthropogenic activities in relation to urbanisation and agricultural intensification are poorly studied in Africa (Coetzee & Chown, 2016), a continent with incredible natural diversity (Linder *et al*., 2012). In many parts of Africa, habitats may change depending on the season; similarly, different bird species require different habitats. Unfortunately, much of the areas in Africa are yet to be explored by ornithologists (Dowsett & Dowsett-Lemaire, 1989; Brooks & Thompson, 2001).

Africa has more than 1,230 Important Bird Areas (IBAs) with restricted-range species, globally threatened species, significant congregations or biome-restricted assemblages (Fishpool & Evans, 2001; Manu *et al*., 2010). Most of the biologically rich (IBAs, Endemic Bird Areas (EBAs), Hotspots) areas in Africa are threatened by agricultural expansion and deforestation (Birdlife International, 2008; Buchanan *et al*., 2009; Sritharan & Burgess, 2012; Birdlife International, 2013). Anthropogenic land use had modified local habitat and vegetation structure which in turn influenced bird diversity, plant composition and faunal assemblages (Seymour & Dean, 2010). One of the areas for major avian endemism in Africa is the upper Guinea rain forest of West Africa (ICBP, 1991). About 172 threatened bird species were reported in Africa with eight species found in the Upper Guinea rainforest (Kofron & Chapman, 1995).

Another important site for bird conservation is the Uluguru Mountains in Tanzania which harbours bird species of conservation concern (Werema *et al*., 2016). The Eastern Arc in Africa holds the highest number of the world's endemic plants and vertebrates (Myers *et al*., 2000; Burgess *et al*., 2004; Lovett *et al*., 2005; Brandt & Cresswell, 2008; Blackburn & Measey, 2009). The Eastern Afromontane Hotspot which is part of the Eastern Arc mountains in Tanzania has about 1300 bird species, from which 110 species are endemic. Sadly, these areas are under pressure due to habitat loss. Conversion of land for farming, logging, grazing, fuelwood and building of residential areas leading to habitat loss are continuously posing threats to much of African biodiversity and hotspot areas (Birdlife International, 2008; Sritharan & Burgess, 2012).

In addition to habitat clearance and agricultural encroachment (Fishpool & Evans, 2001; Soderstrom *et al*., 2003), human population growth is one of the greatest challenges to a successful conservation implementation in Africa (Brooks & Thompson, 2001). Anthropogenic-driven habitat alteration is a major cause of species extinction and has been positively correlated with human population size (Thompson & Jones, 1999; Evans *et al*., 2006). Human population growth has also been connected to environmental degradation (Tappan & McGahuey, 2007; Douglas *et al*., 2014; Mallord *et al*., 2016). Areas of dense human settlement typically coincide with areas of high bird's species richness (Balmford *et al*., 2001; Fairbanks, 2004). Compared to other continents, Africa has the fastest growing human population accounting for 2.7% of the annual population growth rate (Tappan & McGahuey, 2007). Meeting the demand of an increasing human population through agricultural expansion had resulted in habitat loss of many bird species in the Sub-Saharan Africa (Thiollay, 2007; Liminana *et al*., 2012a; Douglas *et al*., 2014).

International conservation organizations such International Council for Bird Preservation, Endemic Bird Areas (EBAs), and Conservational International's Hot Spot Areas (Mittermeier *et al*., 1999; Myers *et al*., 2000) have focused on incorporating bird (and other biodiversity) data with information on opportunities and threats to set conservation priorities for various geographic areas (Brooks & Thompson, 2001). However, information on bird abundance, diversity and distribution remains the most urgent data required for conservation of African birds (Brooks & Thompson, 2001). Sanderson *et al*. (2006) has emphasized that bird conservation should be targeted at African countries. Similarly, Kelsey (1992) suggested that more attention should be focused on West African Sahelian habitats where many migrant birds spend their wintering period and the impact of human activities and environmental change is significant.

2.2 Status of birds in Nigeria

In West African countries (including Nigeria), agricultural intensification and extension of cultivated land is rapidly changing the habitat of many bird species, especially for the migrant birds in the Sahel (Tappan *et al*., 2000; Tappan *et al*., 2004; Atkinson *et al*., 2014). Western Sahel countries such as Nigeria have experienced an increase in human population size from less than 20 million (mid-20th century) to the current population of more than 60 million (Zwarts *et al*., 2009; Liminana *et al*., 2012b). Increase in human population had increased the demand for food, resulting in higher demand for croplands.

Nigeria is endowed with rich avian diversity, with 27 IBAs, four EBAs and three endemic bird species (Birdlife International, 2016a) which are all threatened by wood removal (for firewood), grazing, and habitat destruction (Sritharan & Burgess, 2012; Birdlife International, 2016a). The Biafran forest and highlands of Nigeria is a centre of biodiversity both at global and continental scale with several endemic species of primates, amphibians, dragonflies, butterflies, fish and birds. Unfortunately, the remaining forest is still being degraded and fragmented (Bergl *et al*., 2007). The Cross-river rainforest in south-eastern Nigeria is one of the globally recognised biodiversity hotspot area in Nigeria (Myers *et al*., 2000). It harbours a diverse number of both endemic and critically endangered primates, and range-restricted and threatened avian species such as White-throated Mountain-babbler (*Kupeornis gilberti*), Bannerman's Weaver (*Ploceus bannermani*), Green-breasted Bush-shrike (*Malaconotus gladiator*) and Grey Parrot (*P. erithacus*) (Atuo *et al*., 2016). However, human activities pose serious threatson these rich biodiversity areas (Ezealor, 2002; Wilson & Cresswell, 2006; Abalaka & Manu, 2007; Cresswell *et al*., 2007).

According to Birdlife International (2016a), about 67% of Nigerian bird species are presently categorized as vulnerable, 14% are endangered and 19% are critically endangered. This classification has been attributed to habitat loss and agricultural encroachment (Fishpool & Evans, 2001; Soderstrom *et al*., 2003; Birdlife International, 2016a, 2016b). In addition, corruption and lack of good economic opportunities has caused habitat loss and constantly mounted pressure on the fast disappearing biodiversity. Furthermore, many cultures in Africa, including Nigeria, have certain belief in the value of animal parts such as vultures (*Gyps* spp, *Necrosyrtes* spp, *Sarcogyps* spp, *Neophron* spp, and *Gypogierax* spp) and other bird species to support a wide range of religious and traditional practices which has culminated in the persecution of more than 354 bird species (Atuo *et al*., 2015).

The lower Niger watershed (EBA) in southern Nigeria which harbours the vulnerable Anambra Waxbill (*Estrilda poliopareia*) and south-west Nigeria (EBA) with the endangered Ibadan Malimbe (*Malimbus ibadanensis*) are faced with similar threats

(BirdLife International, 2017c). Barshep and Manu (2013) reported that breeding failure of Bannerman's weaver (*P. bannermani*) was mainly due to egg collection by humans. The Afi Mountain Wildlife Sanctuary is threatened by logging and wildlife exploitation (Manu *et al*., 2010). In Northern Nigeria, the Kagoro-Nindam forest reserve is one of the areas of conservation concern. It harbours bird species such as Red-capped Robin-Chat (*Cossypha natalensis*), the Yellow-throated Cuckoo (*Chrysococcyx flavigularis*) (Elgood *et al*., 1982; Ezealor, 2002; Abalaka & Manu, 2007; Borrow & Demey, 2014) and the Purple-throated Cuckooshrike (*Campephaga quiscalina*) (Borrow & Demey, 2001; Abalaka & Manu, 2007). The area is facing the problem of timber and firewood collection, farming and hunting (Ezealor, 2002; Abalaka & Manu, 2007). Further north of Nigeria, the Hadejia-Nguru Wetlands (IBA and Ramsar site) with more than 1% of the West African populations of at least nine waterfowl species is threatened by habitat loss and uncontrolled hunting (Akinsola *et al*., 2000).

Lack of bird data, coupled with improper planning and implementation remain major threats facing bird conservation in Africa (Brooks & Thompson, 2001). In North Western Nigeria, places like Dutse are yet to be explored by ornithologists. Considering the enormous contributions of birds in the ecosystem, knowledge on the effects of seasonality, landscape variables and anthropogenic activities on population size, abundance and diversity in time and space is an essential tool when planning conservation priorities (Harrison *et al*., 2014).

2.3 The effects of seasonality on birds

Seasonality is an important factor influencing avian community especially in a fluctuating environment. In Africa, alternation between wet and dry seasons strongly determines ecological conditions of the region. These seasons are controlled by the annual North-South movement of the Inter-Tropical Convergence Zone (Jones, 1995;

Salewski & Jones, 2006). In many African countries like Nigeria, these phenomena cause seasonal differences; wet season is progressively shorter while the dry season is progressively longer (Morel & Morel, 1992). Rainfall distribution in the northern part is a mirror image of the southern part (Morel & Morel, 1992; Salewski & Jones, 2006).

In a seasonally fluctuating environment, rainfall is an important determinant of population size during the breeding season of birds as many bird species breed during period of increased resource availability (Cox *et al*., 2013). In periods of increased food availability, clutch size is expected to be larger (Lepage & Lloyd, 2004). Rainfall patterns were observed to affect the food availability of American redstarts (*Setophaga ruticilla*) (Studds & Marra, 2007), and determined the distribution of the Red-billed Quelea (*Quelea quelea*) which are always found in most recent rainfall areas in Africa (Dallimer *et al*., 2002). In South Africa, reproduction in Blue Crane (*Anthropoides paradiseus*) was positively associated with rainfall in early breeding season. *A. paradiseus* produces a high number of young if early breeding season was wet and survival rate increased with rainfall during late breeding season (Altwegg & Anderson, 2009). Spike-heeled Lark (*Chersomanes albofasciata*) and Sociable Weaver (*Philetairus socius*) on the other hand will increase their clutch size during the period of increased rainfall (Lepage & Lloyd, 2004).

In the arid zone of Africa, rainfall is variable, unpredictable and an important determinant of productivity (Lepage & Lloyd, 2004; Schaefer *et al*., 2006). Breeding activities of most birds in arid zone depend on rainfall (Cox *et al*., 2013), likewise for the survival of migrant bird species on wintering ground (Altwegg & Anderson, 2009). Rainfall influences food supply (Brown & Sherry, 2006) especially in arid region (Schaefer *et al*., 2006; Tøttrup *et al*., 2012; Johnston *et al*., 2016) which in turn affects clutch size and survival in birds (Lepage & Lloyd, 2004). According to Crowley and

Garnett (1999), seed availability in different seasons may influence the behavior of some bird species; most granivorous birds may prefer to breed in the wet rather than in the dry season (Keith *et al*., 1992; Keith & Fry, 2004).

Invertebrate and fruit abundances are connected with seasonal fluctuations; they reach a peak in dry and wet seasons respectively in Western Kenya (Mulwa *et al*., 2013). Food availability in the dry season decreases as the season progresses which strongly affect bird response according to their feeding guilds (Mulwa *et al*., 2013). Among avian food resources, fruits become unevenly distributed both spatially and temporally allowing some bird species like the frugivores to track these resources in and outside their habitat (Mulwa *et al*., 2013). Food availability plays an important role in determining the quality of habitat for birds in non-breeding season (Hutto, 1985). For example, female American redstarts (*Setophaga ruticilla*) produces two additional young and fledge earlier in quality habitats than in poor habitats (Norris *et al*., 2004). Likewise, the processes involve in breeding and wintering grounds determine the seasonal abundance and pattern of habitat occupancy in migrant bird species (Newton, 2008; Girma *et al*., 2017).

In West Africa, amount of rainfall had a positive relationship with the survival of some species of warbler (Johnston *et al*., 2016). Wintering bird species in the mesic region had higher annual survival probabilities than those bird species wintering in xeric areas (the Sahel) (Johnston *et al*., 2016). Reduction in the amount of rainfall coupled with increasing human exploitation and overgrazing has led to considerable changes in the Sahel (Jones *et al*., 1996). The desert expands further as a result of the dryness. The most challenging parts of the migrant birds' journey is the crossing of the Sahara Desert, due to shortage of resting and refuelling sites. Human induced climate change and habitat loss coupled with Sahara expansion makes it almost impossible for the migrants to cross this ecological barrier successfully. Annual survival of migrant bird species wintering in the Sahel (Northern Nigeria) has also been linked to the amount of rainfall (Zwarts *et al*., 2009; Liminana *et al*., 2012b; Atkinson *et al*., 2014). For example, 70% of the population decline of the Common Whitethroat (*S. communis*) in 1969 was attributed to changes in the amount of rainfall in the Sahel zone of West Africa (Winstanley *et al*., 1974; Stevens *et al*., 2010; Atkinson *et al*., 2014). Timing of breeding in birds in Nigeria depend on the amount of rainfall (Cox *et al*., 2013).

Nigeria usually experiences a short-wet season and a long dry season; rainfall varies from one part of Nigeria to another. the southern part of Nigeria experiences high amount of rainfall whereas the northern part receives less rainfall (Morel & Morel, 1992; Cox *et al*., 2013). In Northern Nigeria, the amount of vegetation which may influence food supplies of many bird species is largely determined by rainfall (Newton, 2004; Schaefer *et al*., 2006). In the wet season, many of the habitats may be characterized by dense vegetation cover, fruiting trees and flowers which may support many bird species. However, in the dry season most habitats may have low to no grass.

Seasonality may influence bird abundance, diversity and distribution in Northern Nigeria. Farmlands in the dry season have shown increase in abundance and diversity of some migrant birds such as Whinchat (*S. rubetra*) in their West African wintering ground (Hulme & Cresswell, 2012). In central Nigeria, Brandt and Cresswell (2008) found that home range size of the endemic Rock Fire Finch (*Lagonosticta sanguinodorsalis*) was larger during the dry season as a result of long movement in search of water sources; *L. sanguinodorsalis* also preferred scrub savannah during the dry season compared to inselberg and farmland habitat. In Sahel Savannahs of Nigeria, Garden warblers (*Sylvia borin*) were reported to be more abundant in the wet season than in the dry season; their abundance was associated with an increase in food availability during the wet season (Ottosson *et al*., 2005). Other studies in Nigeria (Newton, 1998; Molokwu *et al*., 2008) have noted that weather patterns may also have direct and indirect effects on bird distribution by affecting their food availability and habitat configuration.

Rainfall in places like Nigeria has been predicted to reduce drastically over the next 50 years (Studds & Marra, 2007). This reduction could affect both resident and migrant birds. Reduction in the amount of food (fruits, insect and nectar), loss of habitats (for resident birds) and wintering ground (for migrant birds), phenology mismatch (for migrant birds) and other severe conditions (both resident and migrant birds) may affect bird's ecology, survival and reproduction (Studds & Marra, 2007). The effect of climatic fluctuations is likely to be critical in human-modified landscapes in areas where pristine forest have been altered and converted into farmlands (Morris, 2010; Mulwa *et al*., 2013).

2.4 The effects of anthropogenic activities, habitat loss and variation on birds

Anthropogenic activities have been shown to negatively influence bird population either directly (hunting) or indirectly by affecting their reproduction and survival through changes in their habitat (Manu *et al*., 2007; Child *et al*., 2009; Magige *et al*., 2009; Douglas *et al*., 2014). Studies have reported changes in bird populations for example, a decrease in farmland species such as Yellow Wagtail (*Motacilla flava*) and Skylark (*Alauda arvensis*) (Chamberlain *et al*., 2000; Vickery *et al*., 2001), as well as increase of agricultural pests like Hooded Crow *Corvus cornix* (Laiolo, 2005). In the United States, the decline of Red-winged blackbird (*Agelaius phoeniceus*) was associated with longtime changes in farming practices (Blackwell & Dolbeer, 2001; Benton *et al*., 2003). Other studies in Europe (Fuller *et al*., 1995; Chamberlain *et al*., 2000; Gregory *et al*., 2005) have attributed the decline of farmland birds to changes in land use. Maron and Lill (2005) reported the negative effects of grazing on ground foraging birds. Gonnet (2001) found species richness and Emberizid density to be higher in ungrazed sites. In the tropics, rich biodiversity areas are found in densely populated areas which are prone to forest loss (Laube *et al*., 2008).

A number of studies have shown positive effects with agricultural land use (agroforestry) by maintaining or increasing bird species richness, abundance and diversity (Farwig *et al*., 2008; Ranganathan *et al*., 2008; Clough *et al*., 2009; Hulme & Cresswell, 2012; Blackburn & Cresswell, 2015; Muñoz-Sáez *et al*., 2017). This can be exemplified by some human-made wetlands such as rice fields which provide a surrogate habitat for waterbirds (Fasola & Ruiz, 1996; Toral *et al*., 2011; Nam *et al*., 2015). In Central Zululand and Maputaland of South Africa, anthropogenic activities such as tree clearance and shrub patches from grazing or coppicing for fuelwood (Scholes, 1997; Fairbanks, 2004) have been shown to increase heterogeneity (mosaic diversity) and in turn promote bird diversity (Harrison *et al*., 1997; Fairbanks, 2004). In Nigeria, bird species such as Yellow Wagtail (*M. flava*) and Whinchat (*S. rubetra*) have been reported to benefit from anthropogenic forest clearing and conversion to farmlands (Salewski & Jones, 2006; Hulme & Cresswell, 2012).

However, in most of these anthropogenic-related studies either the unique species were replaced by generalist bird species (Coetzee & Chown, 2016) or the effects benefited only the generalists. Specialists, scavengers, raptors and other large bodied birds often decline in their abundance, richness and diversity as a result of landscape transformation (Thiollay, 2007; Tscharntke *et al*., 2008; Child *et al*., 2009; Neuschulz *et al*., 2011; Domenech *et al*., 2015). This is because habitat and dietary specialist birds are predicted to have less options than their counterpart generalist species (Hockey & Midgley, 2009). Therefore, moderate amount of anthropogenic activities may result in increase of bird species which tended to be generalist species (Ulfstrand, 1995; Pomeroy & Dranzoa, 1997). However, the anthropogenic and bird species relationship occurs at small scale human transformation and not at large scale level.

As human population continues to grow in Africa, natural areas are modified due to wood removal (fuelwood collection), farming, grazing and other anthropogenic activities such as disturbance (human interference) through human encroachment (Adams *et al*., 2014). Fortunately, birds in the tropical region are easy to monitor and have been used to conduct studies on the effect of land use change (Laube *et al*., 2008) and anthropogenic activities on bird communities. In the Upper Guinea for example, the effect of deforestation in the rainforest might have caused a decrease in the number of species and a dramatic change in species composition (Blankespoor, 1991; Kofron & Chapman, 1995). Kofron and Chapman (1995) found that about 70% of the rainforest bird species were absent in a deforested site in Liberia. Newmark (1991) reveals that interior birds are mostly affected by forest fragmentation in the intermediate moist forests of Eastern Usambara Mountain, Tanzania.

In South Africa changes in land use and climate change are important factors influencing dynamic range shifts by bird species (Hockey *et al*., 2011). Tree felling in miombo woodland in South Africa has transformed the woodland habitat into derived savanna (secondary habitat) resulting in loss of habitat for many bird species. Similar situation had been reported in West African countries such as Nigeria (Newton, 2004; Cresswell *et al*., 2007; Stevens *et al*., 2010). The destruction of woodland habitats in many parts of the world might have been the major reason as to why many woodland bird species have been categorised as "Birds of Conservation Concern" (Gregory *et al*., 2002; Hewson & Noble, 2009).

There are also increases in agricultural developments and desertification process which is threatening most of the West African Sahelian habitats (Morel & Morel, 1992). Rich biodiversity areas such as the Cameroon and Gabon lowlands, and Cameroon Mountains (covering Cameron, Equatorial Guinea, Central African Republic and Nigeria) are faced with forest loss, hunting, wood removal (firewood collection), overgrazing and unsustainable exploitation of timber (Atuo *et al*., 2016; BirdLife International, 2017c). Trapping of bird for trade and felling of large trees on farmland were the primary cause of Grey Parrot (*Psittacus erithacus*) decline in Ghana, (Annorbah *et al*., 2016). Likewise, decline in abundance of large birds in the Sudanian belt of Burkina Faso had been attributed to hunting, wood removal, intensive cattle grazing and habitat degradation (Thiollay, 2006b).

Nigeria is the most populous country in Africa, with a rapid population growth and a corresponding need for food and shelter. The increase in shelter and food demand which cannot be imported or met by higher productivity comes from the conversion of natural habitat into farmlands, human settlement and activities such as hunting, wood removal for firewood and grazing (Manu *et al*., 2007; Brandt & Cresswell, 2008; Birdlife International, 2016). It has significantly contributed to bird habitat loss due to the conversion of natural habitats for agriculture and settlement purposes (Matson *et al*., 1997; Tscharntke *et al*., 2005; Muñoz-Sáez *et al*., 2017).

Activities related to land use changes are widespread in most developing countries (Shahabuddin & Prasad, 2004; Shahabuddin & Kumar, 2006; Thiollay, 2006b), and has a cascading effect on many bird species through habitat loss and change in their pattern of habitat use. For example, bird species frequenting savannah habitats (*Whinchat, Saxicola rubetra*) are found to be associated with low-intensive farming areas in Central Nigeria (Hulme, 2007; Liminana *et al*., 2012b). This scenario might be related to the presence of their prey (insects) that have extended their movement to these new agricultural areas (Liminana *et al*., 2012c). On the other hand, bird species such as Wood Warblers (*Phylloscopus sibilatrix*) may be more affected by the consequences of land-use change due to their fine-scale selection of woodland habitats (Mallord *et al*., 2016).

Many woodland and shrubland habitats have been converted into farmlands areas (Cresswell *et al*., 2007; Adams *et al*., 2014). Farming are among multiple threats to bird survival in Nigeria (Galushin *et al*., 2003; Thiollay, 2006c, 2006a). Some of these bird species include the globally threatened Grey-necked Picathartes (*Picathartes oreas*) (Atuo *et al*., 2016). The presence of *P. oreas* was negatively correlated with disturbed areas (Atuo *et al*., 2016). In many parts of Nigeria, especially in the rural communities, firewood is a major source of energy and majority of these wood are fetched from natural woodland habitat. Fuelwood removal and livestock grazing contribute to the extensive woodland and natural grassland degradation (Thiollay, 2006b, 2006c; Mamo *et al*., 2016). Firewood collection has been shown to change the abundance and diversity of invertebrate species that depend on deadwood microclimate; these changes may have consequences on cavity-nesting birds that are reliant on these invertebrates (Duplessis, 1995). Grazing may influence bird diversity and abundance negatively although the responses depend on the type and severity of disturbances (Mamo *et al*., 2016).

In the Borno State in north eastern Nigeria, Cresswell *et al*. (2007) found 82% decease in bird abundance and diversity with decreased tree density in the Watucal forest area. Woodland habitat declined by 14% between 1976 and 1995 (Cresswell *et al*., 2007; Stevens *et al*., 2010). It is obvious that anthropogenic activities (farming, grazing, wood removal and human disturbance) pose major threats to bird and habitat conservation in Nigeria (Galushin *et al*., 2003; Thiollay, 2006c, 2006a; Cresswell *et al*., 2007; Stevens *et al*., 2010; Birdlife International, 2016b, 2017a, 2017b), with habitat change greatly affecting bird abundance and diversity especially in the Sahel.

Dutse is a sizable area with increasing population growth; it has seen considerable land use change in the last three decades, especially the conversion from vegetated area to township, cultivated land, and bare surfaces (Zangina, 2015). In the wet season, existing farmlands (that are left to fallow) are prepared for new farming season, trees, shrubs and other vegetation are displaced in the process. In the dry season, migrant birds arrive at the wintering ground in Dutse and surroundings. However, at the end of the dry season and prior to wet season, grasses and grazing areas are usually scarce in Dutse and in most sahelian areas in Northern Nigeria. During this period, wood removal (usually branches with leaves) and cutting of various trees and shrubs by the nomadic Fulani people to feed their cattle/livestock causes severe damages to bird habitat and consequently affecting bird abundance and diversity (Mengesha & Bekele, 2008). This yearly migration of the nomadic Fulani people is traditional and common in northern part of Nigeria. A majority of the household in Dutse still depend upon firewood for cooking and in local bakeries. Grazing is pronounced as many of the people engage in livestock rearing. Forested areas in Dutse are rapidly disappearing due to these land use changes, and much of the total land area in Dutse is under some form of human impacts (Zangina, 2015);these changes likely reduce natural habitat available for birds and other species.

2.5 Spatiotemporal utilization of habitat by feeding guild, residence status and population trend

Birds among other organism are the best studied with various significance (Assessment, 2005; Sekercioglu, 2006). About 70% of birds are important seed pollinators and dispersers (Clout & Hay, 1989; Anderson, 2003; Holly *et al*., 2007). Frugivores help with seed dispersal, as exemplified by the White-thighed Hornbill (*Ceratogymna cylindricus*) and the Black-casqued Hornbills (*Ceratogymna atrata*), this in turn contributes to rainforest diversity and regeneration in lowland tropical forest of Cameroon (Holbrook *et al*., 2002).

Furthermore, about 4% (320 plant species) of the world flora are pollinated by nectarivorous bird species (Rebelo, 1987; Pauw & Louw, 2012). The Long-billed Malachite Sunbird (*Nectarinia famosa*) plays a vital role (exclusive pollinator) by pollinating plant species in Cape Town (Pauw & Louw, 2012). Insectivorous birds reduce the abundance of herbivorous arthropods whereas granivorous birds decrease seed survival (Ogada *et al*., 2008). Raptors help with the consumption of carrion and as invertebrate and vertebrate predators. On the other hand, birds serve as important prey for raptors and some mammals (Ogada *et al*., 2008).

Habitat loss and degradation have been associated with migrant birds decline on their West African (like Nigeria) wintering ground (Kelsey, 1992; Wilson & Cresswell, 2006; Cresswell *et al*., 2007; Adams *et al*., 2014; Vickery *et al*., 2014). In comparisons to residents, migrant birds are more susceptible to the effect of habitat loss and environmental degradation (Vickery *et al*., 2014). This could be due to their open nest on trees or ground making them more prone to habitat fragmentation and degradation (Kelsey, 1992). Other factors like variation in rainfall, wetland change, food availability and loss of staging areas, have also been connected to migrant birds decline (Kelsey, 1992; Leisler, 1992; Kanyamibwa *et al*., 1993; Newton, 2004; Sanderson *et al*., 2006; Wilson & Cresswell, 2006; Cresswell *et al*., 2007; Zwarts *et al*., 2009; Cox *et al*., 2013; Adams *et al*., 2014; Vickery *et al*., 2014; Mallord *et al*., 2016). However, long-distance migrants such as Sedge Warbler (*Acrocephalus schoenobaenus*), Common Whitethroat

(*S. communis*), and Sand Martin (*Riparia riparia*) have been reported to experienced greater population decline than their counterpart short distance or resident birds (Sanderson *et al*., 2006; Hewson & Noble, 2009). Because long distance migrants struggle with readjustment to changing temperatures and crossing of the sahara desert, loss of staging and refueling sites, hence suffer more from the impacts of human-induced climate change than other birds.

Global climate change can alter the spatiotemporal distribution of resources and thus affect the seasonal movement patterns of migratory animals through spatio temporal mismatch between important life history events such as breeding and seasonal food abundance (Both *et al*. 2006; Cherry *et al*., 2013). Global warming may alter the timing of numerous seasonally dependent ecological processes, thus affecting migratory behaviour and seasonal habitat use of several species (Cherry *et al*., 2013). Such effects can cause negative energetic and reproductive consequences for migratory wildlife (Cherry *et al*., 2013).

The planet and the organism that live in it are threatened by climate change, as a result of human interference, thus having a negative effect on migratory birds which are very sensitive to environmental changes (BirdLife International, 2007). Increasing temperatures, changing vegetation and extreme weather conditions lead to significant changes of the birds' essential habitats. In many cases, these are likely reasons for the decline of bird populations and changes in migration pattern (BirdLife International, 2007). Quantifying ecological connections between environmental factors and the habitat, spatial and seasonal distribution of populations is therefore important for examining potential effects such as climate change (Post & Forchhammer 2002; Cherry *et al*., 2013).

Despite the extensive work on migrant birds in their West African wintering ground, the causes of their decline are inadequate and still poorly understood (Kelsey, 1992; Mallord *et al*., 2016). Continued loss of wintering ground might affect the following breeding season and continue to cause further decline of migrant birds (Norris *et al*., 2004; Blackburn *et al*., 2017) as well as residents because migrant birds are integral part of African avifauna (Leisler, 1992).

2.6 Abundance of resident and migrant bird species with decreasing population trend across habitat and season

Migration forms an integral component of the life history of many species and a behavioural adaptation to seasonal environmental fluctuation (Cherry *et al*., 2013). The predictable nature of many seasonally dependent ecological processes allows migratory species to best utilize energy gains by altering seasonal habitat use to overlap with abundant or accessible nutritional resources (Cherry *et al*., 2013).

Migration increases foraging efficiency and the likelihood of reproductive success through seasonal fidelity to familiar areas (Cherry *et al*., 2013). Specific seasonal environmental changes are commonly thought to act as migration triggers for species that show predictable and cyclical fidelity to different habitat ranges. For example, onset of migration for migratory birds has been shown to correlate with photoperiod (Cherry, *et al*., 2013) and some bird species appear to alter rates of migration in response to environmental conditions such as weather or plant phenology (Marra *et al*. 2005; Cherry *et al*., 2013).

The Senegal and Niger rivers are two important river basins that support most of the Sahelian habitats in West Africa and the reasons why West African habitats serve as wintering ground for many migrant bird species (Morel & Morel, 1992). As a result, enormous numbers (> 2 billion) of Palearctic migrant birds spend their wintering period in these areas (Rabøl, 1987; Hahn *et al*., 2009; Zwarts *et al*., 2009; Mallord *et al*., 2016). These huge numbers of visitors may influence the ecology of local bird species (residents) through increased competition of habitat and spatial use in different seasons (Rabøl, 1987). Arrival of migrants has been thought to cause a niche shift of resident birds, although no strong evidence exists (Leisler, 1992). Migrants are less neophobic, eurytopic (Leisler, 1992) and generalist (Hulme & Cresswell, 2012; Blackburn & Cresswell, 2015; Ivande & Cresswell, 2016) on their wintering ground, making it easy to change and adapt to varieties of habitat and resources. For example, Willow Warbler (*Phylloscopus trochilus*) was reported to change their habitat distribution from groves to woodland habitat (Rabøl, 1987).

Some studies have shown that, in certain instances, migrants may outnumber their resident congeners in their habitats (Lack, 1985; Kelsey, 1992). In a study by Aidley and Wilkinson (1987a), three species of Palearctic migrants (*Acrocephalus Warblers*) outnumbered their resident congeners in Kano in North western Nigeria. This may result to increased competition for space and habitat use amongst resident and migrant birds. Comparative studies on habitat and spatial use and foraging ecology of resident and migrant birds is lacking in many parts of Nigeria (Jones *et al*., 1996).

Both individual birds and bird species are declining as one moves south (Cresswell *et al*. 2009; Wilson & Cresswell 2010). One of the common and widely spread European bird species that breed across much of the Western Palearctic is the Northern Wheatear (*Oenanthe oenanthe*), with an estimated population of about 4.5 million (Wilson & Cresswell 2010). Generally, the populations of many Palearctic migrant birds are declining (Sanderson *et al*. 2006, Wilson & Cresswell 2010).

Bird population trends are good measures of biodiversity (Gregory *et al*., 2005; Bachler & Liechti, 2007). Unfortunately, many birds in Nigeria (Crested Lark *Galerida* *cristata*, Green-backed Heron *Butorides striata*, Blue-naped Mousebird *Urocolius macrourus*, Bruce's Green Pigeon *Treron waalia*) are shown to have decreasing population trend resulting from the aforementioned human activities (IUCN, 2016; BirdLife International, 2016b). The impact of habitat degradation and loss have been found to affects migrant birds more compared to resident bird species (Vickery *et al*., 2014).

CHAPTER 3: MATERIALS AND METHODS

3.1 Study area

The study was conducted in Dutse (11°42′04″N and 9°20′31″E), an area of 7382 km^2 with an elevation of 780m (Mansur, 2014), located in northwest Nigeria (Figure 3.1). The climate of the area is categorized as tropical with clear wet and dry seasons with a mean annual temperature of 26ºC (Zangina, 2015). Dutse experiences two distinct seasons; the wet season typically from June to September (mean temperature = 31ºC) but may last until October while the dry season starts from October to May. During the dry season, mean daily temperature ranges from 20ºC (in the cooler months of October to February) to 42ºC (during the hotter months of March to May). Annual rainfall ranges from 600 mm to 1000 mm.

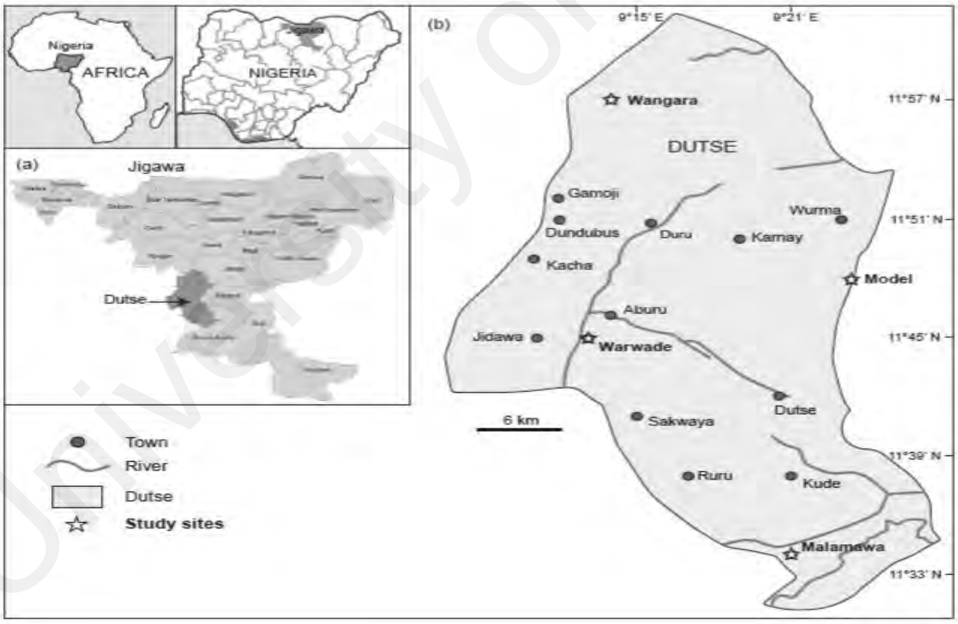

Figure 3.1: Map of (A) Jigawa state showing (B) Dutse and the study sites.

The main vegetation type in Dutse is the Sudan savanna. Vegetation type ranges from dense woodland and shrubland to degraded cultivated farmland and rangeland and characterized by few scattered trees and extensive open woodland and grasslands. There are also traces of the Guinea savannah. A site may appear green and densely vegetated during one season (wet season) but look different in another season (dry season). Most trees belong to the families Ceselpinaceae and Mimosaceae. Dutse is located close (<100 km) to the Important Bird Area (IBA), the Hadejia – Nguru Wetlands. These two sites may have similar avian composition due to their close proximity and similar vegetation and climatic conditions.

As a state capital, Dutse has experienced both small and large-scale habitat conversion for construction of airport and houses in the last two decades. The increasing demand for shelter and food has also accelerated the conversion of natural habitat into farmlands, human settlement and for activities such as hunting, animal grazing and wood removal for firewood. The vegetaion is used for a number of purposes such as medicinal (herbal medicine), mat making, firewood, and building of thatched roofing making Dutse vunerable to desertification.

About 80% of the people in this area are depending on agricultural activities with sorghum and millet being the major food crops (El-Tantawi *et al*., 2017). Most of the farmers in Dutse cannot afford mechanized farming. Therefore, cattle or rudimentary tools are used to plough farming landscape with reliance on rain fed agriculture. These had resulted in small scale farming, with majority of the smallholder farmers practicing polyculture farming system. In most cases, groundnut, sorghum, and beans are planted at the same time within the same area. Average farm size in Dutse is 2.5ha and the farms are allowed to fallow in non-wet season. Cash crops such as potatoes, mangoes, peanuts, beans, cotton, sugar cane, dates, and several types of vegetables are produced in large quantities. In addition to major agricultural activities, a number of people engage in livestock rearing, blacksmithing, basket and mat making, weaving, pottery, leatherwork, fishing and tanning.

3.2 Study design

Four sites in Dutse with different vegetation types were identified for data collection. Site names were represented by major villages in the area, namely Wangara which is 35 km north, Warwade is 10 km west, Malamawa is 30 km south, and Model is seven km east of the Dutse town. Six transects of two km in length were established in each site. Eleven points were created on each transect, with 200 meters spacing between points and between transects. This set up is generally consistent with the recommendations given for bias reduction and for assessment of habitat effects (Manu & Cresswell, 2007). These sampling transects, and points were created using the ruler function in Google Earth (Version 7.1.1.1888). Specifically, a ruler was placed at the first site coordinate to create the first point on the first transect; then 200 meters was measured from the first point to generate the second and subsequent points.

These coordinates were recorded on a handheld Global Positioning System (GPS GARMIN 64S, UTM) that was then used to locate points and transects in the field (Appendix A for point coordinates by site). In total, 264 points on 24 transects of 48 km in length were laid in all sites. Transects and point were permanently established in the four regions. Therefore, same transects and points were surveyed and repeated throughout the entire study. This was to ensure that the detectability of birds was consistent between habitats and seasons. Figure 3.2 shows the satellite view of the study area.

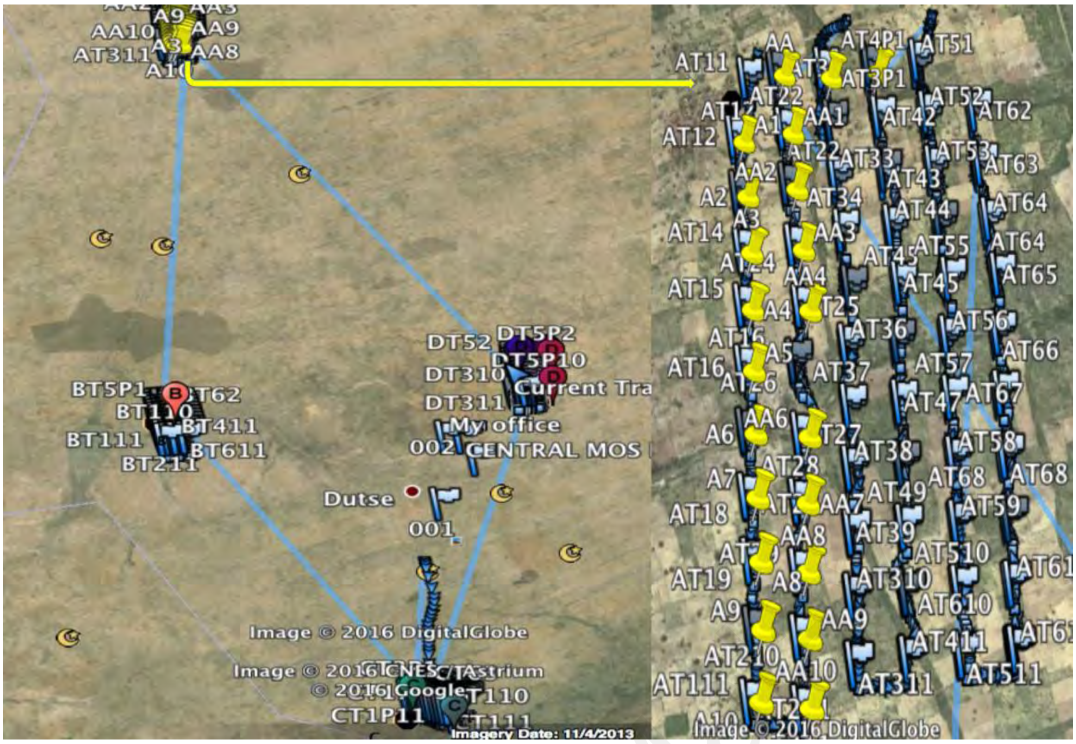

Figure 3.2: Satellite view of study sites (Source: Google Earth).

3.3 Bird count

The point transect method was used to record quantitative bird data during the wet (August to October 2015) and the cool, dry (November to February 2016) seasons. Each site was visited for three consecutive days every month, with at least 25-day intervals between counts. A total of 21 visits per site was made for the entire study. Bird counts were carried out between 0630 to 1100 hour under normal weather conditions on windless and rainless days. Recording would start immediately upon arrival at the site (Cresswell *et al*., 2007; Stevens *et al*., 2010). Birds were observed with a pair of Olivon binoculars (8 x 48). Birds seen, heard or flying over the point count station were recorded during a five-minute period (Sorace & Visentin, 2007; Stevens *et al*., 2010).

Lynch (1995), Sorace *et al*. (2000), Peak (2011) have recommended the use of short survey count (2-5 minutes) to quantify bird communities. The shorter survey period reduces over-estimation of densities due to undetected movement in the area and allows for more number of points to be surveyed in a given time duration (Lee & Marsden, 2008). It also could minimize the risk of double counting and cover larger area within a short period of time (Lynch, 1995; Thompson & Schwalbach, 1995; Marsden, 1999; Sorace *et al*., 2000). Considering the study design and the number of points and transects, five minutes was sufficient for recording of birds and habitat variables; the latter is described further in section 3.4 (Cresswell *et al*., 2007; Sorace & Visentin, 2007; Stevens *et al*., 2010; Peak, 2011).

Only birds present within 50 m radius from the center of the point were counted. On approaching or arrival at a station, flushed or disturbed birds within point count station were recorded as present (Marsden, 1999). When there was doubt as to whether a sighted bird was within the boundary or otherwise, A laser range finder was used (Nikon LASER 350, 6 X 2160) to measure distances of detected birds found greater than 10 m while distances of less than 10 m were visually estimated (Stevens *et al*., 2010). Counts by sound was recorded as a single individual except when they duet or were heard from different locations at the same time. If there was a possibility of double counting, birds were not recorded.

From one point to another on each transect, observer walked along a straight path at a slow and steady pace of approximately 40 m per minute. Equal numbers of points and number of visits across points and sites were sampled for the entire study. The same technique of counting birds, starting at transect one and finishing at transect six, and recorded habitat variable (more details below) was followed for all surveys. All bird identification and habitat recording throughout the entire study period was performed by a single observer to maintain consistency. Bird identification was done following Borrow and Demey (2014). Figure 3.3 shows the graphical explanation of data collection.

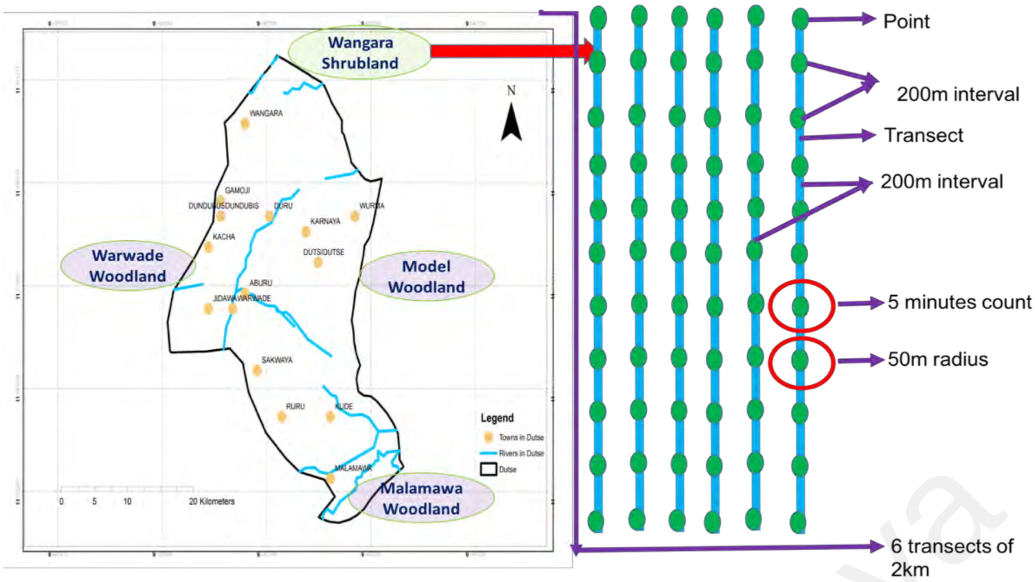

Figure 3.3: Graphical view of data collection system.

3.4 Recording of habitat and anthropogenic variables

Two habitat types, namely woodland and shrubland, were identified in the study sites. The sites were classified as either woodland or shrubland if more than 70% of the vegetation type were either trees or shrubs respectively (Table 3.1 for more details). Sites are ecologically different; Wangara is dominated by shrubland whereas the other three sites are dominated by woodland (Figure 3.4). Model is closest to the township of Dutse which has more human settlements and farmlands than the rest of the sites. Sites closer to Dutse town may experience more conversion of forest areas to farmlands and buildings which is likely to alter bird composition of the area. Tree types and structure differs among the site. The dominant tree species in Model is date palm (*Phoenix dactylifera*), while the other three sites were dominated by Neem trees (*Azadirachta indica*), Baobab (*Adansonia digitate*), Doum Palm (*Hyphaene thebaica*), Acacia species (such as *Acacia seyal, Acacia senegalensis*) and *Ficus* species. Five minutes was allocated at each point to record habitat variables and anthropogenic activities (more details below and in Table 3.1). Trees and shrubs were counted by visual observation at each point within a 50-meters radius.

Table 3.1: Description of habitat and anthropogenic variables recorded within a 50-m radius at each point in all sites.

Variables	Levels	Description
Habitat		
Type	Shrubs	Woody plants below 3 meters in height and often with branches reaching or close to the ground around multiple stems.
	Trees	Woody plants exceeding 3 meters in height
Anthropogenic		
Wood removal	None, Moderate, High	Observed piles of firewood and chopped branches by human or the presence of humans cutting trees or branches
Grazing	None, Moderate, High	Presence of dung, livestock (cattle or sheep) and obvious grazed stems
Farming	Absence, Presence	Presence of farmers, either with or without the use of cattle for ploughing, within farmlands
Human interference	Absence, Presence	Presence of human

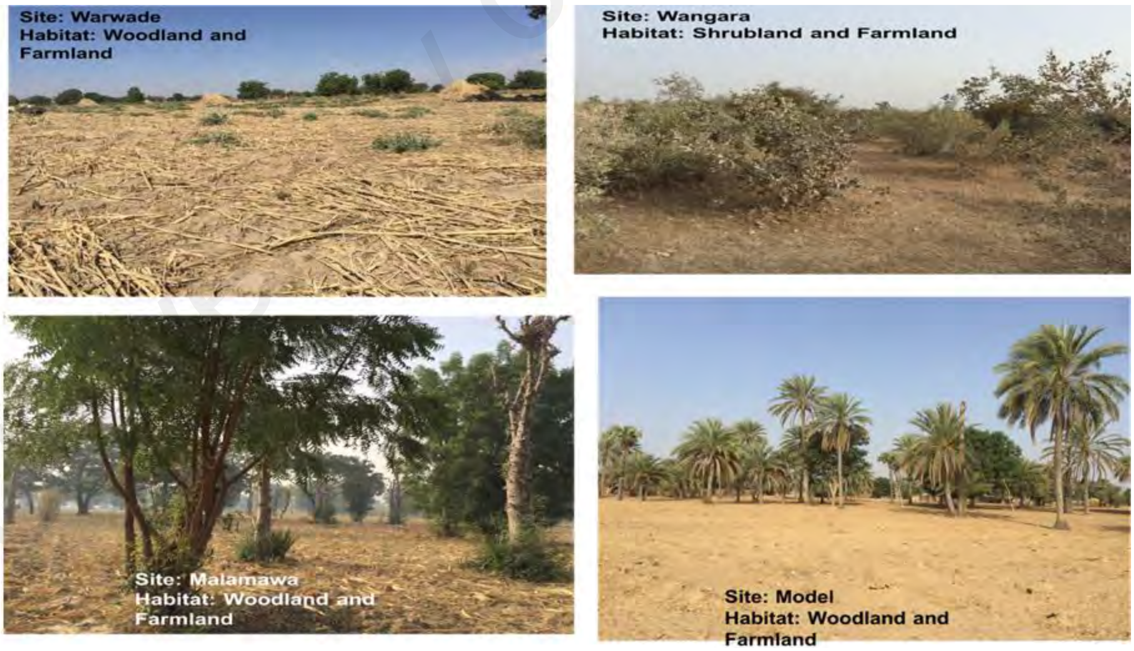

Figure 3.4: Dominant habitat types in the study sites.

At each point, four types of anthropogenic activities were recorded as categorical factors within 50 meters radius. Wood removal was recorded as none (0) when no felled tree or branches was observed around the point, as moderate (1) for ≤ 9 and as high (2) for ≥10 felled trees or branches (Figure 3.5). Animal grazing was recorded as none (0) for absence of dung and of livestock, moderate (1) for presence of few dung balls and/or livestock (≤ 9), and high (2) for many dungs and/ or livestock (≥10) (Figure 3.6). Farming was recorded based on presence (1) or absence (0) of encounter with farmers within the farmlands. This was because farmlands may or may not be actively farmed during time of observation (Figure 3.7). Human interference was also recorded on the basis of absence (0) and presence (1) of encounter with passers-by and human-caused interruptions (Figure 3.8). Appendix B shows a sample of field recording sheet used for data collection in this study.

Figure 3.5: Wood removal at some points during data collection.

Figure 3.6: Grazing activities at some points during data collection.

Figure 3.7: Farming activities at some points during data collection.

Figure 3.8: (Human interference) Disturbance at some points during data collection.

A simple anthropogenic index was constructed by a weighted additive combination of the four anthropogenic variables. Specifically, double weight was given to the wood removal variable since the damage caused can be considered long-lasting and resulted in removal of possible habitat for the birds. The other variables can be considered relatively fleeting in effect and were therefore assigned equal weight. Values for the index ranged from 0 to 6. These values were then recoded as 'low' for values 0 to 1, 'medium' for values 2 to 3, and 'high' for values 4, 5, and 6. The index allowed for analysis of anthropogenic impacts collectively.

3.5 Bird categories

All birds were categorized by feeding guilds (granivores (G), insectivores (I), frugivores (F), omnivores (O), nectarivores (N), carnivores (C) or piscivores (P)) and by population trend (stable, decreasing, increasing and unknown), with the aid of the Handbook of the Birds of the World (del Hoyo *et al*., 2016) and the International Union for Conservation of Nature Red List of Threatened Species (IUCN, 2016). Using Borrow and Demey (2014), residence status of bird species was classified as breeding visitor (BV), non-breeding visitor with main range (NBVMR), non-breeding visitor with sparse occurrence (NBVSO), resident (R), and resident but partially migratory (RPM). Species nomenclature (taxonomy and scientific names) of recorded species followed Borrow and Demey (2014).

3.6 Data analyses

Number of species, i.e., species richness, was determined for each point. Abundance per point was calculated by summing up total number of birds seen and heard. Diversity per point was calculated using the Shannon Wiener diversity index (H) (Ortiz-Burgos, 2016) as follows:

$$H = \sum_{i=1}^{S} -(P_i * \ln P_i) \quad (3.1)$$

where

Pi = proportion of individuals belonging to the ith species

S = total number of species

To determine if the survey effort across sites was generally sufficient and to see if detection of new species by site and sample coverage had reached an asymptote level, iNEXT package (Hsieh *et al*., 2014) was used to create richness (q=0) and Simpson diversity (q=2) rarefaction and extrapolation curves (R/E) in R (R Development Core Team, 2016). Sample-size-based R/E curve, and sample completeness curve were used to show richness and Simpson diversity plots. The rarefaction method has been shown to be the most effective and appropriate method for comparing diversity of unequal samples (James & Rathbun, 1981). Chao richness, Shannon and Simpson diversity were calculated using the vegan package in R (Oksanen *et al*., 2017). Species accumulation curve as a function of sampling unit (transect) was generated to determine if future sampling effort will increase avian species diversity in the study area. Linear regression was used to test if there is relationship between bird abundance and diversity with time of day. Rank abundance curves for all species were constructed to visualize the differences across sites, habitats and seasons. Similarity percentage (SIMPER) analysis was performed to ascertain which bird species was responsible and contributed more to the variation of bird assemblages and to determine the source of differences among habitats, sites and season. This analysis was performed using Paleontological Statistics Software Package (PAST) Version 3.18 (Hammer *et al*., 2001). The Bray-Curtis distance was used to calculate dissimilarity matrix for SIMPER.

Analysis of Variance (ANOVA) was used to test for differences in the response variables (bird species richness and abundance) between four explanatory variables (season, site, habitat and anthropogenic index). Site was confounded with habitat; therefore, ANOVA models with habitat and with site variables were constructed separately. For each response variable, a full three-way ANOVA model (including interaction) was performed. Model simplification was carried out by removing non-significant variables and the F-test was performed to compare between the nested models (appendix C shows the different ANOVA models simplification). Assumptions were examined after each ANOVA fitting. Final ANOVA model was based on log-transformed bird species richness and log-transformed abundance due to heteroscedasticity and non-normality. For bird diversity, the Kruskal-Wallis one-way ANOVA test was performed for all explanatory variables separately as the parametric ANOVA assumptions were not met. Post hoc pairwise multiple comparison (Tukey's and Dunn's tests) were conducted for significant site differences.

To determine whether the bird assemblages differ between habitats, seasons and sites, a permutation-based Analysis of similarity (ANOSIM) test was applied on the Bray-Curtis dissimilarity matrix of the abundance data. The Global R statistic serves as a measure of dissimilarity; the closer R is to one, the greater the separation of assemblages between the categorical variables. A total of 10,000 permutations were conducted on both untransformed and presence-absence data; the latter to give equal weight to both abundant and rare species. The non-metric multidimensional scaling (NMDS) ordination technique was used to visualize these differences in the bird assemblages in a biplot across seasons and habitats.

General linear modelling was initially used to examine the degree of impact of individual anthropogenic activities (farming, grazing, wood removal, and human interference) and other landscape variables (tree and shrub density) on bird variables. Specifically, Poisson and negative binomial regressions were fitted; however, neither model provided satisfactory fit. Therefore, a linear mixed effects model on log-transformed abundance data was used to account for the nature of repeated surveys in the study. Sites, transects, and dates were set as random effects to account for repeats across points, transect and sites as well as variation between the data collection periods. Diagnostic plots were used to assess assumptions of the model.

A one-way Multivariate Analyses of Variance (MANOVA) was performed to test for difference in the abundance of birds by feeding guild, residence status, and population trend across the categorical variables of habitats (woodland and shrubland), sites (Wangara, Warwade, Malamawa and Model) and seasons (wet and dry). The Pillai trace was used as the test statistic. For the feeding guild, only insectivores, granivores and frugivores were included in the MANOVA analysis given the low numbers of piscivores and nectarivores recorded. For the purpose of the MANOVA analysis, birds with the status of resident (R) and resident but partially migratory (RPM) were considered as residents, whereas breeding visitor (BV), non-breeding visitor with main range (NBVMR), and non-breeding visitor with sparse occurrence (NBVSO) were considered as migrants. Partial eta squared was determined using heplots package (Fox *et al*., 2017) in R. Gignac and Szodorai (2016) was followed to define partial eta squared value as <0.1, >0.1 and >2 as low, moderate and strong respectively. Birds with unknown population trend were excluded and only birds with stable, increasing and decreasing population trends were used for analyses.

One-way Analysis of Variance (ANOVA) was performed to test for differences in the abundance of individual birds with decreasing population trend. Between resident and migrant bird species, a two-way was used to test for differences. To test for differences and the effects of habitat and season on the abundance of birds with decreasing population trend, a two-way ANOVA and a linear regression were carried out respectively.

Except for the SIMPER analyses which was analysed using PAST software version 3.18 (Hammer *et al*., 2001), all statistical analyses were conducted using the R computing platform (R Development Core Team, 2016), with additional functions provided by the following packages: vegan (Oksanen *et al*., 2017), BiodiversityR (Kindt & Coe, 2005), nlme (Pinheiro *et al*., 2017), and dunn.test (Dinno, 2017).

3.7 Bird checklist

For the purpose of preparing a comprehensive bird's checklist, a number of unrecorded or unencountered bird species (new to the list) that were recorded outside the point count surveys was added into the checklist although it was excluded from the statistical analyses. Individual bird species recorded by habitat and season and a checklist of bird species showing guild, habitat, population trend and status were compiled.

CHAPTER 4: RESULTS

4.1 Bird abundance and diversity across seasons, habitats and sites

A total of 13,656 individuals belonging to 128 bird species from 46 families were recorded during the entire study (Appendix D). This represented 15% of the total Nigerian bird species recorded to date. Species rarefaction curves suggested that number of individuals surveyed across the sites already reached an asymptote (Figure 4.1). This implied that the sampling effort for the avian community in the study areas was adequate. Therefore, further effort was unlikely to add many more species. However, since the study was largely on land bird species, it is expected that future avian sampling will increase species richness for Dutse, albeit at a slower rate (species accumulation curve Figure 4.2). A summary of the spatiotemporal sampling effort, habitat and bird variables is shown in Table 4.1.

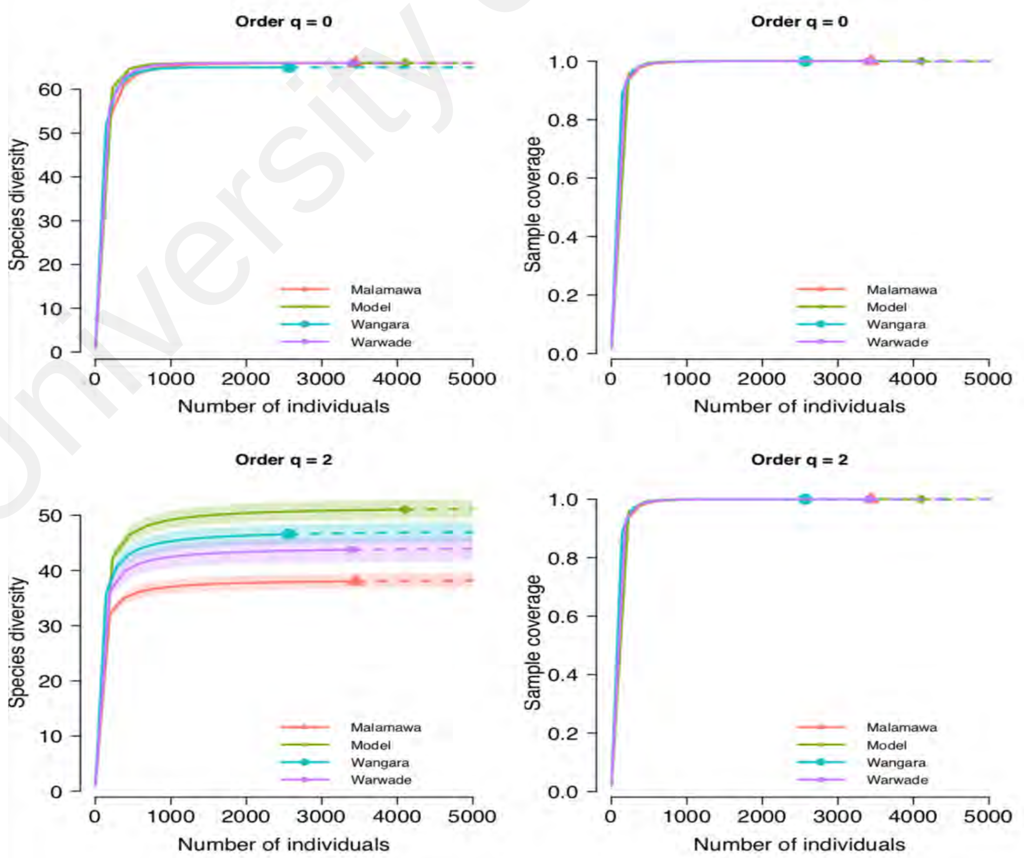

Figure 4.1: Species rarefaction curves of avian bird species richness (q=0) and Simpson diversity (q=2).

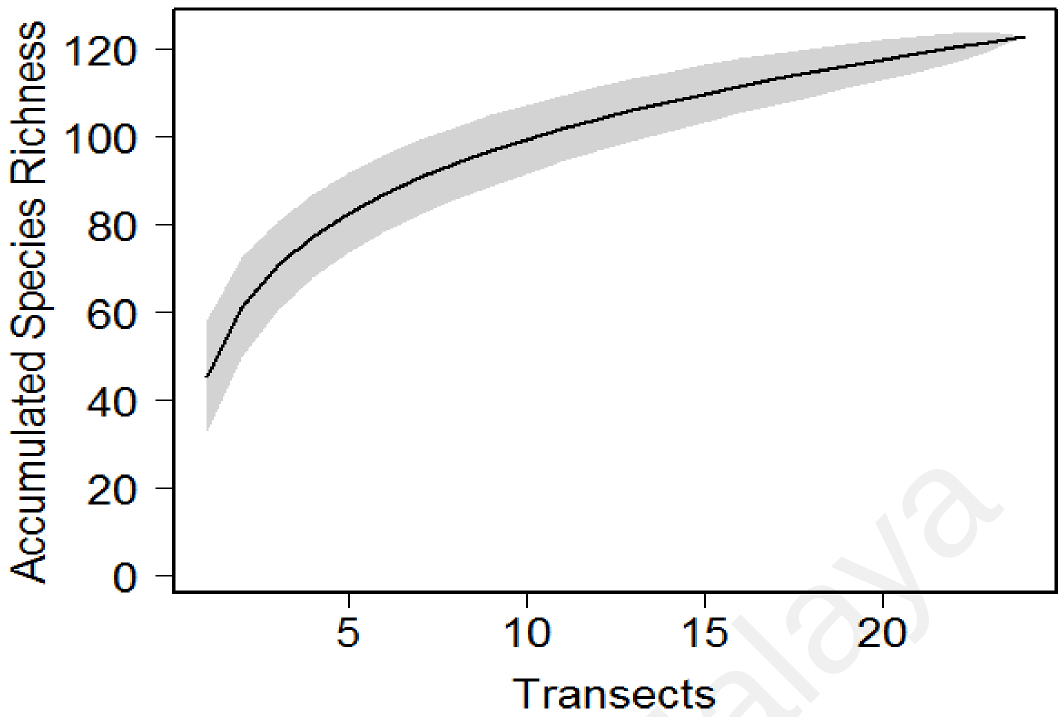

Figure 4.2: Species accumulation curve for bird species in Dutse.

Table 4.1: Summary of sampling effort, habitat variables, bird species richness, abundance and diversity estimates in Dutse, Nigeria.

Site	Model	Malamawa	Wangara	Warwade
Dominant Habitat	Woodland	Woodland	Shrubland	Woodland
No of transects in cold season	24	24	24	24
No of transects in wet season	18	18	18	18
Total no of transects surveyed	42	42	42	42
Total no of individuals recorded	4148	3489	2580	3429
Observed richness (no. of species)	86	74	77	87
Chao (richness)	66	66	65	66
Chao (Shannon-Weiner)	4.062	3.881	3.996	3.980
Chao (Simpson)	0.981	0.974	0.979	0.977
Tree density	9.1	9.2	8.9	7.7
Average no of shrubs per transect (SD)	22.7	21.7	22.9	27.4
No. of Vulnerable Species	1	0	0	1
No. of Threatened Species	0	0	0	1

Of the 14 vulnerable and near threatened bird species in Nigeria, the Beaudouin's Snake Eagle (*Circaetus beaudouini*) (categorized as vulnerable under the IUCN Red List of Threatened Species) and Pallid Harrier (*Circus macrourus*) (categorized as nearly threatened) were both recorded (Appendix D). *C. beaudouini* was recorded both in Model and Warwade sites, as well as in both dry and wet seasons. *C. macrourus* was recorded only in Warwade and during the dry season (Appendix E). Total number of individual birds (abundance), number of species (richness) and diversity recorded in each site is shown in Table 4.1 above while Figure 4.3 shows bird species richness, abundance and diversity across site in Dutse.

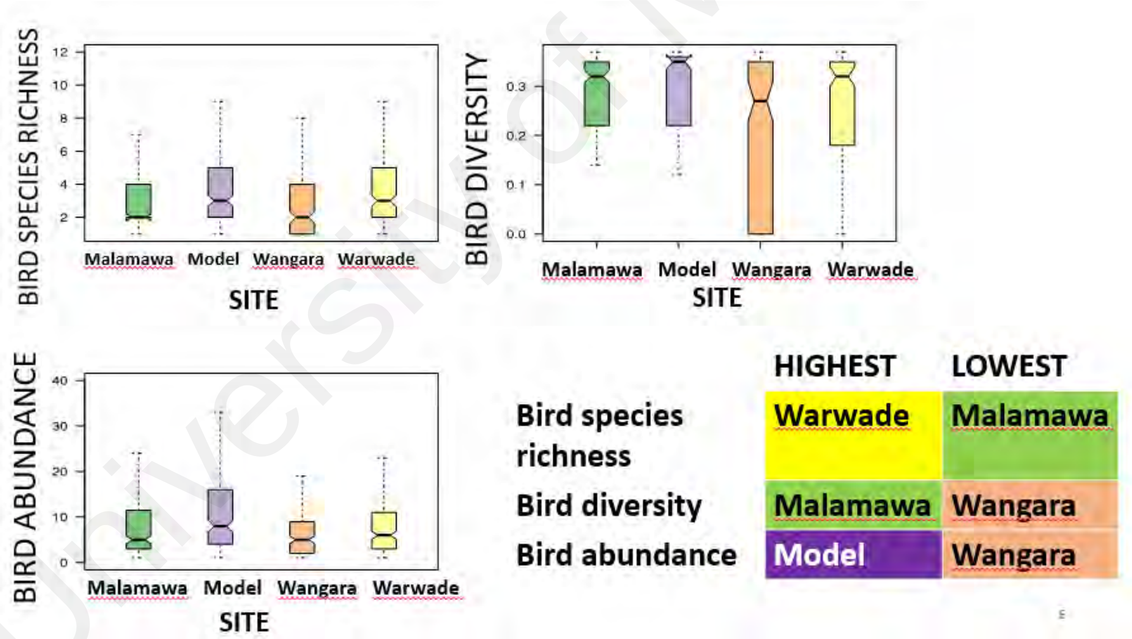

Figure 4.3: Bird species richness, abundance and diversity across sites in Dutse, Nigeria.

Among the bird families, Accipitridae (from which the nearly threatened bird species *C. macrourus* was recorded) had the highest number of bird species with 30% of the total number of species, followed by Sylviidae with 22% and Estriididae with 15% (Figure 4.4). Higher bird species richness was recorded in the months of November (mean = 3.5) and February (mean = 3.6). Highest bird diversity and abundance were recorded in the month of February (means of 0.28 and 11.08 respectively) and lowest in September (means of 0.1 and 4.8 respectively) (Figure 4.5).

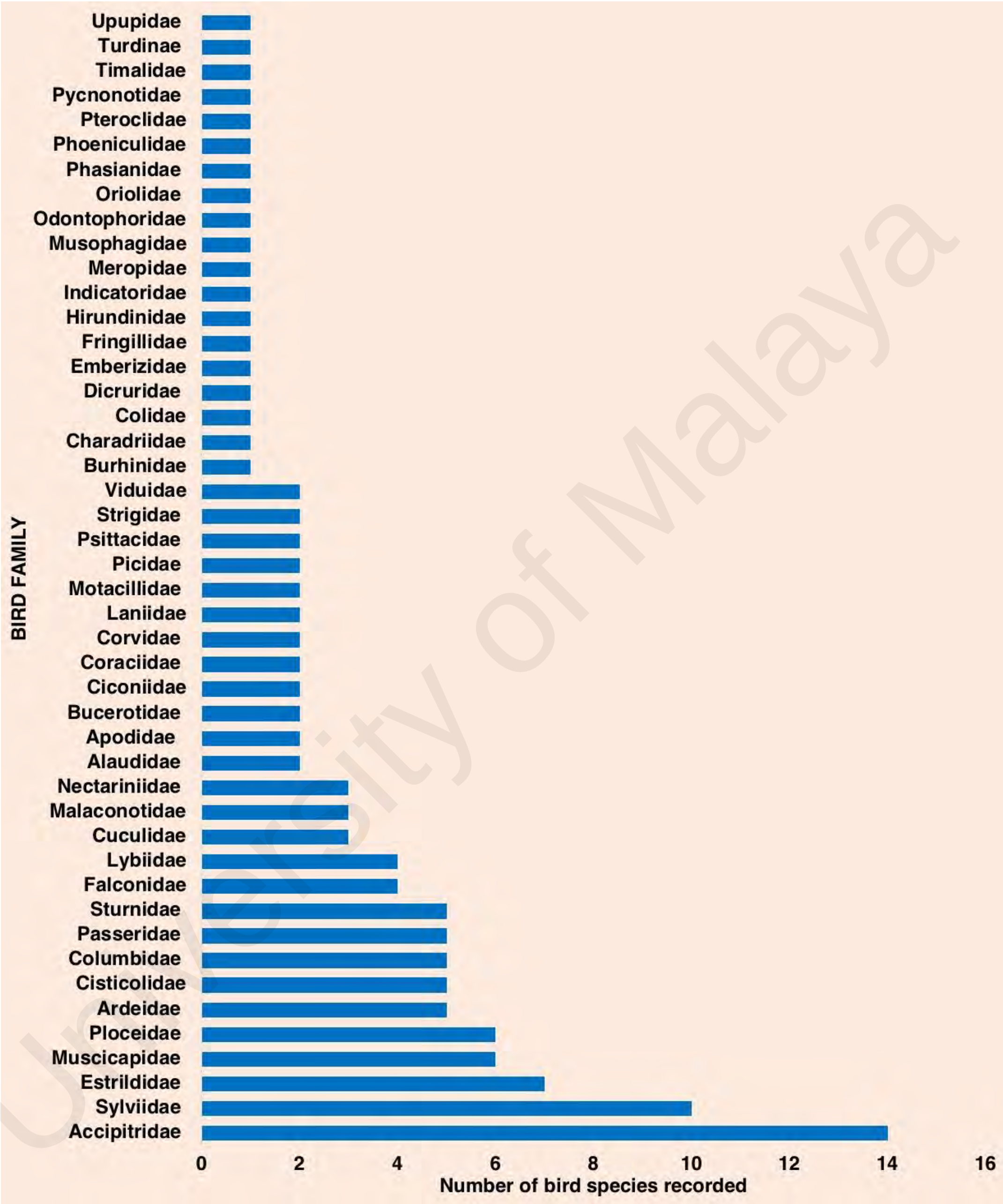

Figure 4.4: Number of bird species by family in Dutse, Nigeria.

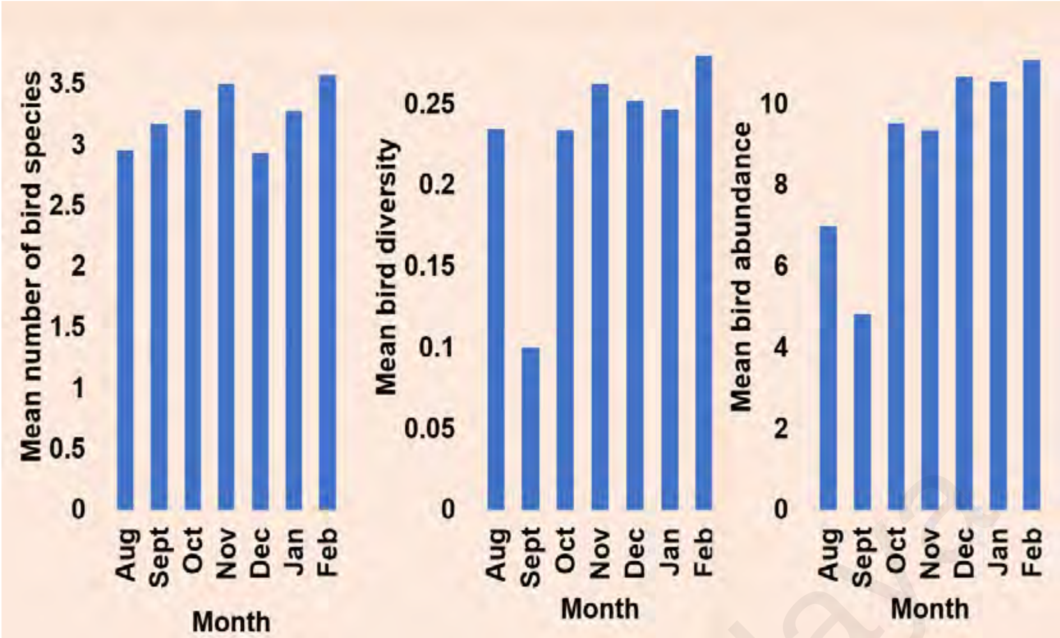

Figure 4.5: Bird species richness, abundance and diversity across months in Dutse, Nigeria.

There was a significant effect (P<0.001) of time of day on bird diversity and abundance (Table 4.2). On average, high number of bird diversity and abundance were recorded during the early hours (0700 and 0800) which decreased as time progresses (Figure 4.6). The number of bird species and diversity increased with higher tree abundance whereas the number of bird species and abundance increased with higher shrub abundance (Figure 4.7). Model had the highest mean density of trees, followed by Malamawa, Warwade and Wangara (Figure 4.8).

Table 4.2: Relationship between bird diversity and abundance with time of day.

	Model	Estimate	SE	t-value	p-value
Bird diversity	Intercept	0.35	0.04	9.99	P < 0.001
	Time	-0.01	0.00	-2.86	P < 0.004
Bird abundance	Intercept	19.59	2.58	7.59	P < 0.001
	Time	-1.23	0.31	-4.02	P < 0.001

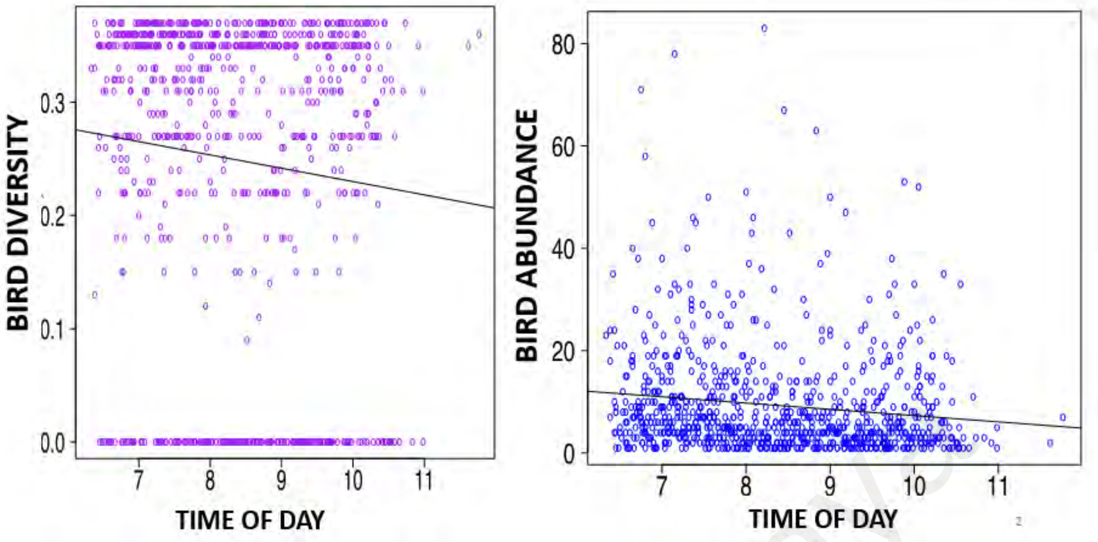

Figure 4.6: Effect of time of day on bird abundance and diversity in Dutse.

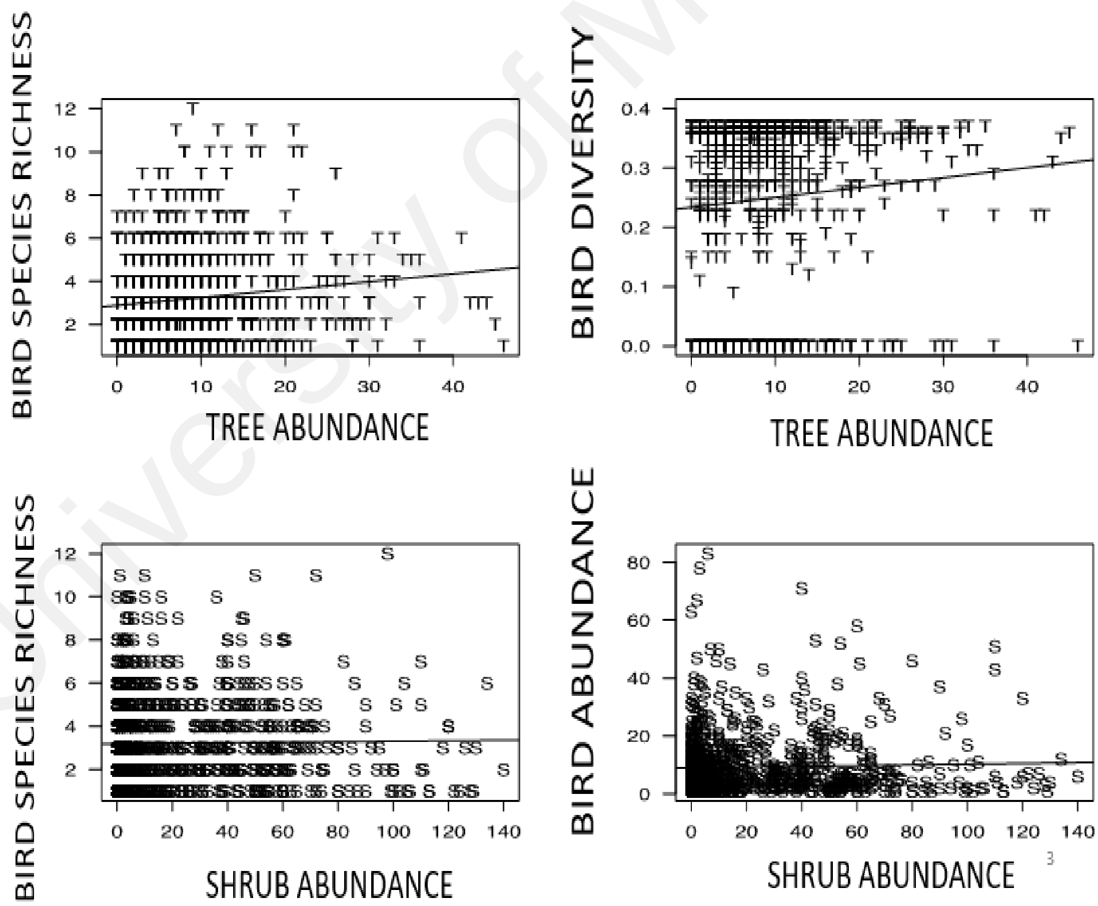

Figure 4.7: Bird species richness and diversity as a function of tree and shrub abundances in Dutse, Nigeria.

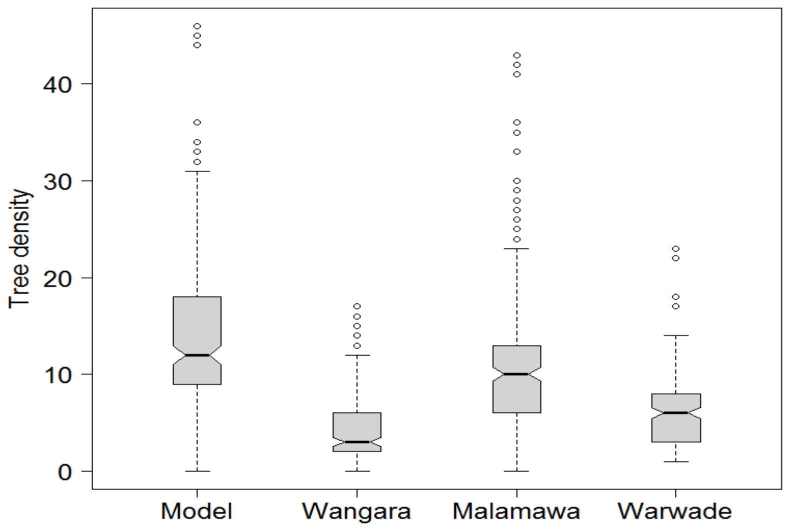

Figure 4.8: Tree densities across sites in Dutse, Nigeria.

Of the total individuals recorded, 11,066 and 2,570 were recorded in woodland and shrubland habitats respectively, with 46 species being unique to the woodland habitat and eight species limited to the shrubland only (Appendix F). The most abundant species among different habitats was White-billed Buffalo Weaver (*B. albirostris*) with 703 and 1640 individuals in shrubland and woodland habitat respectively and Chestnut-bellied Starling (*L. pulcher*) with 296 and 1376 individuals in shrubland and woodland habitat respectively. This was followed by Common Whitethroat (*S. communis*) which was represented by 118 individuals and Rose-ringed Parakeet (*P. krameri*) with 757 individuals in shrubland and woodland habitats respectively.

Across sites, abundant species such as the White-billed Buffalo Weaver (*B. albirostris*) and Chestnut-bellied Starling (*L. pulcher*) were common across all sites and were ranked first and second respectively in all sites except Warwade (Figure 4.9). The rank abundance curves clearly indicated different dominant bird species between sites and highest species evenness in Warwade.

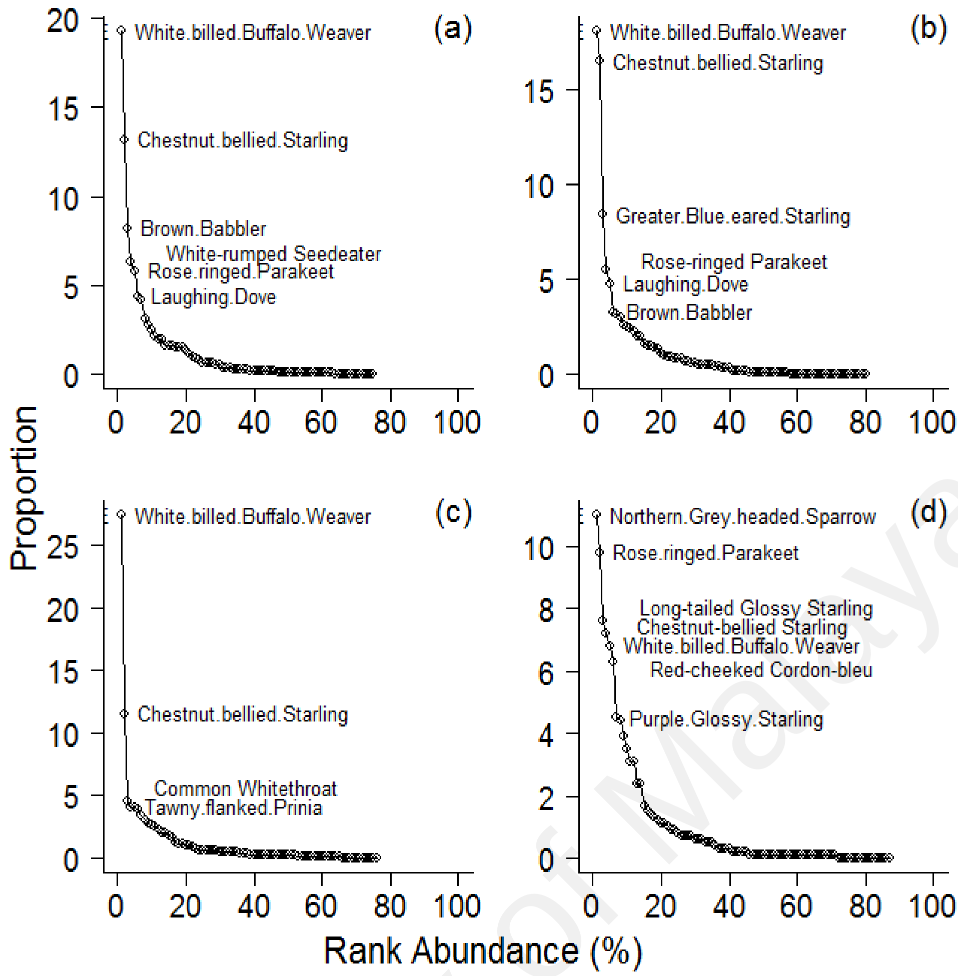

Figure 4.9: Rank abundance curves for bird species in (a) Malamawa, (b) Model, (c) Wangara, (d) Warwade. Only top ranked species shown.

The Red-billed Quelea, White-billed buffalo Weaver and Piapiac had higher rankings and were the most abundant bird species recorded across habitats and seasons. The Red-billed Quelea was ranked first in shrubland habitat, whereas in woodland habitat, the White-billed buffalo Weaver, Piapiac and White-rumped seedeater were ranked second and third respectively.

Between seasons, Piapiac and Purple Glossy Starlings were ranked first and second respectively in the dry season. The Red-billed Quelea and White-billed buffalo Weaver were ranked first and second respectively in wet season (Figure 4.10). Highest evenness was recorded in woodland habitat and in dry season.

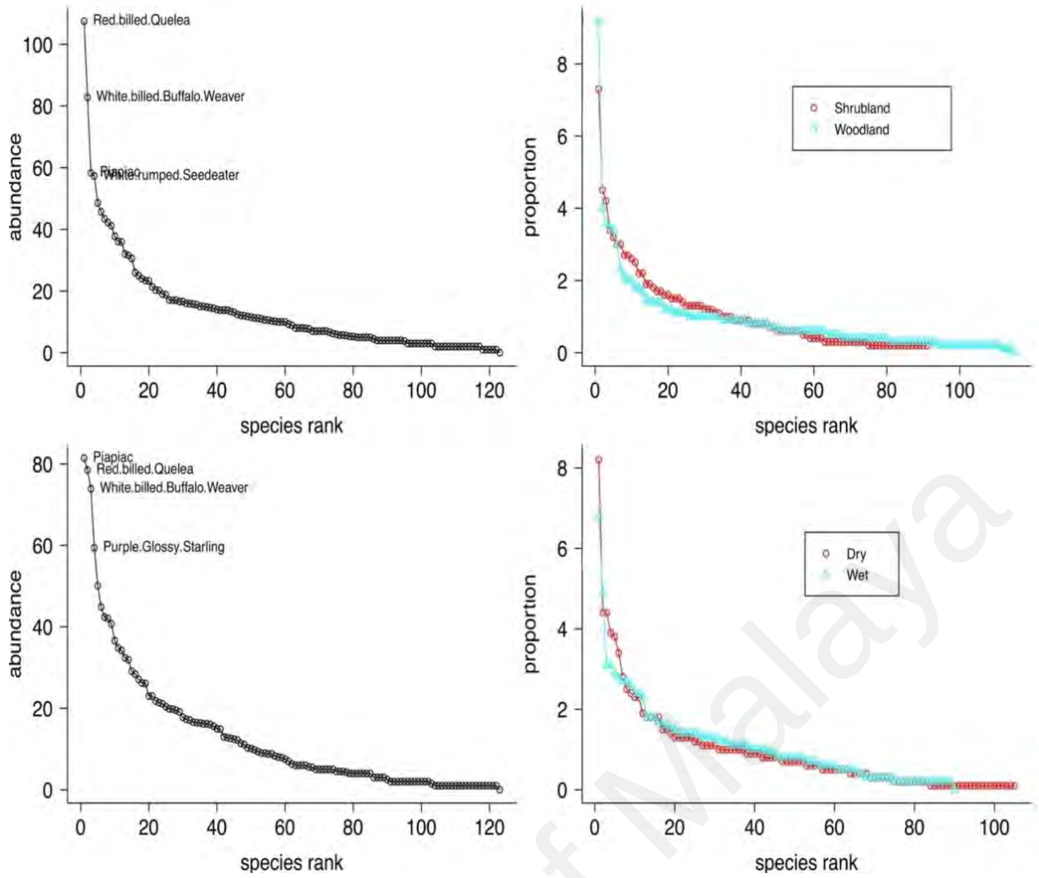

Figure 4.10: Rank abundance of bird species across habitat and season. Only top ranked species shown.

Results based on Similarity Percentages (SIMPER) analysis showed the most important bird species responsible for the dissimilarities in species composition both across and between habitats, sites and seasons (Figure 4.11). The average dissimilarity between habitats, sites and season is 52.24, 51.34 and 87.97% respectively.

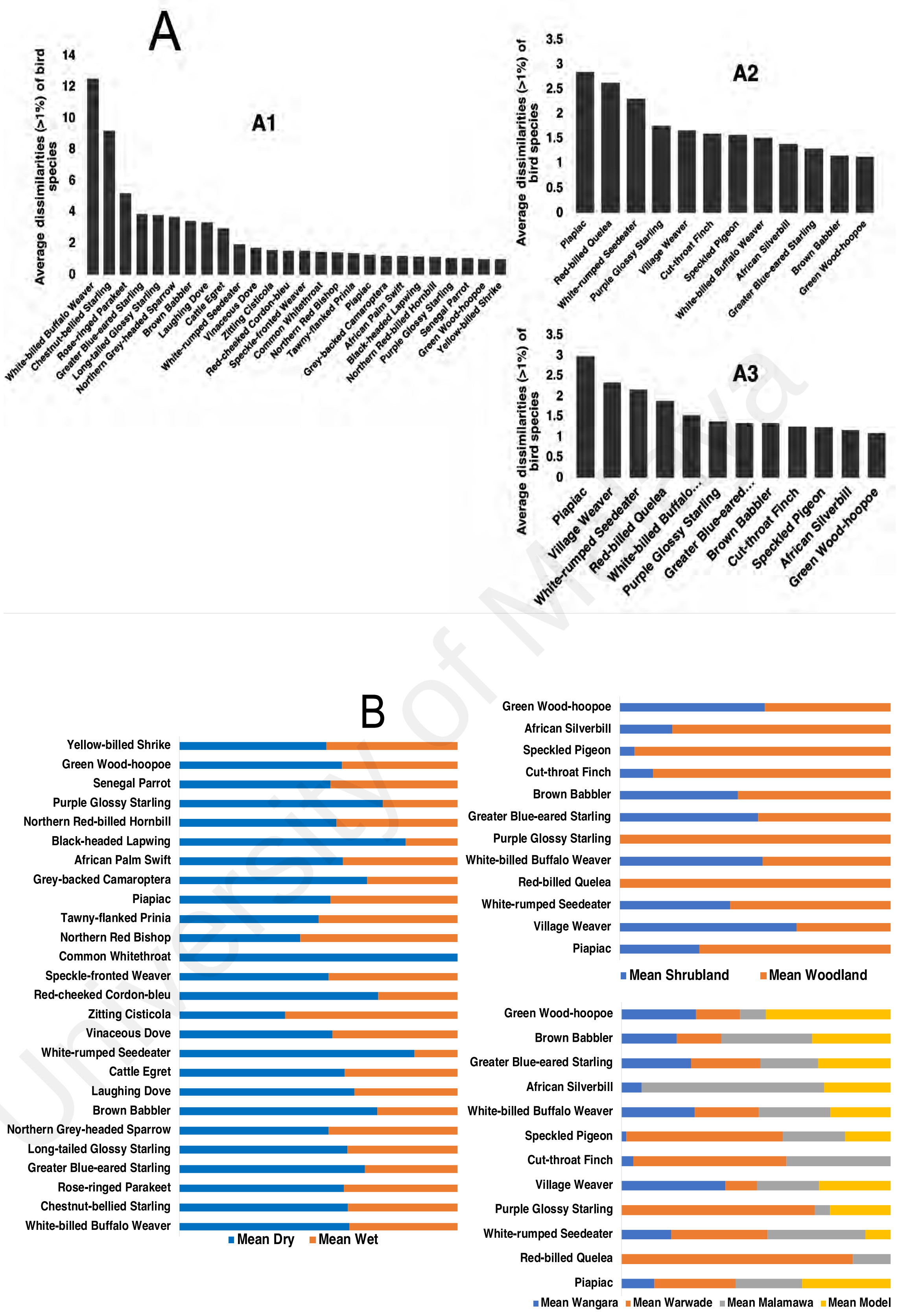

Figure 4.11: A) Bird species that cumulatively had >1 % dissimilarity of the species composition A) across seasons (A1), sites (A2) and habitats (A3) and B) between seasons (dry and wet), habitats (shrubland and woodland) and sites (Wangara, Warwade, Malamawa and Model) in Dutse, Nigeria.

4.2 Effects of seasonality, landscape variables, habitat and site variation on bird species richness, abundance and diversity

There were no significant interactions between the explanatory variables for both log-species richness and log-abundance variables. ANOVA models showed significant site and habitat differences for log-richness while both season and site (habitat) were significant explanatory factors for log-abundance (Table 4.3). Although site was confounded with habitat, these variables were not similar; it would have otherwise expected to see significant pairwise differences between Wangara (the only shrubland habitat) and the other woodland sites (Warwade, Malamawa and Model). Post-hoc comparisons revealed that the main site differences were between Model (a woodland habitat) and other sites (Warwade, Malamawa and Wangara). Kruskal-Wallis tests showed significant differences in species diversity between habitats (χ^2_1 = 8.24, p = 0.004) and between sites (χ^2_3 = 11.84, p = 0.008); the latter was due to pairwise difference between Model and Wangara (p = 0.0018). No significant differences in bird response variables were detected between different levels of the anthropogenic index.

Table 4.3: Final ANOVA models for log-transformed bird species richness and abundance using the explanatory variables of site (Wangara, Malamawa, Warwade, Model), habitat (woodland, shrubland), season (wet, dry), and anthropogenic index (low, medium, high). Significant pairwise comparison from post hoc Tukey's test shown.

	Response Variable	**Explanatory Variables**	**F**	**Pr(>F)**	**Significant pairwise comparison**
Model with Site	Log-Richness	Site	8.47	< 0.001	Wangara – Model (p <0.001) Malamawa – Model (p <0.001)
	Log-Abundance	Season	9.97	< 0.001	
		Site	7.51	< 0.001	Wangara – Model (p <0.001) Malamawa – Model (p=0.029) Warwade – Model (p=0.035)
Model with Habitat	Log-Richness	Habitat	7.60	0.006	
	Log-Abundance	Season	9.88	0.002	
		Habitat	12.16	< 0.001	

At the community level, ANOSIM results indicated that the woodland and shrubland bird assemblages were significantly different from each other (Global R=0.27; p<0.001). Assemblages were also significantly different between seasons (Global R=0.37; p<0.001) and site (Global R=0.416; p<0.001). Global R statistics were considerably higher when ANOSIM was performed on presence-absence data. The Multidimensional Scaling (MDS) ordination biplots showed clear separation in assemblages between seasons and between habitats (Figure 4.12; stress = 0.16). ANOSIM results suggested that habitats in Dutse appeared to be more important in discriminating bird assemblages than seasonality or dominant vegetation structure.

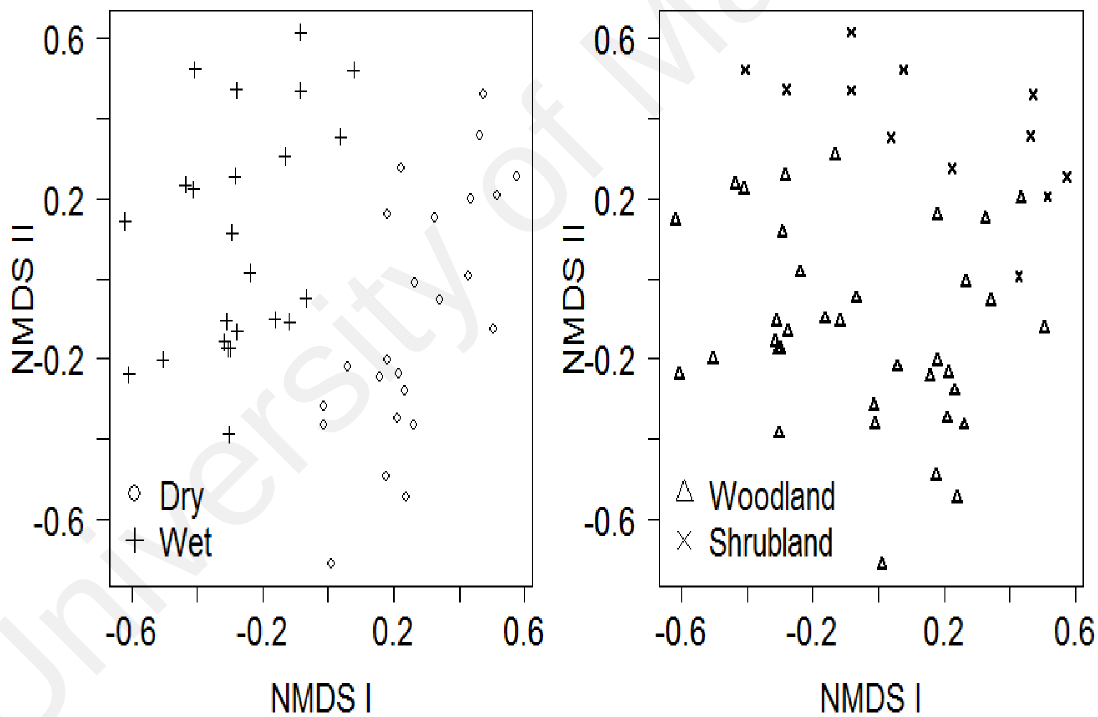

Figure 4.12: Non-metric multidimensional scaling (nMDS) ordination in two dimensions of the bird assemblages surveyed during dry and wet seasons (left) and in woodland and shrubland habitats (right). Ordination was based on Bray-Curtis dissimilarity matrix of species abundance data (with square-root transformation). Stress = 0.16.

After accounting for random effects, individual anthropogenic activities (grazing, farming, human interference and wood removal) also did not significantly impact bird abundance (Table 4.4). Bird abundance was significantly greater during the dry season than the wet season (Table 4.4, Figure 4.13). Relative to shrubland, woodland habitats harbored higher bird abundance (Table 4.4, Figure 4.13). The mean effect of habitat appeared to be greater than season in increasing bird abundance. This effect could be explained by the vegetation structure where tree density was more influential than shrub density in increasing bird abundance in Dutse even though shrubs were considerably more abundant than trees across Dutse as a whole (Table 4.4).

Table 4.4: Linear mixed model on log transformed abundance showing the effect (mean ± standard errors) of habitat, season and anthropogenic activities. The intercept represents shrubland, dry season, and absences of wood removal, grazing, farming and human interference. Site, transect and dates are set as random effects.

	Estimate	SE	t-value	p-value
Intercept	1.369	0.14	10.12	<0.001
Woodland	0.328	0.13	2.60	0.010
Wet	-0.238	0.08	-2.84	0.007
No of trees	0.015	0.01	2.74	0.006
No of shrubs	0.004	0.00	2.51	0.012
Wood removal	-0.067	0.06	-1.09	ns
Farming	-0.015	0.15	-0.09	ns
Grazing	-0.033	0.06	-0.60	ns
Interference	0.007	0.11	0.06	ns

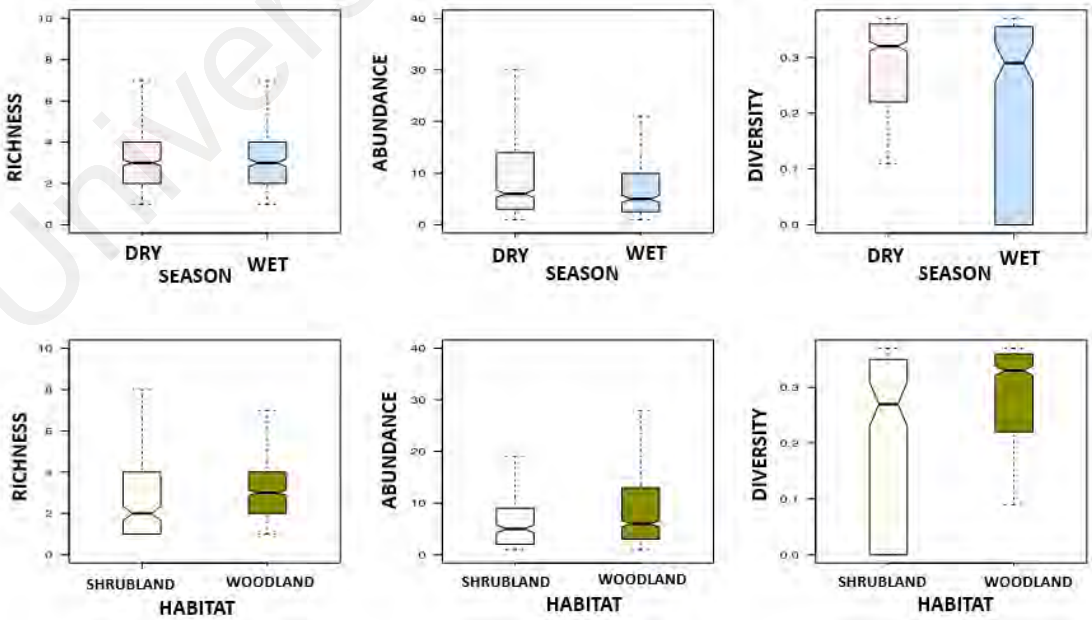

Figure 4.13: Effects of seasonal and habitat variations on bird species richness, abundance and diversity in Dutse, Nigeria.

4.3 Spatiotemporal utilization of habitat according to feeding guilds

The majority of the recorded bird species in this study were insectivores (48%) followed by frugivores (16%), granivores (16%), carnivores (15%), nectarivores (3%) and piscivores (2%) (Appendix D). Within same feeding guild, abundance of birds was significantly different across habitats ($F_{1,\ 259}$ = 14.84, p<0.001, Pillai's Trace = 0.15), sites ($F_{3,\ 774}$ = 6.50, p<0.001, Pillai's Trace = 0.21), and seasons ($F_{1,\ 518}$ = 18.10, p<0.001, Pillai's Trace = 0.10) with a moderate (partial eta-squared = 0.15), low (partial eta-squared = 0.07) and moderate (partial eta-squared = 0.10) effects respectively. Frugivore abundance was significantly different and higher in woodland habitat (Figure 4.14, Table 4.5). Likewise, frugivore abundance was significantly different and higher in Model, followed by Warwade and Malamawa with the least abundance in Wangara site (Figure 4.14, Table 4.5 & 4.6). On contrary, the abundance of insectivorous and granivorous birds did not differ neither across habitats nor sites. The dry season had higher abundance of insectivores, granivores and frugivores than wet season (Figure 4.14, Table 4.5).

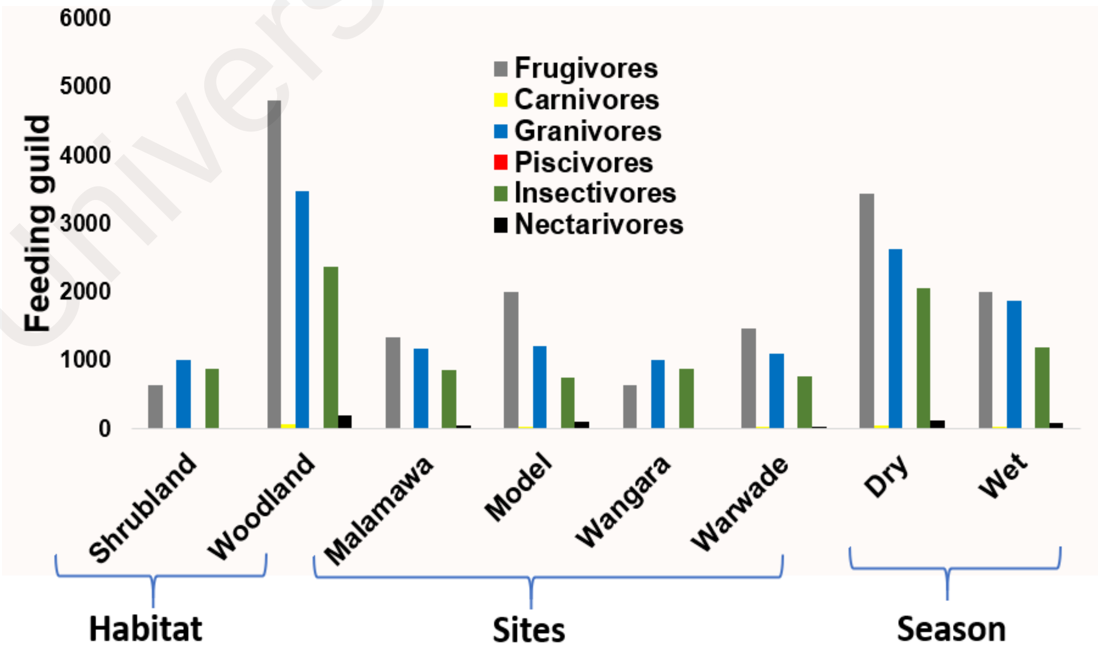

Figure 4.14: Bird abundance by feeding guild across habitats (shrubland and woodland), sites (Malamawa, Model, Wangara and Warwade) and seasons (dry and wet).

Table 4.5: MANOVA results of mean abundances of residents, migrants, stable, decreasing and frugivores bird species across habitats, sites and seasons.

	Variable	DF	F-value	Pr(>F)
Frugivore	Habitat	1	31.38	P<0.001
	Site	3	14.63	P<0.001
	Season	1	29.42	P<0.001
Insectivore	Season	1	40.99	P<0.001
Granivore	Season	1	7.21	0.008
Resident	Habitat	1	11.86	P<0.001
	Site	3	4.95	0.002
	Season	1	32.16	P<0.001
Migrant	Habitat	1	19.90	P<0.001
	Site	3	10.74	P<0.001
	Season	1	64.66	P<0.001
Stable	Habitat	1	11.17	P<0.001
	Site	3	4.78	0.003
	Season	1	28.32	P<0.001
Decreasing	Habitat	1	0.05	0.820
	Site	3	3.51	0.016
	Season	1	8.27	0.004
Increasing	Habitat	1	0.05	0.827
	Site	3	1.55	0.203
	Season	1	23.05	P<0.001

Table 4.6: Pair wise comparison of bird abundance by residence status, feeding guild population trends across sites.

	Pair wise	DF	Pillai	F	Pr(>F)
Guild	Wangara - Model	1	0.33	20.67	P<0.001
	Wangara - Malamawa	1	0.14	6.82	P<0.001
	Wangara - Warwade	1	0.26	14.35	P<0.001
Status	Wangara - Model	1	0.19	15.20	P<0.001
	Wangara - Malamawa	1	0.22	17.54	P<0.001
	Wangara - Warwade	1	0.19	14.49	P<0.001
Trend	Malamawa - Model	1	0.07	3.00	0.033
	Malamawa - Wangara	1	0.13	6.43	P<0.001
	Malamawa - Warwade	1	0.10	4.78	0.003

4.4 Spatiotemporal utilization of habitat according to residence status

Of the recorded bird species in Dutse, 72% were resident birds, 10% non-breeding visitors (main range), 8% residents (partially migratory), 6% non-breeding visitors (sparse occurrence), and 4% breeding visitors (Appendix D). There was statistically significant difference in bird abundance by residence status across habitats ($F_{1,\ 260}$ = 22.6, p<0.001, Pillai's Trace = 0.15), sites ($F_{3,\ 518}$ = 9.16, p<0.001, Pillai's Trace = 0.19) and seasons ($F_{1,\ 519}$ = 41.51, p<0.001, Pillai's Trace = 0.12). Partial eta-squared indicated a moderate effect across habitats (partial eta-squared = 0.15), sites (partial eta-squared = 0.10) and season (partial eta-squared = 0.14). Abundance of resident and migratory birds differed significantly between woodland and shrubland habitats (Table 4.5); higher abundance of resident birds was recorded in woodland habitat than in shrubland habitat, whereas the abundance of migrants was higher in shrubland habitat (Figure 4.15). Abundance of resident and migrant birds differed significantly across sites (Table 4.5), with higher abundance of residents recorded in Model and Malamawa sites followed by Warwade and the least being in Wangara site (Figure 4.15). On the other hand, Wangara recorded the highest abundance of migrant birds followed by Model (Figure 4.15). Comparison between these sites are shown in Table 4.6. Dry season had higher abundance of both residents and migrant birds than wet season (Figure 4.15, Table 4.5).

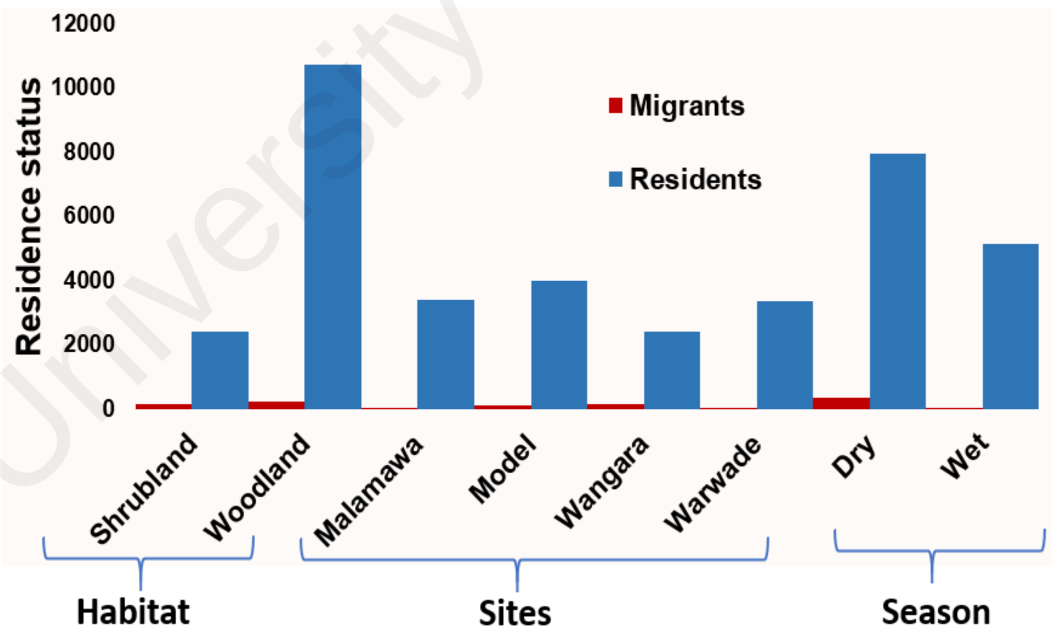

Figure 4.15: Bird abundance by residence status across habitats (shrubland and woodland), sites (Malamawa, Model, Wangara and Warwade) and seasons (dry and wet).

4.5 Spatiotemporal utilization of habitat according to population trend

Population trend assessments by the IUCN Red List of Threatened Species (IUCN, 2016) suggest that 57% of the recorded bird species in the study area were stable, 20% were decreasing, 18% were increasing and 5% were unknown (Appendix D). Majority of the species with decreasing population trend were migrant birds and a few residents. These residents include the Crested Lark (*G. critata*), Hoopoe (*Upupa epops*), Yellow-billed Oxpecker (*Buphagus africanus*), and Northern Carmine Bee-eater (*Merops nubicus*). There were significant differences in the abundance of birds by population trend across habitats ($F1, 259 = 4.45$, $p=0.004$, Pillai's Trace = 0.05), sites ($F3, 774 = 3.26$, $p<0.001$, Pillai's Trace = 0.11) and seasons ($F1, 518 = 14.53$, $p<0.001$, Pillai's Trace = 0.08), but the effect was low across habitats (partial eta-squared = 0.05), sites (partial eta-squared = 0.04) and seasons (partial eta-squared = 0.08). There was no significant difference in bird abundance by population trends between habitats except for the stable population trend (Table 4.5). Woodland habitat had higher abundance of birds with stable population trend than shrubland habitat (Figure 4.16). There was a significant difference in the abundance of birds with stable and decreasing population trend between sites (Table 4.5). Comparison between sites showed that the abundance of bird species with decreasing trend was higher in and similar between Model, Wangara and Warwade sites than Malamawa (Figure 4.16, Table 4.6), whereas Model had a higher abundance of birds with stable population trend. However, there was no significant differences in abundance of bird species with increasing trend between sites. Dry season had higher abundance of birds with stable, decreasing and increasing trends than wet season (Figure 4.16, Table 4.5).

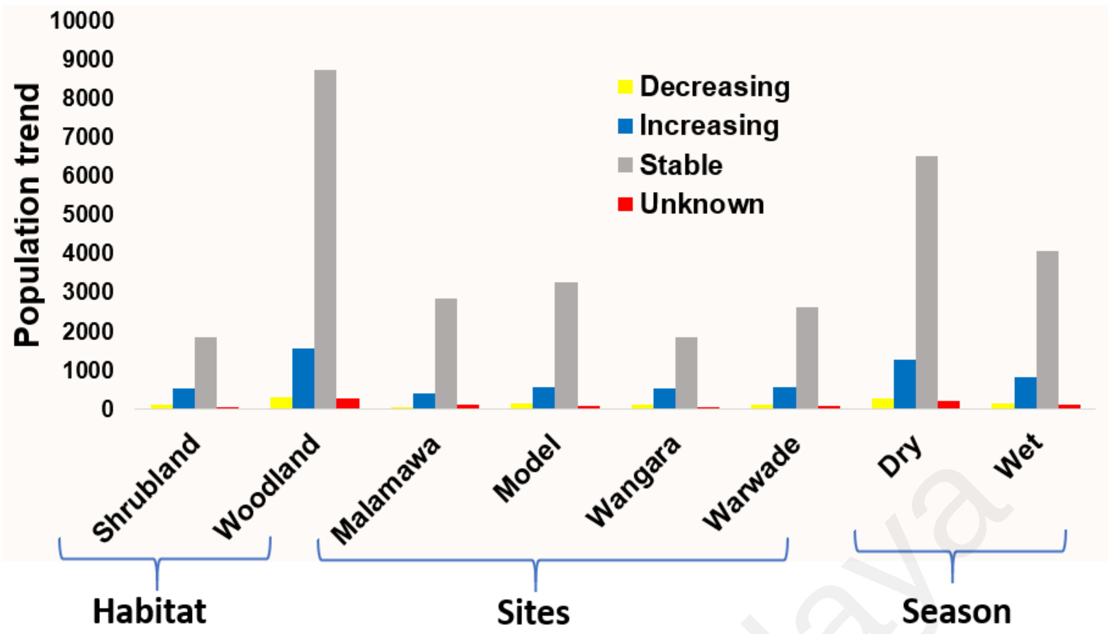

Figure 4.16: Bird abundance by population trend across habitats (shrubland and woodland), sites (Malamawa, Model, Wangara and Warwade) and seasons (dry and wet).

4.6 Fffect of habitat and season on the abundance of resident and migrant bird species with decreasing population trend

A one-way ANOVA showed significant differences in the abundance of individual bird species with decreasing population trend ($p=0.003$, Figure 4.17). Between residents and migrants, no significant difference was seen ($p=0.5651$). Two-way ANOVA showed significant differences in the abundance of bird species with decreasing population trend across habitat ($p<0.001$) and season ($p=0.002$). Within habitat and season, Tukey post hoc showed that woodland habitat and dry season had higher abundance of bird species with decreasing population trend. Similarly, habitat and season had a significant effect on the abundance of bird species with decreasing population trend. The effect was higher in woodland habitat and dry season (Table 4.7. Figure 4.18 and 4.19).

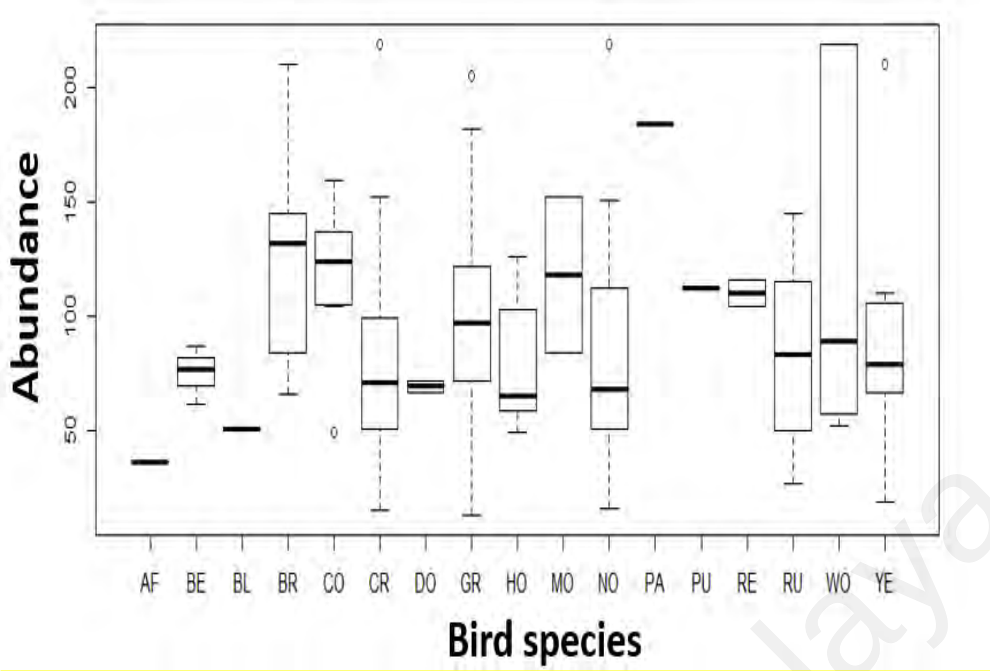

Figure 4.17: The abundance of bird species with decreasing population trend in Dutse, Nigeria (list in Appendix D).

Table 4.7: Effects of habitat and season on the abundance of birds with decreasing population trend in Dutse, Nigeria

	Estimate	S. Error	t value	Pr(>|t|)
(Intercept)	71.375	4.586	15.564	P < 0.001
Woodland	35.129	5.534	6.348	P < 0.001
Wet	-16.918	5.515	-3.068	P < 0.002

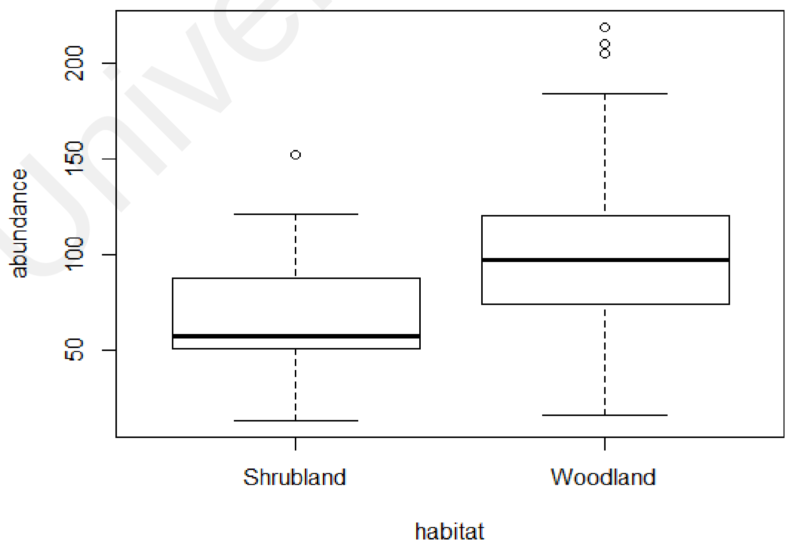

Figure 4.18: The abundance of birds with decreasing population trend between habitat in Dutse, Nigeria.

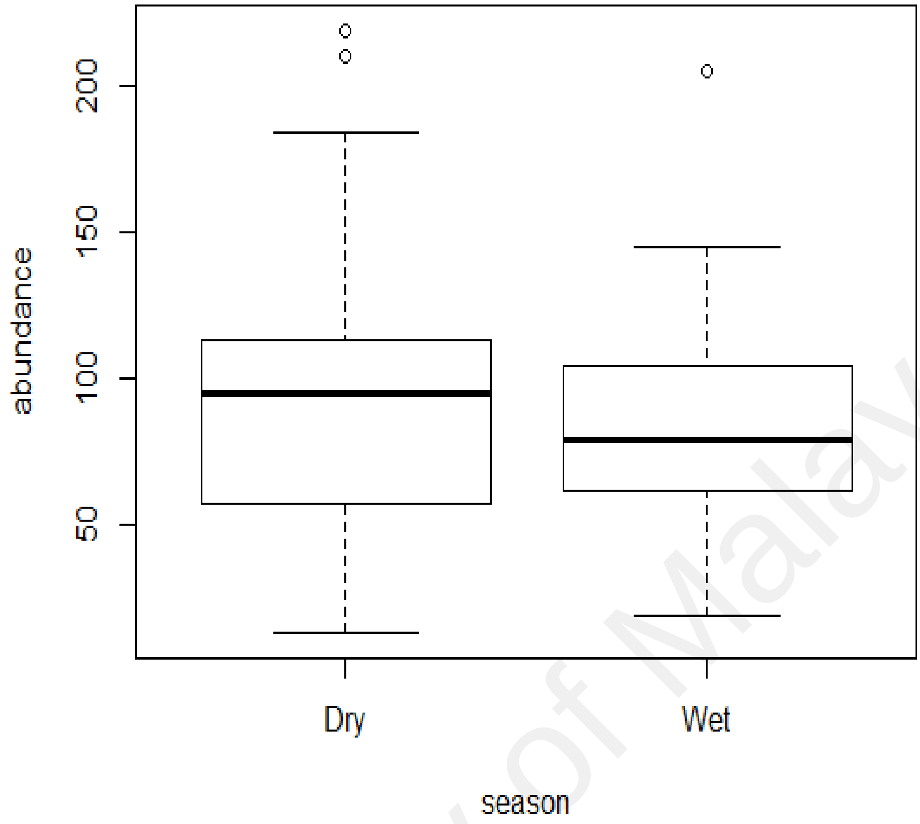

Figure 4.19: The abundance of birds with decreasing population trend between season in Dutse, Nigeria.

CHAPTER 5: DISCUSSION

5.1 Bird abundance and diversity across seasons, habitats and sites

This study serves as the first comprehensive record of avian survey in Dutse, Nigeria. Despite major land change uses in the past three decades, considerable avian diversity could still be found in the area. According to Birdlife International (2016a), Nigeria has a total number of 863 bird species while 894 had been recorded in Fishpool and Evans (2001). Most of these species (94.7%) have been categorized as species of least concern (Birdlife International, 2016a). This study recorded a total of 128 bird species (13,656 individuals) belonging to 46 families, accounting for 15% of the Nigerian bird species.

A recent checklist of the bird assemblage at the neighboring Hadejia-Nguru wetlands reported 191 bird species belong to 54 families (Ringim & Muhammad, 2017). It should be noted that the majority of the birds recorded in Dutse are landbirds whereas water and water related bird species comprised the majority of the bird species recorded in the Hadejia-Nguru Wetlands. However common species are shared between the two areas. Water related bird species are likely under represented in the current Dutse species checklist.

Among bird families, Accipitridae from which the nearly threatened bird species (C. *macrourus*) was recorded had the highest number of bird species, followed by Sylviidae and Estriididae. Members of the family Accipitridae have been known to occupy a variety of habitats (from semi desert to rainforest interior) with both insular and continental species. They have a global distribution and exhibit considerable dietary diversification (Hockey & Curtis, 2009). Many members of the family Accipitridae recorded in this study were raptors. Their presence likely indicates prey abundance in Dutse, thus highlighting the rich diversity of not only bird species but species from which these birds depend upon. A brief information of the Vulnerable *C. beaudouini* and nearly threatened *C. macrourus* recorded in this study is shown in Table 5.1 and Figure 5.1 and 5.2 shows their distribution respectively.

Table 5.1: Information on vulnerable and near threatened bird species in Dutse (Source: BirdLife International, 2017a, 2017b).

Species	Beaudouin's Snake Eagle (*Circaetus beaudouini*)	Pallid Harrier (*Circus macrourus*)
Category	Vulnerable	Near threatened
Occurrence	Native (Nigeria)	Native (Nigeria)
Population trend	Decreasing	Decreasing
Movement Patterns	Nomadic	Full Migrant
Generation Length (years)	12.9	6
Global Population	It occurs at low densities and survey data suggest there are a minimum of 1,000 individuals, but in the context of the species' large range the population is better estimated at 2,500-9,999 mature individuals. This equates to 3,750-14,999 individuals, rounded here to 3,500-15,000 individuals. 83-93 % declined between 1969-1973 and 2004. 30-49% in three generations (39 years)	The global population is estimated at 9,000-15,000 pairs equating to 18,000-30,000 mature individuals. > 30 % declined between 1990-2000
Habitat & Ecology	It inhabits dry savannah but favours more open areas of grassland and even cultivated areas. It is a seasonal migrant, moving between the Sudan zone (and northern Guinea zone) in the dry season and the Sahel (and northern Sudan) zone in the rainy season, but can be seen in some areas all year round, such as The Gambia, and while there has been no nest records there, juveniles have been seen. It is thinly distributed, territorial and generally solitary.	It breeds in semi-desert, steppe and forest-steppe up to 2,000 m, where its favoured nesting sites are wet grasslands close to small rivers and lakes, and marshlands. The species has also been found to breed in agricultural areas, at least when agriculture is non-intensive. A small minority of the population breeds in the boreal forest and forest-tundra zones, north of its main breeding range where it nests in clearings and other open areas. Semi-desert, scrub, savanna and wetlands are used in winter. The species is migratory, with most birds wintering in sub-Saharan Africa or south-east Asia. They leave their breeding grounds between August and November and return in March and April.
Threats	Habitat destruction has resulted from agricultural intensification, overgrazing, woodcutting and major developments such as urbanisation. Woodcutting for fuelwood, timber and charcoal has caused conversion of woodland into shrubland Hunting has also exacerbated the decline.	In its breeding range, it is primarily threatened by the destruction and degradation of steppe grasslands through conversion to arable agriculture, burning of vegetation, intensive grazing of wet pastures and the clearance of shrubs and tall weeds. On its wintering grounds it is thought to be negatively affected by the use of harmful pesticides, rodenticides and other toxic chemicals although this requires further research, and by the loss of grassland due to burning, cutting and overgrazing.

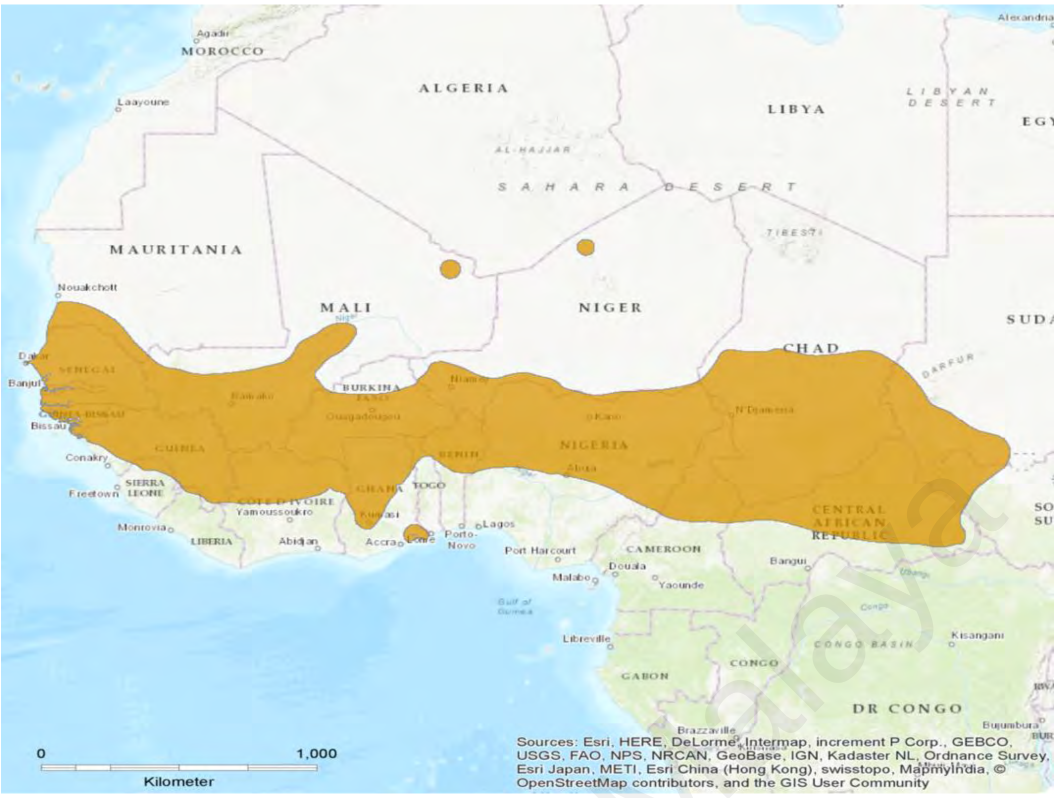

Figure 5.1: Distribution map of Beaudouin's Snake Eagle *C. beaudouini*.

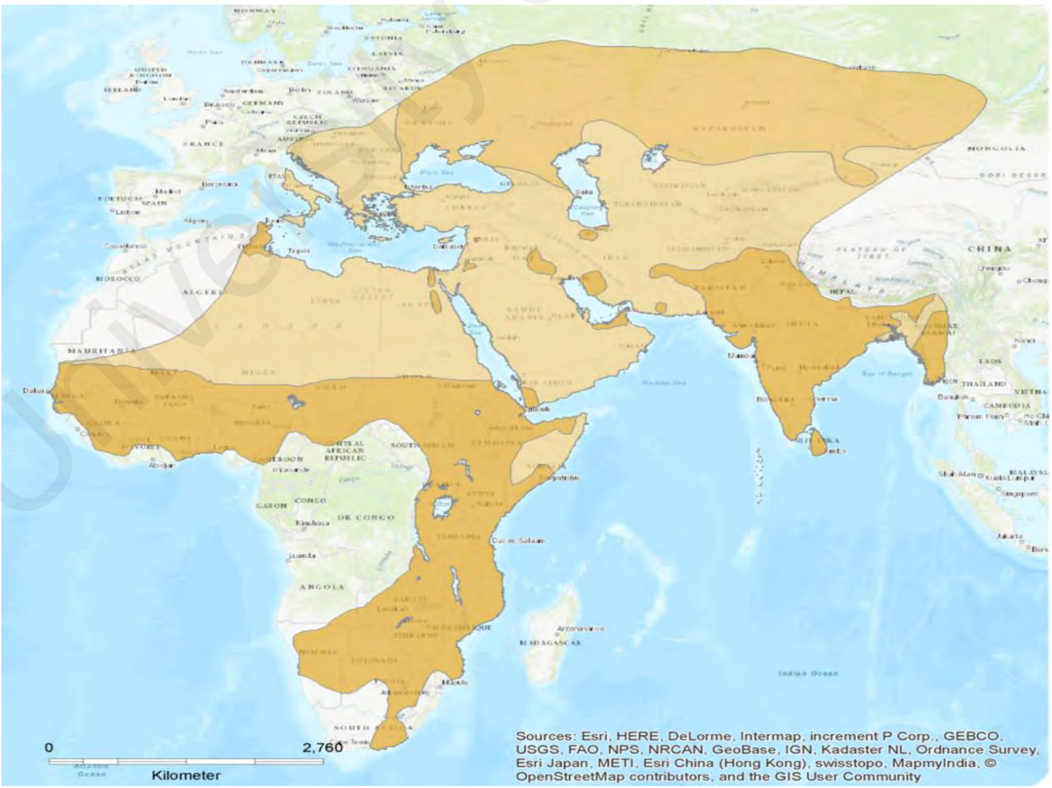

Figure 5.2: Distribution map of Pallid Harrier *C. macrourus*.

The effect of time of day on bird abundance and diversity was prominent. In this study, highest bird abundance and diversity was recorded in the early hours and decreased with time. This is because birds are more active during the early hours of morning (at dawn between 0700 to 0800) and their activities start to decline as time progresses (Manu *et al*., 2007). Most species recorded by sound were recorded in high number in early hours and decreased with time. However, birds were also recorded doing activities such as nest building and foraging.

The dominant and highly gregarious White-billed buffalo Weaver, Piapiac, White-rumped Seedeater, Red-billed Quelea, Village Weaver, Rose-ringed Parakeet and Chestnut-bellied Starling were always recorded in large colonies. These typical sahelian bird species had higher ranking in abundance and were responsible for the spatiotemporal variation in avian composition in Dutse. Their higher abundance and dominance across habitats, sites and season could be explained by their affinity with trees and farmlands that provide food and shelter. For example, the White-billed buffalo Weaver had been observed building a huge stick nest on trees and living in large colony. Likewise, the White-rumped Seedeater was found utilizing trees and get supplementary food from farmlands.

5.2 Effects of seasonality and landscape variables habitat and site variation on bird species richness, abundance and diversity

The effects of seasonal variation on avian community in Dutse were clearly demonstrated. The dry season had the highest number of bird species, abundance, and diversity compared to wet season. In West Africa including Nigeria, migrant bird species arrive at their wintering ground at the beginning of the dry season between September to October (Elgood *et al*., 1982; Aidley & Wilkinson, 1987b; Hedenstrom *et al*., 1993; Jones, 1995). The study during the dry season coincided with the wintering period and a majority of the migrant bird species such as Northern Wheatear (*Oenanthe oenanthe*), Sudan Golden Sparrow (*Passer luteus*), Common Whitethroat (*S. communis*), Wood Warbler (*Phylloscopus sibilatrix*), Western Bonelli's Warbler (*Phylloscopus bonelli*), Subalpine Warbler (*S. cantillans*) and Common Redstart (*Phoenicurus phoenicurus*) were recorded during this time (Appendix E). This is consistent with the findings of Leveau and Leveau (2016). The Pallid Harrier (*C.* macrourus) was also recorded in the dry season.

The Dutse vegetation structure, as measured by the habitat type as well as density of vegetation (trees and shrubs), also plays an important role in the distribution and community structure of the recorded bird species. Common bird species such as Chestnut-bellied Starling (*L. pulcher*), Brown Babbler (*Turdoides plebejus*), Greater Blue-eared Starling (*Lamprotornis chalybaeus*), Long-tailed Glossy Starling (*Lamprotornis caudatus*), White-billed Buffalo Weaver (*B. albirostris*) are usually colonial and gregarious; they are more associated with woodland habitats. However, shrubland bird species are generally smaller in size (Cisticolas and Warblers), cryptic in nature, and are not easily sighted. Decreased detection probability of birds in shrubland may partially account for the differences in bird variables between the two habitats.

As mentioned earlier, the site variable is confounded with the habitat variable. However, analysis suggests site locality accounts for additional variation in the bird variables. Bird abundance and diversity was highest in Model which is the closest site to the Dutse metropolis (7 km) compared to Wangara (35 km), Malamawa (30 km) and Warwade (10 km). This proximity might increase encounter rates with human commensal species such as doves, pigeon, weavers, finches, sparrows and swallows (Bonthoux *et al*., 2013). These bird species (especially omnivores and granivores) are likely attracted to the metropolis area for supplementary food, thus increasing bird abundance in Model. Another likely reason is the higher number of trees in Model (woodland habitat), relative to other sites. The dominant tree species in Model is the date tree (*Phoenix dactylifera*), removal of these trees from the area is unlikely due to their commercial use.

The highest species richness and evenness was recorded in Warwade. The presence of Warwade river may have increased the chances of encounter with water and water related bird species frequenting the riverine area. These bird species such as Squacco Heron (*Ardeola ralloides*) and Western Marsh Harrier (*Circus aeruginosus*) were recorded on few occasions in Warwade. The presence of these water-associated birds in Warwade distinguished this site from the others. Unique characteristics in the different Dutse sites suggest that the bird assemblage is structured by the local landscape variables, habitat type and seasonality in weather patterns.

5.3 Effect of anthropogenic activities on bird species richness, abundance and diversity

The anthropogenic activities recorded in this study, related to farming, grazing, wood removal and human interference did not appear to significantly impact the overall bird species richness, abundance and diversity. In fact, moderate anthropogenic activities appeared to increase bird abundance. This is consistent with the findings of Ulfstrand (1995); Pomeroy and Dranzoa (1997); Evans and Gaston (2005) that moderate amount of anthropogenic activities may result in increase of bird species but often dominated by generalist species. Most studies reporting the negative effect of anthropogenic activities on bird species composition and diversity are related to large scale activities such as monocultures plantations (Raman & Sukumar, 2002) and logging (Sekercioglu, 2002; Shahabuddin & Kumar, 2006). It should be noted that most of these activities in Dutse including wood removal are at small scale. Wood removal is mainly for fire wood and other domestic uses and generally do not affect the vegetation structure in a major way. Small scale human activities and densities may increase habitat productivity and heterogeneity which may benefit common bird species (generalists) and in turn increase species richness (Araujo, 2003; Fairbanks, 2004; Hugo & van Rensburg, 2008). Similarly, habitat transformation may increase number of generalist bird species (Fairbanks *et al*., 2002). Due to their adaptability, these common species can withstand some level of habitat loss and human activities more than rare species (Hugo & van Rensburg, 2008).

Large scale mechanized agricultural intensification in Europe has been identified as a major threat to local bird species richness, abundance and diversity (Chamberlain *et al*., 2000). In many parts of Nigeria, agro-ecosystems are usually in small scale due to lack of access to capital-intensive technology. Small-scale farming may create habitat heterogeneity, which may in turn benefit bird species (Laube *et al*., 2008). Bird diversity generally increases with greater habitat diversity and heterogeneity. Studies by Hulme and Cresswell (2012) and Jones *et al*. (1996) in central Nigeria found farmlands to provide habitats for quite a number of Palearctic migrants.

Approximately 80% of the land in Dutse is arable and used mostly for small scale and polycultures farming (<5 ha), as most farmers in Dutse cannot afford mechanized farming. Grazing and farming activities may expose earthworms and other prey to the surface which makes them noticeable to predators, attracting species such as Yellow Wagtails (*M. flava*), and Crested Lark (*G. cirstata*) to forage in this area. These activities also attract cattle-associated bird species like the Yellow-billed Oxpecker (*Buphagus africanus*) and Cattle Egret (*Bubulcus ibis*). Grazing by cattle can affect habitat features such as grass height and cover which in turn determines the density of birds (Maphisa *et al*., 2017). Elsewhere, farmlands have been shown to increase habitat diversity for bird species which may in turn attract both insectivores and granivores. An example can be seen in the Ethiopian shade coffee farms which support higher bird species richness than adjacent forested areas (Buechley *et al*., 2015).

It should not be concluded that anthropogenic activities are inconsequential. Common and rare bird species respond differently to anthropogenic disturbances. Unlike the rare bird species, common bird species are usually generalists and can inhabit habitat altered by human activities (McKinney & Lockwood, 1999; Fairbanks *et al*., 2002; Davies *et al*., 2004; Hugo & van Rensburg, 2008). Specialist species tend to respond poorly to various forms of anthropogenic impacts such as habitat fragmentation and disturbances. These ecological specialists will become increasingly rare in the face of persistent human pressures in altering local landscapes (Devictor *et al*., 2008). Negative impacts of intensified farming, deforestation and overgrazing by livestock in Dutse have been documented. These include flooding, soil erosion and loss of soil fertility (Mansur, 2014). This implies that the wellbeing of quality habitats for many land bird species in Dutse is at stake. It will be important to examine possible impacts at the individual species level in order to make specific recommendations for decision makers as well as managers of habitats in Dutse.

Another aspect of anthropogenic impact that has strong bearing for the future of Dutse birds is the anticipated human-induced climate change; specifically increasing temperatures, vegetation change and extreme weather conditions such as short or prolonged wet and dry season will affect seasonality and increase drought frequency and desertification. Prolonged dry season for example may result in more wood removal (branches and trees) and intensified grazing by herdsmen (especially the Fulani people), since the lack of rain will reduce growth of grasses and other vegetation that provide food for grazing animals. These events, already seen in Dutse, are anticipated to cause significant changes in the birds' essential habitats and may lead to mismatch in phenology of breeding (residents) and migration (migrants). Given that in many cases these are likely reasons for the decline of bird populations, it is of great urgency to continue efforts of spatiotemporal avian monitoring beyond the present baseline study.

5.4 Spatiotemporal utilization of habitat according to feeding guild, residence status and population trend

Insectivorous, granivorous and frugivorous bird species had higher percentages of bird species with the same feeding guild. The higher number of insectivorous bird species recorded in this study could be associated with the abundance of farmlands (secondary habitat) which provide supplementary food (insects) especially during cultivation and harvest. In a similar study in Mexico, Arizmendi *et al*. (2008) reported similar findings of higher number of insectivorous, granivorous and frugivorous bird species than omnivorous and nectarivorous species. This study found frugivores to be the dominant feeding group in Dutse with highest abundance in woodland habitat and in the Model site that is dominated by woodland habitat.

Borghesio and Laiolo (2004) showed that there were few changes in feeding guild of bird assemblages in a montane forest in Northern Kenya which is concomitant to the findings of this study. The present study did not find significant difference in the abundance of birds by feeding guild between habitats and sites except for frugivores. Between habitat and sites, higher fruigivore abundance was recorded in woodland habitat and Model sites that had higher number of tree density, suggesting habitats and sites with higher number of trees may attract more birds due to fruit availability, cover and nesting areas. A majority of the habitats in this study are categorized as woodland which appeared to support high abundance of frugivores. Several studies have associated the abundance and diversity of fruits in the tropical region (like Nigeria) with frugivore abundance and diversity (Orians, 1969; Bleher *et al*., 2003).

In Dutse, most of the tree species in the woodland areas produce fruits and nectar that attract frugivores and nectarivores (Lack, 1987; Gentry, 1990; Borghesio & Laiolo, 2004; Seoane *et al*., 2013). Certain tree species such as *Ficus* spp., *Premna* spp, *Grewia bicolor,* and *Commiphora* spp (Lack, 1987; Douglas *et al*., 2014) *Acacia* spp*, Balanites egyptica* and *Salvadora persica* (Jones, 1985; Kelsey, 1992) are example of important plant species providing fruits for many bird species in Northern Nigeria and generally in Africa. Frugivores have been known to search for and track fruits as far as outside their habitats (Neuschulz *et al*., 2011). The higher abundance of birds by feeding guilds recorded in the dry season could be explained by the presence of migrant birds wintering in Dutse such as insectivores (Warblers), granivores (Wagtails) and frugivores (African Golden Oriole *Oriolus auratus*). Many trees in northern Nigeria including Dutse produce fruits at the end of wet season and through some months in dry season.

The period of this study coincided with the wintering period of the majority of migrants between September-October (Elgood *et al*., 1982; Aidley & Wilkinson, 1987b; Hedenstrom *et al*., 1993; Hulme & Cresswell, 2012), which allowed them to be recorded. Even though a greater percentage of the recorded bird species were residents, a good number of breeding and non-breeding migratory bird species were recorded, a majority of which are Palearctic migrants. Out of the 251 migratory bird species in Nigeria (Birdlife International, 2016a), 35 (14 %) of them were recorded in this study, while 93 bird species recorded were residents. Percentage of migrants appeared to be quite high, suggesting that Dutse serves as an important wintering ground. A study in another similar habitat in Northern Nigeria recorded 15 migrants and 76 Afrotropical bird species (Jones *et al*., 1996), percentage wise it is similar to the findings of this study. Migrant birds on their wintering ground occupy a greater variety of habitats than their tropical counterparts (Leisler, 1992). They are less neophobic than residents and explore resources and habitats seldom used by residents (Leisler, 1992). Their ability to switch between food resources (opportunists) allow them to vary habitat use on their wintering grounds (Leisler, 1992).

This study showed that higher abundance of resident birds is mostly associated with woodland habitat and in the Model area, while migrants were more abundant in shrubland habitat and the Wangara site (a shrubland dominated habitat). Although certain tree species in Dutse (*Ficus* spp*, Acacia* spp and *Balanites egyptica*) support high number of bird species especially frugivores, some tree species might be avoided by certain bird species. In Burkina Faso, Mallord *et al*. (2016) found that migrant birds avoided common trees such as *Azadirachta indica* which was also a common tree and occur in high abundance in Dutse. This may be one of the reasons for the higher abundance of migrant birds in shrubland habitat and in Wangara.

Another explanation for the higher abundance of migrant birds in shrubland habitat is that the majority of the migrant birds recorded in this study are shrubland related species (Common Whitethroat *S. communis*, Woodchat Shrike *Lanius senator*, Northern Wheatear *O. oenanthe*, Montagu's Harrier *C. pygargus*), farmland related species (Yellow Wagtail *M. flava*) or birds that prefer medium sized trees (Common Redstart *P. phoenicurus*). Hence, the higher abundance of migrants in Shrubland habitat and in Wangara site.

The higher abundance of both residents and migrant bird species in dry season could be explained by the differences in data collection period. Data collection was started in August which is during wet season. At this time new bird species were still being encountered, coupled with the arrival of migrants in the dry season which may cause an increase in avian diversity and abundance recorded. These two phenomena accounted for the higher abundance of both residents and migrants within the dry season.

This study found that 57%, 20% and 18% of the recorded bird species to be having stable, decreasing and increasing population trends respectively, with migrant birds having higher number of species with decreasing trend. In accordance to the findings, previous studies reported a decreasing population trend of migrant birds wintering in central and northern Nigeria (Sanderson *et al*., 2006; Hulme & Cresswell, 2012; IUCN, 2016). No significant difference in bird abundance by population trend was seen across habitats and sites except for the Malamawa site that had lower abundance of birds with decreasing trend and significantly different from the other sites. Migrants such as Montagu's Harrier (*C. pygargus*), Purple Heron (*Ardea purpurea*), Common Kestrel (*Falco tinnunculus*), Woodchat Shrike (*L. senator)*, Yellow Wagtail (*M. flava*), Northern Wheatear (*O. oenanthe*), Common Whitethroat (*S. communis*), Great Reed Warbler (*Acrocephalus arundinaceus*) and Wood Warbler (*P. sibilatrix*) have decreasing population trends whereas others such as the Red-necked Buzzard (*Buteo auguralis*), Western Marsh Harrier (*Circus aeruginosus*), White Stork (*Ciconia ciconia*), Common Redstart (*P. phoenicurus*), Subalpine Warbler (*Sylvia cantillans*), Western Bonelli's Warbler (*Phylloscopus bonelli*) are showing increasing population trends. These circumstances (migrant presence in dry season) may provide a plausible explanation for the higher abundance of bird species with both increasing and decreasing trends in the dry season.

Common bird species that are highly gregarious and colonial such as Chestnut-bellied Starling (*L. pulcher*), Brown Babbler (*Turdoides plebejus*), Greater Blue-eared Starling (*L. chalybaeus*), Long-tailed Glossy Starling (*L. caudatus*), White-billed Buffalo Weaver (*B. albirostris*) recorded in large number had stable population trends. The higher abundance of bird with stable population trend was recorded in woodland habitat, the Model site and dry season which harbored higher bird abundance and diversity. While these bird species do not appear to be of any particular conservation concern presently, ongoing monitoring of their population trends is warranted in light of anticipated future spatiotemporal changes in Dutse.

5.5 Limitation of the study

The name "Dutse" means hilly rocks. These are common landscape components that are abundantly found within and around the Dutse town. But due to the nature of the terrain and difficulty in accessing rocky areas, rocky habitat was not included in the sampling areas; therefore, rock and rock loving species such as Cinnamon-breasted bunting (*Emberiza tahapisi*) and Stone partridge (*Ptilopachus petrosus*), which are known to occur in abundance in Dutse have not been recorded at the point count station. Similarly, bird species like Northern Carmine bee-eater (*Merops nubicus*), White Stork (*Ciconia ciconia*), and some highly seasonal bird species such as the Abdmin Stock (*Ciconia abdimii*) which are breeding visitors in Dutse were sighted often outside the point count stations yet remained unrecorded within the point count stations. However, for the purpose of a detailed and comprehensive checklist of bird species in Dutse, those bird species that were seen but not recorded at point count stations have been included (species denoted with asterisks in Appendix D).

In addition, this study does not cover aquatic and nocturnal species. Given the study area, the present scope of the study is limited to terrestrial and diurnal species. A few water related bird species such as Green-backed Heron (*Butorides striata*), Black-headed Heron (*Ardea melanocephala*) and nocturnal species like Pearl-spotted Owlet (*Glaucidium perlatum*) and Africa Scops Owl (*Otus senegalensis*) were occasionally observed in Dutse but not recorded during the point count surveys.

CHAPTER 6: CONCLUSION

This study provides the first quantitative ornithological data; that is, the first assessment of the effects of seasonal, landscape variables, habitat variation and anthropogenic activities on bird diversity and abundance in Dutse, Nigeria. In addition, this study documents the spatiotemporal utilization of habitat by bird species as well as yields a detailed and comprehensive bird checklist of Dutse. The high bird diversity recorded in this area, including two species of conservation concern, highlight the importance of Dutse as a key bird habitat in the region. The dry season and woodland habitats support higher bird abundance and diversity in Dutse. The Model site, an area dominated by woodland supports highest bird abundance and diversity. Tree and shrub densities are important determinants of bird species richness, abundance and diversity. However, tree density was more important in increasing bird abundance than shrub density.

Small scale anthropogenic activities and habitat modification like farming, grazing, wood removal and human interference did not appear to have affected the birds. However, loss of high tree-density woodland habitats may pose a major threat to the bird community in Dutse. Although the anthropogenic activities in Dutse did not appear to have affected the overall bird species richness, abundance and diversity, but at species level these anthropogenic activities have been reported to negatively affect and have led to decline of both resident (Vulnerable Beaudouin's Snake Eagle *C. beaudouini*) and migrant (Near Threatened Pallid Harrier *C. macrourus*) birds in Nigeria (Galushin *et al*., 2003; Thiollay, 2006a, 2006c; BirdLife International, 2017a, 2017b). Therefore, it is important to examine the impact of these activities at species-specific level in Dutse. Further degradation and destruction (through human activities) of both habitats and removal of certain woodland trees such as *Acacia* spp, *Ficus* spp, and *S. persica* used for feeding (Jones, 1985; Kelsey, 1992) by residents and migrants of different feeding guilds will significantly affect local bird's population.

Both woodland and shrubland in Dutse are vital for bird survival. Resident and migrant birds may utilize woodland habitat. However, migrant birds appeared to utilize shrubland more often than woodland habitat. Therefore, shrubland habitat should be prioritized for conserving migrant birds in Dutse. The high number of both resident and migrant birds wintering in this area highlights the importance of Dutse as a key bird habitat and wintering ground in the region. The dry season generally supports higher abundance of bird species across feeding guilds, residence status and birds of varying population trends.

In a nutshell, this research provides useful and scientific knowledge on abundance and diversity of bird species across different seasons, habitats and sites in Dutse. In addition, the effects of seasons, landscape variables, habitat variation and other anthropogenic activities on bird diversity and abundance were demonstrated. Such information is important for planning future studies and for monitoring the impacts of human activities on local bird community.

6.1 Recommendations

Conservation authorities, local and federal government, local and international conservation organizations in Nigeria (NCF, APLORI and NGOs) should focus on the conservation and management of bird species as well as their habitat. In the case of Dutse, Woodland and Model site should be priotised. Tree planting should be encouraged by the government to reforest the environment. Effort should be emphasized on improving agricultural practices (agroforestry) that will favor biodiversity conservation and at the same time be compatible with poverty alleviation. Specifically, farmlands with trees (agroecosystem) can create more ecological niches that may increase bird species richness, abundance and diversity. Therefore, farmers should be encouraged to plant trees (native trees if possible) and retain existing trees on their farms. These may compensate for the loss of native trees and provide surrogate resource and ecological function of the native trees. Nevertheless, should there be large-scale projects in the future that warrant clearing of large tracts of forested areas, the Dutse government should avoid the Eastern region (the Model area) and focus on less biodiverse area.

Dry (cold) season is the wintering period for migrant birds in Dutse and other parts of Northern Nigeria. Therefore, human activities that negatively affect landscape variables such as forest and bush burning (which is a common practice especially prior to farming season) during the dry season should be avoided or regulated by the Dutse government. This will help to lessen the impacts and avoid further habitat loss and decline of winter migrant birds.

Birdlife International's Site Support Groups (SSGs) should be adopted and implemented in Dutse to get everyone's involvement in the conservation of birds and their habitats, including local people, conservation clubs and government authorities. TVs and radio should promote programmes on bird and habitat conservation in Dutse. Important events dates such as World Wetlands Day, World Migratory Bird Day, and World Wildlife Day should be celebrated to increase public awareness on bird conservation. Lastly, more bird studies are needed in Dutse and many parts of Nigeria especially in areas where ornithological data is lacking. Further research should focus on the following:

1. Study the effects of anthropogenic activities (farming, grazing, wood removal and human disturbance) at species-specific level.

2. Ecological studies such as territoriality, site and habitat fidelity of birds with decreasing population trends.

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LIST OF PUBLICATIONS AND PAPERS PRESENTED

Publication

1. **Muhammad, S. I.**, Ramli, R., & Then, A. Y. (2018). Seasonality, habitat type and locality influenced bird assemblage structure in Nigeria. *Ostrich, 89*(3), 221-231.

2. **Muhammad, S. I.**, Then, A. Y. H., & Ramli, R. (2019). Spatial and seasonal use of habitat by birds in northern Nigeria. *Bird Study*. (Accepted)

Conference paper

First report on bird diversity and abundance in Dutse, Nigeria. Poster Paper presented on 15th – 17th December, 2016. 21st Biological Sciences Graduate Congress (BSGC), University of Malaya, Malaysia.