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Influence of Seasonality on the Diversity, Abundance, and Distribution of Hornbill Species in Bali and Gassol Local Government Areas, Taraba State, Nigeria

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Abstract

This study investigates the seasonal dynamics of hornbill diversity, abundance, and distribution in Bali and Gassol Local Government Areas of the central zone of Taraba State, Nigeria, a biodiverse region currently experiencing hornbill population decline. The objectives were to assess species composition, seasonal abundance, and habitat-specific distribution of hornbills across wet and dry seasons. A multistage stratified sampling method was applied, categorizing the study area into woodland savannah and open grassland as sampling sites. Hornbill surveys were conducted using the point count method. A total of 1,216 individuals representing three species—the African Grey Hornbill, African Pied Hornbill, and Red-billed Hornbill—were recorded, with higher diversity and abundance observed in the wet season due to increased food and water availability. Woodland savannah supported larger populations (753) compared to open grassland (463), attributed to its complex vegetation, nesting opportunities, and favorable microclimates. The African Grey Hornbill

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dominated across habitats and seasons (50–70%). Human activities, particularly bushfires, exacerbated dry season declines in open grasslands. Despite seasonal fluctuations in abundance, species richness remained stable across both habitats. Distribution patterns showed significant deviations from expected uniformity, indicating species-specific habitat and seasonal preferences. The study concludes that hornbill conservation in Central Taraba requires recognition of habitat preferences and seasonal ecological dynamics. It recommends community-based initiatives to raise conservation awareness, promote sustainable land use, and encourage practices that support hornbill population recovery and long-term biodiversity conservation.

Keywords: Seasonality; Diversity; Abundance; Distribution; Hornbills; Taraba State

INTRODUCTION

Avian species display remarkable diversity in their physical characteristics, feeding methods, habitats, and adaptations. The class Aves includes 29 distinct orders and encompasses about 10,721 bird species globally (International Union for Conservation of Nature [IUCN], 2022).

Birds are found on all seven continents, with the highest biodiversity located in tropical regions (Lee. *et. al*., 2020). In Nepal, 892 bird species have been recorded, accounting for around 8.3% of the world ‘s total bird diversity (DNPWC and BCN, 2022). Of these, 42 species are globally threatened, with 10 listed as Critically Endangered, 8 as Endangered, and 24 as Vulnerable (DNPWC and BCN, 2022; Bird Life International, 2022).

Birds serve as valuable ecological indicators due to their sensitivity to environmental degradation (Johnson, *et. al*., 2019). As visible components of ecosystems, birds occupy various tropic levels and play key roles as indicators of environmental health, pollinators, seed dispersers, and natural pest controllers (Wang, *et. al*., 2023). Their adaptability to diverse climates, ranging from Antarctica 's icy terrain to the hottest deserts, often makes birds more observable and appealing than other animals (Kwaga *et al.,* 2017).

Research on avian species has long captivated scientists worldwide, with hornbills (family Bucerotidae) standing out due to their charismatic appearance and ecological significance in tropical ecosystems. Known for their large size, distinctive beaks, and

prominent casques, hornbills are widely distributed across Africa, Asia, and Melanesia (Garcia, *et. al.*, 2021). They play critical roles in forest ecosystems, particularly as seed dispersers and pollinators, which are essential for forest regeneration (Short, 2019; Kemp and Boesman, 2020). Their large beaks and casques are adaptations that support their frugivorous feeding habits, while their nesting in tree cavities creates habitats for other species (Kemp and Wang, 2020).

Hornbills are monogamous and exhibit strong fidelity to their nesting sites, often choosing tall trees in degraded or modified habitats when available. In India, some Asian hornbills are known to track fruiting fig trees (Ficus spp.), a key food source, across various landscapes, causing fluctuations in their local population densities (Naniwadekar amd Datta, 2016; Pawar *et al.*, 2018). Despite their ecological importance, hornbills face significant threats such as habitat loss, illegal hunting, and the pet trade, leading to population declines and local extinctions (Kemp and Boesman, 2020). Understanding the factors that influence hornbill diversity and distribution is critical for their conservation.

In Nigeria, the dry season (November to March) brings resource scarcity, which impacts hornbill diversity as some species migrates or change foraging behaviour. Conversely, the wet season offers abundant resources like fruits and nesting sites, resulting in higher hornbill diversity during this period (Eniang *et al.*, 2020).

Seasonality significantly impacts the availability of essential resources and thus influences the diversity of hornbills and other bird species in Nigeria (Pandey *et al.*, 2020).

Diversity refers to a quantitative measure reflecting the number of different species within a dataset. Numerous objective methods have been developed to assess diversity, with the core aim of obtaining a quantitative estimate of biological variability, enabling comparison of biological entities over time and space (Kira *et al.*, 2021).

Nigeria 's wet season, characterized by lush vegetation, brings a surge of fruits, insects, and other food resources, which boosts species diversity. In contrast, the dry season sees receding rains and shrinking vegetation, prompting some migratory hornbills to depart, thereby lowering species diversity. However, resident species such as the yellow-casqued and Black-casqued Hornbills maintain their numbers by adapting their diets and foraging strategies to utilize available resources. The abundance of food during the wet season also attracts migratory species like the African Grey hornbills and Von Brunn ‘s hornbill, further enhancing species diversity. Resident species benefit from this resource

abundance as well, with increased breeding leading to more juveniles. Woodland savannahs offer hornbills more stable microclimatic conditions, such as cooler temperatures and higher humidity, compared to open grasslands, which are more exposed, and hot (Malik and Singh, 2023). Regarding habitat distribution, hornbill species tend to shift their habitat preferences with the seasons. During the wet season, denser forests provide plentiful food and nesting sites, drawing species like the Red-billed Hornbill. As the dry season progresses and these areas become less hospitable, species like the Crowned Hornbill may move to open woodlands or savannas in search of food and water. Water sources become critical during the dry season, concentrating diverse hornbill species around rivers and watering holes, creating temporary congregations that wouldn 't normally occur. During the wet season, hornbills may venture into more open habitats like savannas and riverine forests, where food and nesting opportunities are abundant. This seasonal migration allows hornbills to exploit various resources and expand their distribution across Nigeria 's ecosystems (Omotade and Oke, 2021). The abundance of hornbills directly correlates with resource availability, which fluctuates with the seasons (Jones *et al.*, 2018). During the wet season, resource richness results in higher population numbers, as the plentiful fruits and increased insect activity provide essential energy for breeding. The wet season also fosters ideal conditions for raising chicks, leading to a spike in juvenile numbers (Adagunodo *et al.*, 2020). In contrast, during the dry season, resource scarcity limits breeding activity, reducing overall hornbill abundance. Some individuals may migrate to more suitable habitats during this period, which contributes to the higher diversity observed in wetter months (Oboh, 2024) Hornbills are wide-ranging birds that track sporadically distributed fruit resources over vast distances, making them important contributors to seed dispersal (Wang *et al.*, 2023). They are found in fragmented, degraded, secondary, or logged forests, as well as plantations and areas surrounding protected forests, though they are generally less abundant in these habitats compared to relatively intact tropical forests (Johnson *et al.*, 2023). However, the extent to which hornbills use habitats like forest fragments and plantations, and whether this use is year round or seasonal, is still unclear. Understanding this is essential for assessing the potential of these modified habitats to support hornbill populations outside protected forest reserves.

Weather influences birds in various ways, not only by affecting their metabolic rates (e.g., cold weather increases energy needs for body maintenance) but also by impacting their behavior directly and indirectly. For example, weather can affect foraging conditions

and limit other vital behaviors like courtship. It also plays a role in breeding success, potentially leading to the chilling or starvation of young birds (Sharp *et al.,* 2021).

Despite their ecological significance, a noticeable decline in hornbill and other bird species 'populations has been observed during the pilot study in the research areas. There is little available information regarding the reasons for their decline or disappearance. Moreover, understanding the complex relationships between seasonality and hornbill ecology is critical for their conservation, yet such knowledge is lacking in Taraba State. Protecting diverse habitats throughout the year, ensuring access to water, and managing fruit and insect resources are essential for maintaining healthy hornbill populations. These resources, crucial for their survival, are increasingly threatened by human activities and climate

The findings from this study are intended for conservation purposes. The research will provide valuable insights to various stakeholders, including conservation organizations, local government authorities, local communities, regional natural resource managers, and academics, to better manage the area. It will also assess the status of the hornbills in terms of their abundance and distribution across different seasons. Additionally, the study will offer information that can aid in developing and implementing effective conservation strategies for preserving bird species diversity and richness.

The study aims to explore how seasonality (wet and dry seasons), habitat types (woodland savannah and open grassland), habitat variation and loss, and human activities (such as farming, wood harvesting, grazing, and human disturbances) affect the diversity, distribution, and abundance of hornbills across spatial and temporal scales. This will help fill gaps in scientific knowledge about avian species in central Taraba State.

METHODS

Description of Study Areas

The research was conducted in the Bali and Gassol Local Government Areas of Taraba State, which is known as the Southern Guinea Savannah zone.

Bali LGA, one of the 16 LGAs in Taraba State, covers approximately 9,146 km² and is located between latitudes 7°30'00"to 8°10'00"North of the equator and longitudes 50°45'00"to 60°15'00"East of the Greenwich Meridian (Taraba State Government, 2005).

It shares its northern borders with Ardo Kola and Gassol, while Donga and Kurmi lie to the west, and Gashaka is to the south. The northeastern boundary is shared with Adamawa State. This region is positioned along the upper course of the Taraba River, approximately 150 km from Jalingo, in the watershed area of the Benue River, at an altitude of 450 meters above sea level. The climate is typically warm to hot year-round, with a cooler period from November to February, and temperatures range from 23°Cto 40°C. Temperatures gradually rise from January to April, increasing the demand for water for domestic use. Bali serves as a significant economic hub due to its vibrant food crops market, which is well connected to other parts of the state and country. According to the 2006 National Population Census, the local government 's population stands at 208,935. The population density leads to diverse land uses associated with the area 's semi-urban character, creating a high demand for water resource. However, water supply in the region is primarily marked by scarcity, especially during the dry season. (see Fig.1)

Gassol Local Government Area (L.G.A) is situated between latitudes 7°32'N and 8°40'N and longitudes 10°25'E and 11°45'E. Covering an area of 5,982 km², it has a population of 244,749, comprising 125,293 males and 119,456 females, according to the 2006 national census. Gassol L.G.A experiences a tropical continental climate with distinct wet and dry seasons; the wet season starts from April to October, and the dry season runs from November to March. The local vegetation is characterized by wooded savanna, featuring scattered trees and dense grasses. The soil consists of sandy loam formed from underlying rock outcrops, as well as clay loam developed from flooding in river valleys. Agriculture is a primary economic activity in central Taraba, particularly within the Southern Guinea Savannah zones of the State. (Oruonye, 2016). (See fig 2)

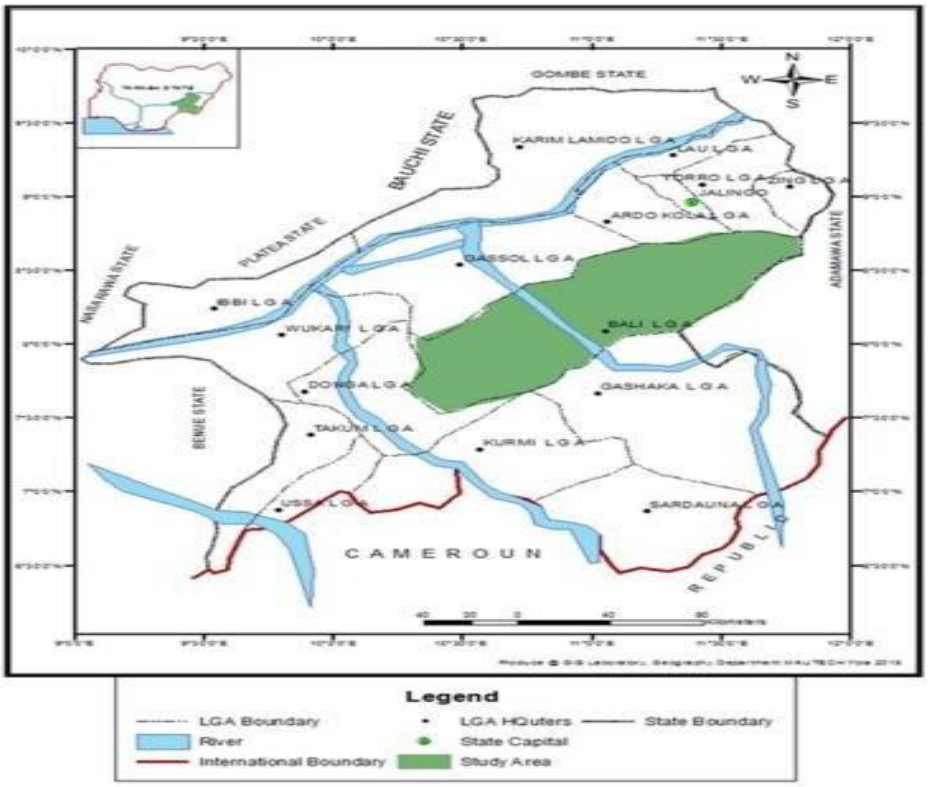


Fig.1Taraba State showing the study area (Bali L.G.A)

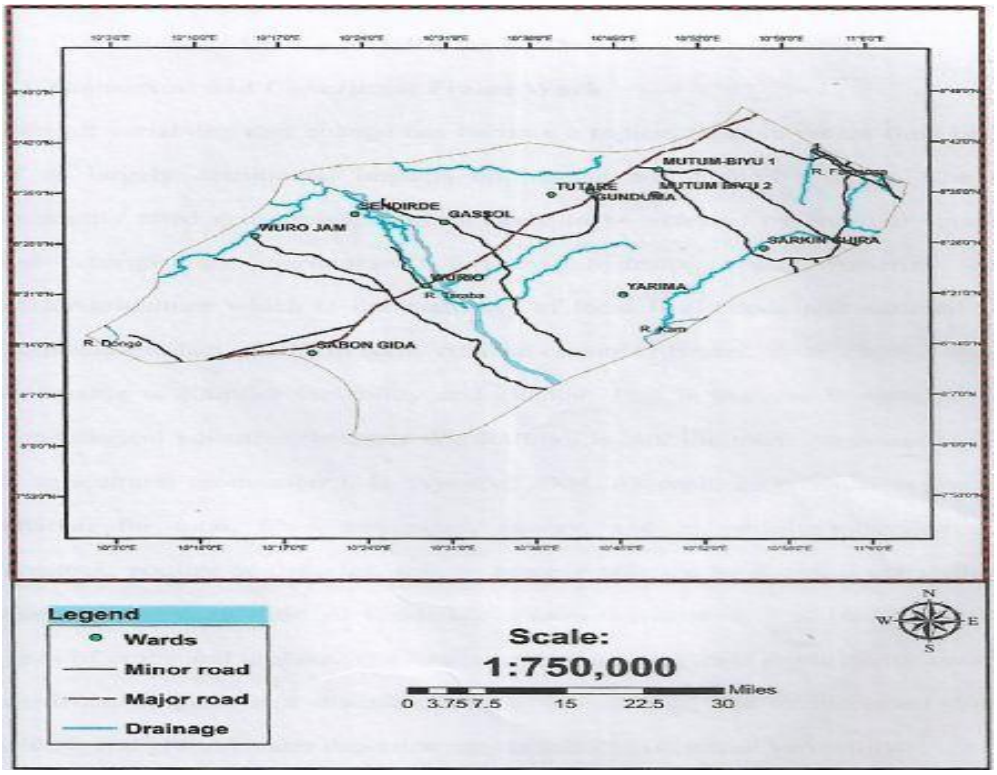


Fig.2 Map showing study area in Gassol L.G.A

Reconnaissance Survey

A preliminary survey was conducted in the two study areas. This is to refine methods, equipment and timing; identify logistical challenges and informs sample size and stratification to improve the accuracy and efficiency of the detailed survey.

Study Design and Collection Techniques

Study Design

The research was carried out in the Bali and Gassol Local Government Areas of Taraba State. Data collection took place during both the dry and wet seasons. Two specific habitats were chosen: Open grassland in Gassol and Woodland savannah in Bali Local Government Areas of Taraba State. The GPS coordinates of these habitats were recorded using a handheld GPS device (eTrex 20X GARMIN).

Sampling Method

The study employed a multistage stratified sampling approach. The primary stratum consisted of the central region of Taraba State, while the secondary strata included the local government areas of Bali and Gassol. In each habitat type, a point count method was utilized, as it was the most appropriate for the uneven terrain (characterized by steepness) and dense undergrowth, where detecting avifauna using alternative methods might prove challenging. A 25-meter radius was established for the counts to facilitate comparisons of hornbill diversity, abundance, and distribution across different habitat types. Thirty permanent counting points were systematically selected, spaced 100 meters apart, in accordance with the methodology described by Bibby *et al.* (1992).

Duration of the Study

Data was collected in the study areas for fifteen (15) days each month from December, 2022 to August, 2023, covering both wet and dry seasons.

Fieldwork plan

The Point Count Method was employed for the hornbill census in the study areas. Counting stations were established, with landmarks such as stones, posts, or trees marked using bright, water-resistant paint or flagging tape, like colorful ribbons. A total of 30 counting stations were set up for each habitat, ensuring that they were arranged to avoid overlap in counting hornbills. The stations were spaced 100 meters apart to prevent counting individual hornbill species at multiple stations, which could artificially inflate the

sample size and affect the results. If the spacing is too close, other species may be overlooked, while excessive distance could lead to overlap.

Census of Birds

The Point Count Method, as described by Bibby *et al.* (1992), Ralph *et al.* (1993), and Sutherland (1997), was utilized for the bird census in each study area. Data were recorded using a data sheet, and the censuses were conducted with the aid of binoculars, field guides, and a watch. Bird counting took place from 6:30 AM to 8:30 AM, as this time is optimal for observing birds when they are most active. Upon reaching a counting station, observers waited for three minutes before commencing the count (Bryan *et al.*, 1984) to allow birds to settle after any disturbance caused by their arrival. Observers recorded all identified birds, whether by sight or call, within a fixed distance of 25 meters, noting those beyond this distance separately. Each species was counted only once.

Data Analysis

The data collected during the survey was analyzed using SPSS version 25.0. Shannon Weiner Diversity Index (Usher, 1991) was used to compare hornbills 'species diversity and the index is stated as follows:

$$\boldsymbol{H}' = -\sum \boldsymbol{P}\text{i}(\ln \boldsymbol{Pi})$$

Where: HI= the Shannon Weiner Index, Pi is the proportion of the ith species in the sample, ie ni/N (ni=abundance of each species and N=total number of individual species), and InPi is the natural logarithm of the species proportion.

Chi-square was used to test significance level for distribution pattern across the two habitat types of study in both seasons while Simple percentage was used to present the abundance of hornbill species of the study areas for different seasons.

RESULTS

Hornbills Specie diversity during dry and wet Seasons in woodland savanna (Bali LGA).

During the study period in woodland savanna, three species of hornbills were identified. The species recorded included the African grey hornbill (*Tockus nasutus*), which had the highest representation at 55%, followed by the Red-billed Hornbill (*Tockus*

erythrorhynchus) at 27%, and the African Pied Hornbill (*Tockus fasciatus*) with the lowest at 18%. Analysis using the Shannon-Wiener Diversity Index showed that the diversity of hornbill species was recorded as H '=-1.00 in the wet season and H '=-0.96 in the dry season within the woodland savanna habitat. Although the wet season had the highest species diversity, both seasons exhibited the same species richness, with ln(s) values of 1.10 each. In terms of Evenness (E), the dry and wet seasons were recorded as-0.87 and-0.90, respectively (see Table 1).

Table 1: Seasonal Species Diversity for woodland Savanna (Bali LGA) at both seasons

Diversity measure	Dry season	Wet season
Shannon(H)	-0.96	-1.00
Richness(In(s)	1.10	1.10
Evenness(E)	-0.87	-0.90

Hornbill Species diversity during dry and wet Seasons in Open grassland habitat (Gassol LGA).

During the study, three hornbill species were identified in open grassland. The recorded species included the African Pied Hornbill (*Tockus fasciatus*) at 27%, the African Grey Hornbill (*Tockus nasutus*) at 70%, and the Red-billed Hornbill (*Tockus erythrorhynchus*) at 13%.

Hornbill species diversity was found to be high during the wet season in open grassland compared to the dry season. However, both seasons exhibited the same species richness, Regarding evenness (E), the dry and wet seasons had values of 0.86 and 0.87, respectively, (Table2)

Table 2: Seasonal Hornbill Species Diversity for Open grassland (Gassol LGA)

Diversity measure	Dry season	Wet season
Shannon(H)	-0.60	-0.61
Richness(In(s)	0.70	0.70
Evenness(E)	-0.86	-0.87

Source: Field survey, 2023

Seasonal abundance of hornbills during dry and wet Seasons in woodland savanna (Bali LGA).

During the study, a total of 753 hornbills were observed in this habitat. Of these, 341 (45.3%) were counted in the dry season, while 412 (54.7%) were noted in the wet season. Although there were fewer individuals recorded during the dry season, the diversity of species was consistent across both seasons. The Grey Hornbill (*Tockus nasutus*) was the most frequently observed species, with 225 in the dry season and 193 in the wet season. The Red-billed Hornbill (*T. erythrorhynchus*), followed, with 92 in the dry season and 109 in the wet season. The least common species recorded in both seasons was the African Pied Hornbill (*T. fasciatus*), with 56 in the dry season and 78 in the wet season. Refer to Table 3 for details.

Table.3 Seasonal abundance of hornbill during both seasons in woodland savanna (Bali LGA)

Species	Dry season(%)	Wet season(%)
African Grey hornbill (*Tockus nasutus*)	193 (56.6)	225 (54.6)
African Pied hornbill (*Tockus fasciatus*)	56 (16.4)	78 (18.9)
Red-billed hornbill (*Tockus erythrorhynchus*)	92 (27.0)	109(26.5)
Total	341(45.3)	412 (54.7)

Source: Field survey, 2023

Seasonal Abundance of Hornbill species for open grassland during both seasons in Gassol LGA

A total of 463 hornbills were observed in this habitat during the study. Of these, 201 (43%) were in the dry season, while 262 (57%) were recorded in the wet season. The population was lower in the dry season compared to the wet season. *Tockus nasutus* (Grey hornbill) was the most frequently observed species in both seasons, with 142 in the dry season and 184 in the wet season. The Red-billed hornbill (*T. erythrorhynchus*) was the least common species during the dry season, with 59, while the African Pied hornbill was absent. Conversely, in the wet season, the African Pied hornbill was the least recorded species with 78, and the Red-billed hornbill was absent. See Table 4 for details.

Table 4: Seasonal Abundance of Hornbill species during dry and wet seasons in Gassol LGA Taraba State.

Species	Dry season(%)	Wet season (%)
African Grey hornbill (*Tockus nasus)*	142 (70.6)	184 (70.6)
African Pied hornbill (*Tockus fasciatus*)	0 (0)	78 (29.8)
Red-billed hornbill (*Tockus erythrorhynchus*)	59 (29.4)	0 (0)
Total	201 **(43.4)**	**262 (54.6)**

Source: Field survey, 2023

Distribution of Hornbill Species in Open Grassland during Wet Season

The distribution of Grey Hornbills observed in open grassland during the wet season (184) differs significantly from the expected distribution (139). In contrast, the observed distribution of Pied Hornbills (78) is not significantly different from the expected distribution (52). This implies that Pied Hornbills have a more random distribution pattern in open grassland during the wet season. The Red-billed hornbills is absent in this habitat during the wet season, deviating sharply from the expectations.

Overall, the study indicates substantial differences in the distribution of various hornbill species in open grassland during the wet season. See table 5 for details

Distribution of Hornbill Species in Open Grassland during Dry Season

The Chi-square value indicates a significant difference between the observed and expected counts of Grey Hornbills in open grassland during the dry season.

In contrast, the observed count of African pied hornbill is lower than the expected count, suggesting a significant discrepancy in the distribution of pied hornbills in the same environment and season.

However, the Chi-square value of Red-billed hornbill indicated no significant difference between the observed and expected counts in the open grassland during the dry season.

Overall, the results suggests a notable difference in the distribution of hornbill species in the open grassland during this season compared to what would be anticipated by chance alone. The findings imply that certain seasonal factors may affect the presence and abundance of Grey and Pied Hornbills in the area during this time, whereas they do not significantly impact the Red-billed Hornbills. See table 6 for details

Distribution of Hornbill Species in Woodland Savanna During Wet Season.

The findings indicated that there are notable variations in the distribution of grey hornbill and Red-billed hornbill in the woodland savannah during the wet season, whereas the distribution of African pied hornbill does not show a notable deviation from the anticipated distribution. See Table7.

Distribution of Hornbill Species in Woodland Savanna during Dry Season

The findings indicated that there are notable variations in the distribution of Grey Hornbills and Pied Hornbills in the woodland savannah during the dry season, whereas the distribution of Red-billed Hornbills does not show a significant deviation from the anticipated distribution. See Table.8.

Table.5: Distribution of Hornbill Species in Open Grassland During Wet Season

Species Obser	ved count	Expected counts	X^2	Df	Significance Level
Grey Hornbill	184	139	12.44	2	Significant
Pied Hornbill	78	52	3.05	2	Not Significant
Red-billed Hornbill	0	36	27.77	2	Significant
Total	262	227			

Source: Field survey, 2023

Table.6: Distribution of Hornbill Species in Open Grass land During Dry Season

Species	Open Grassland	Expected Grassland	X^2	Df	Significance Level
Grey Hornbill	142	99	10.66	2	Significant
Pied Hornbill	0	16	15.75	2	Significant
Red-billed Hornbill	59	45	1.25	2	Not Significant
Total	201	160			

Critical value (5.99) at $\alpha = 0.05$

Table.7: Distribution of Hornbill Species in Woodland Savanna During Wet Season

Species	Observed	Expected	X2	Df	Significance Level
Grey Hornbill	225	219	16.79	2	Significant
Pied Hornbill	78	103	3.05	2	Not Significant
Red-billed Hornbill	109	72	34.18	2	Significant
Total	412	394	53.02		

Critical value (5.99) at $\alpha = 0.05$

Table 8: Distribution of Hornbill Species in Woodland Savanna During Dry Season

Species	Observed	Expected	X2	Df	Significance Level
Grey Hornbill	193	168	14.40	2	Significant
Pied Hornbill	56	39	15.75	2	Significant
Red-billed Hornbill	92	105	0.89	2	Not Significant
Total	341				

Critical value (5.99) at $\alpha = 0.05$

Comparative Analysis for Hornbill Species Distribution between Wet and Dry Seasons

The comparison table presents the results of the chi-square analysis for hornbill species across different habitat types during both the wet and dry seasons. Significant relationships between hornbill species and habitat types were identified in both seasons. Specifically, during the wet season, the Grey Hornbill and Red-billed Hornbill showed significant preferences for particular habitat types, whereas the Pied Hornbill did not display significant associations. In the dry season, both Grey Hornbill and Pied Hornbill revealed significant associations with habitat types, while the Red-billed Hornbill did not show any notable preferences. These results emphasize the necessity of considering habitat types in hornbill distribution studies, as they indicate seasonal variations in habitat preferences among hornbill species in Central Taraba.(Table-9).

Table 9: Comparative Analysis for Hornbill Species Distribution between Wet and Dry Seasons

Season	Species	Habitat Type	X^2	df	Significance Level
Wet Season	Grey Hornbill	Open Grassland	12.44	2	Significant
		Woodland Savanna	16.79		
	Pied Hornbill	Open Grassland	3.05		Not Significant
		Woodland Savanna	3.05		
	Red-billed Hornbill	Open Grassland	27.77		Significant
		Woodland Savanna	34.18		
Dry Season	Grey Hornbill	Open Grassland	10.66	2	Significant
		Woodland Savanna	14.40		
	Pied Hornbill	Open Grassland	15.75		Significant
		Woodland Savanna	15.75		
	Red-billed Hornbill	Open Grassland	1.25		Not Significant
		Woodland Savanna	0.89		

The "Significance Level" column indicates whether the association between hornbill species and habitat types is significant or not at a significance level of $\alpha = 0.05$.

DISCUSSION

Seasonal hornbill species diversity in open grassland (Gassol LGA) during both seasons

During the entire study period, three species of hornbills (*T, nasutus, T. fasciatus, T. erythrorhynchus*) were recorded across all study areas. The research indicated that hornbill diversity was greater during the wet season compared to the dry season in open grasslands. This increase is likely due to better breeding conditions, as well as a higher availability of food and water resources. This finding aligns with Adagunode *et al.* (2020), who noted that the wet season promotes enhanced plant growth and fruit production, resulting in more food for hornbills. Similarly, Omotade and Oke, (2021) highlighted that the wet season offers increased water sources for these birds, while Ayodele *et al.* (2023) mentioned that it serves as the breeding season for many bird species, including hornbills, contributing to a rise in their populations. Conversely, the reduced diversity during the dry season may stem from the scarcity of suitable nesting sites and the effects of hunting or poaching observed in the area throughout the study. This observation is consistent with Imadojemu (2024), who reported that hornbills require specific nesting conditions, relying on large tree cavities or holes for breeding and rearing their young.

Seasonal Hornbill Species Diversity in Woodland Savanna (Bali LGA)

The study revealed that woodland savanna exhibits greater biodiversity during the wet season, likely attributed to the presence of various tree species, nesting sites, and protective cover. These findings align with Thompson *et al.* (2022), who noted that woodland savanna habitats offer hornbills enhanced protection from predators, along with a more intricate and diverse vegetation structure that supplies a range of food sources and opportunities for foraging, nesting, and breeding. Similarly, Ray *et al.* (2023) observed that woodland savanna typically features a more complex and varied vegetation structure, which provides hornbills with abundant food resources and diverse opportunities for foraging, nesting, and breeding.

The increased diversity could also be influenced by weather conditions. This is supported by Malik *et al.* (2023), whose study indicated that woodland savanna habitats offer hornbills more stable microclimatic conditions, such as cooler temperatures and higher humidity, which can enhance their health and survival compared to more exposed, open habitats.

However, evenness appears to be low during the wet season, potentially due to the abundance of food and water resources, which leads hornbills to disperse throughout the habitat where these resources are available.

The reduced diversity observed during the dry season may result from habitat destruction caused by anthropogenic activities, such as logging, agriculture, and urbanization. This is consistent with the findings of Kinnaird *et al.* (2020), who reported significant habitat loss and fragmentation in woodland savanna due to human actions. Such destruction and fragmentation can limit the availability of resources and suitable nesting sites for hornbills, contributing to a decline in their diversity.

Changes in land use and management practices could also play a role. Ng *et al.* (2021), who noted that the conversion of savanna woodlands into intensive agricultural or grazing areas can adversely affect hornbill populations. These transformations can reduce and disrupt nesting sites while increasing disturbance levels, which often leads to decreased hornbill diversity. Additionally, alterations in climatic conditions may impact hornbills, as indicated by Malik (2023), whose research suggests that climate change can affect resource availability, shift seasonal patterns, and modify habitat suitability. Variations in temperature and precipitation can influence food availability, disrupt breeding cycles, and affect the viability of existing nesting sites, ultimately impacting hornbill diversity.

Abundance of hornbills in Woodland Savanna (Bali LGA) during dry and wet seasons

In the woodland savannah, a higher abundance of hornbills was observed during the wet season compared to the dry season, likely due to the presence of large tree species, canopy cover, and food availability. This aligns with findings from Thompson *et al.* (2017), which stated that hornbills typically need large trees with appropriate cavities for nesting and roosting. They found that hornbill populations thrive in mature forests with dense canopy cover. Similarly, Adagunodo *et al.* (2020) noted that hornbills are frugivorous and rely on the availability and diversity of fruits for survival, with their populations positively

impacted by the presence of fruiting trees. Conversely, lower abundance was recorded during the dry season in the woodland savannah, potentially attributed to habitat loss from activities like tree logging and the collection of firewood and charcoal, which negatively affect woodland savanna birds, as observed during field visits. This finding is consistent with research by Frontier-Tanzania (2005) and Gereau *et al.* (2020), who reported that reduced cover for shelter and escape from predators increases competition within and between species, leading to decreased populations. Additionally, the low abundance may be linked to human disturbances, particularly hunting, as evidenced by locals seen with catapults targeting hornbills and other bird species during the survey. This observation supports the findings of Marshall *et al.* (2016), which indicated that hornbills are vulnerable to human disturbances such as hunting and habitat fragmentation, often resulting in population declines in areas with significant human activity.

Abundance of hornbills in open grassland (Gassol LGA) during dry and wet seasons.

The study revealed a significant abundance of hornbills during the wet season, particularly in woodland savannah habitats. This abundance is linked to the presence of nesting sites, food, water, and suitable habitats in open grassland areas. This aligns with the findings of Schwiger *et al.* (2020), who noted that hornbills require appropriate nesting and roosting locations, typically found in large tree cavities. Key factors such as tree density, tree size, and the availability of suitable cavities play crucial roles in their breeding success and overall abundance. Additionally, research by Kasisomayajula and Patel (2020) examined seasonal changes in habitat use and population size of the African grey hornbill (*Tockus nasutus*) in South Africa, finding that their population increased during the wet season due to improved foraging opportunities and enhanced visibility in open grasslands.

Oboh (2024) also indicated that the seasonal migration patterns of hornbills in Africa contribute to the rise in their population (both abundance and diversity) during the wet season, as some species migrate to Nigeria in search of more favorable breeding and foraging conditions. The increased abundance may also be influenced by rainfall, as noted in the field survey. This observation supports the findings of Smith *et al.* (2019), which suggested that heightened precipitation positively affects birds 'habitats by increasing food and cover availability, thereby enhancing their reproductive success and survival, leading to greater abundance.

Distribution of hornbill species in Woodland Savanna (Bali LGA) during dry and wet seasons.

The study observed a lower abundance of hornbills in open grassland habitats during the dry season. This decline may be attributed to the increased susceptibility of these areas to bush burning or bushfires, which negatively impact food availability and the vegetation necessary for shelter and predator accessibility. This finding aligns with the research by Sallabanks *et al.* (2000), which indicated that the frequency and intensity of bushfires can reduce bird populations by affecting food resources and vegetation that support hornbill nesting and increase predation risks. Additionally, the dry season offers fewer varieties of resources and foraging opportunities. Ray *et al.* (2023) also confirmed this by highlighting that woodland savannahs possess a more complex and diverse vegetation structure, providing hornbills with greater resources and opportunities for foraging, nesting, and breeding compared to the more uniform environments found in open grasslands.

Distribution of Hornbill species in open grassland (Gassol LGA) during wet and dry seasons

The distribution of hornbills was found to be higher during the wet season in open grassland, likely due to climatic conditions that are crucial for their survival. This aligns with the findings of Malik *et al.* (2023), who noted that hornbills thrive in stable microclimatic conditions characterized by cooler temperatures and increased humidity, which are advantageous for their health compared to hotter, more exposed environments. The lower distribution seen in the dry season may be attributed to human activities, such as hunting, logging, and infrastructure development. This is consistent with the research by Marshall *et al.* (2016), which indicated that hornbills are vulnerable to human disturbances like hunting and habitat fragmentation.

In woodland savannah, a higher distribution of hornbills was recorded during the wet season, likely due to the habitat 's greater complexity, which offers diverse vegetation structures. This finding supports the work of Ray *et al.* (2023), who reported that woodland savannahs provide a richer variety of resources for hornbills, enhancing their foraging, nesting, and breeding opportunities compared to the more uniform open grasslands. The reduced distribution in the dry season may be linked to limited food and water availability, negatively impacting hornbill populations. This is further corroborated by Ng *et al.* (2021),

who found that woodland savannah habitats offer a wider variety and abundance of food sources for hornbills, such as fruits, insects, and small animals, which helps sustain larger populations compared to open grassland habitats.

CONCLUSION

This study demonstrates clear seasonal and habitat-specific patterns in hornbill communities across Bali (woodland savanna) and Gassol (open grassland) LGAs in Central Taraba. Across 1,216 detections of three species—African Grey Hornbill, African Pied Hornbill, and Red-billed Hornbill—overall abundance and diversity were consistently higher in the wet season, reflecting the seasonal pulse of food and water availability and improved breeding conditions. Woodland savanna supported larger populations than open grassland (753 vs. 463 individuals), plausibly due to its more complex vegetation structure, availability of large cavity-bearing trees, and more stable microclimates. The African Grey Hornbill dominated communities (≈50–70%), yielding lower evenness during the wet season despite stable species richness across habitats. Spatial distributions deviated from uniformity, indicating species-specific habitat and seasonal preferences. Conversely, dry-season declines—especially in open grasslands—were associated with bushfires, logging/fuelwood extraction, and hunting pressure.

From an applied perspective, hornbill conservation in Central Taraba should prioritize (i) protection of mature woodland savanna stands and retention of large cavity trees, (ii) dry-season fire management and prevention of late-season bush burning, (iii) regulation of fuelwood/charcoal harvesting and targeted anti-poaching enforcement, and (iv) community-based outreach to promote sustainable land use and awareness of hornbills' ecological roles. Management should safeguard wet-season breeding habitats and maintain dry-season refugia, integrating local communities and authorities.

Inference is constrained by a single-region, two-habitat design and point-count data without explicit detection correction. Future research should implement multi-year monitoring with occupancy/abundance models that account for detectability, quantify nest-cavity supply and fire frequency via remote sensing, assess movement/migration dynamics, and model microclimate–resource linkages. Such evidence will refine seasonally targeted, habitat-specific interventions to support hornbill recovery and long-term biodiversity conservation.

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