

Chapter

Vegetation and Avifauna Distribution in the Serengeti National Park

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Abstract

In order to examine the bird species changes within different vegetation structures, the variations were compared between *Commiphora*-dominated vegetations with those of *Vachellia tortilis* and *Vachellia robusta*-dominated vegetations, and also compared the birds of grassland with those of *Vachellia drepanolobium* and *Vachellia seyal*-dominated vegetations. This study was conducted between February 2010 and April 2012. A total of 40 plots of 100 m × 100 m were established. Nonparametric Mann-Whitney U-test was used to examine differences in bird species between vegetations. Species richness estimates were obtained using the Species Diversity and Richness. A total of 171 bird species representing 103 genera, 12 orders, and 54 families were recorded. We found differences in bird species distribution whereby *V. tortilis* has higher bird species richness (102 species), abundance, and diversity when compared with *Commiphora* with 66 species and *V. robusta* with 59 species. These results suggest that variations in bird species abundance, diversity, and distribution could be attributed to differences in the structural diversity of vegetation. Therefore it is important to maintain different types of vegetation by keeping the frequency of fire to a minimum and prescribed fire should be employed and encouraged to control wildfire and so maintain a diversity of vegetation and birds community.

Keywords: vegetation changes, abundance, richness, conservation, protected area

1. Introduction

1.1 Vegetation change and birds' distribution

One of the most important concerns in conservation is the cause of change in species abundance and diversity in various vegetation types over time. Conservation relies in part on protecting species in legally fixed areas, but protection is jeopardized if species leave those areas and move into other areas where they are more vulnerable. For example, there is evidence of range shifts in Tanzanian birds [1].

There has been a recent expansion of geographical range in savanna birds such as the White-bellied Go-away-bird *Criniferoides leucogaster* and Taita Fiscal *Lanius dorsalis* (A. Nkwabi pers. obs.). These are dryland species previously confined to the drier north-east areas of the East African central plateau but have now

spread westwards into the much moister parts of the Serengeti National Park by crossing the birds' barrier of the eastern Rift Valley wall and the associated crater highlands [2, 3].

Another species that has shown changes in distribution is the Black-throated Barbet (*Tricholaema melanocephala*) whose center of distribution was the savanna surrounding the Wembere grasslands, south of the Maswa Game Reserve [4]. This species has spread north into Serengeti National Park in 2004 and up to date, such change in birds distribution resulted due to a change in density of its main vegetation such as *Vachellia tortilis* and *Vachellia robusta* woodland, which was low in the 1970s but had increased by the early 2000s (Prof. A. R. Sinclair pers. com.).

1.2 What causes a change in bird species' geographical range?

There are several possible causes for bird changes in geographical distribution and range. Natural vegetation succession, wildlife grazing, and human activities are all possible causes. Change in vegetation in the Serengeti National Park has been well documented [5–8]. Park vegetations have experienced major changes, alternating between open grassland and dense woodland. However, how these vegetation structure changes influence animal distribution, particularly birds is not well documented. Such influences are important for the conservation and management efforts of birds.

The structure of African vegetation is predominantly determined by rainfall, fire, nutrients, and grazing of herbivores [9, 10]. Bird distributions may be related to these differences in vegetation structure due to gradients of latitude, elevation, and isolation [11, 12]. Vegetation structure is known to have a major influence on the abundance and diversity of birds [11, 13–15] and this applies to the Serengeti National Park [16, 17]. Bird species diversity generally increases with increased foliage height, diversity, or increased woody vegetation [18]; vegetation species composition (or floristic) may also strongly affect bird communities [19]. Furthermore, individual bird species often demonstrate strong preferences for certain vegetation types, thus permitting vegetation parameters to describe bird habitats [20].

The diversity of bird species is a function of the diverse and complex vegetations of the Serengeti National Park in which the bird species respond to differences in the structural components of vegetation and availability of food [16, 21, 22]. Ecological studies have described the Serengeti National Park over the past 40 years and much is known about the impact of natural and human disturbances on large mammals [23]. The resource requirements of some species of birds in the Serengeti National Park have been documented [16, 22, 24, 25]. The impact of natural and human disturbances through small-scale agriculture and human habitation on birds has been reported by Estes [21], Sinclair et al. [26], and Nkwabi et al. [27] who examined the influence of disturbances, such as burning and grazing, on bird distribution within the Serengeti National Park.

Studying birds in the Serengeti National Park will open a room for birds-tourism activities and conserve vegetation dynamics. This chapter examines how differences in vegetation structure might influence the richness, abundance, and diversity of birds in the Serengeti National Park. It is firstly predicted that *V. tortilis* and *V. robusta* increase the abundance and diversity of bird species than *Commiphora* spp. Secondly, predicted that *Vachellia drepanolobium* and *Vachellia seyal* increase the abundance and diversity of birds than grassland areas. Thirdly, predicted that bird abundance and diversity decline with changing grass height from tall to short grass.

2. Materials and methods

2.1 Study area

The study was conducted in the Serengeti National Park (14,763 km²) situated between 33°50' and 35°20'E and 1°28' and 3°17'S (**Figure 1**). The park occupies a vast upland area varying in elevation from 1162 m at sea level at the Speke Gulf to 1860 m at sea level in the northeast. The park is bordered by the Maswa Game Reserve to the southwest, Ngorongoro Conservation Area to the southeast, Loliondo Game Controlled Area to the northeast, Maasai-Mara National Reserve in the north, and Ikorongo-Grumeti Game Reserves in the west (**Figure 2**).

2.2 Temperature and rainfall

The temperature of the Serengeti National Park shows a relatively constant monthly mean and maximum temperature of 27–28°C taken daily in the morning (9:00 am) and afternoon (3:00 pm) at the Serengeti National Park weather station and Serengeti Research Station [28]. The minimum temperature varies from 16°C in the hot months of October–March to 13°C during May–August. Rain typically falls in a bimodal pattern, with the long rains during March–May and the short rains in November–December [28]. However, the rains can fuse into one long period, particularly in the north, or the short rains can fail entirely, especially in the southeast of the park [28].

2.3 General sampling design

A total of 40 plots of 100 m × 100 m were established and locations were marked using the global positioning system (GPS) manufacturer model Garmin 12 XL.

2.4 Vegetation categorization

Vegetations were categorized on the basis of physiognomic features and dominant plant species when present.

1. Grassland (*mbuga*): This was devoid of trees (**Figure 3**) except for an occasional *Vachellia* spp. or *Balanites aegyptiaca* and one or two regenerating *V. seyal*, *V. drepanolobium*, or *Vachellia hockii*. The grass layer was dominated by *Themeda triandra* and *Pennisetum mezianum*. Open grasslands were found on poorly drained soils on the Ndabaka flood plain in the west and at Kogatende in the northern part of the Serengeti National Park.
2. *V. robusta* (**Figure 4**) and *V. tortilis* (**Figure 5**) dominated vegetations: This vegetation is comprised of *V. robusta* and *V. tortilis* that grew up to 14 m in height and is characterized by a wide canopy, umbrella-shaped crown, which could reach 21 m in diameter [29, 30]. This vegetation was found on various sites from ridge tops, and gently sloping valley sides to alluvial benches beside major streams, but it sometimes reached valley bottoms around Banagi areas in the central Serengeti National Park. The soil layer in this vegetation is covered by grass species that form a mixture of *T. triandra*, *P. mezianum*, and *Digitaria macroblephara*.

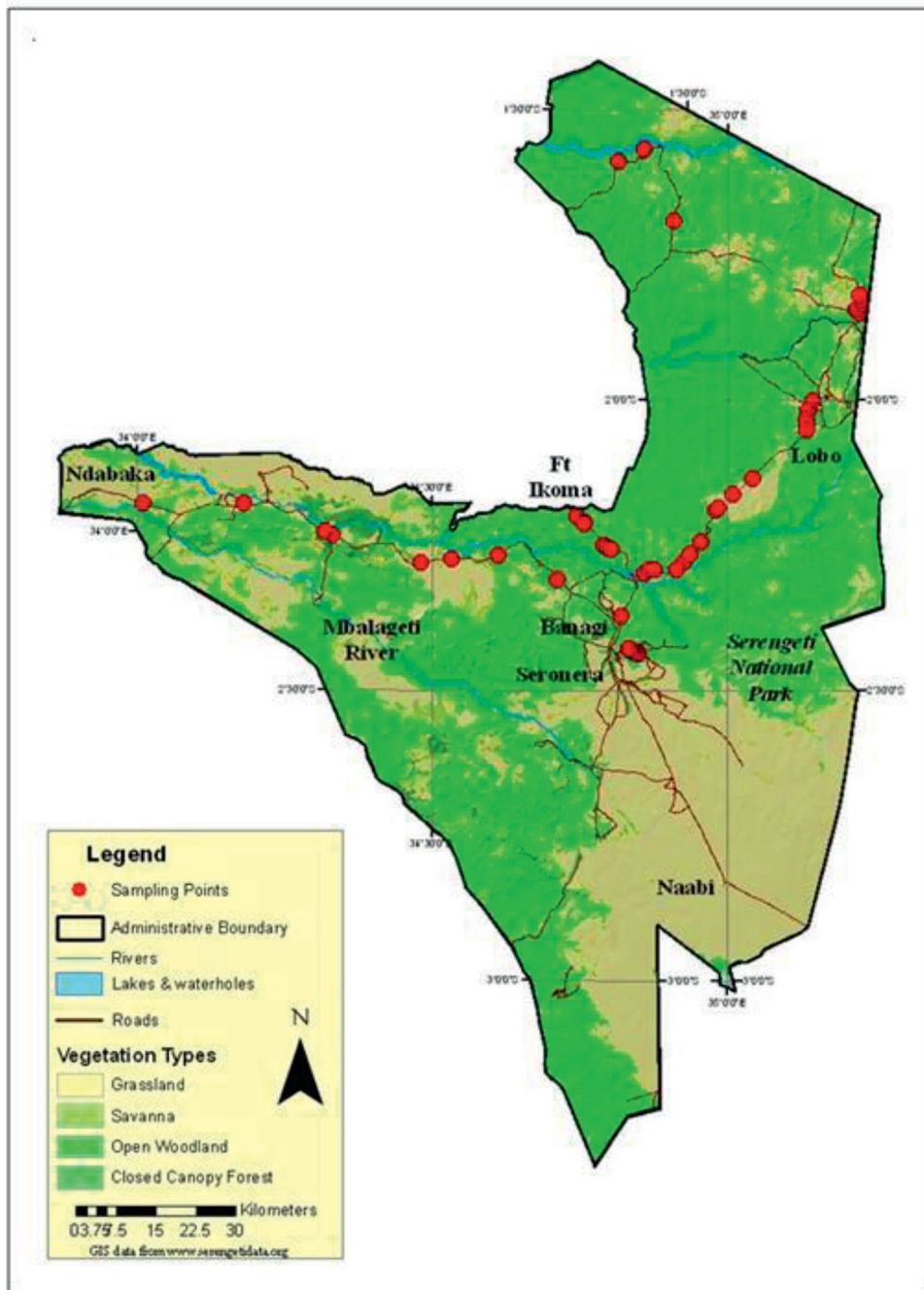


Figure 1.
Map of Serengeti National Park showing vegetation types. Red dots show birds sampling plots (Map produced by the Serengeti GIS Office, 2022).

3. *Commiphora* spp.: This was found mainly on ridge tops in shallow stony soils along the road to Fort Ikoma village, in the north to Lobo, and in the eastern woodlands [29, 31, 32]. This vegetation is comprised of *Commiphora schimperi*,

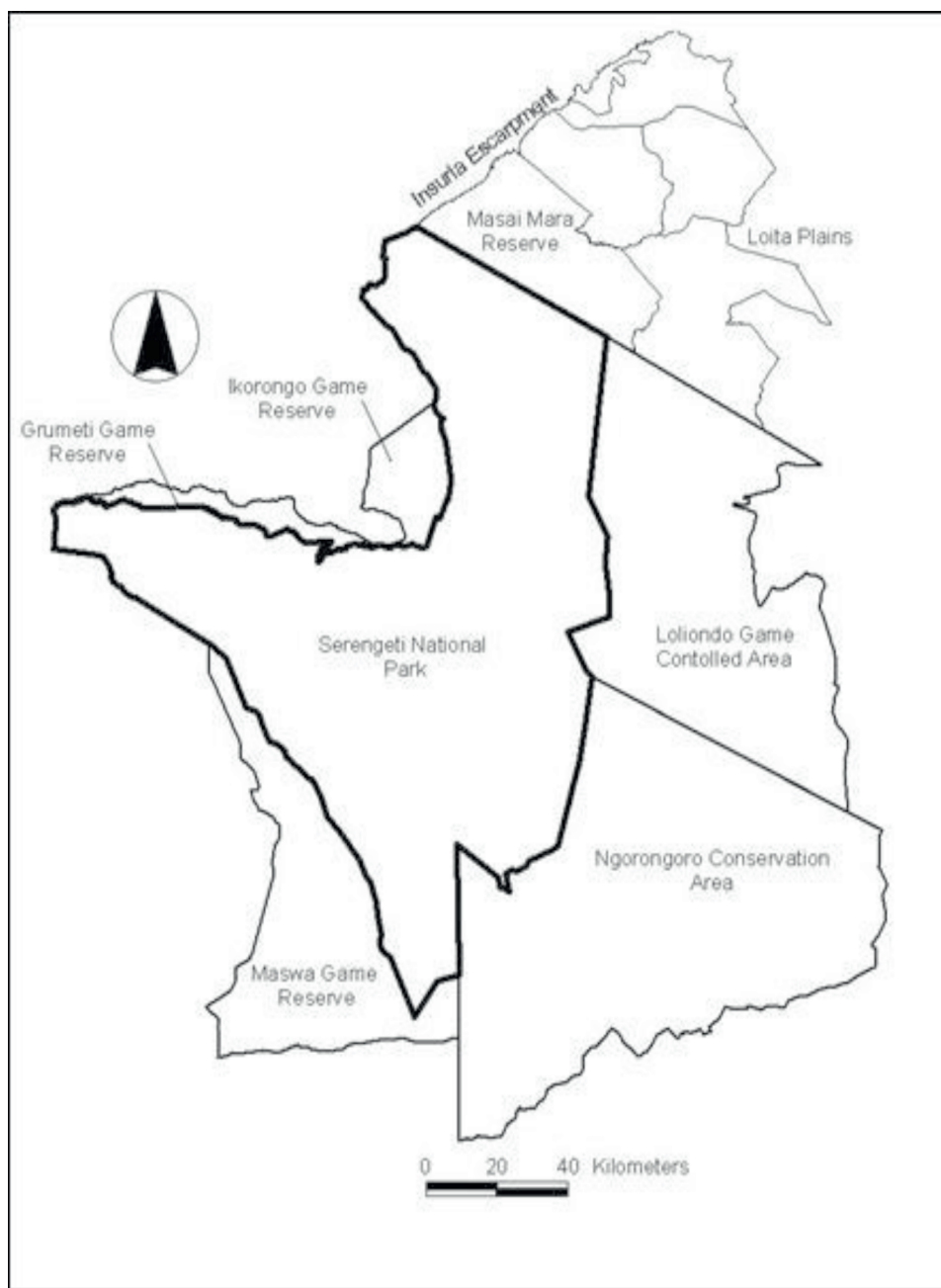


Figure 2.
 Map of Serengeti National Park (solid line) and adjacent protected areas (Source: Serengeti GIS Office, 2022).

Commiphora trothae, and *Commiphora africana* mixed with *Senegalia senegal* (Figure 6). Trees of this vegetation grew to 5 m high and were characterized by a small canopy that may reach 6.5 m in diameter [29, 30]. Some *V. hockii*, a tree of similar height, sometimes occurs with *S. senegal*. The grass layer within the stand is dominated by *P. mezianum* and *Sporobolus pyramidalis* [29].



Figure 3.
One of the grassland areas in Serengeti National Park.



Figure 4.
A pure stand of Vachellia robusta at Seronera area in Serengeti National Park.



Figure 5.
Vachellia tortilis observed near Serengeti Wildlife Research Centre (SWRC) in Serengeti National Park.

4. *V. drepanolobium* and *V. seyal*-dominated habitats: This vegetation occurs on poorly drained soils in valley bottoms, and on foot slopes at the base of rocky hills [29]. The two tree species were found in different regions of the park; *V. drepanolobium* occurs widely in the north and west of the park, whereas *V. seyal* was found largely on the Ndabaka flood plain of the far western Serengeti National Park. Both are characterized by a small canopy that may reach 6.5 m in diameter and grow to 6 m in height. The grass layer is dominated by *T. triandra*, *D. macroblephara*, and *P. mezianum* [29].

2.5 Birds assessment

A total of 10 plots in each of the 4 habitat categories mentioned above were established. Grassland in the park was divided into western at Ndabaka and northern



Figure 6.
Stand of Commiphora spp and Senegalia Senegal observed near Banagi hill, central Serengeti National Park.

at Kogatende, each having five plots and these were paired with their equivalent *V. drepanolobium* and *V. seyal*-dominated habitats, namely five plots of *V. seyal* in the west and five plots of *V. drepanolobium* in the north. Five plots in each of *V. tortilis* and *V. robusta*-dominated vegetations were established, and these were compared with five plots in *Commiphora* spp.-dominated vegetation.

The locations of the sampling plots in the woodland were situated at least 500–800 m apart, marked using the global positioning system (GPS). Plots were surveyed on a monthly basis between February 2010 and February 2012, with 20 min per plot between 6:30 am and 10:30 am. The time of survey for each plot was rotated so that all plots were surveyed equally during the morning from 6:30 am to 10:30 am to avoid bias for the time of day. For example, if a plot was surveyed early on one visit then on the next visit was surveyed last so that effects of time of day were distributed equally over all plots. Birds were counted using the total count method by walking slowly across the plot and back again [33]. Birds were identified by both sight and call, and numbers were recorded. Bird naming was adopted from those published by Zimmerman et al. [4] and Gill and Wright [34].

2.6 Grass height measurement and grass cover estimates

The grass layer included both grasses and forbs, but as the grass was usually the dominant group, the term “grass” was used in the following analysis and the data from grasses and forbs were pooled. Measurements of grass height were obtained

in all habitats where birds were counted. At each of the plots, grass height and grass cover were estimated. A small hole was made at the center of the plastic plate of 37 cm diameter and inserted in a 1 m ruler, which was placed vertically in the grass, and detailed explanations of the method on how to prepare and use a plastic plate were well explained by McNaughton [35]. The plastic plate rested on the surface of the grass, and its position on the meter ruler was recorded as the standardized grass height [35]. Three height measurements were made and the average was used for each plot, only three points were selected in each plot due to the large area coverage in the Serengeti National Park and surrounding areas. Grass cover was estimated by direct observation and recorded as a percentage cover. Measurements were taken during dry and wet seasons from February 2010 to April 2012.

2.7 Data analysis

Birds were classified according to feeding guild (insectivores, granivores, omnivores, and frugivores) and foraging guild (ground vs. tree canopy feeding) [36, 37]. Bird species that spent time on ground foraging were grouped as ground feeding and those that spent time on trees searching for food were termed as tree feeding [36, 37]. All ground, aerial, water, and tree canopy feeding birds were recorded, but the analysis concentrated on ground- and tree-feeding birds because the study concentrated on habitat structure in the terrestrial environment. All bird species that fed on insects, seeds, and fruits, and foraged either on the ground or in the grass layer were classified as ground-feeding birds; and all species that foraged in bushes, shrubs, and tree canopy were classified as tree-feeding birds [38, 39]. Ground-feeding birds were also sorted based on the grass height they were associated with.

2.8 Species richness, diversity, and abundance of the ground- and tree-feeding birds

Data were tested for normality by using the Shapiro-Wilk (W) test and the Kolmogorov-Smirnov (KS) test. The data were found not to be normally distributed even after transformation. Therefore a nonparametric Mann-Whitney U-test was used to examine differences in independent samples [40]. Species richness estimates were obtained using the Species Diversity and Richness (SDR) computer program [41]. The first-order Jackknife estimator was chosen for species richness because it has been shown to perform well on bird communities distribution [42, 43].

Abundance was measured as the number of individuals found per unit time. Comparisons between pairs of habitats for an abundance of birds at similar grass heights were tested for normality using Kolmogorov-Smirnov (KS) test. In this case, the data were found to be normally distributed. Therefore, differences in the abundance of ground bird species at similar grass heights were compared using the parametric paired sample *t*-test from the computer software Statistix-10 [44].

The diversity of bird species was determined by the Shannon-Wiener diversity (H') index denoted as:

$$H' = -\sum_{i=1}^k p_i \ln p_i, \quad (1)$$

where k is the total number of species and p_i is the proportion of individuals found in the i th species. The Shannon-Wiener diversity (H') value obtained from each habitat type was tested for differences by using the randomization test [41, 45]

to observe whether bird diversity of ground- or tree-feeding bird species differ in the *Commiphora* spp. habitat when compared with those in *V. tortilis* and *V. robusta* and when grassland compared with *V. drepanolobium* and *V. seyal* vegetations.

3. Results

3.1 Birds in *Commiphora* spp. compared with those in *Vachellia*-dominated vegetations

A total of 171 species in 103 genera, 12 orders, and 54 families of birds were recorded. The results show that *V. tortilis*-dominated vegetation supported the highest species richness of ground-feeding birds, followed by the *Commiphora* spp. vegetations. In contrast, *V. robusta* remained with lower bird species richness (**Table 1**). In terms of abundance, *Commiphora*-dominated vegetation supported a higher abundance of birds followed by *V. tortilis* and then *V. robusta*-dominated vegetations (**Table 1**). There was no significant difference in the abundance of bird species between *Commiphora* and *V. tortilis* ($U = 8896.5$, $n_1 = 34$, $n_2 = 29$, $P = 0.246$). However, the difference in abundance between *Commiphora*- and *V. robusta*-dominated vegetations was significant ($U = 8085.5$, $n_1 = 34$, $n_2 = 30$, $P = 0.017$, **Table 1**). The Shannon-Wiener index shows that *V. tortilis* and *Commiphora* accommodated higher bird species diversity values than *V. robusta*-dominated habitat and the randomization test showed that these values of diversity were significantly different ($P = 0.0001$, **Table 1**).

The result from tree-feeding bird species shows that *V. tortilis*-dominated vegetation has the highest bird species richness with 102 species, followed by *Commiphora* spp. with 66 species and *V. robusta*-dominated vegetation with 59 species (**Table 2**). Bird abundance of tree-feeding species in *V. tortilis*-dominated vegetation showed the highest value of 25 individual birds. The *V. robusta*-dominated vegetation remained with 20 individual birds when compared with *Commiphora* spp. which had 19 individual birds, the difference of individual birds between the two vegetations was not significant ($U = 5151$, $n_1 = 28$, $n_2 = 24$, $P = 0.905$, **Table 2**). The abundance of birds in *V. tortilis*-dominated vegetation was significantly higher than that in *Commiphora* spp. ($U = 4123$, $n_1 = 28$, $n_2 = 22$, $P = 0.0102$). The randomization test results showed that the index of diversity for birds was higher in *V. tortilis* than that for *V. robusta*- and *Commiphora* spp.-dominated vegetations ($P = 0.0001$, **Table 2**).

Index	<i>V. tortilis</i>	<i>V. robusta</i>	<i>Commiphora</i> spp.	<i>V. tortilis</i> vs. <i>Commiphora</i> spp.	<i>V. robusta</i> vs. <i>Commiphora</i> spp.
Richness	62	45	56		
Abundance	20	15	29	$U = 8896.5$, $P = 0.246$	$U = 8085.5$, $P = 0.017$
Shannon- Wiener (H')	3.117	2.651	3.097	$P = 0.65$	$P = 0.0001$

Table 1.

Richness, abundance, and diversity of ground-feeding birds in *V. tortilis*, *Commiphora* spp., and *V. robusta* of the Serengeti National Park.

Index	<i>V. tortilis</i>	<i>V. robusta</i>	<i>Commiphora spp.</i>	<i>V. tortilis</i> vs. <i>Commiphora spp.</i>	<i>V. robusta</i> vs. <i>Commiphora spp.</i>
Richness	102	59	66		
Abundance	25	20	19	$U = 4123$, $P = 0.0102$	$U = 5151$, $P = 0.905$
Shannon- Wiener (H')	3.444	2.926	3.167	$P = 0.0001$	$P = 0.0001$

Table 2.

Richness, abundance, and diversity of tree-feeding birds in *V. tortilis*, *Commiphora spp.*, and *V. robusta* of the Serengeti National Park.

3.2 Grassland compared with *V. drepanolobium* and *V. seyal*

V. drepanolobium and *V. seyal*-dominated vegetations supported higher ground-feeding bird species richness but lower overall abundance compared with that of grassland vegetation (Table 3). The difference in abundance between *V. seyal* and the western grasslands was significantly different ($U = 7684.0$, $n_1 = 48$, $n_2 = 40$, $P = 0.003$), but not between *V. drepanolobium*-dominated vegetation and the northern grasslands ($U = 8791.5$, $n_1 = 44$, $n_2 = 42$, $P = 0.186$, Table 3). However, the results from the randomization test showed that there was a significant difference in diversity between both the *V. drepanolobium* and *V. seyal*-dominated vegetations and their adjacent grassland plots (Table 3).

3.3 Tree-feeding bird species in *V. drepanolobium* and *Acacia seyal*

Concerning tree-feeding bird species both *V. drepanolobium* and *V. seyal*-dominated vegetations accommodated higher bird species richness compared with that in grassland habitats (Table 4). However, the abundance of birds showed a different pattern: abundance of tree-feeding birds was higher in grassland than in *V. drepanolobium*-dominated vegetations, *V. seyal*-dominated habitats supported a higher abundance of birds when compared with that of grassland vegetation (Table 4).

Index	<i>V. drepanolobium</i>	Northern grassland	<i>V. seyal</i>	Western grassland	<i>V. drepanolobium</i> vs. Northern grassland	<i>V. seyal</i> vs. Western grassland
Richness	73	53	112	70		
Abundance	13	19	33	43	$U = 8791.5$, $P = 0.186$	$U = 7684$, $P = 0.003$
Shannon- Wiener (H')	2.730	2.878	2.910	2.759	$P = 0.004$	$P = 0.0002$

Table 3.

Abundance of birds, species richness, and diversity of ground foraging birds in *V. drepanolobium*, *V. seyal*, and grasslands of western and northern Serengeti National Park.

Index	<i>V. drepanolobium</i>	Northern grassland	<i>V. seyal</i>	Western grassland	<i>V. drepanolobium</i> vs. Northern grassland	<i>V. seyal</i> vs. Western grassland
Richness	38	12	69	27		
Abundance	6	7	22	20	$U = 4329$, $P = 0.0314$	$U = 3628$, $P = 0.0002$
Shannon–Wiener (H')	2.778	1.571	3.045	1.73	$P = 0.0001$	$P = 0.0001$

Table 4.

Estimation of richness, abundance, and diversity of tree-feeding birds in *V. drepanolobium*, *V. seyal*, and grassland in the western and northern Serengeti National Park.

Grass height (cm)	Abundance of birds						
	<i>Commiphora spp</i>	<i>V. robusta</i>	<i>V. tortilis</i>	<i>V. drepanolobium</i>	Northern grassland	<i>V. seyal</i>	Western grassland
0–10	147 (21.3)	16 (4.3)	36.4 (11.9)	48.6 (17.7)	21.8 (4.6)	252.6 (179)	202.6 (61.9)
10–25	137.2 (15.0)	47.6 (17.5)	73.8 (15.5)	53.8 (12.2)	54.2 (5.5)	188.6 (94.3)	300.2 (97.7)
25–50	93 (23.8)	50 (7.7)	45.2 (16.0)	47.6 (3.3)	62.8 (12.4)	168.8 (44.7)	171 (93.4)
50–75	19.4 (2.8)	49.6 (12.4)	0	16.6 (6.6)	98.4 (20.6)	12.8 (5.3)	28.6 (3.5)
75–100	0	2.4 (2.4)	0	9.2 (2.4)	12 (5.8)	3.8 (3.8)	63.2 (9.6)
>100	0	0	0	0	0	6.2 (4.1)	0

Table 5.

Abundance of ground feeding birds in different habitat types relative to grass height in the Serengeti National Park ($n = 6$, standard error in brackets).

3.4 The effect of grass height on the abundance of ground-feeding bird species

The abundance of ground-feeding birds in *Commiphora spp.*-dominated vegetations was higher in short grass height and declined consistently as the grass grew taller (from 75 to >100 cm). The abundance of birds in short grass (≤ 25 cm) in *Commiphora spp.* was significantly higher than that in *V. tortilis* and *V. robusta*-dominated vegetations. In contrast, the abundance of birds in tall grass in *Commiphora spp.*-dominated vegetations was lower than those in *V. tortilis* and *V. robusta*-dominated habitats (**Table 5**). The highest abundance of birds in *V. tortilis* and *V. robusta*-dominated habitats were at the intermediate level of grass heights (10–25 and 25–50 cm levels, **Table 5**). However, the abundance of birds did not decrease linearly with grass height; it reached a peak at the intermediate level of grass heights (10–25 cm, **Figure 7**).

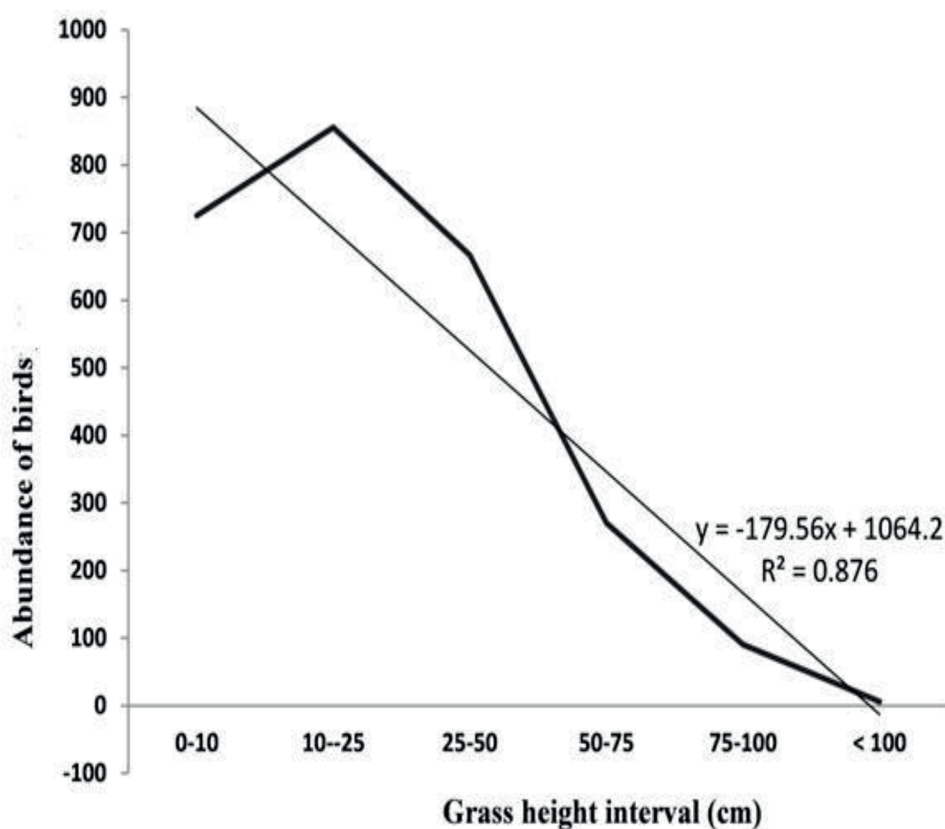


Figure 7.
 Linear estimate of birds' abundance in different grass height interval in the Serengeti National Park habitats.

4. Discussion

4.1 Birds' distribution in *Commiphora* spp. compared with *V. tortilis*- and *V. robusta*-dominated vegetations

The higher species richness, diversity, and abundance of tree-feeding birds in *V. tortilis*-dominated vegetation were due to greater tree density and underlying grass cover; which attracted birds for feeding and perching. The results are consistent with the first prediction which suggested that the greater structural complexity of the *Vachellia* trees provided more resources for birds to exploit, and thus increases species diversity [46, 47]. However, the results for *V. robusta*-dominated vegetation, which showed lower richness, abundance, and diversity than those for *Commiphora*-dominated vegetation, are not consistent with this prediction. This suggests that it is not just canopy size that matters but also other factors such as the abundance of food from insects and fruits. The tannin content of leaves in *V. tortilis*-dominated vegetation is much lower than that in *V. robusta*-dominated vegetation making the former more palatable and attractive to insects and hence attracting birds [48, 49].

The higher abundance and diversity of ground-feeding birds in *Commiphora*-dominated vegetation was due to the low canopy cover of *Commiphora* spp. which

provided bare ground for birds to forage. It was observed that *Commiphora*-dominated vegetation changed by succession into *Vachellia* vegetation in the same area over the 1970–2000 period [8], change in geology and soil properties and a change in the herb layer species communities probably affected ground-feeding birds. The herb layer does differ between these vegetation type [50–52] in most habitats, vegetation determine the physical structure of the environment, and therefore, have a considerable influence on the distributions and interactions of bird species. Renwald [53], however, pointed out that the ecological distinction between plant communities does not uniformly correlate with differences in animal communities. Such apparent inconsistency is explained by the observation that wildlife species including birds most often select vegetation on the basis of structure rather than plant species composition [15, 54].

4.2 Birds in grassland habitats compared with *V. drepanolobium* and *V. seyal*

Secondly, it is predicted that higher diversity and abundance of birds in *V. drepanolobium*- and *V. seyal*-dominated vegetations than in grassland. The higher abundance of birds in *A. seyal*-dominated vegetation than those in the western grassland of the Serengeti National Park was consistent with this prediction; the differences observed were due to the trees providing greater food resources, trees providing hiding areas from predators, and provision of nesting sites compared with the grassland. However, the opposite result occurred in the northern Serengeti National Park with grassland having a higher abundance than that in *V. drepanolobium*-dominated vegetation, which was inconsistent with the hypothesis. Some of this effect was due to tree-feeding birds moving into grasslands to exploit the available resources, for example, Rufous-tailed weaver *Histurgops ruficauda* and buffalo weavers were frequently observed to forage in grasslands next to *V. drepanolobium* but not *V. seyal*-dominated vegetations. The reason why the mentioned bird species avoid foraging very close to *V. seyal*-dominated vegetation needs more investigation. Mwangomo et al. [22] observed that Rufous-tailed weaver preferred to forage in grassland and avoided feeding in most *Vachellia*-dominated vegetation. This pattern of birds that nest and roost in *V. seyal* moving into grassland to feed was not observed suggesting more research to determine the reason why did not forage close to *V. seyal*-dominated vegetation. So some but not all of the results were consistent with the second hypothesis which predicted that changing habitat structure from grassland to *V. drepanolobium* or *V. seyal*-dominated vegetations may influence increases in the abundance of the birds' fauna. Thus, individual tree species provide particular resources for birds not found in grassland.

4.3 The effect of grass height on the abundance of ground-feeding bird species

The lack of difference in abundance with grass height between this vegetation was due to different groups of birds compensating for each other. For example, widowbird and whydahs were abundant in tall grass but larks, lapwing, coursers, storks, and pipits were abundant in short grass. The higher abundance of ground-feeding birds observed in shorter grass levels (0–25 cm) was contrary to the third hypothesis which predicted that bird abundance and diversity would decline with changing grass height from tall to short grass due to lower grass cover and structure. Grass structure and cover may not be the only factors determining the types of bird species using the grassland. Some species prefer tall grass while others prefer short grass and densities may not be related to the biomass and structure.

Lower grass height in the Serengeti National Park was created by herbivore grazing and anthropogenic fires, which changed the vegetation cover by exposing ground and creating short grass habitats for specialized birds such as the Red-capped Lark *Calandrella cinerea*, Crowned Lapwing *Vanellus coronatus*, African Pipit *Anthus cinnamomeus*, and Fischer's Sparrow-lark *Eremopterix leucopareia*. Although grass height was lower, habitat heterogeneity was greater than in tall grass. In addition, short grass increases the visibility of food sources for birds. Thus, the short grass community was abundant or even more than that in grass height taller than 75 cm community, one may replace the other, a replacement can be of species that prefer to forage in tall grass replaced with those forage in short grass as has been observed on the Serengeti National Park plains [55].

However, there was a higher abundance of birds on short grass areas in *Commiphora*-dominated vegetation than in *V. tortilis* and *V. robusta*-dominated vegetations. Grass height could not explain this observation, which suggests that it is the vegetation structure that is affecting ground bird abundance rather than just the height of the herb layer.

This study found that the abundance of birds did not decrease with grass height; it reached a peak at an intermediate level of grass heights interval of 10–25 cm, contrary to the initial prediction. This was especially clear in the western part of the Serengeti National Park but was also evident in the northern part of the park where bird diversity increased as grass height became shorter (≤ 25) due to fire and grazing by ungulates. These findings are consistent with the generally accepted pattern that ecological succession following intermediate disturbance is characterized by increases in species richness, equitability, and similarity due to an increase in patchiness of habitat [56–58]. It is generally accepted that animal species richness increases with increasing habitat complexity, given that more complex habitats offer a greater variety for potential exploitation of resources. For example, Brown [59] reported that bird species diversity increased with an increase in grass height in America. However, the present results conform more to the intermediate disturbance hypothesis developed by Connell [60] which suggests that the highest diversity of living things is maintained at intermediate scales of disturbance. Nkwabi et al. [61] reported that both bird species diversity and composition change with grass height. There have been similar results in southern Africa by Jansen et al. [62] who described that both density and species richness of francolins (*Francolinus* spp.) change with changes in grass height. Several studies have revealed that the structure of the vegetation, its complexity, and vertical arrangement are primary defining factors in bird community nesting and foraging [46, 60, 63–68].

5. Conclusion

The results show that *V. tortilis*-dominated habitat has greater species richness, abundance, and diversity compared with *Commiphora*-dominated vegetation or *V. robusta* suggesting that the species of the tree itself, was an important factor determining the distribution of birds. Grasslands in the western and northern part of the Serengeti National Park accommodated a higher abundance of birds due to tree-feeding birds moving into grasslands to exploit the available resources. This pattern of birds nesting and roosting in *Vachellia*-dominated vegetation and moving into grassland to feed was not observed in the grassland and *V. seyal*-dominated vegetation. In addition, *V. seyal*-dominated vegetation provided different food resources from those

of *V. drepanolobium*-dominated vegetation so it was the difference in tree species that explained the differences in the abundance of birds. This study found that bird diversity did not decrease linearly with grass height, it reached a peak at intermediate grass heights. In the western and northern parts of the park, bird diversity increased as grass height became shorter due to fire and grazing by ungulates.

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Conflict of interest

The authors declare no conflict of interest.

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