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Research Article

Butterfly Abundance and Diversity in Different Habitat Types in the Usangu Area, Ruaha National Park

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Insects are key fauna species that respond quickly to disturbances and environmental changes. They act as good indicators of habitat, community, or ecosystem quality. Among the great diversity of insects, butterflies stand as ideal bio-indicators for ecosystem function and are sensitive to changes in habitat composition and structure. This study was carried out to examine the diversity and abundance of butterflies across the restored habitats in Usangu area part of Ruaha National Park (RUNAPA) from May 2022 to June 2022 using the walking transect method supplemented by sweep nets and butterfly baited traps. A total of six transects of 1 km in length were laid in the four main habitat types selected in Usangu area including grassland, Miombo woodland, Vachellia/Commiphora woodland, and riverine forest. Searches were conducted in the morning and evening. The Miombo woodland and riverine forest habitats exhibited relatively higher species diversity, richness, evenness, abundance, and a higher number of habitat-restricted species, while Vachellia/Commiphora woodland and grassland habitats recorded the lowest diversity and abundance as well as the lowest number of habitat-restricted species. Family Nymphalidae was the most dominant followed by Pieridae while Papilionidae and Hesperiidae were scarce in the study area. This study clearly shows the importance of Miombo woodland and riverine forest habitats in sustaining rich butterfly diversity and abundance in Usangu area. The two habitats must be effectively managed and conserved for sustaining ecological health and integrity of Usangu area. The Usangu area's Miombo woodland and riverine forest habitats have immense potential for butterfly tourism and they can offer an excellent opportunity to promote conservation efforts and raise public awareness. However, it is crucial to monitor these habitats closely as any environmental changes that may occur could harm the butterfly diversity and abundance in the area. Preserving this wilderness to maintain a thriving butterfly population is of utmost importance.

1. Introduction

Conservation and sustainable management of biodiversity in the face of ongoing global climate change require updated information to evaluate species' geographic distributions and changes over time [1, 2]. With an increase in human disturbances globally, numerous species are being adversely affected, hence accelerating biological diversity loss and extinction [3, 4]. The loss and extinction of biodiversity is perhaps the most important concern in many African savannah regions, which are greatly rich in biodiversity but experiencing rapid habitat fragmentation and degradation [5, 6]. Therefore, there is an urgent need to understand how species respond to changing environmental conditions in African savannah ecosystems over time to improve the management of species or their habitats [7].

Invertebrates such as insects are key fauna species that respond quickly to disturbances and environmental changes and therefore act as good indicators of habitat, community, or ecosystem quality [8, 9]. This is because arthropods comprise the most tremendous taxonomic and functional diversity group of multicellular organisms on the planet, and they contribute significantly to vital roles in ecosystems such as pollinators, pest controllers, decomposers, scavengers, and prey species [10, 11]. Among the great diversity of arthropods, butterflies stand as ideal bio-indicators for ecosystem function and habitat conditions [12]. They are the second largest, the most widespread, and most widely recognizable arthropods in the phylum Arthropoda, making up the insect order Lepidoptera. They have been widely promoted as potential land use change, climate, and habitat quality bio-indicators [13, 14]. Butterflies have often been used as indicator species for reflecting environmental changes as well as habitat conditions or development after natural and anthropogenic disturbances, especially in highly diverse tropical regions of sub-Saharan Africa, where conditions are too difficult or expensive to measure directly [15, 16].

Despite the ecological importance of butterflies as bio-indicator species, no study has been conducted to document the status, distribution, and diversity of butterflies in Usangu area, in Ruaha National Park, Tanzania. The Usangu area has been subjected to and thus experienced large-scale habitat fragmentation and degradation caused by both natural forces and anthropogenic activities [17–19]. However, the Usangu area was annexed into Ruaha National Park in 2008 to protect the important wetlands and biodiversity. Various scholars have documented the importance of Usangu area and its restored habitats in protecting mammals of the area [20, 21], but very little attention has been given to the understanding of insects such as butterflies, despite their significance as excellent indicator species for monitoring environmental conditions or assessing the efficacy of management. Therefore, the current study has been undertaken to address this knowledge gap by assessing the butterfly species' abundance, richness, and diversity in relation to restored habitats in the poorly studied Usangu area, part of Ruaha National Park. Because butterflies are sensitive to environmental perturbations, an effort has been made to understand the causes of changes in butterfly biodiversity with respect to their habitat type and assess the suitability of using these arthropods as indicators of the health of the environment in Usangu area. The objectives of this study were to provide baseline information on the status and spatial distribution of butterfly species and to determine if there is a significant difference between butterfly species diversity, richness, and abundance in the four main habitat types. This study also intends to examine how the butterfly community structures vary in different surveyed habitat types in Usangu area. Findings from this study would be very important as it would serve as the first approach of using the butterfly as part of bio-indicator tools for subsequent assessment and monitoring of restored habitat condition and quality within the Usangu area and its surroundings.

2. Materials and Methods

2.1. Study Area. The study was carried out in Usangu area part of Ruaha National Park (RUNAPA) in Southern Tanzania (Figure 1). Usangu is located in latitude 08° 30′ south and longitude 34° 15′ east with an elevation of 1,026 meters above mean sea level (amsl) [17]. The Usangu area is made up of wetlands including the Usangu wetland and upper drier alluvial fan ecosystems [19]. The mean annual temperature of Usangu is 24°C, and the average annual rainfall is 650 mm. Usangu is characterized by a range of habitat types including the montane forest, Miombo woodlands, riverine forest, and lowland savannah with Vachellia and mixed woodland [22–24]. The Usangu area was previously a game reserve that was fragmented and degraded by uncontrolled human activities [25]. However, in 2008, the Usangu area together with other nearby important and remarkable wetlands was annexed into Ruaha National Park (RUNAPA), making it the second largest National Park in Tanzania and East Africa with an area of about 20,226 km^2 [26]. All sampling sites for this study were located in the Usangu area within Ruaha National Park.

2.2. Study Design and Data Collection. Ground surveys were carried out along the main administrative and patrol roads between May and June 2022. Walking transects of 1 km long were established perpendicular to roads to complement the effects of roads on butterfly species distribution. These transects were established in the four main habitat types selected in Usangu area including grassland, Miombo woodland, Vachellia/Commiphora woodland, and riverine forest (Figure 1). At least, 6 transects of 1 km each were established in every habitat making a total of 19 transects. The research team walked a straight line of 1 kilometer perpendicular to the park administrative roads (left or right side) using a handheld GPS to maintain the straight line depending on the terrain and vegetation cover of the area. Each transect was sampled using three complementary methods. Firstly, the transect method was used by visual watching of flying butterflies along transects by the team of specialized identification skills [27–29]. The visual observation method was conducted in the same transect before a handheld butterfly net and the baited trap were used. The method was used to record butterfly species that are common and easy to identify to avoid overcollection. The method involved counting the number of flying butterflies that crossed a strip of known length (between 30 m and 60 m) and 20 m wide for 10 minutes, and time lapsed was recorded by a handheld stopwatch [28].

Secondly, the collection of butterflies using a handheld sweep net (35 cm in diameter) following [29] was commenced after visual watching of flying butterflies. Searches in each transect were conducted by two to three collectors for 5 hours for each trap day from 09:00 to 12:00 in the morning and from 15:00 to 17:00 in the evening. Timed sweep netting was conducted within the transect established. Data on species type and associated habitat types in its specific transects were recorded on standardized data sheets. Unidentified individuals were kept in special envelopes for later identification at the species level with the aid of field guidebooks [30–32].

Thirdly, butterflies were sampled using cylindrical butterfly traps baited with fermented banana along transects (measuring 1000 m), and baited traps were used to capture fruit-feeding butterflies that may not be captured in

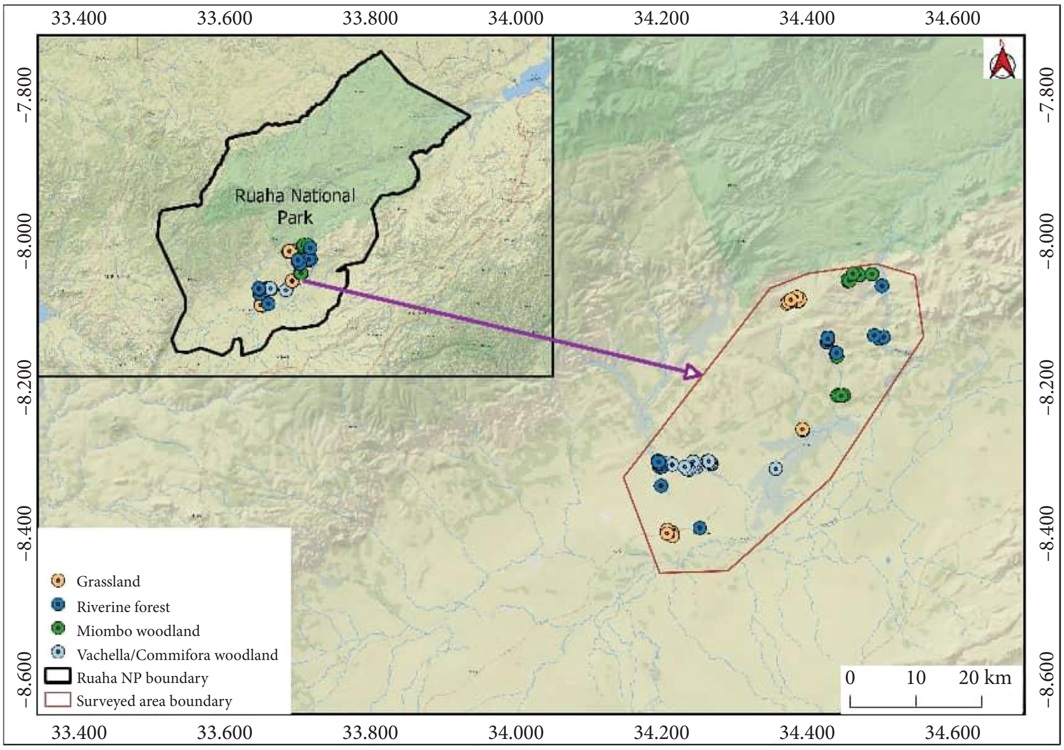


Figure 1: Map showing the location of four sampled habitat types in Usangu area, Ruaha National Park.

handheld sweep net [33]. Traps were placed at 30 m intervals from each other making a total of 16 traps per habitat selected; three habitat types were selected except grassland because of the absence of trees used to hang traps. A total of sixteen traps were placed in each habitat, summing up to a total of 48 traps in the study area. The traps were baited with yellow ripe bananas that were smashed, uniformly mixed, and allowed to ferment in a plastic bucket for six days. Three teaspoonfuls of bait were placed on a small plastic plate fitted on a cotton base. Traps were baited on the first day of setting and hanged at 50–100 cm height above the ground [34, 35]. The baited traps were checked once a day for three consequent days between 09:00 and 17:00. Caught butterfly individuals were identified using standard identification field guides [30–32], and numbers of each species were recorded.

3. Data Analyses

3.1. Butterfly Species Composition. In this study, butterfly data from walking transect, sweep-netting, and baited traps were pooled to obtain total butterfly diversity and abundance per habitat type. Several community parameters were used to compare butterfly species diversity. The Shannon–Wiener index (H′), species richness (S), relative abundance (A), and evenness (E) parameters were computed for each surveyed habitat type using the PAST 4.04 statistical software [36]. The butterflies were classified into five categories based on the number of sightings in the study area as follows: VC, very common (>100 sightings), C, common (51–100 sightings), NR, not rare (16–50 sightings), R, rare (3–15 sightings), and VR, very rare (1-2 sightings) [37].

Butterfly species restricted to only one habitat type were categorized as habitat-restricted species. Butterfly richness in the study area was estimated using the Chao 1 estimator. Chao 1 estimator is suitable for nonparametric data containing single and doubletons and uses abundance data [38]. Species richness was computed for each habitat type in the program EstimateS v.9.0 [39], using 100 randomizations. The species accumulation curves were generated for each habitat type by using EstimateS v.9.0 [39], to evaluate the completeness of butterfly sampling. Species accumulation curves represent the observed butterfly species number (Sobs) and the estimated butterfly species number which was collected as the number of samples approaches the population size. The differences in butterfly species richness and abundance types were tested with Kruskal–Wallis tests after confirming nonnormal distribution [40]. Species evenness and diversity across habitats were compared using a one-way analysis of variance (ANOVA) [41].

3.2. Comparison of Butterfly Assemblages among Habitat Types. The similarity matrix using the Bray–Curtis index was generated to assess how butterfly communities organized across the surveyed habitat types in Usangu area, using the square root of log transformed data, pooled within sampled days. Furthermore, the metaMDS function of the vegan R package was used to perform nonmetric multidimensional scaling (NMDS) to understand the ordination of butterfly communities between habitat types [42]. When clustering was evident, a one-way analysis of similarities (ANOSIM) was used to analyze the significant differences in butterfly assemblage across the habitat types ($\alpha = 0.05$) [43].

All statistical analyses were undertaken using R software (R Development Core Team, 2022), with the Community Ecology Package “vegan” [42].

4. Results

4.1. Butterfly Species Composition. A total of 1,995 individuals representing 96 different butterfly species belonging to five families, 23 subfamilies, and 50 genera were recorded in the four surveyed habitats of Usangu area (see Table 1). Among these 96 species, 37 species (38.54%) were rare, 36 (37.5%) were very rare, 16 (16.67%) were not rare, 5 (5.52%) were common, and 2 (2.08%) were very common (Figure 2(b)). The study findings indicated that *Belenois aurota aurota*, *Belenois creona severina*, *Colotis daira jacksoni*, *Colotis eris eris*, *Colotis evenina xantholeuca*, *Hamanumida daedalus*, *Pinacopteryx eriphia melanarge*, *Zizula hylax*, *Colotis antevippe zera*, and *Colotis danae eupompe* were widely distributed (presented on all four surveyed habitat types in Usangu area) and constituted about 61.10% of the total abundance (Table 2). *Belenois aurota aurota* was the most abundant species in all four habitat types with 742 individuals (37.19% of total individuals). *Pinacopteryx eriphia melanarge* was the second most abundant species, with 125 individuals (6.27%). On the other hand, a total of 40 habitat-restricted species were recorded in the study area. Among these, 55% (22 species) were restricted to Miombo woodland habitats, 22.5% (9 species) to riverine forest habitats, 17.5% (7 species) to grassland habitats, and 5% (2 species) to Vachellia/Commiphora woodland habitat (Tables 2 and 3).

The variation in the number of species belonging to each family was also observed in the study area. Nymphalidae had the highest representative species, comprising 46 species (47.92%), followed by Pieridae 30 species (31.25%) and Lycaenidae 16 species (16.67%) while Hesperiidae and Papilionidae families were represented by two species each (2.08%) (Figure 2(a)). Family-wise composition of butterflies in terms of species richness recorded in each habitat type in Usangu area is presented in Table 3. Only two out of five butterfly species families were recorded in all the habitat types in the study area. Both Nymphalidae and Pieridae families had the highest species richness recorded in Miombo woodland (Table 3). Lycaenidae was the co-dominant family with 7, 9, and 7 individual species recorded in grassland, Miombo woodland, and riverine forest habitats, respectively (Table 3). Hesperiidae had the highest number of species recorded in Miombo woodland while Papilionidae family was represented by only two species that were recorded in grassland and riverine forest (Table 3).

4.2. Patterns of Butterfly Species Richness, Diversity, and Abundance in Four Habitat Types in Usangu Area. The highest species richness was recorded in Miombo woodland followed by riverine forest and grassland habitats while Vachellia/Commiphora woodland habitat had the lowest species richness (Table 4 and Figures 3(a) and 3(b)). Species richness was not significantly different among the habitat types ($\chi^2 = 5.15$, df $= 3$, $P = 0.16$). The comparison of the estimated species richness (Chao 1) is shown in Table 4 and Figure 3(b). The estimation of species richness in the four habitat types in Usangu area by Chao 1 shows that species richness was not close to the observed values in all habitat types except for Vachellia/Commiphora woodland (Figure 3(b) and Table 4). The highest variation between the observed and expected richness was recorded in the three habitat types in Miombo woodland, grassland, and riverine forest, and this was evident from the low values of their sampling completeness as indicated in Table 4. The rarefaction curves for the three habitat types also failed to reach an asymptote when plotted against the cumulative number of individuals (Figure 4). The rarefaction curves for Miombo woodland, grassland, and riverine forest continued to rise even when all individual butterflies were accumulated (Figure 4). However, the rarefaction curve for Vachellia/Commiphora woodland seems to approach asymptote gently, showing that species saturation had been reached and sampling effort was adequate (Figure 4).

In terms of species diversity and evenness, Miombo woodland had the highest species diversity index (H′) (Figure 3(d)) and community evenness (Figure 3(c)) among the surveyed habitats. Generally, Vachellia/Commiphora woodland had the lowest species diversity index (H′) (Figure 3(d)) and community evenness (Figure 3(c)) than either Miombo woodland, riverine forest, or grassland habitats (Figures 3(c) and 3(d)). Species diversity was not significantly different among habitat types ($F3, 18) = 1.39$, $P = 0.28$ (Figure 3(d)), and community evenness was also not significantly different across the surveyed habitats in Usangu ($F3, 17) = 1.99$, $P = 0.15$ (Figure 3(c)). Species abundance across habitat types shows butterfly individuals were on average relatively higher in Miombo woodland followed by riverine forest and Vachellia/Commiphora woodland while grassland had the lowest number of individuals (Table 2 and Figure 3(e)). The number of butterfly individuals was not significantly different among habitat types ($\chi^2 = 2.65$, df $= 3$, $P = 0.45$) (Figure 3(e)).

4.3. Butterfly Community Structure in the Four Habitat Types in Usangu Area. The results of butterfly community similarity based on the Bray–Curtis index show that the butterfly species composition in Usangu area was structured into two main clusters (Figure 5). The similarity of butterfly communities showed that butterfly species between Miombo woodland and riverine as well as Vachellia/Commiphora woodland and grassland habitats resembled each other, while those in grassland and Miombo woodland were greatly distinct (Table 5 and Figure 5). The scatter plots based on NMDS ordination plot (Figure 6) also showed a separate clustering of points for Miombo woodland and riverine suggesting similar distribution patterns. Vachellia/Commiphora woodland and grassland habitats clustered together, while the butterfly species in Miombo woodland were clearly separated from the grassland habitat. The analysis of similarity (ANOSIM) test showed a significant difference in the butterfly communities across the four

Table 1: Butterfly species caught in Usangu area, Ruaha National Park, Tanzania.

Latin name	Family name	Subfamily	RA	Genus
Borbo borbonica borbonica (Boisduval), 1833	Hesperiidae	Hesperiinae	R	Borbo
Zenonia zeno (Trimen), 1864	Hesperiidae	Hesperiinae	VR	Zenonia
Anthene lunulate (Trimen), 1894	Lycaenidae	Polyommatinae	VR	Anthene
Anthene princeps princeps (Butler), 1967	Lycaenidae	Polyommatinae	VR	Anthene
Axiocerses harpax ugandana (Clench), 1963	Lycaenidae	Aphnaeini	R	Axiocerses
Azanus jesous (Guérin-Méneville), 1849	Lycaenidae	Polyommatinae	VR	Azanus
Euchrysops albistriatus severini (Hulstaert), 1924	Lycaenidae	Polyommatinae	VR	Euchrysops
Euchrysops malathana (Boisduval), 1833	Lycaenidae	Polyommatinae	VR	Euchrysops
Euchrysops subpallida (Bethune-Baker), 1923	Lycaenidae	Polyommatinae	VR	Euchrysops
Lampides boeticus (Linnaeus), 1767	Lycaenidae	Polyommatinae	VR	Lampides
*Leptotes marginalis (*Aurivillius), 1925	Lycaenidae	Polyommatinae	VR	Leptotes
Leptotes pirithous (Linnaeus), 1767	Lycaenidae	Polyommatinae	R	Leptotes
Pseudonacaduba sichela sichela (Wallengren), 1857	Lycaenidae	Polyommatinae	VR	Pseudonacaduba
Tuxentius cretosus usemia (Neave), 1904	Lycaenidae	Polyommatinae	VR	Tuxentius
Tuxentius melaena melaena (Trimen), 1887	Lycaenidae	Polyommatinae	VR	Tuxentius
Zintha hintza hintza (Trimen), 1864	Lycaenidae	Polyommatinae	VR	Zintha
Zizeeria knysna (Trimen), 1862	Lycaenidae	Polyommatinae	VR	Zizeeria
Zizina anatanossa (Mabille), 1877	Lycaenidae	Polyommatinae	R	Zizina
Zizula hylax (Fabricius), 1775	Lycaenidae	Polyommatinae	NR	Zizula
Acraea acrita (Hewitson), 1865	Nymphalidae	Heliconiinae	R	Acraea
Acraea caecilian (Fabricius), 1781	Nymphalidae	Heliconiinae	VR	Acraea
Acraea caldarena caldarena (Hewitson), 1877	Nymphalidae	Heliconiinae	R	Acraea
Acraea epaea epitellus (Staudinger), 1896	Nymphalidae	Heliconiinae	R	Acraea
Acraea eponina eponina (Cramer), 1780	Nymphalidae	Heliconiinae	R	Acraea
Acraea neobule neobule (Doubleday), 1847	Nymphalidae	Heliconiinae	VR	Acraea
Bicyclus anynana (Butler), 1879	Nymphalidae	Satyrinae	VR	Bicyclus
Bicyclus campinus carcassoni (Condamin), 1963	Nymphalidae	Satyrinae	R	Bicyclus
Bicyclus campus (Karsch), 1893	Nymphalidae	Satyrinae	R	Bicyclus
Bicyclus ena (Hewitson), 1877	Nymphalidae	Satyrinae	R	Bicyclus
Bicyclus golo (Aurivillius), 1893	Nymphalidae	Satyrinae	VR	Bicyclus
Bicyclus mollitia (Karsch), 1895	Nymphalidae	Satyrinae	R	Bicyclus
Bicyclus safitza safitza (Westwood), 1850	Nymphalidae	Satyrinae	C	Bicyclus
Bicyclus sandace (Hewitson), 1877	Nymphalidae	Satyrinae	VR	Bicyclus
Bicyclus sophrosyne sophrosyne (Plötz), 1880	Nymphalidae	Satyrinae	NR	Bicyclus
Byblia anvatara acheloia (Wallengren), 1857	Nymphalidae	Biblidinae	R	Byblia
Byblia ilithyia (Drury), 1773	Nymphalidae	Biblidinae	NR	Byblia
Catacroptera cloanthe cloanthe (Stoll), 1781	Nymphalidae	Nymphalinae	VR	Catacroptera
Charaxes achaemenes achaemenes (Felder), 1970	Nymphalidae	Charaxinae	R	Charaxes
Charaxes aubyni ecketti (van Someren), 1966	Nymphalidae	Charaxinae	VR	Charaxes
Charaxes bohemani (Felder), 1859	Nymphalidae	Charaxinae	R	Charaxes
Charaxes cithaeron nairobicus (van Son), 1953	Nymphalidae	Charaxinae	VR	Charaxes
Charaxes guderiana rabaiensis (Poulton), 1929	Nymphalidae	Charaxinae	R	Charaxes
Charaxes saturnus (Butler), 1866	Nymphalidae	Charaxinae	R	Charaxes
Charaxes varanes vologeses (Mabille), 1876	Nymphalidae	Charaxinae	VR	Charaxes
Coenyropsis carcassoni (Kielland), 1976	Nymphalidae	Satyrinae	VR	Coenyropsis
Danaus chrysippus chrysippus (Linnaeus), 1758	Nymphalidae	Danainae	R	Danaus
Dixeia orbona vidua (Butler), 1900	Nymphalidae	Pierinae	R	Dixeia
Eurytela dryope angulate (Aurivillius), 1898	Nymphalidae	Biblidinae	NR	Eurytela
Hamanumida daedalus (Fabricius), 1775	Nymphalidae	Limenitidinae	C	Hamanumida
Hypolycaena buxtoni rogersi (Bethune-Baker), 1924	Nymphalidae	Theclinae	VR	Hypolycaena
Junonia artaxia (Hewitson), 1864	Nymphalidae	Nymphalinae	R	Junonia
Junonia hierta cebrene (Trimen), 1870	Nymphalidae	Nymphalinae	NR	Junonia
Junonia natalica natalica (Felder & Felder), 1860	Nymphalidae	Nymphalinae	NR	Junonia
Junonia oenone oenone (Linnaeus), 1758	Nymphalidae	Nymphalinae	R	Junonia
Junonia orithya madagascariensis (Guenée, 1865)	Nymphalidae	Nymphalinae	R	Junonia
Junonia terea elgiva (Hewitson), 1864	Nymphalidae	Nymphalinae	VR	Junonia
Lampides boeticus (Linnaeus), 1767	Nymphalidae	Polyommatinae	VR	Lampides
Melanitis leda (Linnaeus), 1758	Nymphalidae	Satyrinae	R	Melanitis
Neptis morosa (Overlaet), 1955	Nymphalidae	Limenitidinae	NR	Neptis
Neptis saclava marpessa (Hopffer), 1855	Nymphalidae	Limenitinae	VR	Neptis

Table 1: Continued.

Latin name	Family name	Subfamily	RA	Genus
Pardopsis punctatissima (Boisduval) 1833	Nymphalidae	Heliconiinae	C	Pardopsis
Precis antilope (Feisthamel), 1850	Nymphalidae	Nymphalinae	NR	Precis
Precis octavia sesamus (Trimen), 1883	Nymphalidae	Nymphalinae	R	Precis
Precis pelarga actia (Distant), 1880	Nymphalidae	Nymphalinae	VR	Precis
Ypthima granulosa (Butler), 1883	Nymphalidae	Satyrinae	VR	Ypthima
Papilio constantinus constatinus (Ward), 1871	Papilionidae	Papilioninae	VR	Papilio
Papilio demodocus demodocus (Esper), 1798	Papilionidae	Papilioninae	VR	Papilio
Belenois aurota aurota (Fabricius), 1793	Pieridae	Pierinae	VC	Belenois
Belenois calypso minor (Talbot), 1943	Pieridae	Pierinae	R	Belenois
Belenois creona severina (Grose-Smith), 1890	Pieridae	Pierinae	NR	Belenois
Belenois subeida sylvander (Grose-Smith), 1890	Pieridae	Pierinae	R	Belenois
Belenois zochalia agrippinides (Holland), 1896	Pieridae	Pierinae	R	Belenois
Catopsilia florella (Fabricius), 1775	Pieridae	Coliadinae	VR	Catopsilia
Colotis amatus amatus (Fabricius), 1775	Pieridae	Pierinae	NR	Colotis
Colotis antevippe zera (Lucas), 1891	Pieridae	Pierinae	NR	Colotis
Colotis aurigineus (Butler), 1883	Pieridae	Pierinae	VR	Colotis
Colotis aurora (Cramer), 1780	Pieridae	Pierinae	VR	Colotis
Colotis celimene celimene (Lucas), 1852	Pieridae	Pierinae	R	Colotis
Colotis daira jacksoni (Sharpe), 1890	Pieridae	Pierinae	C	Colotis
Colotis danae eupompe (Klug), 1829	Pieridae	Pierinae	NR	Colotis
Colotis eris eris (Klug), 1832	Pieridae	Pierinae	NR	Teracolus
Colotis euippe complexivus (Butler), 1886	Pieridae	Pierinae	R	Colotis
Colotis evagore antigone (Boisduval), 1836	Pieridae	Pierinae	R	Colotis
Colotis evenina xantholeuca (Sharpe), 1904	Pieridae	Pierinae	C	Colotis
Colotis hildebrandti (Staudinger), 1885	Pieridae	Pierinae	VR	Colotis
Colotis ione (Godart), 1819	Pieridae	Pierinae	R	Colotis
Colotis regina (Trimen), 1863	Pieridae	Pierinae	R	Colotis
Colotis rogersi (Dixey), 1915	Pieridae	Pierinae	R	Colotis
Colotis venosus (Staudinger), 1885	Pieridae	Pierinae	R	Colotis
Eurema brigitta brigitta (Stoll), 1780	Pieridae	Coliadinae	NR	Eurema
Eurema floricola orientis (Butler), 1888	Pieridae	Coliadinae	NR	Eurema
Eurema hapale (Mabille), 1882	Pieridae	Coliadinae	VR	Eurema
Eurema hecabe solifera (Butler), 1875	Pieridae	Coliadinae	R	Eurema
Eurema regularis regularis (Butler), 1876	Pieridae	Coliadinae	NR	Eurema
Nepheronia thalassina (Boisduval), 1836	Pieridae	Pierinae	VR	Nepheronia
Pinacopteryx eriphia melanarge (Butler), 1886	Pieridae	Pierinae	VC	Pinacopteryx
Pontia helice johnstoni (Crowley), 1887	*Pieridae*	*Pierinae*	*R*	*Pontia*

surveyed habitat types in Usangu area (Global $R = 0.2902$, $P = 0.0022$) using the Bray–Curtis similarity index.

5. Discussion

This study presents the diversity, richness, and composition of butterfly species community into four main habitat types in the Usangu area, mainly the grassland, Miombo woodland, Vachellia/Commiphora woodland, and riverine forest. Since there had been no study of butterfly composition in Usangu area, the present study forms the first checklist records on butterfly species of Usangu area, in Ruaha National Park. The generated checklist serves as baseline information for future studies, butterfly conservation action plans, and attraction for tourists as well as a monitoring tool for assessing the impacts of environmental changes such as global climatic change in Usangu area. The occurrence of five families in Usangu accounts for 71.43% of the total butterfly families that are known to occur in Tanzania [29, 30]. The occurrence of 10 species (10.42%) in all four habitat types of Usangu area indicated that the species recorded are habitat generalists and therefore they are described as ubiquitous [44, 45]. The general occurrence of generalist butterfly species would benefit them by providing a greater distribution as well as maintaining a bigger population size [45]. On the other hand, 40 species (41.67%) were restricted to single habitats only (Tables 2 and 3). The presence of these species in a single habitat indicates that these species might be habitat specialists and are sensitive to changes in plant community diversity, composition, and structure. Many butterfly species prefer only a particular set of microenvironments that is found in each habitat [46, 47]. In the present study, we reported 96 butterfly species occurring in the Usangu area, and these results can be compared with the study by Nkwabi et al. [29] who reported a total of 96 species of butterfly species from Ntakata Forest in Western Tanzania. However, the number of butterfly species and genera found in this study was lower compared to the number of butterfly species found elsewhere in Southern Tanzania. For example, Jew et al. [15] found 104 species of butterfly

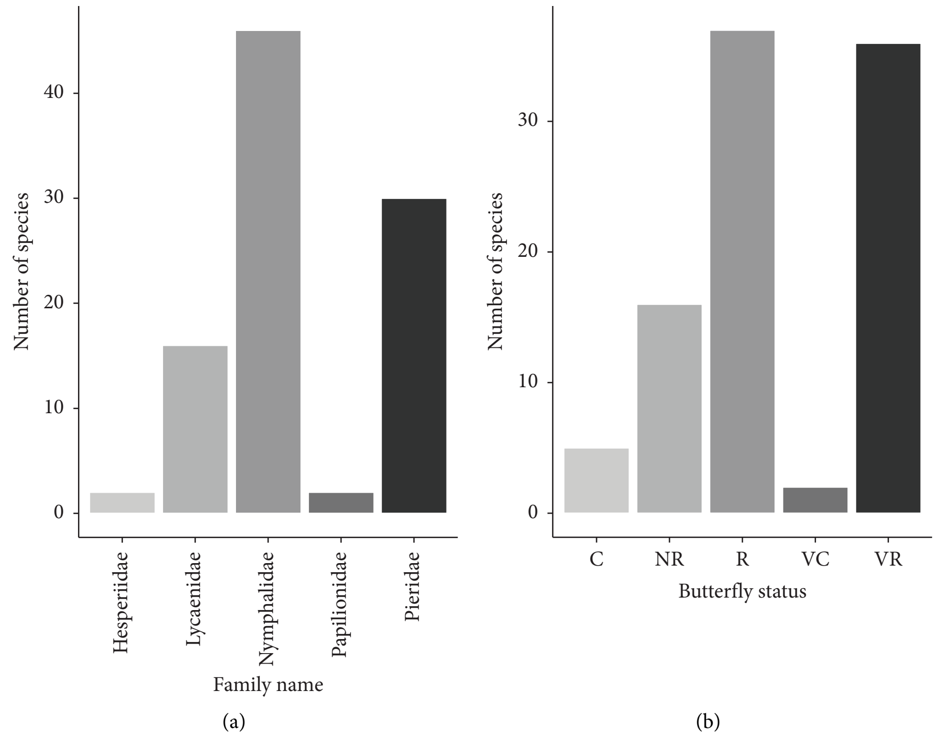


Figure 2: (a) Family-wise composition of butterfly species in Usangu area. (b) Status of butterfly species in Usangu area. C = common, NR = not rare, R = rare, VC = very common, and VR = very rare.

belonging to 51 genera and five families in Kipembawe Division in Chunya District, Mbeya Region. On the other hand, in the wildlife management areas, in the Ruvuma landscape, Nkwabi et al. [48] have reported a smaller number of butterflies (90 species) compared to the current study. The differences in habitats, seasons, study period, size of the study area, and sampling design could be the plausible reason for the variation in the number of butterfly species and genera recorded in these areas. For instance, this study was a one-time butterfly survey that was conducted in a dry season for eight days as compared to that of the Kipembawe Division which sampled butterflies in four months [15]. The rapid survey is commonly acknowledged to be missing the essential rare species and is usually biased toward the common popular species [49, 50]. In addition, different methods of data collection used by the researchers may have contributed to such variation in the number of butterfly species. Furthermore, the higher number of butterfly species obtained from the current study compared to those in the wildlife management areas, in Southern Tanzania [48], could be due to geographic and climatic variations as well as difference in the level of anthropogenic disturbances. Wildlife management areas of the Ruvuma landscape are significantly being influenced by anthropogenic disturbances which might be negatively affecting its butterfly species compared to Usangu area which has a restriction of human-induced activities and strong protection after being annexed into Ruaha National Park.

In this study, Nymphalidae had the highest species richness (46 species) followed by Pieridae (30 species) which were sampled in all surveyed habitats. The findings echo those of other researchers in Southern Tanzania and other parts of the country who reported Nymphalidae had the highest species richness in their studies [29, 51]. The highest number of Nymphalidae species could be attributed to several factors. First, Nymphalidae species owing to their polyphagous nature and greater ability to fly are capable of inhabiting different habitats in search of resources [52–54]. Second, the Nymphalidae family is one of the most diverse groups of butterflies [55, 56]. It is worth noting that butterfly species within Nymphalidae and Pieridae families were also sampled within all surveyed habitat types in Usangu area. The broad range of adaptation and the broad range of habitat preferences within Usangu area might be contributing to their occurrence in all surveyed habitats. The Nymphalidae are mostly fruit-feeding butterflies; therefore, they occurred in large numbers in Miombo woodland followed by riverine forest [57–59]. Pieridae also showed a greater dominance in all four surveyed habitat types in Usangu area. Their higher dominance might be attributed to the availability of host plant species for Pieridae butterflies in all surveyed habitat types in Usangu area [60]. Furthermore, it is worth noting that the greater dominance and highest number of Pieridae emphasize the fact that the majority of species in this family are indications of disturbed environments [61, 62]. Although Usangu area has been annexed into the national park with strong protection measures, the area still contains habitat patches that were exposed to intense anthropogenic pressure and ornamental plants which contribute to the greater dominance of these species. Results also show for the first

Table 2: The distribution and abundance of butterfly species in the four habitat types in Usangu area, Ruaha National Park.

Latin name	Grassland	Miombo woodland	Riverine forest	Vachellia/Commiphora woodland	Total	RA (%)
Hesperiidae						
Borbo borbonica borbonica (Boisduval), 1833	2	1	0	0	3	0.15
Zenonia zeno (Trimen), 1864	0	1	1	0	2	0.10
Total (Hesperiidae)	2	2	1	0	5	0.25
Lycaenidae						
Anthene lunulate (Trimen), 1894	0	0	1	0	1	0.05
Anthene princeps princeps (Butler), 1967	1	0	0	0	1	0.05
Axiocerses harpax ugandana (Clench), 1963	0	2	1	0	3	0.15
Azanus jesous (Guérin-Méneville), 1849	1	0	0	0	1	0.05
Euchrysops albistriatus severini (Hulstaert), 1924	0	0	2	0	2	0.10
Euchrysops malathana (Boisduval), 1833	0	1	0	0	1	0.05
Euchrysops subpallida (Bethune-Baker), 1923	0	2	0	0	2	0.10
Lampides boeticus (Linnaeus), 1767	0	1	1	0	2	0.10
*Leptotes marginalis (*Aurivillius), 1925	1	5	2	0	8	0.40
Leptotes pirithous (Linnaeus), 1767	1	0	0	0	1	0.05
Pseudonacaduba sichela sichela (Wallengren), 1857	0	1	0	0	1	0.05
Tuxentius cretosus usemia (Neave), 1904	0	1	0	0	1	0.05
Tuxentius melaena melaena (Trimen), 1887	0	1	0	0	1	0.05
Zintha hintza hintza (Trimen), 1864	1	0	1	0	2	0.10
Zizeeria knysna (Trimen), 1862	3	0	0	0	3	0.15
Zizina anatanossa (Mabille), 1877	13	4	4	0	21	1.05
Total (Lycaenidae)	21	18	12	0	51	2.56
Nymphalidae						
Acraea acrita (Hewitson), 1865	0	2	1	0	3	0.15
Acraea caecilian (Fabricius), 1781	0	1	1	0	2	0.10
Acraea caldarena caldarena (Hewitson), 1877	1	4	4	0	9	0.45
Acraea epaea epitellus (Staudinger), 1896	0	0	4	0	4	0.20
Acraea eponina eponina (Cramer), 1780	0	2	1	0	3	0.15
Acraea neobule neobule (Doubleday), 1847	0	1	0	0	1	0.05
Bicyclus anynana (Butler), 1879	0	2	0	0	2	0.10
Bicyclus campinus carcassoni (Condamin), 1963	0	5	0	0	5	0.25
Bicyclus campus (Karsch), 1893	0	5	0	0	5	0.25
Bicyclus ena (Hewitson), 1877	0	11	0	0	11	0.55
Bicyclus golo (Aurivillius), 1893	0	1	0	0	1	0.05
Bicyclus mollitia (Karsch), 1895	0	2	1	0	3	0.15
Bicyclus safitza safitza (Westwood), 1850	0	59	20	7	86	4.31
Bicyclus sandace (Hewitson), 1877	0	0	1	0	1	0.05
Bicyclus sophrosyne sophrosyne (Plötz), 1880	0	22	3	0	25	1.25
Byblia anvatara acheloia (Wallengren), 1857	0	6	5	0	11	0.55
Byblia ilithyia (Drury), 1773	0	21	21	1	43	2.16
Catacroptera cloanthe cloanthe (Stoll), 1781	1	0	0	0	1	0.05
Charaxes achaemenes achaemenes (Felder), 1970	0	5	0	2	7	0.35

Table 2: Continued.

Latin name	Grassland	Miombo woodland	Riverine forest	Vachellia/Commiphora woodland	Total	RA (%)
Charaxes aubyni ecketti (van Someren), 1966	0	1	0	0	1	0.05
Charaxes bohemani (Felder), 1859	0	2	0	2	4	0.20
Charaxes cithaeron nairobicus (van Son), 1953	0	1	0	0	1	0.05
Charaxes guderiana rabaiensis (Poulton), 1929	0	9	0	3	12	0.60
Charaxes saturnus (Butler), 1866	0	10	0	3	13	0.65
Charaxes varanes vologeses (Mabille), 1876	0	1	0	0	1	0.05
Coenyropsis carcassoni (Kielland), 1976	1	0	0	0	1	0.05
Danaus chrysippus chrysippus (Linnaeus), 1758	0	0	12	0	12	0.60
Dixeia orbona vidua (Butler), 1900	0	0	0	7	7	0.35
Eurytela dryope angulate (Aurivillius), 1898	0	6	9	1	16	0.80
Hamanumida daedalus (Fabricius), 1775	1	50	19	4	74	3.71
Hypolycaena buxtoni rogersi (Bethune-Baker), 1924	0	1	0	0	1	0.05
Junonia artaxia (Hewitson), 1864	0	5	2	0	7	0.35
Junonia hierta cebrene (Trimen), 1870	0	27	8	0	35	1.75
Junonia natalica natalica (Felder & Felder), 1860	0	27	10	0	37	1.85
Junonia oenone oenone (Linnaeus), 1758	0	9	3	0	12	0.60
Junonia orithya madagascariensis (Guenée, 1865)	0	2	4	1	7	0.35
Junonia terea elgiva (Hewitson), 1864	0	2	0	0	2	0.10
Lampides boeticus (Linnaeus), 1767	0	1	2	0	3	0.15
Melanitis leda (Linnaeus), 1758	0	1	3	0	4	0.20
Neptis morosa (Overlaet), 1955	0	17	1	0	18	0.90
Neptis saclava marpessa (Hopffer), 1855	0	1	0	0	1	0.05
Pardopsis punctatissima (Boisduval) 1833	0	78	8	0	86	4.31
Precis antilope (Feisthamel), 1850	0	27	8	0	35	1.75
Precis octavia sesamus (Trimen), 1883	0	6	0	0	6	0.30
Precis pelarga actia (Distant), 1880	0	0	1	0	1	0.05
Ypthima granulosa (Butler), 1883	0	1	0	0	1	0.05
Total (Nymphalidae)	4	434	152	31	621	31.13
Papilionidae						
Papilio constantinus constatinus (Ward), 1871	0	0	1	0	1	0.05
Papilio demodocus demodocus (Esper), 1798	1	0	0	0	1	0.05
Total (Papilionidae)	1	0	1	0	2	0.100
Pieridae						
Belenois aurota aurota (Fabricius), 1793	105	179	145	313	742	37.19
Belenois calypso minor (Talbot), 1943	1	1	0	1	3	0.15
Belenois creona severina (Grose-Smith), 1890	8	19	5	1	33	1.65
Belenois subeida sylvander (Grose-Smith), 1890	0	5	3	0	8	0.40
Belenois zochalia agrippinides (Holland), 1896	0	3	0	0	3	0.15
Catopsilia florella (Fabricius), 1775	0	2	0	0	2	0.10
Colotis amatus amatus (Fabricius), 1775	18	2	1	0	21	1.05
Colotis antevippe zera (Lucas), 1891	3	13	2	10	28	1.40
Colotis aurigineus (Butler), 1883	0	0	1	0	1	0.05

Table 2: Continued.

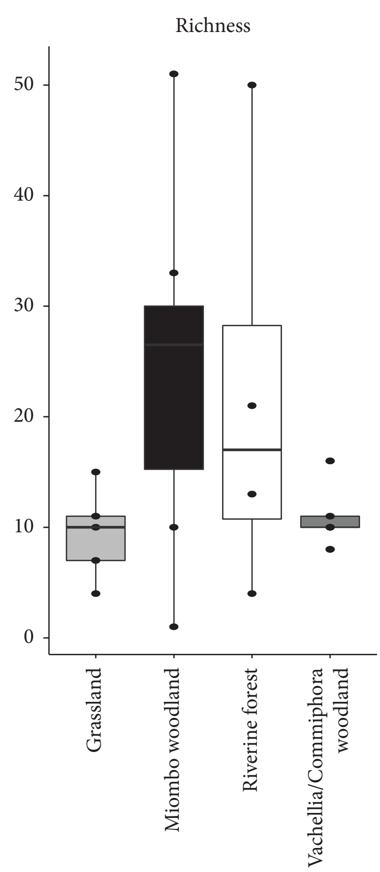
Latin name	Grassland	Miombo woodland	Riverine forest	Vachellia/Commiphora woodland	Total	RA (%)
Colotis aurora (Cramer), 1780	0	0	0	2	2	0.10
Colotis celimene celimene (Lucas), 1852	3	0	1	6	10	0.50
Colotis daira jacksoni (Sharpe), 1890	9	25	16	19	69	3.46
Colotis danae eupompe (Klug), 1829	3	4	11	3	21	1.05
Colotis eris eris (Klug), 1832	2	8	0	10	20	1.00
Colotis euippe complexivus (Butler), 1886	2	6	1	0	9	0.45
Colotis evagore antigone (Boisduval), 1836	0	5	2	3	10	0.50
Colotis evenina xantholeuca (Sharpe), 1904	4	21	9	52	86	4.31
Colotis hildebrandti (Staudinger), 1885	0	1	0	1	2	0.10
Colotis ione (Godart), 1819	1	1	3	0	5	0.25
Colotis regina (Trimen), 1863	0	3	1	0	4	0.20
Colotis rogersi (Dixey), 1915	0	5	0	2	7	0.35
Colotis venosus (Staudinger), 1885	1	3	0	8	12	0.60
Eurema brigitta brigitta (Stoll), 1780	0	29	6	2	37	1.85
Eurema floricola orientis (Butler), 1888	0	11	7	2	20	1.00
Eurema hapale (Mabille), 1882	0	1	0	0	1	0.05
Eurema hecabe solifera (Butler), 1875	0	4	7	0	11	0.55
Eurema regularis regularis (Butler), 1876	0	18	1	0	19	0.95
Nepheronia thalassina (Boisduval), 1836	0	0	2	0	2	0.10
Pinacopteryx eriphia melanarge (Butler), 1886	28	6	27	64	125	6.27
Pontia helice johnstoni (Crowley), 1887	1	0	0	2	3	0.15
Total (Pieridae)	189	375	251	501	1316	65.96
Total	217	829	417	532	1995	100

Table 3: Family-wise composition of butterflies in terms of species richness and number of species restricted in four habitat types in Usangu area.

	Family					
Habitat type	Hesperiidae	Lycaenidae	Nymphalidae	Papilionidae	Pieridae	Habitat restricted species
Grassland	1	7	4	1	15	7
Miombo woodland	2	9	39	0	25	22
Riverine forest	1	7	25	1	20	9
Vachellia/Commiphora woodland	0	0	10	0	18	2
Total	4	23	78	2	78	40

Table 4: Species richness and sampling completeness in the four habitat types in Usangu area.

Habitat type	Observed species richness	Chao 1	Sampling completeness
Miombo woodland	75	94.250	79.576
Riverine forest	54	75.375	71.642
Grassland	28	50.750	55.172
Vachellia/Commiphora woodland	28	29.875	93.724



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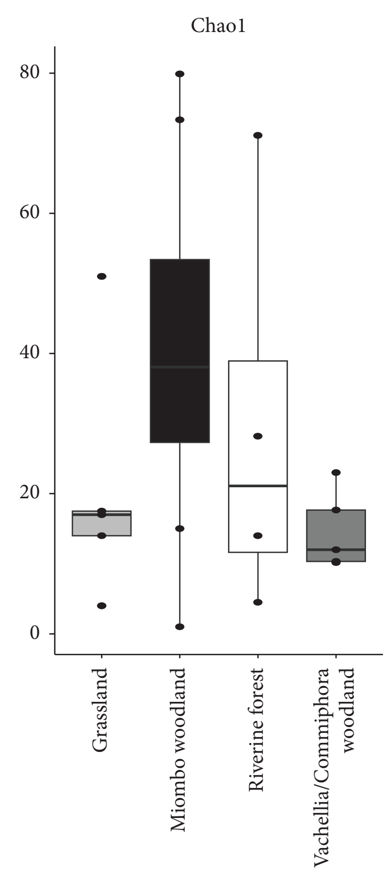
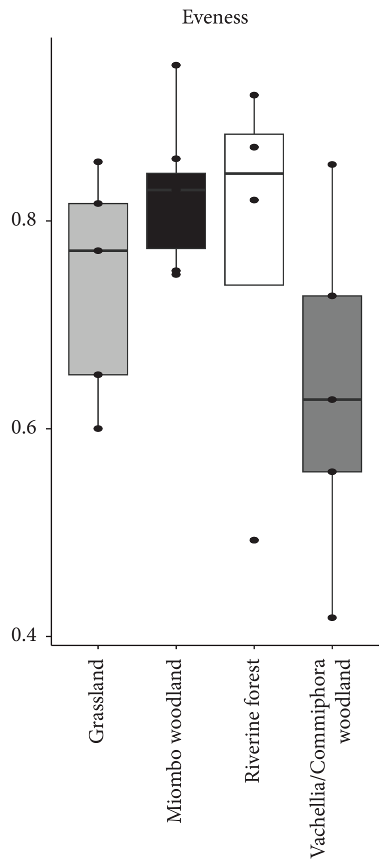


(b)

Figure 3: Continued.



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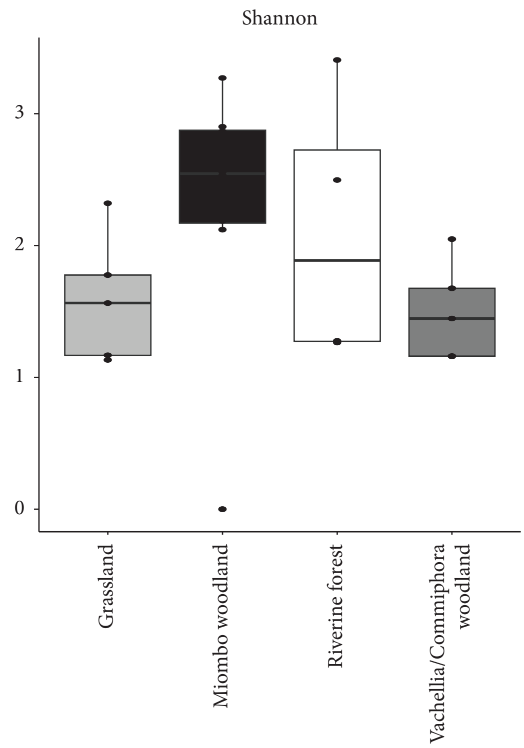

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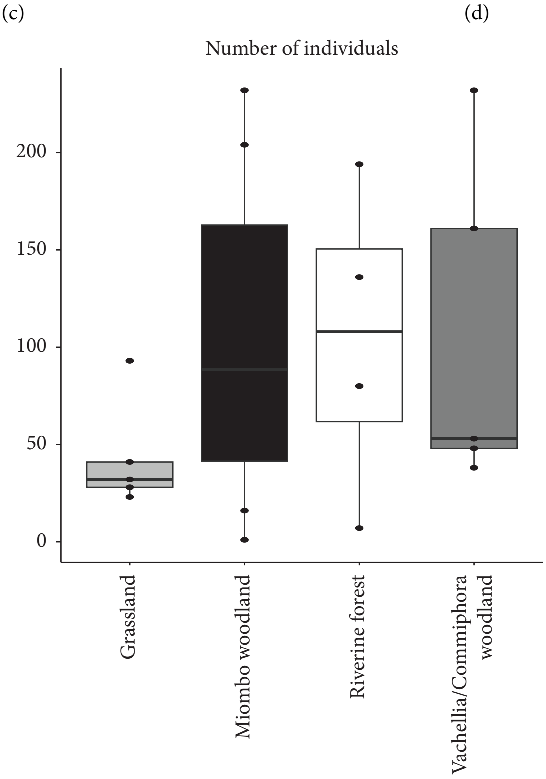

(e)

Figure 3: Pattern of butterfly (a) richness, (b) estimated richness (Chao 1), (c) evenness, (d) species diversity index (H′), and (e) abundance across the four habitat types in Usangu area.

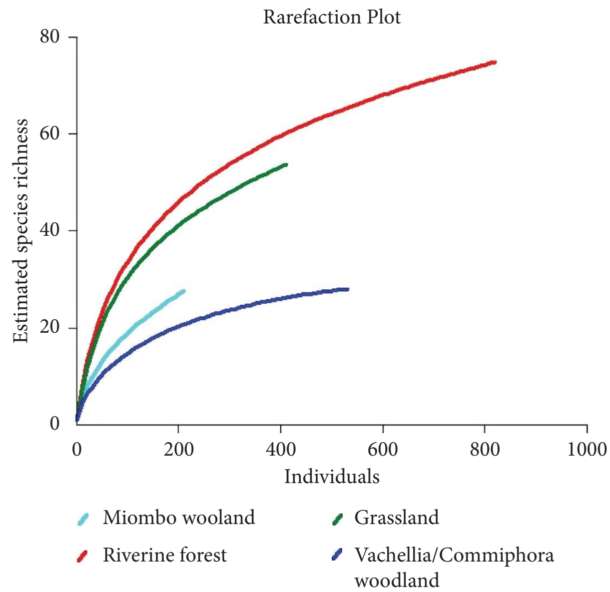

FIGURE 4: Sample-based rarefaction curves of estimated species richness in four habitat types in Usangu area, Ruaha National Park.

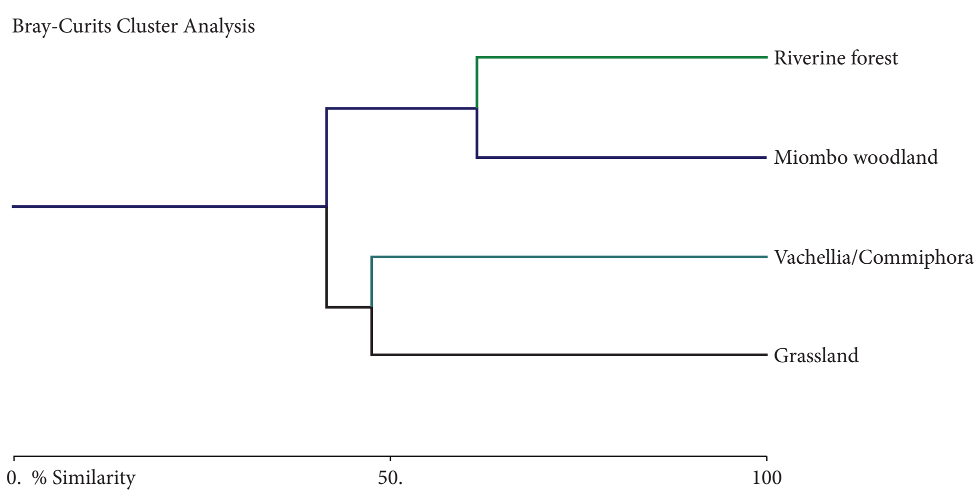

FIGURE 5: The dendrogram of butterfly species composition obtained in the four surveyed habitat types in Usangu area, Ruaha National Park, analyzed using the Bray–Curtis similarity index.

TABLE 5: Bray–Curtis index for observed butterfly assemblages across different habitat types in Usangu area.

Habitats	Miombo woodland	Grassland	Riverine forest	Vachellia/Commiphora woodland
Miombo woodland	—	29.798	61.8841	42.2816
Grassland	*	—	38.5414	47.3665
Riverine forest	*	*	—	40.0306
Vachellia/Commiphora woodland	*	*	*	*

*Already indicated.

time that even after long-term habitat restoration (over 15 years), it was not enough to eliminate the impacts of past anthropogenic disturbance on butterfly fauna. Conversely, Lycaenidae was a co-dominant family with 16 species that were recorded. Lycaenidae was found in the grassland, Miombo woodland, and riverine forest habitats and no other species of this family were recorded in the Vachellia/Commiphora woodland habitat. Lycaenidae are commonly known to associate negatively with disturbance and they usually decrease in richness in disturbed environments [61, 63]. Based on the impacts of anthropogenic activities previously reported in the Usangu area [20], it is fair to suggest that the average number of species belonging to Lycaenidae has been influenced by past disturbances and

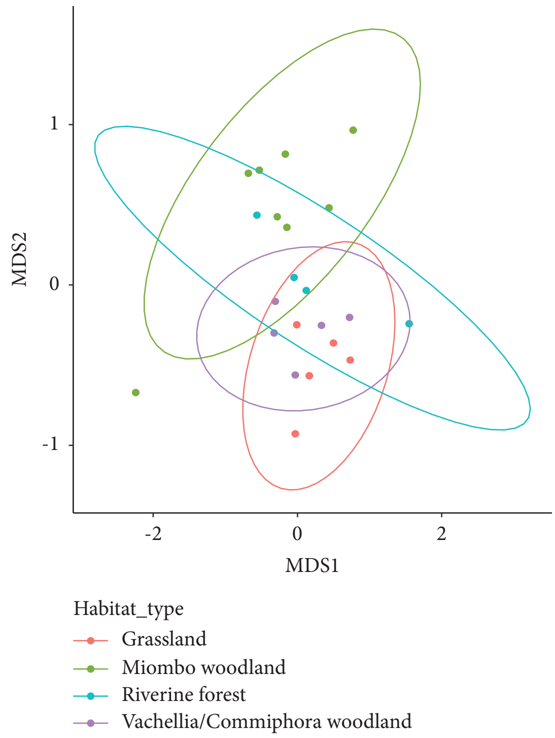

Figure 6: Nonmetric multidimensional scaling (NMDS) plot based on a Bray–Curtis abundance matrix, showing patterns of butterfly community structure among the four habitat types in Usangu area.

changes in their habitat conditions in the area. On the other hand, Hesperiidae and Papilionidae families were poorly represented in the surveyed habitat types. Hesperiidae family showed low abundance and richness in grassland, Miombo woodland, and riverine forest while members of this family were completely absent in Vachellia/Commiphora woodland habitat (Tables 2 and 3). In addition, only two individuals of Papilionidae family were sampled only in grassland and riverine forest (Tables 2 and 3). This finding is consistent with the results of the authors of [51, 64] who reported that the group members of the Hesperiidae and Papilionidae families were least represented in their research studies in the country. The low family abundance Hesperiidae and Papilionidae that was observed in grassland, Miombo woodland, and riverine forest may be attributed to the type of habitat and host plant availability as butterfly species richness and abundance are linked to the host specificity and niche preferences [65]. In addition, the difficulties in detection and identification by observers which are attributed to their small size, inconspicuousness, dull color, rapid and erratic flight patterns after any disturbance, and their low dispersal ability may also be among the probable reasons for low richness in families in Usangu area [65, 66].

Overall, various habitat types of Usangu area in Ruaha National Park are suitable for the survival of butterflies. In this study, we aimed to assess the biodiversity of arthropods using butterflies as an indicator species and setting up the foundation for different habitat type preservation and butterfly conservation in Usangu area. Our study design included various habitats with different species composition and coverage, permitting us to conclude which habitat type management was sufficient to improve biodiversity conservation in Usangu area. The findings showed that the four habitat types in Usangu area did not have differential effects on butterfly species diversity, richness, evenness, and abundance. However, there was evidence that Miombo woodland and riverine forest habitats exhibited relatively higher species diversity, richness, evenness, abundance, and higher number of habitat-restricted species, which supports the arguments that habitats with high abundance of trees and canopy cover contribute more to biodiversity conservation than in open areas such as grassland habitats [45, 67, 68]. This study has shown that Miombo woodland had the highest species diversity, richness, evenness, and abundance compared to other habitat types; this concurred with previous findings [29, 48, 69, 70]. Furthermore, the availability of open areas in the Miombo woodland such as glades, bogs, and clearcuts that could serve as alternative habitats for grassland butterfly species is another possible reason for the highest species richness, diversity, evenness, and abundance in the Miombo woodland [71–73]. The riverine forest was the second most diverse and rich habitat in our study area. Higher species richness and diversity in riverine forest habitats might be attributed to the availability of water which is well known for providing an ideal environment for butterflies, allowing for increased abundance, diversity, and richness due to the availability of resources such as basking sites with high sunlight, supporting butterfly behavior like puddling and through its beneficial effects to the host plant species for most butterfly species [74–76]. The findings of the present study are also in line with the findings in Miombo woodland ecosystems, where the increase in woodland and canopy cover and high tree density resulted in higher butterfly species abundance, evenness, richness, and diversity in Miombo woodland habitats compared to deforested or grassland habitats [51, 77]. Furthermore, additional indirect evidence for the importance of high tree density and high canopy cover in the tropics is provided by this research indicating that the negative effects of habitat fragmentation on butterflies in Miombo woodland ecosystems decrease as the environment becomes more dominated by high tree density and greater forest cover.

On the other hand, Vachellia/Commiphora woodland and grassland habitats recorded the lowest butterfly diversity and abundance among the habitats in the Usangu area perhaps due to their small areas or shortage of varied microclimatic conditions. This observation supports other studies comparing habitats with high tree density and forest cover and low tree density or grassland habitats, which found low species abundance and richness in habitats with low tree density or grasslands compared to those with high plant species richness and tree density [15, 29]. Habitat and larval host plants are among the fundamental resources that are required by butterflies for their survival and reproduction [40, 78]. During the study, it was observed that the Vachellia/Commiphora woodland and grassland habitats have a low species diversity, richness, and abundance. The main reason behind this could be attributed to the lack of vegetation heterogeneity. This lack of heterogeneity can cause the lack of adequate larval food plants as well as reduce suitable microhabitat conditions that are essential for the survival of butterfly species [43, 79, 80], low plant species richness and density [80–82], and limited nectar sources for adult butterflies and developing larvae due to insufficient host trees, shrubs, and herbs [83, 84] can negatively impact butterfly species richness, abundance, and community structure.

Although Miombo woodland, riverine forest, and grassland habitats had the highest species richness compared to Vachellia/Commiphora woodland habitat, the species accumulation curve and the estimated species richness (Figure 4 and Table 4) indicated that the sampling effort in the three habitats in Usangu was incomplete and there was a possibility to discover more butterfly species at each of these habitats with a substantial investment of more sampling effort [85]. The low species richness in Miombo woodland, riverine forest, and grassland habitats shows that short-time insect surveys tend to be biased toward common, well-known species and therefore leave behind the rare species which are usually added later with an increased sampling effort [86]. The rare and less common species are usually very important from a conservation perspective, and rapid diversity assessments may miss important elements of conservation interest [86, 87]. The rapid and short inventory assessment might have missed many species in the surveyed habitats in the Usangu area. Therefore, our results suggest that different survey efforts may be required to equally assess butterfly biodiversity in different habitat types in the Usangu area. On the other hand, the small sizes, and habitat separation as a result of habitat fragmentation and sampling season, might have also contributed to the low butterfly species richness obtained from these habitats [88, 89]. Aaden et al. [74] denoted that most insects in tropical regions usually have high fecundity in the wet season and drops in the dry season. This study was conducted during the dry season between May and June, and hence most butterfly species could have remained undetected or unrecorded in the surveyed habitats during this nonflowering season in the Usangu area. The estimates of species richness are essentially a scale-dependent process and are very strongly influenced by the sampling period [87, 90].

The Bray–Curtis similarity index of butterfly species between the four habitat types in Usangu area showed that the level of species similarity between habitats of Usangu area was generally low, except similarity between Miombo woodland and riverine forest habitats. Generally, the composition of butterfly species had many similarities in the Miombo woodland and riverine forest followed by Vachellia/Commiphora woodland and grassland habitat, while the lowest similarity was observed between Miombo woodland and grassland habitats (Table 5 and Figure 5). The lowest species similarity recorded between habitats in Usangu area could be contributed to habitat specificity of butterfly for host plant species that provide food for butterfly. Jj and Emana [45] stressed that the distribution of any species is regulated by the distribution of its habitats as well as the availability of food, shelter, and other essential resources found within that particular habitat. Furthermore, habitat loss, fragmentation, and isolation which resulted from past unregulated anthropogenic activities in the Usangu area could also be plausible reasons for the low species similarity between these habitats. Habitat loss and fragmentation have also been acknowledged as among the leading causes of the current biodiversity reduction globally [91]. Fragmented habitats can constrain species movement, disrupt species dispersal behavior and population, and reduce connectivity by increasing spatial isolation between suitable patches and hence negatively impact biodiversity [92–94]. The study findings align with other previous works in the country [29, 51] that reported the same conclusions. It is worth noting that Miombo woodland and riverine forest were the favorable habitats for the butterfly in the Usangu area. These two habitats provide them with suitable environmental conditions for their survival and growth all year round. They support high tree abundance, host plants to carry out their life cycle, and high richness and diversity of vegetation, thus meeting butterfly requirements such as food, shelter, and physical environmental factors, such as the presence of water flow and favorable weather conditions [80, 82, 95].

6. Conclusions

The current investigation is the first to generate a butterfly checklist of Usangu area and document the spatial distribution of butterfly species in the four main habitat types that are found in Usangu area, Ruaha National Park (RUNAPA). Regardless of its size, Usangu area is rich in butterfly species that are known to occur in Tanzania. The situation reflects the availability of diverse and rich habitats that provide suitable habitats for butterfly in Usangu area, Ruaha National

Park. The study findings also have provided baseline information to conservationists and researchers for more studies in similar restored areas annexed to National Park. The study recommends that further studies on abiotic characteristics of habitat types, degree of connectivity or isolation between habitats, and types of host plants that provide food for butterflies in various habitats in Usangu area should be done. The investigation should consider different seasons in Usangu area as this study was only carried out during the dry season only with repeated sampling efforts. From a conservation perspective, the results presented here suggest that the habitat types in Usangu area are still recovering from past anthropogenic impacts, and for butterfly conservation, RUNAPA should focus on preserving the Miombo woodland and riverine forest by maintaining the habitat stability of the two habitats as they harbor greatest species richness and abundance of butterflies in Usangu area compared to other habitat types. The Miombo woodland and riverine forest habitats in Usangu have the potential for butterfly tourism, which can aid in conservation efforts and raise public awareness. However, it is crucial to carefully monitor the impact of tourism development on these areas, as any alteration to the Miombo woodland, plant biomass, and water resources in the riverine forests could harm the butterfly diversity in this region. To ensure the preservation of this unique ecosystem, conservationists and park managers should establish a plan for ongoing monitoring and research to observe any changes in butterfly species composition, diversity, and richness in the Usangu area.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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