Sokoine University of Agriculture

MSc. Dissertation

Butterfly Species Diversity across ecological gradients in Mpanga Kipengere Game Reserve and Surrounding Farmlands, Tanzania

KASIS, Privatus Maximillian

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Butterfly Species Diversity Across Ecological Gradients in Mpanga/Kipengere Game Reserve and Surrounding Farmlands, Tanzania

This Dissertation Is Submitted in Fulfillment of the Requirements for the Master's Degree of Science in Forestry to Sokoine University of Agriculture, Morogoro

by

KASISI, Privatus Maximillian

Supervisors

Dr. Nsajigwa Mbije
Dr. Paulo Lyimo

Department of Ecosystems and Conservation
College of Forestry, Wildlife and Tourism
Sokoine University of Agriculture, Morogoro, Tanzania

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EXTENDED ABSTRACT

Butterflies are a species that are particularly sensitive to environmental changes. Identifying indicator species is crucial for assessing ecosystem health and ecological monitoring. Maintaining natural habitats is crucial for preserving insects and other species that indicate environmental changes. However, the Mpanga/Kipengere Game Reserve and its surrounding farmlands are facing disturbance due to human activities, putting many wildlife species, particularly larger mammals, at risk. To determine the impact of human activities on butterfly species diversity and abundance in the reserve and its surrounding areas, we conducted a study from November 2021 to October 2023.

The study had three main goals. Firstly, to determine how altitude affects the composition and diversity of butterfly species in the Mpanga/Kipengere Game Reserve. Secondly, to assess how habitat impacts the composition and diversity of butterfly species in the same reserve. Lastly, to evaluate the effect of human activities on butterfly species composition and diversity in both the Mpanga/Kipengere Game Reserve and the adjacent Farmlands. The study was conducted between July 2021 and June 2022 at three different altitudinal levels low altitude, mid-altitude, and higher altitude ranging from 1000m to >2000 above sea level. To study the diversity and similarities in species composition between habitats, butterflies were collected using baited traps and sweep nets. A 1000m long line transect was used in each site for sampling. Shannon Index was employed to calculate diversity, while variations were tested using ANOVA and TUKEY-HSD. Bray-Curti's dissimilarities were used to identify similarities in species composition.

The results observed during the study are as follows: A total of 2091 butterfly specimens from 5 different families, which included 124 species were observed. Among these species, there were 2 endemic ones, namely Charaxes Congdon and Harpendyreus Juno. The research showed a significant difference in butterfly species diversity based on altitude, with the Mid-Altitude having higher diversity ($P < 0.001$). However, there was no significant difference in butterfly species diversity between different habitats (Bray-Curtis's value < 0.23). Furthermore, the study reveals that Mpanga Kipengere Game Reserve has higher butterflies' diversity compared to surrounding Farmlands. It is also observed that 77% of the species were recorded in April when there was high temperature and rainfall. These findings are crucial for ecological monitoring and the evaluation of the MPKGR ecosystem.

The study concluded that: There is a significance difference in butterfly species composition and diversity between altitudes. There is no significance difference in species composition and diversity between vegetation types. Therefore, the variation is influenced by altitudes rather than habitat types. Butterfly species composition and diversity is higher in MPKGR compared to surrounding farmlands. Therefore, the study find that human activities have direct impact on butterfly species composition and diversity. Most of butterfly species recorded immediately after intensive rain season compared to dry season.

Keywords: Altitudinal gradient, Protected areas, Highlands, Species Composition

IKISIRI KUU

Vipepeo ni aina muhimu ya wadudu ambayo ni nyeti sana kwa mabadiliko ya mazingira. Kudumisha makazi ya asili ni muhimu kwa kuhifadhi wadudu na spishi zingine zinazoashiria mabadiliko ya mazingira. Hata hivyo, Hifadhi ya Mpanga/Kipengere na mashamba yanayozunguka yanakabiliwa na usumbufu kutokana na shughuli za kibinadamu, hivyo kuhatarisha uwepo wa wanyamapori, hasa wanyama wakubwa, katika hatari. Ili kubaini athari za shughuli za binadamu kwa utofauti wa aina ya vipepeo na wingi katika hifadhi na maeneo yake ya karibu, tulifanya utafiti kuanzia Novemba 2021 hadi Oktoba 2023.

Utafiti huu ulikuwa na malengo makuu matatu. Kwanza, kuamua jinsi urefu unavyoathiri muundo na utofauti wa aina ya vipepeo katika Hifadhi ya Mpanga/Kipengere. Pili, kutathmini jinsi makazi yanavyoathiri muundo na utofauti wa aina za vipepeo katika hifadhi hiyo Hivyo, kutathmini athari za shughuli za binadamu juu ya muundo wa aina ya vipepeo na utofauti katika Hifadhi ya Mchezo wa Mpanga / Kipengere na mashamba ya karibu. Utafiti huo ulifanywa kati ya Julai 2021 na Juni 2022 katika viwango vitatu tofauti vya altitudinal chini ya urefu, urefu wa kati, na urefu wa juu kutoka 1000m hadi >2000 juu ya usawa wa bahari. Ili kujifunza utofauti na kufanana katika muundo wa spishi kati ya makazi, vipepeo walikusanywa kwa kutumia mitego ya baited na nyavu. Transsect ya mstari wa 1000m ilitumika katika kila tovuti kwa sampuli. Shannon Index iliajiriwa kuhesabu utofauti, wakati tofauti zilijaribiwa kwa kutumia ANOVA na TUKEY-HSD. Utofauti wa Bray-Curti ulitumika kutambua kufanana katika muundo wa spishi.

Matokeo yaliyozingatiwa wakati wa utafiti ni kama ifuatavyo: Jumla ya vipepeo 2091 kutoka kwa familia 5 tofauti, ambazo zilijumuisha spishi 124 zilionekana. Miongoni mwa aina hizi, kulikuwa na 2 endemic, ambayo ni Charaxes Congdon na Harpendyreus Juno. Utafiti ulionyesha tofauti kubwa katika utofauti wa aina ya kipepeo kulingana na urefu, na Mid-Altitude kuwa na utofauti wa juu ($P < 0.001$). Hata hivyo, hakukuwa na tofauti kubwa katika utofauti wa aina ya kipepeo kati ya makazi tofauti (thamani ya Bray-Curtis < 0.23). Futhermore utafiti unaonyesha kuwa Hifadhi ya Mpanga Kipengere ina utofauti mkubwa wa vipepeo ikilinganishwa na mashamba ya jirani. Pia imebainika kuwa asilimia 77 ya spishi hizo zilirekodiwa mwezi Aprili ambapo kulikuwa na joto kali na mvua. Matokeo haya ni muhimu kwa ufuatiliaji wa mazingira na tathmini ya mazingira ya MPKGR.

Utafiti huo ulihitimisha kuwa: Kuna tofauti kubwa katika muundo wa aina ya kipepeo na utofauti kati ya muinuko. Hakuna tofauti kubwa katika muundo wa spishi na utofauti kati ya aina za mimea. Kwa hivyo, tofauti inaathiriwa na muinuko badala ya aina za makazi /mimea. Aina za kipepeo na utofauti ni kubwa katika MPKGR ikilinganishwa na mashamba ya karibu. Kwa hiyo, utafiti huo unagundua kuwa shughuli za binadamu zina athari za moja kwa moja kwa muundo wa aina ya vipepeo na utofauti. Aina nyingi za vipepeo zilirekodiwa mara tu baada ya msimu wa mvua kubwa ikilinganishwa na msimu wa ukame.

Maneno muhimu: Altitudinal gradient, maeneo yaliyohifadhiwa, Nyanda za Juu, Muundo wa Aina

DECLARATION

I, **PRIVATUS MAXIMILLIAN KASISI**, do hereby declare to the Senate of Sokoine University of Agriculture, that this dissertation is my original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

______________________________ ____________________

Privatus Maximillian Kasisi Date
(MSc. ECOSMA Candiate)

The above declaration is confirmed

____________________________ ____________________

Dr. Nsajigwa Mbije Date
(Supervisor)

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Dr. Paulo Lyimo Date
(Supervisor)

LIST OF MANUSCRIPTS

Manuscript 1: The Influence of Altitude and Vegetation Types on Butterfly Species Composition and Diversity in Mpanga/Kipengere Game Reserve, Tanzania.

Manuscript 2: The influence of human activities and season on butterfly species diversity and abundance in MPKGR and surrounding Farmlands, Tanzania

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I am deeply grateful to the Almighty God for guiding me throughout my studies. I would like to acknowledge several individuals who have contributed to the success of my research. Firstly, I want to thank my supervisors, Dr. Nsajigwa Mbije, Dr. Paul Lyimo, and Dr. Kayombo, for providing valuable intellectual guidance, motivation, and critical insights that helped shape and direct my study. I also wish to express my sincere appreciation to Mr. Mabula Misungwi Nyanda, the Conservation Commissioner of Tanzania Wildlife Management Authority (TAWA), for granting me permission to pursue my MSc studies at Sokoine University of Agriculture. I am also grateful to Leonard Nsajigwa and Enock Kimayani for their assistance during the fieldwork. Lastly, I would like to thank Mr. Abraham Mulokozi and Malila for their help with data analysis.

I want to express my gratitude to the Management of Mpanga Kipengere Game Reserve for giving me permission to conduct a field survey at the reserve. I also want to acknowledge my family for their patience, comfort, and care. Specifically, I want to thank my mother Adelgiza Makero, and my wife Betwana C. Lilangala for supporting me in pursuing my master's studies. Additionally, I appreciate the moral support provided by my colleagues Omary Mgowo, Nandera Lolila, and Zena Mng'ong'o during the most challenging moments of my studies.

DEDICATION

This work is dedicated to my father, the late Mr. P.M Kasisi, and my mother Adelgiza Makero for their best care and the great ambitious heart they built in me. They laid a strong foundation for my education.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABREVIATIONS AND ACRONYMS

ANOVA	Analysiss of variance
PA	Protected Area
MPKGR	Mpanga Kipengere Game Reserve
Km	Kilomiter
C	Centigrade
ECOSMA	Ecosystem Science and Management
H	Height
WWF	World Wildlife Fund
GR	Game Reserve
FL	Farmland
df	Degree of freedom
TAWA	Tanzania Wildlife Management Authority

CHAPTER ONE

1.0 General Introduction

1.1 Background Information

Mpanga/Kipengere Game Reserve (MPKGR) was gazette in the Government Notice No. 483 of 25thOctober 2002 covering an area of about 1,574km2. The reserve was upgraded from Kipengere Forest Reserves and Mpanga open areas and it lies in Makete (46%) and Wanging'ombe (43%) districts in Njombe region and Mbarali (11%) District in Mbeya region. Human activities conducted in 24 village surrounded the reserve had negatively affected biodiversity of the area. Human pressure resulted into expansion of settlements, soil erosion and blockage of wildlife corridor from Usangu plains leading to severe reduction and disappearance of large ungulates such as elephant, greater kudu, zebra and eland. Efforts to conserve the area in 1990's was a result of national concern about the decreased flow of Ruaha river to sustain the Mtera Hydro-electric dam.

Butterflies are indicator species of environmental changes in their environment they occur (Brändle *et al*., 2002). Being responsive to any changes of environmental parameters such as temperature, humidity, light and rainfall patterns, these insects are identified as useful bioindicators (Lee *et al*., 2020). They have different requirements for different habitat types for matting, breeding and nectaring and are thus, in sync of diversity and quality of their habitats (Brändle *et al.,* 2002). Mountain ecosystems are particularly sensitive to changes in climate and land cover, but at the same time they can offer important refuges for species on the opposite of the more altered lowland (Khan *et al.,* 2011). For effective biodiversity conservation in reserves, extensive knowledge of classification, distribution and biogeography of wide range of indicator group is required. The butterflies undoubtedly are prime group for making such assessments Ackery *et al.,* 1995).

Mpanga/Kipengere Game Reserve (MPKGR) is depended by adjacent villages for provisioning of water for domestic and irrigation uses. In spite of ecological and economic important, the reserve has undergone extensive environmental changes since its establishment in 2002 due to factors such as deforestation for farming expansion and charcoal production, collection of fuel woods, introduction of invasive species and human settlements increase on the peripheral of the reserve. While information of large animals such as vertebrates is abundantly available, there is scarce information on the invertebrates especially indicator species such as butterflies. Study therefore, aims at establishing baseline information on butterfly species distribution in MPKGR.

1.2 Problem Statement and Justification

Although Tanzania harbors about 1,699 species of butterflies (Congdon, 1998), insufficient studies have been done in terms of species composition and diversity of butterflies especially in protected areas particularly game reserves. Few studies on butterflies have been conducted in Tanzania including Congdon & Bampton (1998) provided some data on endemic butterflies in Tanzania. Fitzherbert *et al*. (2006) assessed the abundance and diversity of butterflies in Katavi National Park. Roche *et al.*, (2015) examined the influence of the sex of fruit-feeding butterflies and time of the day on the vertical stratification in Mtai Forest Reserve. Nkwabi *et al.* (2017) assessed the influence of anthropogenic activities on the diversity and abundance of butterflies in five Wildlife Management Areas found in Ruvuma landscape, and Mtui *et al.* (2019) provided a checklist of butterfly's species in Kihansi Gorge.

Although, such studies have been conducted in the country, there are no recent studies on butterfly's species composition and diversity in relation to altitude, habitat, anthropogenic disturbance and different seasons have been done in MPKGR. The only information on butterflies of MPKGR is the resource survey conducted by the University of Dar es Salaam in collaboration with WWF in 2003. However, it has been 19 years since that survey was conducted and different ecological changes might have already taken place affecting the community structure. Butterflies have been mentioned to be important tool for conservation monitoring as they are sensitive to the changes in the environment (Ackery *et al.,* 1995), vegetation structure (MacNally *et al.,* 2004; Fitzherbert et al.2006), and climate (Zografou *et al.,* 2014). This study will assess butterfly species composition and diversity in MPKGR and how they vary in a response to altitude, habitat types and human activities. The study findings will play significant role in provide necessary information for conservation of MPKGR. Information obtained from the study will be used as a reference base by the Management in the MPKGR to justify on the conservation practices to be implemented.

1.3 Objective of the Study

1.3.1 General objective

The overall objective of this study was to determine factors influencing butterfly species composition and diversity in Mpanga/Kipengere Game Reserve and surrounding farmlands.

1.3.2 Specific objective

The specific objectives of the study were to determine: -

i. The influence of altitude on butterfly species composition and diversity in MPKGR
ii. The influence of vegetation types on the butterfly species composition and diversity in MPKGR
iii. The effect of human activities on butterfliy species composition and diversity in MPKGR and surrounding Farmland

1.3.3 Hypotheses

i. There is a significant difference in butterfly species composition and diversity between four types of vegetation in MPKGR
ii. There is a significant difference in butterflies' abundance and diversity across elevation gradients in MPKGR.

1.4 Dissertation Structure

This dissertation consists of five main chapters in the format of publishable manuscripts. The introduction, which includes background information, problem statement, justification, objectives, and research questions, is covered in chapter one. Chapter two is the first manuscript: The Influence of Altitude and vegetation types on Butterfly Species Composition and Diversity in Mpanga/Kipengere Game Reserve, Tanzania. Chapter three is the second manuscript which is about the influence of human activities and season on butterfly's species diversity and abundance in MPKGR and surrounding Farmlands, Tanzania. Chapters four and five summarizes the general discussion, and chapter five is all about general conclusions and recommendations.

CHAPTER TWO

Manuscript One

2.0 Influence of Altitude on Butterfly Species Composition and Diversity in Southern Highlands of Tanzania, East Africa

Privatus M. Kasisi [1*], Dr. Nsajigwa Mbije [2], Dr Paulo Lyimo[1]

[1]Departiment of Ecosystem Science and Management, College of Forest, Wildlife and Tourism, Sokoine University of Agriculture, P.O Box 3000 SUA-Morogoro, Tanzania

[2]Departiment of Wildlife Management, College of Forest, Wildlife and Tourism, Sokoine University of Agriculture, P.O Box 3000 SUA-Morogoro, Tanzania

*****_Corresponding author e-mail address:_ ***privawapili@yahoo.com***
Co-author e-mail address: ***mbije@sua.ac.tz***
Co-author e-mail address: **paulo.lyimo@sua.ac.tz**

Abstract

To determine the impact of altitude and vegetation types on butterfly species diversity and abundance in the reserve, we conducted a study from July 2021 to June 2022. We collected butterfly data using transect walks and baited traps from three sites including low altitude, mid-altitude, and higher altitude ranging from 1000m to >2000 above sea level. Our study yielded 2091 butterfly Individuals ranging in 124 species divided into five families including 2 endemic species *charaxes congdon* and *harpendyreus juno*. Altitude and vegetation types are significant influencing species diversity and abundance of butterflies. Our study findings provide essential information for ecological monitoring and future assessment of the Mpanga/Kipengere Game Reserve ecosystem health.

Keywords: Altitudinal gradient, Protected areas, Highlands, Species Composition

2.1 Introduction

Previous studies indicate that there is a tendency for different butterfly species to be found in specific plant types or groups (Aduse-Poku *et al.,* 2006, DeCesare *et al.,* 2014). However, butterflies, like other terrestrial animals, face several threats, including habitat destruction and pollution, the introduction of exotic species, and commercial exploitation of forests (Edge *et al.,* 2008). Despite their mobility, many butterfly species are confined to specific habitats due to their reliance on particular food plants and their narrow climatic preferences (Collins and Larsen, 2008). Mountain ecosystems offer essential refuges for butterfly species that face challenges in the altered lowland areas (Khan *et al.,* 2011). These mountain ecosystems provide diverse and quality habitats that support butterfly matting, breeding, and nectar sources (Roche *et al.,* 2015).

The Mpanga Kipengere Game Reserve (MPKGR) is a biodiverse area with a high level of endemism in both flora and fauna. To effectively conserve this biodiversity, it is necessary to have a broad understanding of the classification, distribution, and biogeography of different indicator species (Congdon, 2005). Butterflies are considered a prime group for such assessments (Mtui *et al.,* 2022). They can provide valuable information on environmental changes and help monitor and assess ecosystem health (Collins and Lasern, 2008). However, the only available information on the butterflies in MPKGR is from a biodiversity survey conducted by Frontier Tanzania in collaboration with the University of Dar es Salaam and WWF in 2003. Previous research has mostly focused on vertebrate species in the area, with little attention given to invertebrates beyond the game reserve where human activities take place.

To better understand the diversity patterns of invertebrate species across different areas with varying conservation designations, it is crucial to collect more data on a wider range of taxa. This will help us gain valuable insight into effective biodiversity management on a larger scale. By establishing a baseline for future monitoring, we can work towards preserving the biodiversity in this ecosystem, which has been impacted by human activities. Thus, the purpose of this study was to (i) evaluate the diversity and species composition of butterflies across elevation gradients characterized by five different habitats with varying structures and within the Mpanga Kipengere Game Reserve (ii) investigate the structure of the butterfly community in this forest and examine how local habitat impact butterfly abundance, diversity, and species richness. We hypothesized that butterfly diversity and richness would vary across different vegetation types and elevation gradients.

2.2 Materials and Methods

2.2.1 Site description

The Mpanga/Kipengere Game Reserve covering an area of approximately 1574 square kilometers. The reserve is bordered by the Kipengere Range and escarpment in the west, the Kitulo Plateau in the east, and the Kipengere Plateau in the north. Its coordinates fall between 8° 50’ and 9°10’ South latitude and 34° 00’ and 34° 30’ East longitude. The altitude of the reserve ranges from 1080 to 2289 meters above sea level, while the average annual rainfall is between 1800 and 2000 mm. The reserve is characterized by two main vegetation types, namely, afro-montane forest-grassland mosaic and mid-altitude miombo woodland. Other vegetation types include riverine forests and bushland.

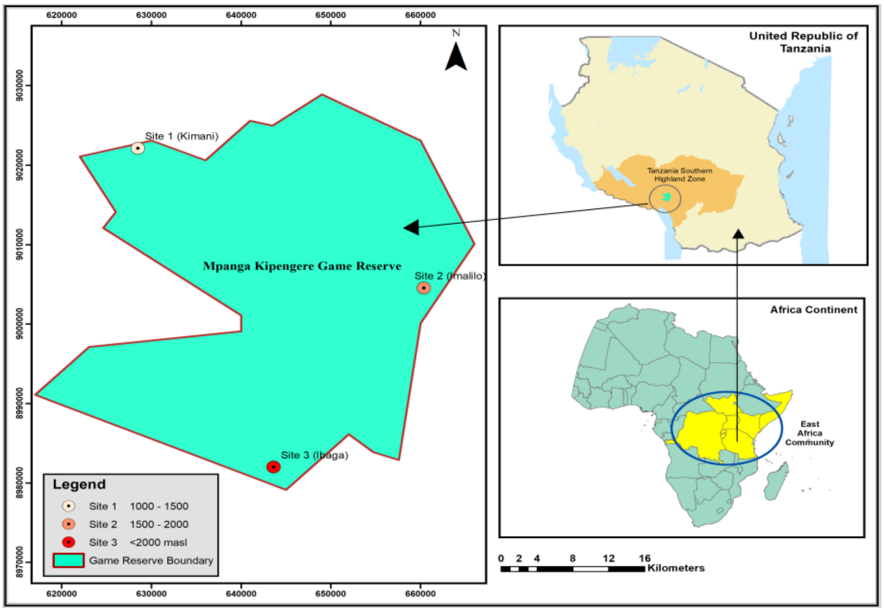

Figure 2.1: Map of MPKGR showing the location of study sites

2.2.2 Sampling design and data collection

Three sites were established along an altitudinal gradient and based on the different vegetation types they exhibited. The first site was located at the lowest elevation, between 1000-1500 meters above sea level (masl), and was characterized by miombo woodlands and riverine forests. The second site was situated at a mid-altitude between 1500-2000 masl, and featured miombo woodlands, riverine forest, and Afromontane Forest. The third site was located at the highest elevation, above 2000 masl, and was characterized by bushlands and grassland. At each site, two parallel transect lines, each 1000 meters in length, were established, with a 100-meter distance between them. Along each transect, 10 sampling plots of 50m × 10m where the distance between one plot to another was 50 meters (where sampling was not done). To collect butterfly samples, traps baited with fermenting bananas were used, following the methodology described by Fitzherbert et al. (2006) and Mingarro (2021). Sampling was conducted between 9:00 am and 5:00 pm for ten days per month, from November 2021 to February 2022, with samples collected concurrently from all sites with few modifications. The modifications include the placement of baited traps at the center of each plot 25m between traps. Every day, the banana used as bait was changed and new samples were taken. To collect butterflies from foliage and long grass where traps couldn't be placed, sweep netting was used. In each plot, a trap was set in the center and butterflies were swept in a circle with a 5m radius. The process took 20 minutes to collect a sample at each point. After collection, the butterflies were counted and identified to the species level using field guides and a key described by Farook et al., (2020). Any unidentified butterflies were photographed, as they were not allowed to be carried outside the Game reserve, and the photos were sent to butterfly taxonomists for identification. During the butterfly sampling process, four variables were recorded: species name, family, location (lower, mid and upper), and habitats of species occurrence.

2.2.3 Data analysis

To analyze butterfly species distribution among altitudes, we used Computer software Palaontological Analysis (PAST) to compute the Shannon-Wiener Index (H) and to plot rarefaction curves. We used Analysis of Variance (ANOVA) to test for variation in species diversity between altitudes and Tukey-HSD to determine specific differences by comparing pair-wise diversity among the altitudes. To compare butterfly species composition between habitat types, we used Bray-Curtis's dissimilarity index. The formula for the Bray-Curtis Dissimilarity Index (BCij) is BCij = 1 (2*Cij) / (Si + Sj) (Bray and Curtis, 1957), where Cij is the total of the least values for the species found in each site, Si is the total number of specimens counted at site I, and Sj is the total number of specimens counted at site j. The Bray-Curtis Dissimilarity ranges between 0 and 1, where 0 shows that the two sites have zero dissimilarity, meaning they share the same number of each type of species. A Bray-Curtis Dissimilarity of 1 indicates that the two sites are dissimilar and do not share any species.

2.3 Results and Discussion

2.3.1 Composition of butterfly species across altitudes

A total of 2091 individual butterflies belong to five (5) Families and 124 species were recorded between November 2021 to February 2022 across three different altitudinal gradients in MPKGR. Among the 124 recorded species, 64 (51.6%) belong to the family Nymphalidae, 26 (20.97%) Pieridae, 18 (14.5%) Lycaenidae, 12 (9.7 %) Papilionidae and the remaining 4 (3.2%) belonged to the family Hesperiidae. The low number of species recorded in MPKGR may be due to the sampling period, which occurred during the dry season (November to February). During this time, many plants were dried up, and although trees and shrubs were present, their deciduous phenology prevented them from being used by butterflies. As a result, this study may have missed out on important species that are more prevalent during the rainy season. This study highlights the presence of two endemic species, *charaxes congdon* and *harpendyreus juno*, in the Livingstone mountains and southern highlands, including the MPKGR area. These species were previously reported in Frontier Tanzania (2003) and Congdon & Bampton (2001).

2.3.2 Species found in a specific altitudinal gradient

Thirty-nine species were recorded from two of the three altitudinal levels either lower and mid altitude, lower and higher altitude, or mid and higher altitude. Thirteen (13) species (10.8%) were found at specific altitudes where four (4) species were observed from lower altitudes, eight (8) mid altitudes, and one (1) species was recorded from higher altitudes. The rest Seventy-two (72) species (58.06% of all the butterfly species were recorded throughout the MPKGR (Table 2.1). This suggests that the environmental and climatic conditions across altitudes are favorable for some species. Vegetation is also a factor that affects butterfly composition across habitats. Conversely, butterfly species that are only observed at specific locations indicate that they have specific requirements for survival at that particular location.

2.3.3 Butterflies' Species diversity across altitudes

Mid-altitude was the most diverse altitude (H= 4.39), and Low-altitude and High-altitude had 4.29 and 4.26 Shannon diversity values respectively. We believe that our butterfly sampling was thorough enough for the time and season of our survey, as the rarefaction extrapolation curves almost reached asymptotes across all altitudes (Figure 2.2). Tukey-HSD was used to test for specific variations and the result showed that variation in butterfly species diversity was between Low-Altitude and High-Altitude ($p < 0.001$) as well as between Mid-Altitude and High-Altitude ($p < 0.001$) However, no significant variation in butterfly species diversity was observed between Mid-Altitude and Low-Altitude ($p > 0.05$). The study revealed that butterfly diversity was higher at mid-altitude. The MPKGR's mid-altitude region provides a diverse range of vegetation types such as miombo woodland, Afromontane Forest, and riverine forest. The presence of those kinds of vegetation may offer abundant resources for butterfly foraging and reproduction as explained by Rija (2022). On the other hand, higher altitude regions in the MPKGR, comprised of bushland and grassland vegetation, could limit food and microclimate availability, resulting in lower butterfly diversity. Studies have shown that altitude affects species composition and diversity, with a point beyond which increasing altitude leads to a decrease in species diversity (Thomas, 2005). The variation found in species composition between altitudes originates from the presence of food and other requirements which are modified along the altitudinal gradient (Eleanor *et al*., 2015). It is common for some insects, particularly butterflies, to gather at elevated locations such as hilltops, ridges, and cliffs. This behavior is observed in *Hesperidae, Lycaenidae*, and *Papilinoidea,* which possess strong wings that allow them to reach higher elevations (Liseki & Van-Wright, 2014, Liseki & Van-Wright, 2016). The optimal ecological conditions for butterfly survival and reproduction are met at mid-altitude, as evidenced by the higher species diversity value described by Mtui (2019). Several hypotheses have been explained that species diversity tends to increase with the increase in altitude and reach a point where the increase in altitude decreases the species diversity (Edge & Mecenero, 2015, Lee *et al.,* 2020).

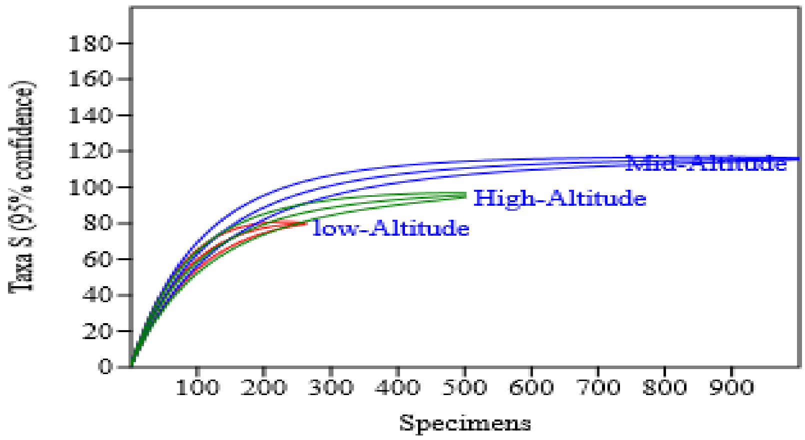

Figure 2.2: The size-based rarefaction and extrapolation curves show the species richness across altitudes, with the inner line representing interpolation and the outer line representing the 95% confidence intervals

2.4 Conclusion

It is important to understand how altitude and habitat factors affect butterfly species composition and diversity in Mpanga Kipengere Game Reserve for the conservation of indicator species. Our findings indicate that there are significant differences in species diversity across altitudinal gradients, with higher diversity at the mid-altitude. However, there is no significant difference in species composition and diversity between habitats. Altitude is the main factor influencing the observed variation, not habitat types. Two species, *Charaxes condonii* and *Hapendyreus juno,* are endemic to the study area or represent an extension of the range of southern highlands mountains. The presence of endemic species shows that MPKGR is important for conservation. Some species are observed throughout the MPKGR, while others are only found in specific altitudinal levels. Species specific to certain altitudinal levels serve as ecological indicators since they are favored by the environmental conditions of those locations (Davros, 2006, Dino, 2016). Our findings may help formulate conservation plans to sustain butterfly species composition and diversity in the Southern Highlands of Tanzania and similar ecosystems elsewhere. There is currently no effective population monitoring system to track changes in the butterfly community, making the study's findings valuable for MPKGR management in future conservation planning and ecological monitoring. It is recommended that future studies investigate how individual butterfly species are influenced by environmental factors, which would provide insight into species-specific needs to improve conservation efforts in the MPKGR.

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We would like to express our sincere gratitude to the Conservation Commissioner of Tanzania Wildlife Management Authority (TAWA) and the Management of Mpanga Kipengere Game Reserve for permitting us to conduct field surveys at the reserve and for their invaluable support during our work. We also extend our thanks to Leonard Nsajigwa and Enock Kimayani for their assistance in the field, as well as Mr. Abraham Mulokozi and Malila for their contributions to the data analysis.

Conflict of Interest

We declare that we do not have any conflict of interest in connection with the work submitted.

Data Availability Statement

Data will be available upon the request of the corresponding author.

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APENDICES

Apendix 2.1: A checklist of butterflies of Mpanga Kipengere Game Reserve

(Abbreviations for altitude: LMU= lower, Mid and Upper altitude, LM= lower & Mid altitude, LU= Lower & Upper altitude, M= Mid altitude, L=lower altitude and U= Upper altitude), (Abbreviation for habitats A=Afro Montane Forest, B=Bushland, M=Miombo woodland, R=Riverine Forest

S/N	Family/Species	Common name	Location (Altitude)	Habitat of occurrence
	Hesperiidae			
1	*Acada biceriatus*	Axehead skipper	LMU	ABMR
2	*Calleagris jamesoni*	Jamesoni's skipper	LMU	BM
3	*Spialia dromus*	Forest sandman	LMU	BR
4	*Spialia spio spio*	Mountain sandman	LMU	BMR
	Lycaenidae			
5	*Actizera lucida*	Rayed blue	LMU	ABMR
6	*Anthene lunulata*	Red spot scarlet	LMU	ABMR
7	*Azanus isis*	White-banded babul blue	LMU	ABMR
8	*Azanus ubaldus*	Desert blue	LMU	ABMR
9	*Cacyreus lingeus*	Common bush blue	LMU	ABMR
10	*Cacyreus palemon palemon*	*Geranium blue*	LU	ABMR
11	*Cacyreus viritis*	*Eastern bush blue*	LMU	ABMR
12	*Euchrysops malathana*	Common smoky blue	M	AMR
13	*Euchrysops subpallida*	Ashen smoky blue	LMU	ABMR
14	*Harpendyreus juno*		MU	ABR
15	*Harpendyreus major*		LU	AMR
16	*Lepidochrysops desmond*		LM	ABR
17	*Lepidochrysops neonegus*		LMU	ABMR
18	*Lepidochrysops persimon*	Persimon	M	BMR
19	*Lepidochrysops polydialecta*		LMU	AMR
20	*Leptotes pirthous*	Common zebra blue	LMU	ABMR
21	*Lolaus crawshayi*	Crawshay's saphire	LMU	ABMR
22	Lycaena phlaeas	Small coppers	M	ABMR
23	*Acraea acerata*		LMU	ABMR

S/N	Family/Species	Common name	Location (Altitude)	Habitat of occurrence
24	*Acraea alicia*		LMU	ABMR
25	*Acraea enemosa*		LMU	ABMR
26	*Acraea eponia eponia*	Dancing acraea	L	AMR
27	*Acraea esebria*		LMU	ABMR
28	*Acraea jodutta jodutta*		LMU	ABMR
29	*Acraea leocopyga*		LMU	ABMR
30	Acraea macarista macarista		MU	MR
31	*Acraea penelope*		LMU	ABMR
32	*Acraea perenna*		LMU	ABMR
33	*Acraea pharsalus*		LMU	BM
34	*Acraea pudorina*		LMU	ABMR
35	Acraea serena		LU	ABR
36	*Acraea servona*		M	AB
37	*Acraea sotikensis*	Sotik acraea	LMU	AMR
38	*Amauris echeria*		LMU	ABMR
39	*Amauris eliot*	Ansorge's danaid	LU	AR
40	*Antanartia abyssinica jacksoni*		LMU	AMR
41	*Antanartia dimorphica*	*Dimorphic admiral*	LMU	ABMR
42	*Bebearia cocalia orientis*	Spectre	LMU	ABMR
43	*Bebearia orientis*		LMU	ABMR
44	*Bicyclus compus*		LU	BM
45	*Bicyclus cottrelli*	Bush brown	LMU	ABMR
46	*Bicyclus safitza safitza*		LMU	ABMR
47	*Byblia anvatara acheloia*		MU	BMR
48	Charaxes berkeyi		LMU	ABMR
49	*Charaxes bohemani*		LM	ABM
50	*Charaxes brutus*		LMU	ABMR
51	*Charaxes Candiope candiope*		M	AM
52	*Charaxes cithaeron*		LM	AMR
53	*Charaxes condonii*		LM	BMR
54	*Charaxes elesipe gordoni*	*Savannah charaxes*	L	BM
55	*Charaxes ethalion*	*Satyr charaxes*	MU	ABR
56	*Charaxes gudeliana rabeiensis*	*Blue spangled charaxes*	L	AR
57	*Charaxes jusius*	*Foxy Charaxes*	LM	BMR
58	*Charaxes kirki*	*Kirki's charaxes*	M	AMR
59	*Charaxes paphianus*	Falcate red charaxes	MU	MR
60	*Charaxes pollux pollux*	*Black-bordered charaxes*	M	BMR

S/N	Family/Species	Common name	Location (Altitude)	Habitat of occurrence
61	Charaxes protoclea azota	Flame bordered charaxes	LM	BMR
62	*Danaus chrysippus aegyptius*	*African queen*	LMU	ABMR
63	*Eurytela dryope angulata*	Golden piper	LMU	ABMR
64	*Hamanumida daedalus*	Guineafowl	M	ABR
65	*Junonia hierta cebrene*	Yellow pansy	LM	ABR
66	*Junonia artaxia*	Commodore/African pansy	LMU	ABMR
67	*Junonia natalica natalica*	Natal pansy	LMU	ABMR
68	*Junonia oenone oenone*	Dark blue pansy	LMU	ABMR
69	*Junonia orithya madagascariensis*	Blue pansy	LMU	ABMR
70	*Neocoenyra heckmanni*	*Fritillary*	LM	ABMR
71	*Neptis kiriakoff*	Kiriakoff's sailor	LMU	ABMR
72	*Neptis morosa*	Savannah sailor	MU	ABR
73	*Neptis pennington*	Penningtony's sailor	MU	ABM
74	*Neptis saclava marpessa*	Small spotted sailor	LM	ABR
75	*Neptis serena serena*	River sailor	LMU	ABMR
76	*Phatanta phatanta aethiopica*	Common leopard fritillary	U	AR
77	*Precis actia*	Air commodore	LMU	ABMR
78	*Precis antilope*	Darker commodore	LMU	ABMR
79	*Precis ceryne ceryne*	Mash commodore	LMU	ABMR
80	*Precis octavia sesamus*	Gaudy commodore	LM	ABR
81	*Precis pelarga actia*	Fashion commodore	LMU	ABM
82	*Precis tugela*	Eared commodore	LM	ABMR
83	*Pseudacraea boisduvali*	Trimens's false acraea	LM	BMR
84	*Pseudacraea lucretia expansa*	False chief	MU	AMR
85	*Salamis anacardii*	Clouded mother of pearl	LM	AMR
86	*Vanessa cardui cardui*	Painted lady	LU	ABM

S/N	Family/Species	Common name	Location (Altitude)	Habitat of occurrence
	Papilionidae			
87	*Graphium antheus*	Large striped swordtail	LMU	ABMR
88	*Graphium colonna*	Black swordtail	LMU	ABMR
89	*Graphium leonidas leonidas*	Veined swordtail	MU	ABMR
90	*Graphium policene*	Small striped swordtail	LMU	ABMR
91	*Papilio bromius chrapkowskii*		LMU	ABMR
92	*Papilio demodocus demodocus*	Citrus swallowtail	LMU	ABMR
93	*Papilio desmondi teita*		MU	ABR
94	*Papilio horniman*	Hornimani's swallowtail	LMU	ABMR
95	*Papilio lormieri*	Central emperor swallowtail	LMU	ABMR
96	*Papilio ophidicephalus*	Emperor swallowtail	LMU	AM
97	*Papilio phorcas*	Green banded swallowtail	LMU	ABMR
	Pieridae			
98	*Appias sabina*		LMU	ABMR
99	*Belenois aurota*	Caper white	LM	BM
100	*Belenois creona*	African caper white	LMU	ABM
101	*Belenois gidica*	African veined white	LM	AMR
102	*Belenois zochalia agrippinides*	Forest caper white	LMU	ABMR
103	*Colias electo pseudohecate*	African clouded yellow	LM	AM
104	*Colotis amantus amantus*	Small salmon arab	LMU	ABMR
105	*Colotis antevipe zera*	Large orange tip	LMU	ABMR
106	*Colotis auxo incretus*	Yellow orange tip	LM	ABMR
107	*Colotis eris eris*	Banded gold tip	LMU	ABMR
108	*Colotis evagore antigone*	Tiny orange tip	MU	ABR
109	Colotis evenina	Common orange tip	MU	ABMR
110	*Colotis hataera*		LMU	ABMR
111	*Colotis regina*	Regal purple tip	LMU	ABMR
112	*Colotis vesta*	Veined golden arab	LMU	ABMR
113	*Eronia leda*	Orange and lemon	LMU	ABMR
114	*Eurema brigitta brigitta*	Small grass yellow	LMU	ABMR
115	*Eurema desjardinsii*	Angeled grass yellow	LMU	ABMR
116	*Eurema hecabe solifera*	Common grass yellow	L	BM
117	*Eurema hepale*	Maarsh grass yellow	LMU	ABMR

S/N	Family/Species	Common name	Location (Altitude)	Habitat of occurrence
	Papilionidae			
119	*Eurema senegalensis*	Forest green yellow	LU	BMR
120	*Eurema upembana*	Mountain grass yellow	LMU	ABMR
121	Leptosia hybrida		LMU	ABMR
122	*Mylothris agathina*	Eastern dotted border	MU	AMR
123	Mylothris sagala	Dusky dotted border	LM	BMR
124	*Nepheronia thalassina*	Blue vagrant	LM	ABM

CHAPTER THREE

Paper One

Impacts of Human Activities and Season on Species Diversity and Abundance of Butterflies in Mpanga Kipengere Game Reserve and Surrounding Farmlands, Tanzania

Privatus M. Kasisi [1], Dr. Nsajigwa Mbije[2] Dr. Paul Lyimo[1]*

[1]Departiment of Ecosystem Science and Management, College of Forest, Wildlife and Tourism, Sokoine University of Agriculture, P.O Box 3000 SUA-Morogoro, Tanzania

[2]Departiment of Wildlife Management, College of Forest, Wildlife and Tourism, Sokoine University of Agriculture, P.O Box 3000 SUA-Morogoro, Tanzania

******Corresponding author e-mail address:* ***privawapili@yahoo.com***
Co-author e-mail address: ***mbije@sua.ac.tz, paulo.lyimo@sua.ac.tz***

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Impacts of Human Activities and Season on Species Diversity and Abundance of Butterflies in Mpanga Kipengere Game Reserve and Surrounding Farmlands, Tanzania

Privatus M. Kasisi[1*], Nsajigwa Mbije[2], Paul Lyimo[1]

[1]Department of Ecosystem Science and Management, College of Forest, Wildlife and Tourism, Sokoine University of Agriculture, Morogoro, Tanzania
[2]Department of Wildlife Management, College of Forest, Wildlife and Tourism, Sokoine University of Agriculture, Morogoro, Tanzania
Email: *privawapili@yahoo.com, mbije@sua.ac.tz, paulo.lyimo@sua.ac.tz

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Abstract

Maintaining natural habitats is crucial for the preservation of insects and other species that indicate environmental changes. However, the Mpanga/Kipengere Game Reserve and its surrounding farmlands are facing disturbance due to human activities, which is putting many wildlife species, particularly larger mammals, at risk. To determine the impact of human activities on butterfly species diversity and abundance in the reserve and its surrounding areas, we conducted a study from November 2021 to October 2023. We collected butterfly data using transect walks and baited traps in two habitat types. Our study yielded 2799 butterfly Individuals ranging in 124 species divided into five families habitat, season, and anthropogenic factors are significant environmental variables influencing species diversity and abundance of butterflies. Therefore, it's important to protect habitat and dry-season water for the conservation of invertebrates such as butterflies. Our study findings provide essential information for ecological monitoring and future assessment of the Mpanga/Kipengere Game Reserve ecosystem health.

Keywords

Mpanga Kipengere Game Reserve, Species Diversity, Habitat, Butterflies, Season, Human Activities

1. Introduction

Identifying high-value sites based on their biodiversity content is a crucial aspect of any conservation strategy [1]. Unfortunately, in recent years, human activity has put increasing pressure on biodiversity, posing challenges for biologists dealing with anthropogenic disturbances [2] [3]. Human activities are known to cause environmental changes that have adverse effects on plants and animal species in protected areas [4] [5]. Human activities that cause disturbances in natural areas can have a direct impact on important species' needs, such as food, cover, and nesting sites, according to [6]. Among these species, butterflies are known to be particularly sensitive to environmental changes, as noted by [2] [7]. Natural habitats play a crucial role in the conservation of insects and other arthropods, providing them with essential elements like food, shelter, and nectar [8] [9] [10]. When natural ecosystems are disrupted, it can have negative consequences for plants and animal species [11]. Insects, as a major taxonomic group, have been particularly impacted, exemplifying these challenges [12] [13].

The Mpanga Kipengere Game Reserve (MPKGR) is known for its rich biodiversity and high levels of endemism in both flora and fauna [14]. To effectively conserve this biodiversity, it is necessary to have a broad understanding of the classification, distribution, and biogeography of various indicator species [11] [15]. Among these, butterflies are considered a prime group for such assessments [16] as they can provide valuable information on environmental changes and help monitor and assess ecosystem health [13] [17] [18] However, the only available information on the butterflies in MPKGR is from a biodiversity survey conducted by Frontier Tanzania in collaboration with the University of Dar es Salaam and WWF back in 2003. Previous research has mostly focused on vertebrate species in the area, with little attention given to invertebrates beyond the game reserve where human activities take place.

To gain a better understanding of the diversity patterns of invertebrate species in different areas with varying conservation designations, it is essential to gather more data on a wider range of taxa [19] [20]. This will provide valuable insight into effective biodiversity management on a larger scale. By establishing a baseline for future monitoring, we can work towards preserving the biodiversity in this ecosystem, which has been impacted by human activities. Therefore, this study was conducted to provide valuable information to MPKGR Management regarding butterfly conservation, ecological monitoring, and ecosystem health assessment. Its objectives were to:

1) Evaluate the impact of human activities on butterfly species diversity and abundance in both MPKGR and adjacent farmlands.

2) Analyze the occurrence and seasonal variations of butterflies in MPKGR and compare them to those in adjacent Farmlands.

The study's hypothesis is that butterfly species composition and diversity will differ between natural and disturbed habitats during various seasons.

2. Material and Method

2.1. Study Area

The Mpanga Kipengere Game Reserve (MPKGR) is situated in the Southern

Highlands within Wanging'ombe and Makete districts of the Njombe Region, as well as the Mbarali District in the Mbeya Region. Its latitude ranges from 8˚50' to 9˚10' South, while its longitude ranges from 34˚00' to 34˚30' East. The reserve is surrounded by 24 villages, which are divided into five divisions: Wanging'ombe (7 villages), Imalinyi (3 villages), Ikuwo (9 villages), Lupalilo (1 village), and Rujewa (4 villages). To reach the reserve, one can use road, railway, or air transportation as it is located near Mbeya (135 km) to the southwest, Njombe (80 km) to the southeast, and Iringa (195 km) to the northeast. Other towns such as Makambako, Ilembula, Igawa, and Chimala are also nearby and are experiencing rapid growth. The rainfall distribution in MPKGR is greatest at higher altitudes and is peaking between March and May [21]. Rainfall is greatest in the southeast of the mountains, increasing from 1200 mm annually in the foothills to over 2300 mm at higher altitudes [21]. The dry season occurs from June to August and the wet season starts from November to May. The vegetation of these forests' ranges includes lowland forests at 300 m on the Eastern side, sub-montane forests, and montane forests (Figure 1).

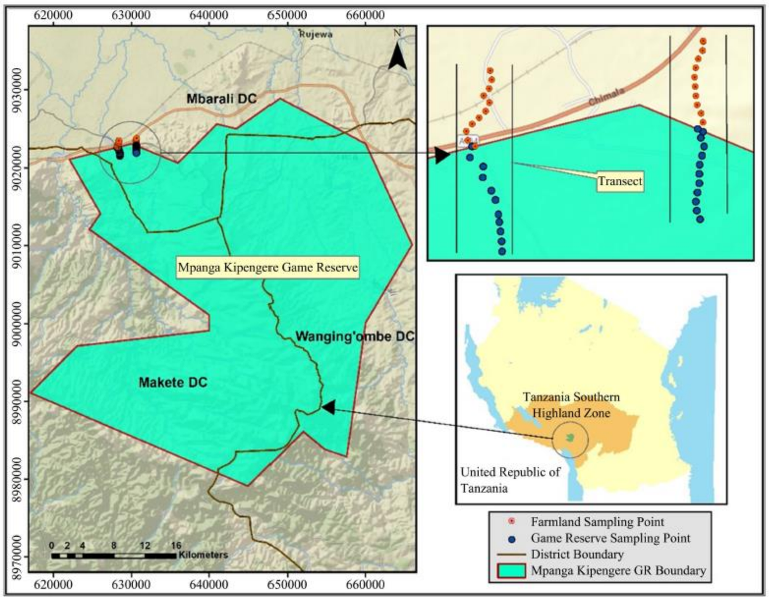

Figure 1. Map of Mpanga Kipengere Game Reserve showing location, districts, transects, and sampling points along MPKGR and adjacent Farmlands.

2.2. Sampling Design and Data Collection

For the study, two transects measuring 1000 m each were created. One-half of each transect spanned 500 m inside the MPKGR while the other half extended 500 m into adjacent farmlands. Within each transect, 20 sampling points with 50-meter distance from one point to another were established, and the study period lasted for 12 consecutive months, from November 2021 to October 2022. During this time, butterflies were sampled for 10 days each month, during two time slots: 9:00-11:00 am and 3:00-5:00 pm. The sampling methodology outlined by [14] was followed, and two methods were employed to collect butterfly samples: baited traps and sweep nets.

2.3. Data Collection

Field data sampling

To catch butterflies attracted to fermenting fruit, we used traps baited with fermented bananas. We followed the process described by [22] [23] and constructed the traps from local materials based on the Van Someren-Raydon Trap design [24]. The bait was made by mashing ripe bananas and pineapples and then allowing them to ferment for three days. We placed traps at the center of each sampling point, 100 meters apart. Regular checks were performed, and the number of butterflies caught was recorded as individuals per trap per day.

To collect butterflies from areas where traps couldn't be placed easily, we used sweep nets based on the methodology outlined by [25]. We spotted flying butterflies along the transect or around the traps and caught them using the nets. Once collected, we identified each butterfly species using the key described by [17] and counted them. For harder-to-identify individuals, we took photos since we couldn't remove them from the Game reserve. These photos were then shared with butterfly taxonomists to confirm their identification.

Environmental data

To comprehend the impact of environmental factors on species richness, abundance, and community composition, we obtained data on annual temperature, mean annual precipitation, and solar radiation from (https://weatherandclimate.com/tanzania/njombe/kipengere#t3). Furthermore, we recorded the type of habitat at all sampling points. Topographic factors including elevation, slope, and aspect were extracted from the raster layer derived from the SRTM 30 m-based DEM-USGS Earth Explorer (https://earthexplorer.usgs.gov/).

2.4. Data Analysis

To compute variations between habitats (MPKGR and Farmlands) and seasons (Dry and Wet) we calculate their butterfly species abundance, diversity, richness, and evenness. In determining the species richness and abundance of butterflies, a species checklist was created. This checklist consisted of four variables: the name of the butterfly species, its family, the number of individuals counted, and its habitat and season of occurrence. Jaccard's Similarity Index was used to measure similarities of butterfly species diversity between MPKGR and Farmlands. The formula for Jaccard's Index was $J(A, B) = |A \cap B|/|A \cup B|$ where the Jaccard's Similarity Index value is 1 indicates that two datasets share the same members, and if there are no common members then the Jaccard Similarity Index will be 0.

Computer software Palaontological Analysis (PAST) was used to compute the Shannon Wiener Diversity Index (H) and to plot rarefaction interpolation and extrapolation curves to ensure that the sample size we use is enough and Pielou's evenness index to compare butterfly species distribution between MPKGR and Farmlands. The formula for the Shannon index $H = -\Sigma [(pi)*\log(pi)]$ (Shannon-Wiener, 1949) was used where; Pi is a proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of calculations and s is the number of species while Pielou's Index formula was $J = H'/\ln(S)$ where H' is Shannon Weiner diversity and S is the total number of species in a sample, across all samples in a dataset. Indicator species analysis was performed to identify significant dominant species of the butterflies' communities, using the computer software PAST.

3. Results

3.1. Butterflies' Community Composition Diversity, Richness, and Abundance

In our study, we documented 124 butterfly species from five Lepidoptera families (Nymphalidae, Pieridae, Lycaenidae, Hesperiidae, and Papilionidae), with a total of 2799 individuals observed. *Neptis morosa* was observed to be the most dominant of all species with a total abundance of 0.03358 whereas *Pseudacraea lucretia expansa* were the most dominant species of all individuals recorded in farmlands (**Appendix**). Shannon wiener diversity index indicates that MPKGR is more diverse (H = 4.49) compared to Farmlands (Figure 2). Butterfly species in MPKGR and Farmlands have even distribution according to Pielou's evenness index, with values of 0.947 and 0.91 respectively. Additionally, the results reveal that both habitats share most of the same species, as the Jaccard's Index value calculated was 0.629.

3.2. Species Found in Specific Habitat

A total of 124 butterfly species (MPKGR-110 and Farmland-92) were observed, whereby 78 butterfly species, which account for 62.9% of all recorded species, were observed in both MPKGR and Farmlands. Out of these, 32 species (25.8%) were only seen in MPKGR, while 14 species (11.29%) were exclusive to Farmlands. The family Nymphalidae accounted for the majority of species observed in both locations. Most of the butterfly species observed to be specific in either MPKGR or Farmlands belong to the families Lycaenidae, Pieridae and Nympharidae (**Appendix**). We believe that our butterfly sampling was thorough enough for the time and season of our survey, as the rarefaction extrapolation curves almost reached asymptotes in both MPKGR and farmlands (Figure 3).

Additionally, the rarefaction and extrapolation curves based on coverage percentage suggested that the diversity in our study region was well-represented with a sample coverage percentage above 95% as shown in (Figure 4).

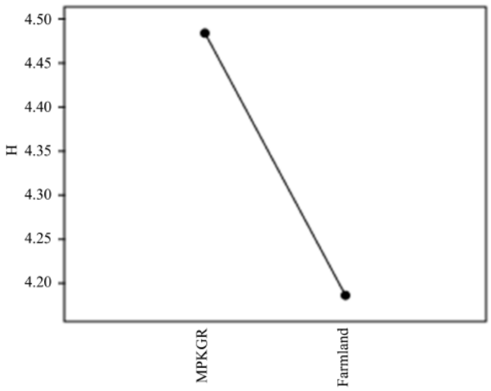

Figure 2. Shannon wiener diversity index (H) computed from Computer software Palaontological Analysis (PAST). The result indicates the diversity is higher in MPKGR compared with Farmlands.

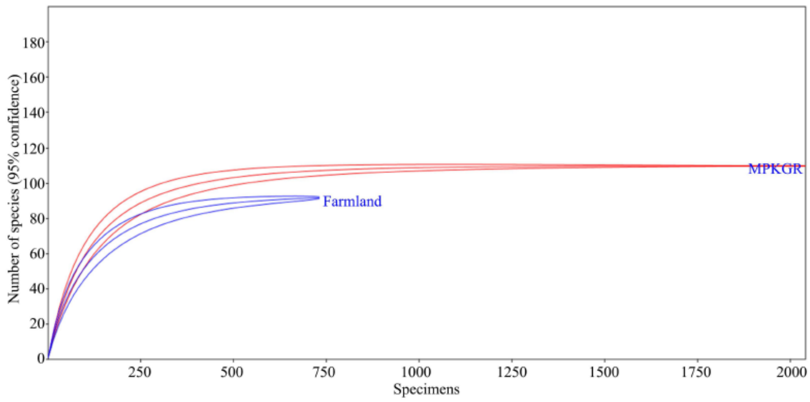

Figure 3. The size-based rarefaction and extrapolation curves show the species richness at MPKGR and adjacent Farmlands, with the inner line representing interpolation and the outer line representing the 95% confidence intervals.

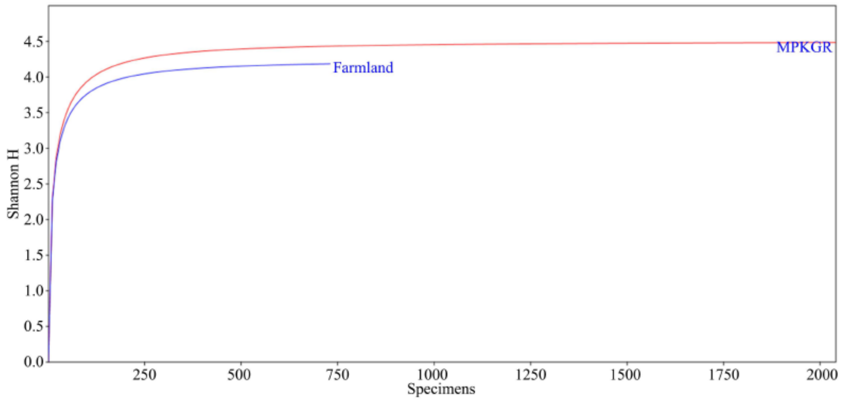

Figure 4. The rarefaction and extrapolation curves based on size display butterfly diversity and sample representation at MPKGR and adjacent Farmlands with 95% confidence intervals.

3.3. Seasonal Variations and Monthly Occurrences of Butterflies

According to the results, the month of April during the rainy season had the highest number of species (96) with a total of 524 individuals making up 77% and 18%, respectively of all species and individuals collected. The average temperature and rainfall were recorded at 26.44˚C and 6.7 mm. On the other hand, during the dry season in September, the number of species dropped to 39 (31.45%) with only 146 individuals (5.22%). The average temperature and rainfall were reported at 24.94˚C and 0.02 mm, respectively (Table 1).

3.4. Indicator Species and Endemic Species

We have identified a total of 9 butterfly species that serve as indicators for both MPKGR and Farmland. Of these 9, 6 species (*Neptis morosa*, *Neptis serena serena*, *Colotis antevipe zera*, *Colotis auxo incretus*, *Azanus ubaldus*, *Graphium antheus*) are considered generalists as they can be found throughout the year in both habitats. The remaining 3 species are specific to their respective habitats and can only be found during the wet season. These species are *Acraea servona*, *Pseudacraea lucretia expansa*, and *Acraea pudorina*. This study also observes the presence of two endemic species, *Charaxes congdoni* and *Harpendyreus juno* which are endemic to the southern highlands, including the MPKGR area.

4. Discussion

Species diversity and abundance

Our findings indicate that MPKGR recorded a significantly larger diversity and abundance of butterflies than the adjacent Farmlands. The reason behind the high number of individual and species of butterflies observed in Mpanga

Table 1. Monthly occurrence of butterfly species in relation to the influence of temperature and rainfall.

Month	Number of species	% of Species	Number of counts	% of count	Average temperature (˚C)	Average Rainfall (mm)
January	45	36.29	163	5.82	26.73	17.94
February	56	45.16	209	7.47	26.19	17.72
March	71	57.26	473	16.90	25.59	20.13
April	96	77.42	524	18.72	26.44	6.7
May	68	54.84	286	10.22	25.87	1.23
June	53	42.74	198	7.07	16.51	0.51
July	49	39.52	172	6.15	15.63	0.37
August	47	37.90	164	5.86	17.22	0.02
September	39	31.45	146	5.22	24.94	0.02
October	41	33.06	147	5.25	27.49	0.23
November	43	34.68	151	5.39	28.22	0.65
December	39	31.45	166	5.93	26.69	10.66

Kipengere Game Reserve could be due to the miombo woodland present there, as opposed to the cultivated areas in the Farmlands. This suggests that woodland and wooded grassland habitats may provide a better quality of life for butterflies as explained by [26] [27]. These qualities include the availability of larval host plants and food resources in these habitats [28] [29]. Additionally, the low abundance and species richness recorded in the Farmlands could be attributed to the habitat disturbance caused by human activities like tree cutting [30] [31] [32]. Such habitat disturbances directly remove the required conditions for butterfly breeding, thus affecting their overall abundance and richness [33] [34].

Species found in specific habitat

A total of 78 butterfly species, which account for 62.9% of all recorded species, were observed in both MPKGR and Farmlands. Out of these, 32 species (25.8%) were only seen in MPKGR, while 14 species (11.29%) were exclusive to Farmlands. The family Nymphalidae accounted for the majority of species observed in both locations. Most of the butterfly species observed to be specific in either MPKGR or Farmlands belong to the families Lycaenidae, Pieridae and Nympharidae (**Appendix**) This suggests that the environmental and climatic conditions in both habitats are favorable for some species. Vegetation is also a factor that affects butterfly composition across habitats. Conversely, butterfly species that are only observed at specific locations indicate that they have specific requirements for survival at that particular location [17] [29].

Seasonal variation and Temporal occurrence of butterfly

During the wet season (January to June), there is a significant increase in butterfly species diversity compared to the dry season. In MPKGR, there is a small number of species recorded during the dry season (July to December) which may be due to environmental conditions. During this season, most of the plants are dry and affected by the dry conditions. Although trees and shrubs are present, many of them cannot be used by butterflies due to their deciduous phenology.

The study noticed a seasonal population fluctuation as there were more butterflies during February, March, April, and May, but fewer during June to December. Research has indicated that seasons play a role in influencing the quantity and variety of insects present. It is also revealed that during the transition from short to long rains (January to March), we observed a higher number of butterfly species and a greater abundance of them than during the long to short rains transition that is April to June (Figure 5) These findings align with previous research conducted on Kihansi gorge, which found that butterfly species richness and abundance were higher during the dry season compared to other seasons [23].

The months of June and July are the coldest in Mpanga Kipengere and adjacent farmlands, with maximum temperatures around 16˚C (Table 1 and Figure 6). Additionally, from June to mid or late October, a dry season occurs in the reserve which can result in scarce butterfly food. These cold conditions and low food availability may have contributed to poor detection or resulted in lower numbers of Hesperiids, Lycaenids, and Pierids in the reserve and surrounding farmlands. The Nymphalidae is currently the largest butterfly family in Tanzania, with 657 species [24] [25] and therefore has the highest occurrence throughout the year compared to other butterfly families (**Appendix**).

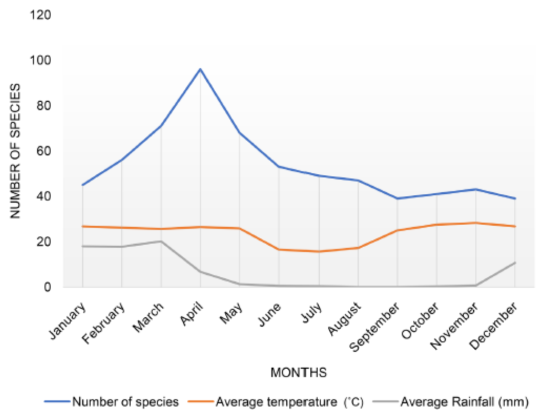

Figure 5. Butterfly species observed each month in MPKGR and adjacent Farmlands during the wet season (January-June) and dry season (July-December).

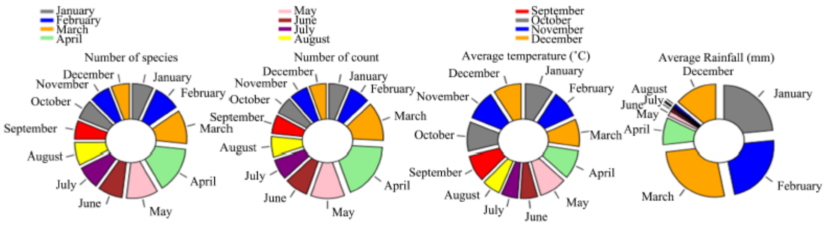

Figure 6. Show the butterfly species and individual counts in relation to climatic variables (temperature and rainfall).

Indicator Species and endemic species

It is crucial to identify a set of indicator species for long-term environmental monitoring in conservation and biodiversity management [35] [36] [37]. We have discovered 9 indicator butterfly species that are associated with different habitat quality in the ecologically sensitive areas. These species can be helpful for future monitoring and assessment of biodiversity in the area. The majority of these indicator species are habitat generalists and polyphagous, while a few are habitat specialists, monophagous, and have a small wingspan, such as *Euryphula concordia*, *Colotis danae*, and *Neptis jordani*. This suggests that they have limited dispersal ability and are highly dependent on specific habitats that may only occur in certain environmental conditions, as observed in previous studies [38] [39]. Furthermore, studies have shown that the plant-abundance relationship is strongest for butterfly species that are habitat specialists, monophagous, and less mobile, as reported by [40] [41]. This study highlights the presence of two endemic species, *Charaxes congdoni* and *Harpendyreus juno*, in the Livingstone mountains and southern highlands, including the MPKGR area as previously reported by [21] [42]. Their existence in this region underscores the significance of MPKGR as a crucial area for biodiversity preservation.

5. Conclusion

Understanding the impacts of human activities and seasonal variations on species diversity and the abundance of butterflies in an ecosystem is important to inform the conservation of existing Game Reserves. Our findings suggest that there is a significant difference in butterfly diversity and abundance between MPKGR and adjacent farmlands with higher diversity in MPKGR where the land is free from anthropogenic disturbance. The large and significant variation in butterfly diversity and species community explained by anthropogenic and environmental factors suggests a need for conservation plans for the natural habitats of MPKGR which is under threat from anthropogenic disturbance from adjacent farmlands. The butterfly species that were specific to certain locations may serve as ecological indicators because they appear to be favored by the environmental conditions of those locations. Future studies looking into how various individual butterfly species are influenced by the available qualities of the habitats will be necessary in generating information that will be useful in identifying species-specific needs for improving the conservation of the butterfly community in MPKGR. This study reveals that Southern Highlands, including the MPKGR area, is home to two unique species, *Charaxes congdoni* and *Harpendyreus juno*. Their presence in this region emphasizes the importance of MPKGR as a critical area for conserving biodiversity. We need further research to determine how the anthropogenic activities on the farmlands could be affecting the diversity and abundance of these indicator species in MPKGR which has already recorded the extinction of large mammals in the recent decade due to human development activities.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix

Table A1. Abundance, species richness, and species occurrence in specific habitat *i.e.*, in MPKGR, Farmlands, or both. The abbreviation GR-Represent species recorded from MPKGR only, FL-Represent species recorded from farmlands only, and GR + FL-Represent species found in both MPKGR and Farmlands.

Species	Family	MPKGR Count	Abundance MPKGR	Farmland Count	Abundance Farmland	Total Count	Total Abundance	Uniqueness
Graphium colonna	Papilionidae	2	0.00097	0	0.00000	2	0.00071	GR
Lepidochrysops polydialecta	Lycaenidae	4	0.00194	0	0.00000	4	0.00143	GR
Bicyclus compus	Nymphalidae	0	0.00000	4	0.00540	4	0.00143	FL
Charaxes congdoni	Nymphalidae	0	0.00000	5	0.00675	5	0.00179	FL
Vanessa cardui cardui	Nymphalidae	5	0.00243	0	0.00000	5	0.00179	GR
Harpendyreus juno	Lycaenidae	6	0.00292	0	0.00000	6	0.00214	GR
Harpendyreus major	Lycaenidae	3	0.00146	3	0.00405	6	0.00214	GR + FL
Lepidochrysops desmond	Lycaenidae	6	0.00292	0	0.00000	6	0.00214	GR
Eurema upembana	Pieridae	6	0.00292	0	0.00000	6	0.00214	GR
Acraea leocopyga	Nymphalidae	5	0.00243	2	0.00270	7	0.00250	GR + FL
Charaxes berkeyi	Nymphalidae	4	0.00194	3	0.00405	7	0.00250	GR + FL
Neptis kiriakoff	Nymphalidae	3	0.00146	4	0.00540	7	0.00250	GR + FL
Anthene lunulata	Lycaenidae	8	0.00389	0	0.00000	8	0.00286	GR
Charaxes paphianus	Nymphalidae	4	0.00194	4	0.00540	8	0.00286	GR + FL
Charaxes pollux pollux	Nymphalidae	8	0.00389	0	0.00000	8	0.00286	GR
Neocoenyra heckmanni	Nymphalidae	8	0.00389	0	0.00000	8	0.00286	GR
Precis octavia sesamus	Nymphalidae	8	0.00389	0	0.00000	8	0.00286	GR
Calleagris jamesoni	Hesperiidae	9	0.00437	0	0.00000	9	0.00322	GR
Belenois zochalia agrippinides	Pieridae	0	0.00000	9	0.01215	9	0.00322	FL
Spialia spio spio	Hesperiidae	10	0.00486	0	0.00000	10	0.00357	GR
Bicyclus safitza safitza	Nymphalidae	7	0.00340	3	0.00405	10	0.00357	GR + FL
Papilio bromius chrapkowskii	Papilionidae	8	0.00389	2	0.00270	10	0.00357	GR + FL
Bicyclus cottrelli	Nymphalidae	6	0.00292	5	0.00675	11	0.00393	GR + FL
Precis tugela	Nymphalidae	11	0.00534	0	0.00000	11	0.00393	GR
Colotis regina	Pieridae	8	0.00389	3	0.00405	11	0.00393	GR + FL
Lolaus crawshayi	Lycaenidae	12	0.00583	0	0.00000	12	0.00429	GR
Acraea alicia	Nymphalidae	12	0.00583	0	0.00000	12	0.00429	GR
Acraea esebria	Nymphalidae	11	0.00534	1	0.00135	12	0.00429	GR + FL
Acraea pharsalus	Nymphalidae	9	0.00437	3	0.00405	12	0.00429	GR + FL
Byblia anvatara acheloia	Nymphalidae	12	0.00583	0	0.00000	12	0.00429	GR

Continued

Charaxes Candiope candiope	Nymphalidae	12	0.00583	0	0.00000	12	0.00429	GR
Charaxes jusius	Nymphalidae	11	0.00534	1	0.00135	12	0.00429	GR + FL
Belenois gidica	Pieridae	9	0.00437	3	0.00405	12	0.00429	GR + FL
Cacyreus lingeus	Lycaenidae	9	0.00437	4	0.00540	13	0.00464	GR + FL
Bebearia cocalia orientis	Nymphalidae	13	0.00632	0	0.00000	13	0.00464	GR
Charaxes bohemani	Nymphalidae	13	0.00632	0	0.00000	13	0.00464	GR
Charaxes gudeliana rabeiensis	Nymphalidae	7	0.00340	6	0.00810	13	0.00464	GR + FL
Papilio phorcas	Papilionidae	12	0.00583	1	0.00135	13	0.00464	GR + FL
Spialia dromus	Hesperiidae	14	0.00680	0	0.00000	14	0.00500	GR
Lepidochrysops neonegus	Lycaenidae	8	0.00389	6	0.00810	14	0.00500	GR + FL
Leptotes pirthous	Lycaenidae	0	0.00000	14	0.01889	14	0.00500	FL
Acraea macarista macarista	Nymphalidae	8	0.00389	6	0.00810	14	0.00500	GR + FL
Bebearia orientis	Nymphalidae	14	0.00680	0	0.00000	14	0.00500	GR
Acraea enemosa	Nymphalidae	8	0.00389	7	0.00945	15	0.00536	GR + FL
Acraea eponia eponia	Nymphalidae	8	0.00389	7	0.00945	15	0.00536	GR + FL
Acraea perenna	Nymphalidae	9	0.00437	6	0.00810	15	0.00536	GR + FL
Belenois aurota	Pieridae	10	0.00486	5	0.00675	15	0.00536	GR + FL
Azanus isis	Lycaenidae	12	0.00583	4	0.00540	16	0.00572	GR + FL
Cacyreus palemon palemon	Lycaenidae	13	0.00632	3	0.00405	16	0.00572	GR + FL
Acraea acerata	Nymphalidae	0	0.00000	16	0.02159	16	0.00572	FL
Charaxes protoclea azota	Nymphalidae	10	0.00486	6	0.00810	16	0.00572	GR + FL
Salamis anacardii	Nymphalidae	6	0.00292	10	0.01350	16	0.00572	GR + FL
Cacyreus viritis	Lycaenidae	17	0.00826	0	0.00000	17	0.00607	GR
Lycaena phlaeas	Lycaenidae	17	0.00826	0	0.00000	17	0.00607	GR
Acraea serena	Nymphalidae	14	0.00680	3	0.00405	17	0.00607	GR + FL
Amauris eliot	Nymphalidae	0	0.00000	17	0.02294	17	0.00607	FL
Danaus chrysippus aegyptius	Nymphalidae	15	0.00729	3	0.00405	18	0.00643	GR + FL
Junonia orithya madagascariensis	Nymphalidae	15	0.00729	3	0.00405	18	0.00643	GR + FL
Antanartia dimorphica	Nymphalidae	14	0.00680	5	0.00675	19	0.00679	GR + FL
Eurytela dryope angulata	Nymphalidae	14	0.00680	5	0.00675	19	0.00679	GR + FL
Graphium leonidas leonidas	Papilionidae	10	0.00486	9	0.01215	19	0.00679	GR + FL
Graphium policene	Papilionidae	19	0.00923	0	0.00000	19	0.00679	GR

Continued

Papilio demodocus demodocus	Papilionidae	16	0.00777	3	0.00405	19	0.00679	GR + FL
Eurema senegalensis	Pieridae	19	0.00923	0	0.00000	19	0.00679	GR
Mylothris sagala	Pieridae	16	0.00777	3	0.00405	19	0.00679	GR + FL
Charaxes kirki	Nymphalidae	15	0.00729	6	0.00810	21	0.00750	GR + FL
Junonia oenone oenone	Nymphalidae	21	0.01020	0	0.00000	21	0.00750	GR
Precis ceryne ceryne	Nymphalidae	16	0.00777	5	0.00675	21	0.00750	GR + FL
Colotis amantus amantus	Pieridae	13	0.00632	8	0.01080	21	0.00750	GR + FL
Actizera lucida	Lycaenidae	19	0.00923	3	0.00405	22	0.00786	GR + FL
Euchrysops malathana	Lycaenidae	21	0.01020	1	0.00135	22	0.00786	GR + FL
Acraea jodutta jodutta	Nymphalidae	18	0.00875	4	0.00540	22	0.00786	GR + FL
Antanartia abyssinica jacksoni	Nymphalidae	0	0.00000	22	0.02969	22	0.00786	FL
Charaxes ethalion	Nymphalidae	14	0.00680	8	0.01080	22	0.00786	GR + FL
Precis pelarga actia	Nymphalidae	23	0.01118	0	0.00000	23	0.00822	GR
Leptosia hybrida	Pieridae	0	0.00000	23	0.03104	23	0.00822	FL
Euchrysops subpallida	Lycaenidae	0	0.00000	24	0.03239	24	0.00857	FL
Acraea penelope	Nymphalidae	22	0.01069	2	0.00270	24	0.00857	GR + FL
Charaxes cithaeron	Nymphalidae	22	0.01069	2	0.00270	24	0.00857	GR + FL
Belenois creona	Pieridae	0	0.00000	24	0.03239	24	0.00857	FL
Charaxes brutus	Nymphalidae	17	0.00826	8	0.01080	25	0.00893	GR + FL
Colias electo pseudohecate	Pieridae	25	0.01215	0	0.00000	25	0.00893	GR
Colotis evagore antigone	Pieridae	19	0.00923	6	0.00810	25	0.00893	GR + FL
Colotis evenina	Pieridae	16	0.00777	9	0.01215	25	0.00893	GR + FL
Eurema desjardinsii	Pieridae	21	0.01020	4	0.00540	25	0.00893	GR + FL
Papilio horniman	Papilionidae	23	0.01118	3	0.00405	26	0.00929	GR + FL
Eronia leda	Pieridae	21	0.01020	5	0.00675	26	0.00929	GR + FL
Eurema brigitta brigitta	Pieridae	23	0.01118	3	0.00405	26	0.00929	GR + FL
Mylothris agathina	Pieridae	19	0.00923	7	0.00945	26	0.00929	GR + FL
Charaxes elesipe gordoni	Nymphalidae	19	0.00923	9	0.01215	28	0.01000	GR + FL
Hamanumida daedalus	Nymphalidae	0	0.00000	28	0.03779	28	0.01000	FL
Papilio desmondi teita	Papilionidae	24	0.01166	4	0.00540	28	0.01000	GR + FL
Colotis eris eris	Pieridae	22	0.01069	6	0.00810	28	0.01000	GR + FL
Neptis pennington	Nymphalidae	16	0.00777	13	0.01754	29	0.01036	GR + FL
Phatanta phatanta aethiopica	Nymphalidae	29	0.01409	0	0.00000	29	0.01036	GR

Continued

Papilio lormieri	Papilionidae	29	0.01409	0	0.00000	29	0.01036	GR
Precis antilope	Nymphalidae	21	0.01020	10	0.01350	31	0.01108	GR + FL
Acraea sotikensis	Nymphalidae	26	0.01263	6	0.00810	32	0.01143	GR + FL
Neptis saclava marpessa	Nymphalidae	19	0.00923	13	0.01754	32	0.01143	GR + FL
Eurema hecabe solifera	Pieridae	32	0.01555	0	0.00000	32	0.01143	GR
Nepheronia thalassina	Pieridae	0	0.00000	32	0.04318	32	0.01143	FL
Acraea pudorina	Nymphalidae	0	0.00000	33	0.04453	33	0.01179	FL
Amauris echeria	Nymphalidae	26	0.01263	7	0.00945	33	0.01179	GR + FL
Lepidochrysops persimon	Lycaenidae	30	0.01458	4	0.00540	34	0.01215	GR + FL
Papilio ophidicephalus	Papilionidae	33	0.01603	1	0.00135	34	0.01215	GR + FL
Pseudacraea lucretia expansa	Nymphalidae	0	0.00000	35	0.04723	35	0.01250	FL
Acada biceriatus	Hesperiidae	32	0.01555	4	0.00540	36	0.01286	GR + FL
Appias sabina	Papilionidae	29	0.01409	7	0.00945	36	0.01286	GR + FL
Acraea servona	Nymphalidae	38	0.01846	0	0.00000	38	0.01358	GR
Graphium antheus	Papilionidae	29	0.01409	9	0.01215	38	0.01358	GR + FL
Junonia natalica natalica	Nymphalidae	33	0.01603	8	0.01080	41	0.01465	GR + FL
Precis actia	Nymphalidae	35	0.01701	6	0.00810	41	0.01465	GR + FL
Colotis vesta	Pieridae	35	0.01701	8	0.01080	43	0.01536	GR + FL
Junonia artaxia	Nymphalidae	41	0.01992	3	0.00405	44	0.01572	GR + FL
Pseudacraea boisduvali	Nymphalidae	42	0.02041	6	0.00810	48	0.01715	GR + FL
Colotis hataera	Pieridae	39	0.01895	9	0.01215	48	0.01715	GR + FL
Eurema regularis regularis	Pieridae	42	0.02041	6	0.00810	48	0.01715	GR + FL
Eurema hepale	Pieridae	32	0.01555	17	0.02294	49	0.01751	GR + FL
Junonia hierta cebrene	Nymphalidae	46	0.02235	6	0.00810	52	0.01858	GR + FL
Azanus ubaldus	Lycaenidae	53	0.02575	1	0.00135	54	0.01929	GR + FL
Colotis auxo incretus	Pieridae	49	0.02381	9	0.01215	58	0.02072	GR + FL
Colotis antevipe zera	Pieridae	39	0.01895	20	0.02699	59	0.02108	GR + FL
Neptis serena serena	Nymphalidae	67	0.03256	19	0.02564	86	0.03073	GR + FL
Neptis morosa	Nymphalidae	76	0.03693	18	0.02429	94	0.03358	GR + FL

CHAPTER FOUR

4.0 General Discussion

The mid-altitude region of MPKGR has a greater range of biodiversity compared to the low and high-altitude regions. This is because of the various habitats present, including miombo woodland, Afromontane Forest, and riverine forest, which provide abundant resources for butterfly foraging and reproduction. However, the higher altitude regions of MPKGR, comprised of bushland and grassland vegetation, have limited food and microclimate availability, resulting in lower butterfly diversity.

The monitoring of biodiversity and the impacts of global environmental change are vital for implementing effective adaptation and mitigation strategies to prevent further loss of biological diversity. In mountain ecosystems, divergent distribution patterns of species and community composition are influenced by rapid environmental changes occurring over short altitudinal distances (Hernández *et al.,* 2012; Zhang *et al.,* 2016; Hailemariam & Temam, 2020; Rahman *et al.,* 2022). However, human activities can impose constraints that lead to environmental modifications (Bentsi-Enchill *et al.,* 2022), potentially pushing species beyond their evolutionary ranges (Tilman & Lehman, 2001) and impacting species composition (Sinha *et al.,* 2018).

The study revealed that Mpanga Kipengere consists greater number and variety of butterfly species compared to Farmlands. This is because Mpanga Kipengere Game Reserve is a natural habitat that has a wide range of plant species in over 45 different families (Frontier,2003). More than 60% of these plants are used by butterflies that have been observed in the reserve (Kielland 1990, Larsen 1991). If a butterfly species is commonly found throughout the MPKGR, it may suggest that their food plants are readily available in the area and the climate is favorable for them (Mtui *et al.,*2017). However, if a butterfly species is only found in specific locations within the gorge, such as the lower, middle, or upper sections, it could mean that they require certain conditions found only in those areas to survive.

This current checklist of butterflies serves as a starting point for future research and evaluation of the health of the Mpanga Kipengere ecosystem. Certain butterfly species found in specific locations may be useful as indicators of the ecological conditions in those areas.

CHAPTER FIVE

5.0 Conclusions and Recommendations

5.1 Conclusion

This study observed that:

i. There is a significance difference in butterfly species composition and diversity between altitudes. There is no significance difference in species composition and diversity between vegetation types. Therefore, the variation is influenced by altitudes rather than habitat types.

ii. Butterfly species composition and diversity is higher in MPKGR compared to surrounding farmlands. Therefore, the study find that human activities have direct impact on butterfly species composition and diversity. Most of butterfly species recorded immediately after intensive rain season compared to dry season. The MPKGR natural habitat has been found to have a higher number of species and a greater abundance compared to the disturbed habitat of Famlands. This is likely due to the fact that the reserve consists mainly of natural vegetation with indigenous flora and minimal human interference. Additionally, the area is located in the southern highlands, which is known as a world biodiversity hotspot, rich in both flora and fauna. In contrast, the lower number of butterfly species and abundance in Farmlands is a result of regular human activity in those areas, reducing habitat quality and limiting food sources for butterfly survival.

iii. During the wet season, the diversity of butterfly species was significantly higher compared to the dry season. The small number of species recorded during the dry season (November to February) may be due to environmental conditions, as during this season most of the plants were dried up. Many plants were affected by the dry conditions, and although trees and shrubs were present, many of them could not be used by butterflies due to their deciduous phenology.

iv. In the study area, two species - *charaxes condonii* and *hapendyreus juno* - have been observed. These species are either endemic to the area or represent an extension of the range of the southern highland's mountains. The fact that there are endemic species present suggests that the MPKGR area is significant for conservation efforts. This information is supported by studies conducted by Davros in 2006 and Dino in 2016.

5.2 Recommendations

Following the conclusion from this study, it is recommended that:

i. To ensure the sustainable existence of observed indicator species, MPKGR's management should create and execute a comprehensive conservation plan.

ii. The management of Mpanga Kipengere should make an effort to conduct an awareness campaign for the surrounding community. The goal is to help them understand the importance of conserving the environment. This will improve habitat quality for wildlife survival and reproduction by reducing anthropogenic activities that have a direct impact on biodiversity.

iii. To obtain more information about the factors that affect the distribution of butterflies as an indicator species for environmental changes, further research should be conducted in Mpanga Kipengere. The emphasis should be on studying other variables such as plant species, habitat characteristics, and infrastructure development.

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