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Butterfly diversity (Lepidoptera: Papilionoidea) within the Ibanda Makera forest remnant, Eastern Province of Rwanda.

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Jean de Dieu Uwizelimana[1, 2] *, Constantin Sibomana[2], Alphonse Nzarora[1, 2] & Ian James Gordon[2]
[1] University of Rwanda, College of Science and Technology, Biology Department, P.O.Box 3900 Kigali, Rwanda.
[2] Center of Excellence in Biodiversity and Natural Resource Management (CoEB), University of Rwanda, P.O. Box 117 Butare, Rwanda.
*Corresponding author e-mail: juwizelimana@gmail.com

Abstract: Forest fragments in a human-dominated landscape are threatened by anthropogenic activities, especially in regions with high population growth, like Rwanda. Such is the case of the Ibanda Makera forest fragment, which is threatened by human activities, including agricultural encroachment, and drought. To mitigate these threats, an effort has been made to protect the forest's indigenous plant and animal species. In this regard, a study has been undertaken to document the butterfly diversity within the forest to obtain baseline data for future monitoring of environmental change and forest restoration. Butterfly specimens were collected in May and June 2023 using hand sweep nets along transects, baited traps, and opportunistic sampling. A first species checklist of 112 butterfly species is reported from the forest. More sampling is clearly needed; our results showed a bias towards large-bodied species and two important butterfly families Lycaenidae (eight species) and Heperiidae (four species) were under sampled. Additional studies are required to compliment this first baseline assessment, including surveys of additional areas and habitats within the Ibanda Makera forest remnant, and spanning seasonal times.

Key words: Biological indicator, monitoring, restoration, species checklist.

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INTRODUCTION

Anthropogenic activities are among the major drivers of biodiversity loss (Christian, 2023). In some areas with high population density, such as Rwanda, natural habitats, including tropical forests have been completely converted into agricultural fields and human settlements, while in some other parts, only a few small natural forest fragments are remaining (Lewis *et al.*, 2015; Taubert *et al.*, 2018). This forest fragmentation might have driven some biodiversity to extinction before they are even known to science in underexplored forests (Fahrig, 2003; Benedick *et al.*, 2006; Hill *et al.*, 2011; Hansen *et al.*, 2020).

In Rwanda, due to its high population depending mainly on subsistence agriculture (Imasiku & Ntagwirumugara, 2020), the remaining natural forest fragments face threats from anthropogenic activities, including agricultural encroachment. These forest fragments likely host important biodiversity, including endemics, because they are the only remaining refugia in human-dominated landscapes (Hill et al., 2011). Therefore, it is important to document their biodiversity to establish protection and conservation measures.

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Ibanda Makera forest in the eastern part of Rwanda is among the few remaining remnant forest patches; however, it is threatened by encroachment and anthropogenic activities from surrounding communities (Kalinda *et al.*, 2023). To mitigate this threat, the government of Rwanda through its Rwanda Environment Management Authority (REMA) institution is preserving the forest by establishing a buffer zone around the forest and initiating its restoration by planting indigenous trees, including *Vachellia siberiana* (DC.) Kyal. & Boatwr. 2013 and *Markhamia lutea* (Benth.) K.Schum., within the established buffer zone and in its most degraded patches. Furthermore, because the region is known to experience more drought than the rest of the country (Niyonsenga *et al.*, 2024), this restoration effort was undertaken as an ecosystem-based adaptation approach to help mitigate climate change within the region (Munang *et al.*, 2013). However, it appears from the literature that little is known about the biodiversity of the Ibanda Makera forest, while its effective conservation would rely on the knowledge of its biodiversity, including the use of biological indicators (Osborn *et al.*, 1999; Maes & Dyck, 2005; Maleque *et al.*, 2009). A study on butterfly diversity was designed to increase our knowledge about its biodiversity and to provide baseline data on a potential biological indicator group. Butterflies were selected as a biological indicator because they are excellent indicators of environmental change and useful for the monitoring of forest restoration (Oostermeijer & Van Swaay, 1998; Maleque *et al.*, 2009; Nyafwono *et al.*, 2014; Oloya *et al.*, 2021). This first butterfly study in the Ibanda Makera forest remnant aims to provide baseline data for the future monitoring of environmental change and the impact of restoration on the forest's biodiversity.

Methods and Materials

Study site

Ibanda Makera forest (2°6'31"S, 30°51'16"E) is a small remnant forest located in the Kirehe district, Mpanga sector, Nasho cell in the Southeastern province part of Rwanda (Fig. 1). The forest remnant comprises savannah woodland (Ibanda), and a gallery forest (Makera), making a total area of 169.78 ha. With an elevation of 1300 m.a.s.l., the forest experiences a mean annual precipitation of 1106 mm per year, a mean annual temperature of 20.6°C, with a mean daily temperature of 24°C (Manishimwe *et al.*, 2022). The vegetation is an evergreen forest and semi-evergreen bushland type. Dominant plants include *Phoenix reclinata* Jacq., *Vepris nobilis* (Delile) Mziray, *Ficus vallis-choudai* Delile, *Dracaena afromontana* Mildbr., *Chaetachme aristata* E.Mey. ex Planch. and *Markhamia lutea* within the dense gallery forest and *Vachellia sieberiana* within the savannah woodland. Moreover, some orchids such as *Eulophia guineensis* Lindl., *Platylepis glandulosa* (Lindl.) Rchb.f. and *Malaxis weberbaueriana* (Kraenzl.) Summerh. are found in the interior part of the gallery forest, and *Cyperus papyrus* L. vegetation within the swamp extending to the Akagera River on the border of Tanzania. Ibanda Makera forest remnant hosts also a variety of animal biodiversity, including the hippopotamus (*Hippopotamus amphibius*) within the Akagera swamp river, blue monkey (*Cercopithecus mitis dogetti*), baboon (*Papio anubis*) and velvet monkey (*Chlorocebus aethiops*) among the primates; and a variety of birds including migratory birds such as the European bee-eater (*Merops apiaster*); amphibians and reptiles, including the black mamba (*Dendroaspis polylepis*) and African python (*Python setae*).

Butterfly sampling

Sampling of the butterflies was conducted in May and June 2023 from two broad habitat types: savannah woodland and gallery forest. To produce a species list of butterflies occurring in the Ibanda Makera forest remnant, butterfly specimens were collected using a hand butterfly net and fruit-baited traps along transects (Uwizelimana *et al.*, 2021, 2022) and opportunistic sampling where access was possible because some patches in the interior of the gallery forest were full of stagnant water. Butterfly individuals encountered along the transect walk of 5 m width, where access was possible, were collected by two collectors (Royer *et al.*, 1998). Baited traps were hung in trees at least 1 m from the ground, and set at 50 m intervals along the transect walk. Butterfly bait was made of a fermented mixture of bananas, pineapple, sugar, and honey because this bait was found effective for fruit-feeding butterfly trapping within Rwandan ecosystems (Uwizelimana *et al.*, 2022). The bait was replaced after two days in a trap. Traps were checked two times a day, morning and afternoon, and trapping lasted seven consecutive days per month, making 14 sampling days in a two-month sampling period. Sampling took place every day from 8 am to 5 pm, depending on the weather conditions, and all butterfly specimens caught with a butterfly hand net or trapped were stored in an envelope, labelled for species identification. All collected specimens will be maintained at the Center of Excellence in Biodiversity and Natural Resource Management (CoEB) at the University of Rwanda.

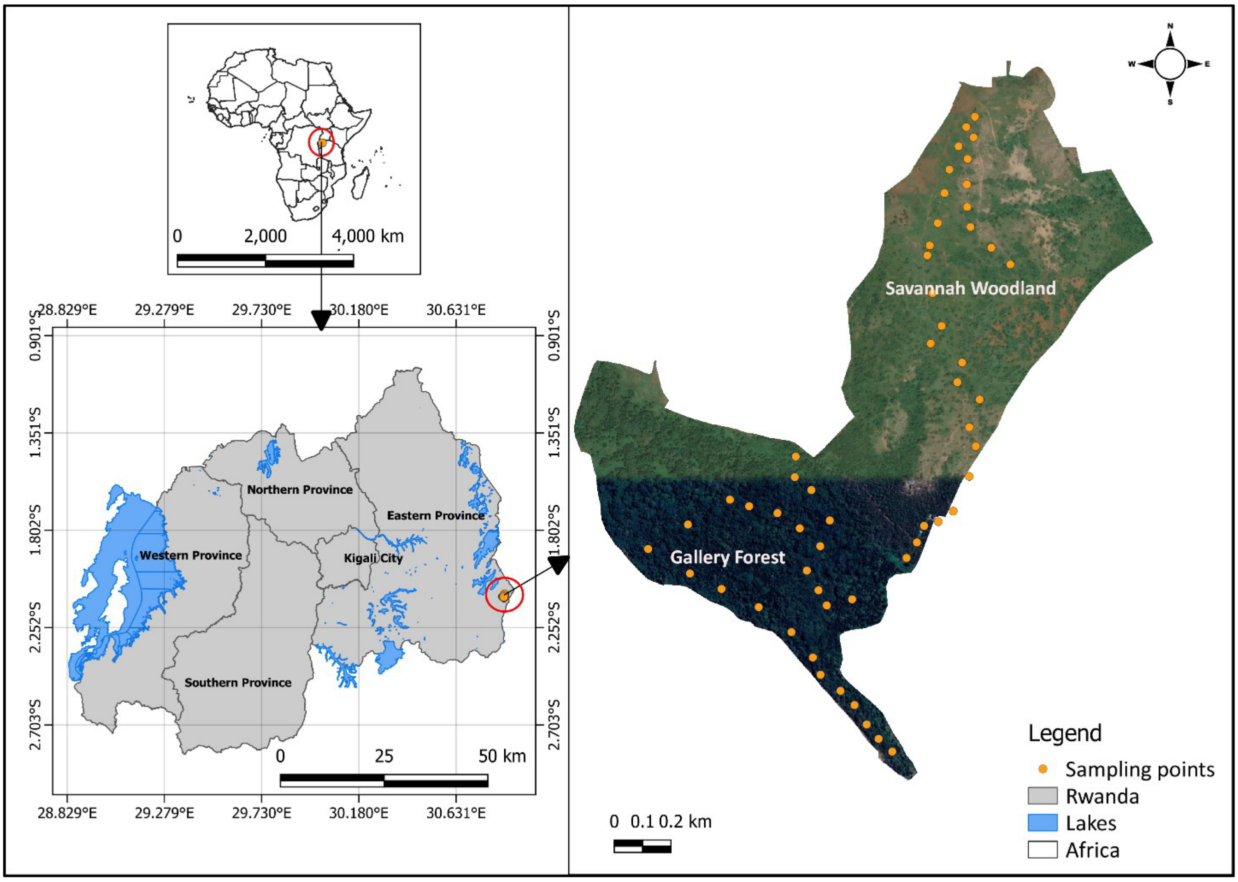

Figure 1 – Location of the study site with sampling points

Species identification and data analysis

Identification of butterfly species was performed using available literature on African butterflies (Larsen, 1991, 2005; Vande Weghe, 2010; Martins & Collins, 2016; Kioko *et al.*, 2021) and the African Butterfly Database (ABDB) (https://www.abdb-africa.org/); experts of the region were consulted for species confirmation in case of doubt. A preliminary butterfly species checklist occurring in the Ibanda Makera remnant forest is provided. The classification of the butterfly species follows Williams, 2015; Dhungel & Wahlberg, 2018; Espeland *et al.*, 2018. Sampling completeness was assessed using BioDiversity Pro software version 2 (McAleece *et al.*, 1997).

RESULTS

A hundred and twelve butterfly species with five families and 17 subfamilies were documented for the Ibanda Makera forest with a total of 510 butterfly individuals collected. This first butterfly survey at Ibanda Makera remnant forest recorded a higher number of Nymphalidae species, followed by Pieridae, while Hesperiidae and Lycaenidae were less represented. Some species were unique to the gallery forest or savannah woodland, while others have been recorded in both habitat types (Table 1). A performed rarefaction curve to test sampling completeness showed incomplete sampling because the curve did not reach an asymptote, which means more sampling effort is still needed (Fig. 2)

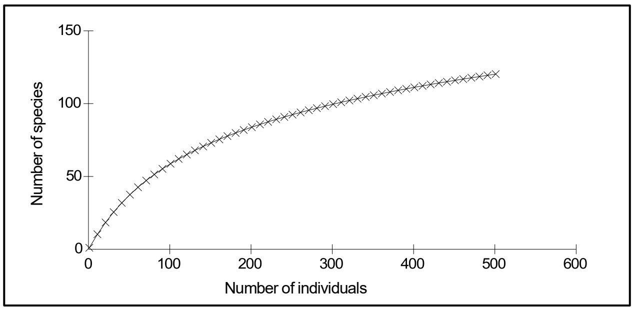

Figure 2 – Rarefaction curve of sampled butterflies at Ibanda Makera forest remnant indicating that further surveying is required.

DISCUSSION

The finding of the dominance of Nymphalid species is similar to the Cyamudongo forest fragment in the western part of Rwanda (Uwizelimana *et al.*, 2021). A similar dominance of Nymphalidae has been documented in some neighbouring Tanzanian ecosystems, either in lowland forest ecosystems (Nkwabi *et al.*, 2021; Rija, 2022) or in similar savannah woody shrubs (van Noort & Stone, 1999, 2000) and gallery forest vegetation (Munisi *et al.*, 2024) as found in the Ibanda Makera forest remnant. Furthermore, similar Nymphalid dominance was recorded in the eastern part of the Democratic Republic of Congo (Ducarme, 2018) and some ecosystems of Uganda (Forbes, 2018).

The dominance of the Nymphalids in the Ibanda Makera forest remnant is probably due to the phenology of the forest, which provides nectar and fruits at the adult stage and vegetative growth at the larval stages. However, a study on the phenology of the forest is needed to confirm this. A smaller representation of Hesperiidae and Lycaenidae at Ibanda Makera is likely due to the difficulty in collecting species from these families. Being not easily trapped in baited traps, these groups were difficult to sample with a hand net because most of the gallery forest was very dense, and some parts were full of stagnant water during the sampling period.

Concerning the habitat types, some species have been recorded only in savannah woodland or gallery forest, while others have been recorded in both habitat types. This highlights the species' habitat specificity of butterflies in the forest fragment. For example, the record of *Eriboea jahlusa* in savannah woodland is due to the dominant open Acacia vegetation which is its preferred habitat (Kioko *et al.*, 2021). This record is likely due to the replanted *Acacia* trees in degraded patches of savannah, which had been negatively affected by firewood collection and overgrazing in the past. Similar to *Eriboea jahlusa*, *Polyura zoolina* prefers drier areas, and its presence in savannah woodland and gallery forest is likely due to the replanted *Acacia* trees which are known larval host plants (Kioko *et al.*, 2021). However, we cannot know for certain if the presence of these species is due to restoration efforts because there is no available baseline data before restoration activities to assess the restoration impacts on the butterfly population of the forest. Therefore, this species checklist should be a baseline for future use to monitor the restoration success on butterfly diversity of the forest. Furthermore, as the sampling was incomplete due to a short period of the study, an extended sampling including different seasons should be conducted.

CONCLUSION

This preliminary survey of butterflies inhabiting the Ibanda Makera remnant forest recorded 112 butterfly species, with dominance of Nymphalids. Given that the forest is under restoration, the findings of this first study should serve as a baseline to monitor environmental change and restoration success over time. A complete inventory for important indicator groups such as butterflies is essential to providing baseline data for policymakers to establish protection measures for forest fragments.

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Table 1 – Butterfly species recorded at Ibanda Makera forest remnant within each habitat type.

	Habitat type	
Family/Subfamily/species	**Savannah Woodland**	**Gallery Forest**
Family Hesperiidae		
Coeliadinae		
Coeliades forestan forestan (Stoll, [1782])		X
Hesperiinae		
Borbo fatuellus fatuellus (Hopffer, 1855)		X
Zenonia zeno (Trimen), 1864		X
Pyriginae		
Eretis lugens (Rogenhofer, 1891)		X
Family Lycaenidae		
Aphnaeinae		
Axiocerses harpax (Fabricius, 1775)	X	
Polyommatinae		
Azanus jesous (Guérin-Méneville, 1849)	X	
Cacyreus lingeus (Stoll, [1782])		X
Lampides boeticus (Linnaeus, 1767)		X
Leptotes pirithous (Linnaeus, 1767)	X	
Zizeeria knysna knysna (Trimen, 1862)	X	X
Poritiinae		
Mimacraea marshalli Trimen, 1898	X	
Theclinae		
Hypolycaena hatita ugandae Sharpe, 1904		X
Family Nymphalidae		
Biblidinae		
Ariadne pagenstecheri (Suffert, 1904)		X
Byblia anvatara (Boisduval, 1833)	X	X

Eurytela dryope angulata Aurivillius, 1899	X	X
Eurytela hiarbas hiarbas (Drury, 1782)		X
Neptidopsis ophione nucleata Grünberg, 1911		X
Sevenia boisduvali omissa (Rothschild, 1918)		X
Sevenia garega (Karsch, 1892)		X
Sevenia umbrina (Karsch, 1892)		X
Charaxinae		
Charaxes brutus alcyone Stoneham, 1943		X
Charaxes candiope (Godart, [1824])	X	X
Charaxes castor (Cramer, 1775)		X
Charaxes eupale (Drury, 1782)		X
Charaxes protoclea Feisthamel, 1850		X
Charaxes tiridates tiridatinus Röber, 1936		X
Charaxes varanes vologeses (Mabille, 1876)		X
Eriboea cfr etheocles (Cramer, 1777).		X
Eriboea jahlusa (Trimen, 1862)	X	
Polyura zoolina (Westwood, [1850])	X	X
Danainae		
Amauris hecate hecate (Butler, 1866)		X
Amauris niavius niavius (Linnaeus, 1758)		X
Amauris tartarea Mabille, 1876		X
Danaus chrysippus chrysippus (Linnaeus, 1758)	X	X
Tirumala formosa mercedonia (Karsch, 1894)		X
Tirumala petiverana (Doubleday, 1847)		X
Heliconiinae		
Acraea asboloplintha Karsh, 1894		X
Bematitses quadricolor (Rogenhofer, 1891)		X
Issoria hanningtoni (Elwes, 1889)	X	
Lachnoptera anticlia (Hübner, [1819])		X
Phalanta eurytis eurytis (Doubleday, [1847])		X
Telchinia acerata (Hewitson, 1874)		X
Telchinia aurivillii aurivillii (Staudinger, 1896).		X
Telchinia cabira (Hopffer, 1855)		X
Telchinia encedana (Pierre, 1976).		X
Telchinia encedon encedon (Linnaeus, 1758).		X
Telchinia lycoa (Godart, [1819])		X
Telchinia serena (Fabricius, 1775)	X	X
Telchinia sotikensis sotikensis (Sharpe, 1892)		X
Telchinia uvui uvui (Grose-Smith, 1890)		X
Limenitidinae		
Aterica galene extensa Heron, 1909		X
Bebearia cocalia cocalia (Fabricius, 1793)		X
Euphaedra medon fraudata van Someren, 1935		X
Hamanumida daedalus (Fabricius, 1775)	X	
Neptis carcassoni Van Son, 1959		X
Neptis saclava marpessa Hopffer, 1855		X
Neptis serena Overlaet, 1955	X	X
Pseudacraea lucretia protracta (Butler, 1874)		X

Nymphalinae		
Hypolimnas anthedon anthedon (Doubleday, 1845)		X
Hypolimnas misippus (Linnaeus, 1764)		X
Junonia oenone oenone (Linnaeus), 1758	X	X
Junonia hierta cebrene (Trimen), 1870	X	X
Junonia natalica natalica (Felder & Felder, 1860)		X
Junonia sophia (Fabricius, 1793*)*		X
Junonia terea tereoides (Butler, 1901)	X	X
Precis archesia (Cramer, 1779)		X
Precis sinuata hecqui Berger, 1981		X
Protogoniomorpha parhassus (Drury, 1782)		X
Vanessula milca latifasciata Joicey & Talbot, 1928		X
Satyrinae		
Bicyclus safitza safitza (Westwood, [1850])	X	X
Bicyclus saussurei (Dewitz, 1879)		X
Bicyclus vulgaris (Butler, 1868)		X
Bicyclus jefferyi Fox, 1963		X
Gnophodes betsimena (Boisduval, 1833)		X
Melanitis leda helena (Westwood, 1851	X	X
Ypthima albida albida Butler, 1888	X	X
Ypthima asterope (Klug, 1832)	X	X
Family Papilionidae		
Papilioninae		
Papilio constantinus Ward, 1871		X
Papilio dardanus dardanus Brown, 1776	X	X
Papilio demodocus demodocus Esper, [1798]	X	X
Papilio echerioides joiceyi Gabriel, 1945		X
Papilio nireus nireus Linnaeus, 1758	X	X
Papilio phorcas congoanus Rothschild, 1896	X	X
Family Pieridae		
Coliadinae		
Catopsilia florella (Fabricius, 1775)	X	X
Eurema brigitta brigitta (Stoll, [1780])	X	X
Eurema desjardinsii regularis Butler, 1876	X	X
Eurema floricola leonis Butler, 1886		X
Eurema hapale Mabille, 1882	X	X
Eurema hecabe solifera Butler, 1875	X	X
Pierinae		
Appias epaphia epaphia (Cramer, [1779])		X
Appias sabina sabina (Felder & Felder, [1865])		X
Belenois aurota (Fabricius, 1793)		X
Belenois crawshayi Butler, 1894		X
Belenois creona (Cramer, [1776])	X	X
Belenois solilucis Butler, 1874		X
Belenois thysa (Hopffer, 1855)	X	
Belenois zochalia agrippinides (Holland, 1896)	X	X
Colotis danae annae (Wallengren, 1857)	X	
Colotis aurigineus (Butler, 1883)	X	

Colotis elgonensis basilewskyi Berger, 1956		X
Colotis euippe euippe (Linnaeus, 1758)	X	X
Colotis evagore (Klug, 1829)	X	
Colotis hetaera (Gerstaecker, 1871)	X	
Colotis vestalis castalis (Staudinger, 1884)	X	X
Eronia cleodora Hübner, 1823	X	
Eronia leda (Boisduval, 1847)	X	
Leptosia alcesta alcesta (Stoll, [1782])		X
Leptosia nupta pseudonupta Bernardi, 1959	X	X
Mylothris agathina richlora Suffert, 1904	X	X
Mylothris rubricosta (Mabille, 1890)		X