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Diversity and abundance of butterfly (Lepidoptera, Papilionoidea) fauna in golden mining sites of Minkebe region, Gabon

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Abstract

Butterflies are the most well-known insects found in all parts of the world. They are excellent indicators of changes in environmental impacts on biodiversity. In Gabon, this group is understudied, particularly in industrial sites. This study aims to quantify the abundance and species richness of butterflies in the gold mining sites of Minkebe for their conservation. Data was collected from April to May 2023 (rainy season) using the line transect method in three study sites with sweep nets (n=2) and butterfly traps (n=7). A total of 1063 individuals representing 143 species and 43 genera belonging to 10 families were recorded during the study. Butterflies were represented by the families of Nymphalidae, comprising 104 species; Pieridae, with 11 species; Papilionidae, with 8 species; Lycaenidae, with 7 species; Saturniidae and Sphingidae, with 4 species each; Geometridae, with 2 species; Erebidae, Eupterotidae, and Riodinidae, with 1 species each. Nymphalidae was the most dominant butterfly family, accounting for 104 species (73%) of the total butterflies captured, while Erebidae, Eupterotidae, and Riodinidae were the least abundant families. Among the 143 species recorded, 10 were very common, 13 were common, 79 were rare, and 40 were very rare. Regarding species richness and composition, Minkebe site had the greatest diversity with 80 species and 36 genera, while Cratere-Mikouka site had the lowest species composition with 61 species and 25 genera. Overall, the study region was found to be rich in butterfly diversity across all three study sites. Therefore, it is necessary to protect Lepidoptera biodiversity of Minkebe forest massif.

Keywords: Lepidoptera, species, abundance, richness, diversity, minkebe, gabon

Introduction

Butterflies belong to a phylum of the animal kingdom (Arthropoda) and the order Lepidoptera (Ojianwuna, 2015) [14]. They are among the most studied, well-known, and successful insects, found in all parts and habitats of the world (Kristensen, 2013) [8]. Butterflies are crucial to humans and environmental health (Sharma *et al.,* 2020) [19], playing significant roles in crop pollination and serving as aesthetic elements in nature (Ghazanfar *et al.,* 2016) [5]. Additionally, they are considered one of the main ecological indicator taxa for assessing the conservation status of any region, as demonstrated by several environmental investigations (Marini *et al.,* 2009; Munyuli, 2013) [11, 12].

In the Central African sub-region, where Gabon is located, butterflies have been extensively documented (Vande Weghe, 2005, 2008, 2013) [22, 23, 25]. Studies conducted in Gabon have identified 1090 butterfly species (Vande Weghe, 2010) [24]. However, these studies were limited to a few localities. The Minkebe region, which is close to Ivindo National Park and hosts a rich diversity of plant and insect species (Vande Weghe, 2013) [25], is now facing threats from gold mining activities. This highlights the urgent need for comprehensive studies to understand the abundance and diversity of butterfly species in this area.

The present study aims to fill this gap by determining the abundance and diversity of butterflies in the Minkebe forest massif to establish their local status. Understanding butterfly diversity in this region is not only important for ecological and conservation purposes but also for assessing the impacts of anthropogenic activities such as mining. Butterflies, being sensitive to environmental changes, can provide valuable insights into the health of ecosystems and the effectiveness of conservation efforts (Lourenço *et al.,* 2020) [10].

Moreover, this study will contribute to the broader knowledge of butterfly distribution in Central Africa, offering a baseline for future research and conservation strategies. By documenting the species present and their relative abundances, we can better understand the ecological dynamics of the Minkebe forest massif and develop targeted conservation measures to protect these vital pollinators and indicators of environmental health.

Materials and methods

Study area

This study was conducted in the Minkebe forest massif located in the Woleu-Ntem province in North-East of Gabon (Figure 1). This region has an equatorial climate with two rainy seasons and two dry seasons (Vande Weghe, 2013) [25]. The rainy seasons extend from October to December and from March to May. Furthermore, the dry seasons extend from January to February and from June to August. Average annual rainfall varies between 1,600 and 1,800 mm (Vande Weghe, 2013) [25]. In general, average temperatures are between 23°C and 24°C, while humidity levels usually exceed 80%.

The vegetation of this study area is composed of Guinean-Congolian dense forests. These forests cover a large part of the region and form an almost continuous vegetation carpet marked by a mosaic of evergreen and semi-deciduous plant formations (Sally, 2002) [18]. Waterbodies are often bordered by vast areas of floodplain and swamp forests (Vande

Weghe, 2013) [25]. Regarding savannahs, they are found only at Mvadi and in the south-west of the Minkébé National Park (Sally, 2002) [18].
Moreover, the Minkebe forest massif has undergone several human disturbances, especially in the Minkebe area, due to the increase of the gold-washing between the 1950s and the 2000s (Sally, 2002) [18]. This activity has had important repercussions on this forest massif through the establishment of gold-washing camps and the significant decline of wildlife in areas of human activities (Sally, 2002) [18].

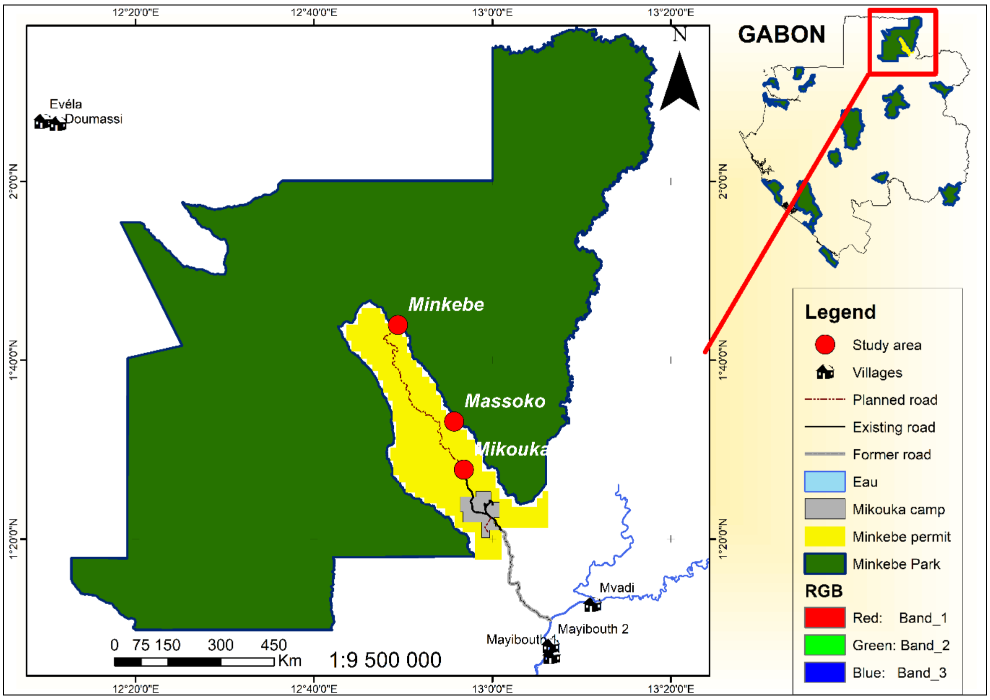

Fig 1: Location of study area and study sites

Butterfly collection

The data of butterflies was collected from April to May 2023 (rainy season) following the line transect method in the three study sites using sweep nets (n=2) and butterfly traps (n=7) baited with palm wine and banana (Baliteau and Chabrol, 2007; Lecomte, 2007) [2, 9]. For each study site, the transect lines were produced for each habitat (groundland forets, flounding forests and river banks). Each habitat was sampled every day during the study period. The sampling of butterflies was done was carried out between 7:30 am and 5:00 pm in order to establish butterfly abundance, richness and diversity. The collected specimens were sorted and identified to family level. These samples were euthanized by a ball of cotton wool soaked in chloroform solution and kept in a well-labeled Ziploc showing location and date of collection. Moreover, they have been transported in Libreville for further identifications.

Butterfly identification

The identification of the species was conducted in the Laboratory of Vector Ecology of the Institute of Research in Tropical Ecology (IRET). We used the African Butterfly Database species list (Safian and Siklosi, 2023) [17] and the identification guides for butterflies of Bernardi (1996) [3], Vande Weghe (2003, 2010) [21, 24], Vingerhoedt and Vande Weghe (2011) [26].

Data analysis

The specific richness (S), relative abundance (RA), specific abundance (N) and diversity indices as Shannon's diversity index (H') and Pielou's equitability index (J) were calculated using Microsoft Excel 2013 and R 1.4.11.
The specific richness (S) was the number of butterflies collected in each study site, while the relative abundance (RA) was calculated for each species by using the following formula:

$$\text{Relative abundance} = \frac{\text{Abundance of the species x 100}}{\text{Total abundance of all species}}$$

Based upon the value of RA, butterfly species were categorized into four classes to study the local status of the butterflies: Very Common (VC): if the RA was more than 2.0%; Common (C): if the RA was comprising between 1.0% and 2.0%; Rare: if the RA was comprising between 0.30% and 1.0%, and Very Rare: if the RA was less than 0.30%.
The Shannon-Wiener index (H') is the sum of total species number within a locality with the relative abundance of each species. The higher values of H' represent higher diversity. It was calculated as follows: $H' = -\Sigma pi \ Ln \ pi$, where: pi is the proportion of the species in the total sample.
The Pielou's index (E) was calculated by using the following formula: $E = H'/\log(S)$, where: S is the species number.

Results

Global composition of butterfly in the study area

In total, 1063 individuals representing 143 species and 43 genera belonging to 10 families of butterflies were recorded during the entire study period (Table 1).

Table 1: Species composition of butterflies in the study area

Family name	Number of genera	Number of species	Number of individuals
Nymphalidae	19	104	761
Pieridae	6	11	140
Papilionidae	2	8	53
Lycaenidae	6	7	28
Saturniidae	3	4	30
Sphingidae	2	4	30
Geometridae	2	2	8
Erebidae	1	1	4
Eupterotidae	1	1	7
Riodinidae	1	1	2
Total	43	143	1063

Family composition and species distribution pattern in the study area

The Nymphalidae family was the most dominant butterfly family, accounting for 104 species (72.73%) of the total butterflies collected from all the study area (Table 1; Figure 2). It is followed by Pieridae (n=11; 7.69%), Papilionidae (n=8; 5.60%), Lycanidae (n=7; 4.89%), Saturniidae (n=4; 2.80%) and Sphingidae (n=4; 2.80%). The other families of butterfly were weakly collected in study area (n<3) (Table 1; Figure 2).

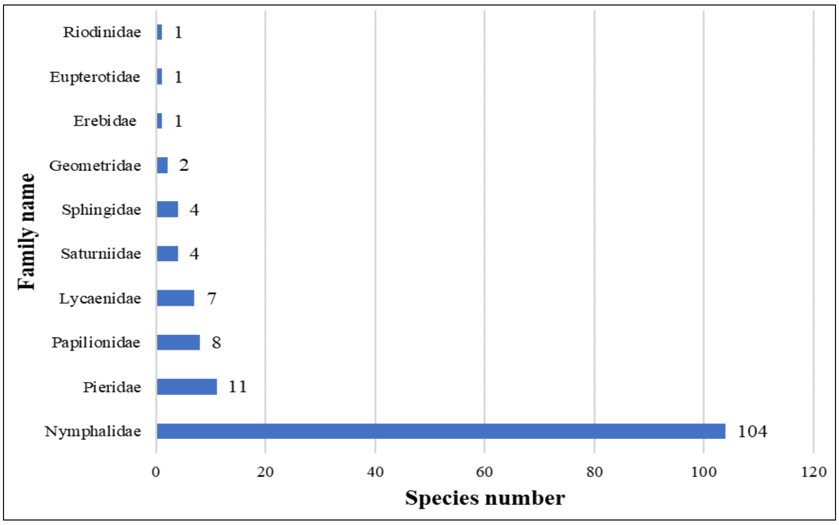

Fig 2: Family composition of butterflies in the entire study area

Family abundance of butterflies

In Figure 3, the family abundance of butterflies of the study area is presented. This figure shows that the Nymphalidae family had the highest percentage of butterflies collected from the study area, with 71% (n=761), followed by Pieridae with 13% (n=140), Papilionidae with 5% (n=53), Saturniidae with 3% (n=30), Sphingidae with 3% (n=30), and Lycanidae with 3% (n=28). The others families of butterfly contributed the least (Table 1; Figure 3).

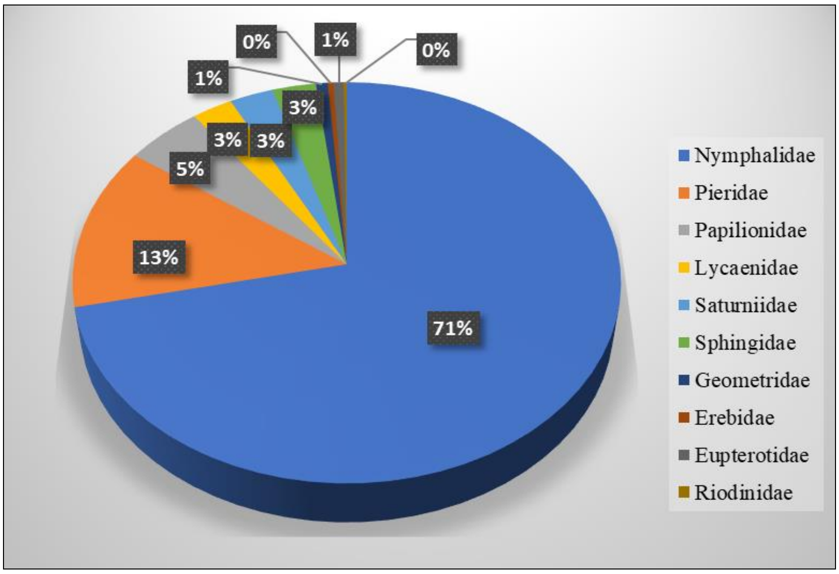

Fig 3: Family abundance of butterflies in the study area

Comparison of family number and butterfly effective among study sites

The results of figure 4 show that Massoko was the study site where we observed the highest number of butterflies (n=427) followed by Minkebe with 413 individuals collected, while Cratere-Mikouka had the lowest number of butterflies (n=223).

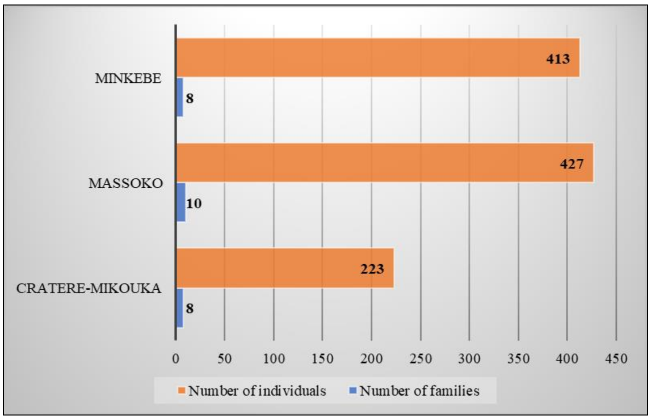

Fig 4: Butterfly abundance in each study site

Based upon diversity of butterfly families, Massoko (n=10) was more diversified than two others study sites where we encountered only 8 families of butterflies.

Relative abundance and status of butterfly species in the entire study area

The abundance of butterfly species in the different study sites and the relative abundance of the entire study area are presented in the Table 2. The analysis of this table 2 showed that *Charaxes imperialis* had the highest relative abundance (4.23%) while *Bicyclus sophrosyne, Bebearia sp.,* and *Acraea sp.* had the lowest relative abundance (0.09%, 0.09% and 0.09%) in all the study area.

Furthermore, this analysis revealed that *Leptosia sp.* had the maximum relative abundance (5.83%; n=13), followed by *Papilio lormieri* (4.93%; n=11) and *Appias sabina* (4.93%; n=11). While *Euphaedra hewitsoni* (0.45%; n=1), *Euphaedra harpalyce* (0.45%; n=1), *Euryphura chalcis* (0.45%; n=1), *Acraea sp.* (0.45%; n=1), and *Bicyclus sophrosyne* (0.45%; n=1) had the minimum relative abundance at Cratere-Mikouka.

The present study revealed also that *Charaxes imperialis* (10.54%; n=45) and *Euphaedra medon* (7.73%; n=33) had the highest relative abundance at Massoko, while *Euphaedra hebes* (0.23%; n=1) had the lowest relative abundance in this study site.

However, *Euphaedra ravola* (9.69%; n=40) and *Eurema senegalensis* (8.72%; n=36) had presented the highest relative abundance at Minkebe, while *Graphium tynderaeus* (0.24%; n=1), *Euryphura chalcis* (0.24%; n=1) and *Bebearia sp.* (0.24%; n=1) had the lowest relative abundance in this study site.

Table 2: Checklist and status of butterflies collected in the study area

Family name	Species name	Cratère-Mikouka	Massoko	Minkebe	Total	TRA	Ls
Riodinidae	*Abisara rutherfordii* (Hewitson, 1874)	0.90%	0%	0%	2	0.19%	VR
Papilionidae	*Papilio lormieri* (Distant, 1874)	4.93%	0%	0%	11	1.03%	C
	Graphium auriger (Butler, 1876)	1.79%	1.41%	0%	10	0.94%	R
	Papilio gallienus (Distant, 1879)	0%	0%	1.94%	8	0.75%	R
	Graphium policenes (Cramer, 1775)	0.90%	0.94%	0%	6	0.56%	R
	Papilio sp. (Linnaeus, 1758)	1.79%	0%	0.48%	6	0.56%	R
	Graphium tynderaeus (Fabricius, 1793)	0.90%	0.47%	0.24%	5	0.47%	R
	Papilio nireus (Linnaeus, 1758)	0.90%	0%	0.48%	4	0.38%	R
	Papilio chrapkowskoides (Storace, 1952)	1.35%	0%	0%	3	0.28%	VR
Erebidae	*Lithosini sp.* (Fabricius, 1798)	0%	0.94%	0%	4	0.38%	R
Eupterotidae	*Parajana gabunica* (Aurivillius, 1892)	0.90%	0.70%	0.48%	7	0.66%	R
Geometridae	*Pingasa hypoxantha* (Louis Beethoven Prout, 1916)	0%	0.94%	0%	4	0.38%	R
	Plegapteryx sp. (Herrich-Schäffer, 1856)	0%	0.47%	0.48%	4	0.38%	R
Lycaenidae	*Mimeresia sp.* (Stempffer, 1961)	0%	0%	2.18%	9	0.85%	R
	Liptena catalina (Grose-Smith & Kirby, 1887)	0%	1.17%	0%	5	0.47%	R
	Telipna cuypersi (Libert, 2005)	0%	0.47%	0.48%	4	0.38%	R
	Phlyaria cyara (Hewitson, 1876)	1.35%	0%	0%	3	0.28%	VR
	Oboronia ornata (Mabille, 1890)	0%	0%	0.73%	3	0.28%	VR
	Citrinophila unipunctata (Bethune-Baker, 1908)	0%	0%	0.48%	2	0.19%	VR
	Oboronia sp. (Karsch, 1893)	0%	0%	0.48%	2	0.19%	VR
Nymphalidae	*Charaxes imperialis* (Butler, 1874)	0%	10.54%	0%	45	4.23%	VC
	Euphaedra ravola (Hewitson, 1866)	0%	0%	9.69%	40	3.76%	VC
	Euphaedra medon (Linnaeus, 1763)	0%	7.73%	0%	33	3.10%	VC
	Sevenia amulia (Cramer, 1777)	3.14%	2.81%	3.15%	32	3.01%	VC
	Cymothoe lucasii (Doumet, 1859)	0%	3.98%	1.69%	24	2.26%	VC
	Euphaedra fulvofasciata (Holland, 1920)	1.79%	3.28%	1.45%	24	2.26%	VC
	Euphaedra limbourgi (Oremans, 2006)	3.14%	3.75%	0%	23	2.16%	VC
	Bicyclus dubia (Aurivillius, 1893)	0%	3.04%	1.45%	19	1.79%	C
	Charaxes cynthia (Butler, 1874)	3.14%	1.17%	1.21%	17	1.60%	C
	Euphaedra ruspina (Hewitson, 1865)	0%	2.58%	0.97%	15	1.41%	C
	Cynandra opis (Drury, 1773)	1.35%	1.17%	0.97%	12	1.13%	C
	Euphaedra uniformis (Berger, 1981)	2.69%	1.41%	0%	12	1.13%	C
	Catuna crithea (Drury, 1773)	1.35%	0.94%	0.97%	11	1.03%	C
	Charaxes brutus (Cramer, 1779)	2.24%	0%	1.45%	11	1.03%	C
	Cymothoe caenis (Drury, [1773)	0%	0%	2.66%	11	1.03%	C

	Cymothoe hypatha (Hewitson, 1866)	2.24%	1.41%	0%	11	1.03%	C
	Euphaedra margaritifera (Schultze, 1920)	0%	0.94%	1.69%	11	1.03%	C
	Cymothoe sp. (Hubner, 1819)	1.79%	0%	1.45%	10	0.94%	R
	Hypolimnas anthedon (Doubleday, 1845)	0%	0.70%	1.69%	10	0.94%	R
	Acraea epaea (Cramer, 1779)	1.35%	1.41%	0%	9	0.85%	R
	Bicyclus hewitsoni (Doumet, 1861)	0%	1.41%	0.73%	9	0.85%	R
	Cymothoe beckeri (Herrich-Schaeffer, 1858)	1.79%	0%	1.21%	9	0.85%	R
	Cymothoe ogova (Plötz, 1880)	2.24%	0.94%	0%	9	0.85%	R
	Cymothoe weymeri (Suffert, 1904)	0%	0.94%	1.21%	9	0.85%	R
	Euphaedra hewitsoni (Hecq, 1974)	0.45%	1.17%	0.73%	9	0.85%	R
	Euphaedra xypete (Hewitson, 1865)	0%	0%	2.18%	9	0.85%	R
	Cymothoe sangaris (Godard, 1824)	2.24%	0.70%	0%	8	0.75%	R
	Euphaedra justitia (Staudinger, 1886)	0.90%	0.47%	0.97%	8	0.75%	R
	Neptis metella (Doubleday, 1848)	0%	1.17%	0.73%	8	0.75%	R
	Sevenia occidentalium (Mabille, 1876)	0%	0%	1.94%	8	0.75%	R
	Bebearia carshena (Hewitson, 1871)	0%	0%	1.69%	7	0.66%	R
	Bicyclus sp. (Kirby, 1871)	0%	0.70%	0.97%	7	0.66%	R
	Cymothoe hesiodotus (Staudinger, 1890)	1.35%	0.94%	0%	7	0.66%	R
	Cynandra sp. (Schatz, 1887)	0%	0%	1.69%	7	0.66%	R
	Euphaedra preussi (Staudinger, 1891)	1.35%	0.94%	0%	7	0.66%	R
	Euphaedra simplex (Hecq, 1978)	1.79%	0.70%	0%	7	0.66%	R
	Euphaedra variabilis (Guillaumin, 1976)	0.90%	1.17%	0%	7	0.66%	R
	Hypolimnas dinarcha (Hewitson, 1865)	0%	1.17%	0.48%	7	0.66%	R
	Bicyclus medontias (Hewitson, 1873)	0%	0.94%	0.48%	6	0.56%	R
	Charaxes pleione (Godart, 1824)	0%	0%	1.45%	6	0.56%	R
	Cymothoe haynae (Dewitz, 1887)	1.35%	0.70%	0%	6	0.56%	R
	Euphaedra adonina (Hewitson, 1865)	0%	1.41%	0%	6	0.56%	R
	Euphaedra vicina (Hecq, 1984)	0%	0.94%	0.48%	6	0.56%	R
	Euriphene abasa (Hewitson, 1866)	0%	1.41%	0%	6	0.56%	R
	Neptidopsis ophione (Cramer, 1777)	0%	0%	1.45%	6	0.56%	R
	Phalanta eurytis (Doubleday, [1847)	0%	0%	1.45%	6	0.56%	R
	Amauris niavius (Linnaeus, 1758)	0%	0%	1.21%	5	0.47%	R
	Bebearia cocalia (Fabricius, 1793)	0%	0%	1.21%	5	0.47%	R
	Bebearia plistonax (Hewitson, 1874)	0.90%	0.70%	0%	5	0.47%	R
	Bebearia subtentyris (Strand, 1912)	0%	0%	1.21%	5	0.47%	R
	Bicyclus moyses (Condamin & Fox, 1964)	0%	1.17%	0%	5	0.47%	R
	Charaxes castor (Cramer, 1775)	0%	1.17%	0%	5	0.47%	R
	Charaxes etesipe (Godart, 1824)	0.90%	0.70%	0%	5	0.47%	R
	Cymothoe lurida (Butler, 1871)	0%	0%	1.21%	5	0.47%	R
	Euphaedra alacris (Hecq, 1978)	2.24%	0%	0%	5	0.47%	R
	Euphaedra eleus (Drury, 1782)	0.90%	0.70%	0%	5	0.47%	R
	Euphaedra harpalyce (Cramer, 1779)	0.45%	0.94%	0%	5	0.47%	R
	Euphaedra hybrida (Hecq, 1978)	0%	0%	1.21%	5	0.47%	R
	Euphaedra losinga (Hewitson, 1864)	0.90%	0.70%	0%	5	0.47%	R
	Euphaedra rezia (Hewitson, 1866)	0%	0%	1.21%	5	0.47%	R
	Euphaedra sudanensis (Talbot 1929)	0%	1.17%	0%	5	0.47%	R
	Protogoniomorpha parhassus (Drury, 1782)	0%	0%	1.21%	5	0.47%	R
	Bebearia eliensis (Hewitson, 1866)	0%	0.47%	0.48%	4	0.38%	R
	Bicyclus italus (Hewitson, 1865)	0%	0.47%	0.48%	4	0.38%	R
	Bicyclus mollitia (Karsch, 1895)	1.79%	0%	0%	4	0.38%	R
	Catuna angustatum (Felder & Felder, 1867)	1.79%	0%	0%	4	0.38%	R
	Euphaedra amieti (Hecq, 1993)	0%	0.94%	0%	4	0.38%	R
	Euphaedra edwardsii (Van der Hoeven, 1845)	0%	0.94%	0%	4	0.38%	R
	Neptis camarensis (Schultze, 1920)	1.79%	0%	0%	4	0.38%	R
	Pseudacraea lucretia (Cramer, 1775)	0%	0.94%	0%	4	0.38%	R
	Pseudargynnis hegemone (Godart, 1819)	0%	0%	0.97%	4	0.38%	R
	Sevenia boisduvali (Wallengren, 1857)	0%	0%	0.97%	4	0.38%	R
	Acraea althoffi (Dewitz, 1889)	0%	0%	0.73%	3	0.28%	VR
	Bebearia bouyeri (Vande Weghe, 2007)	0%	0.70%	0%	3	0.28%	VR
	Bebearia octogramma (Grose-Smith & Kirby, 1889)	1.35%	0%	0%	3	0.28%	VR
	Bebearia tini (Oremans, 1998)	0%	0%	0.73%	3	0.28%	VR
	Cymothoe excelsa (Neustetter, 1912)	0%	0.70%	0%	3	0.28%	VR
	Cymothoe orphnina (Karsch, 1894)	1.35%	0%	0%	3	0.28%	VR
	Euphaedra hebes (Hecq, 1980)	0%	0.23%	0.48%	3	0.28%	VR
	Euphaedra jacksoni (Hecq, 1980)	1.35%	0%	0%	3	0.28%	VR
	Neptis lermanni (Aurivillius, 1896)	1.35%	0%	0%	3	0.28%	VR
	Sevenia trimeni (Aurivillius, 1899)	0%	0.70%	0%	3	0.28%	VR
	Bebearia bena (Vande weghe, 2009)	0.90%	0%	0%	2	0.19%	VR

	Bebearia partita (Aurivillius, 1895)	0%	0.47%	0%	2	0.19%	VR
	Bicyclus ewondo (Libert, 1996)	0%	0%	0.48%	2	0.19%	VR
	Bicyclus sciathis (Hewitson, 1866)	0%	0%	0.48%	2	0.19%	VR
	Charaxes ameliae (Doumet, 1861)	0%	0.47%	0%	2	0.19%	VR
	Charaxes numenes (Hewitson, 1865)	0.90%	0%	0%	2	0.19%	VR
	Charaxes sp. (Ochsenheimer, 1816)	0.90%	0%	0%	2	0.19%	VR
	Cymothoe oemilius (Doumet, 1859)	0%	0.47%	0%	2	0.19%	VR
	Euphaedra acuta (Hecq, 1977)	0%	0.47%	0%	2	0.19%	VR
	Euphaedra pervaga (Hecq, 1996)	0.90%	0%	0%	2	0.19%	VR
	Euphaedra temeraria (Hecq, 2007)	0%	0%	0.48%	2	0.19%	VR
	Euphaedra wissmanni (Niepelt, 1906)	0.90%	0%	0%	2	0.19%	VR
	Euphaedra zaddachii (Dewitz, 1879)	0%	0.47%	0%	2	0.19%	VR
	Euriphene atropurpurea (Aurivillius, 1894)	0%	0%	0.48%	2	0.19%	VR
	Euriphene conjungens (Aurivillius, 1909)	0%	0%	0.48%	2	0.19%	VR
	Euryphura chalcis (Felder & Felder, 1860)	0.45%	0%	0.24%	2	0.19%	VR
	Hypolimnas mechowi (Dewitz, 1884)	0%	0%	0.48%	2	0.19%	VR
	Hypolimnas salmacis (Drury, 1773)	0%	0%	0.48%	2	0.19%	VR
	Junonia sophia (Fabricius, 1793)	0%	0%	0.48%	2	0.19%	VR
	Acraea sp. (Fabricius, 1807)	0.45%	0%	0%	1	0.09%	VR
	Bebearia sp. (Hemming, 1960)	0%	0%	0.24%	1	0.09%	VR
	Bicyclus sophrosyne (Plötz, 1880)	0.45%	0%	0%	1	0.09%	VR
Pieridae	*Eurema senegalensis* (Boisduval, 1836)	0%	0%	8.72%	36	3.39%	VC
	Appias sabina (C. & R. Felder, 1865)	4.93%	0%	5.33%	33	3.10%	VC
	Leptosia sp. (Hübner, 1818)	5.83%	4.68%	0%	33	3.10%	VC
	Nepheronia argia (Fabricius, 1775)	0.90%	0.70%	0.73%	8	0.75%	R
	Eurema hecabe (Linnaeus, 1758)	1.35%	0.94%	0%	7	0.66%	R
	Appias perlucens (Butler, 1898)	0%	0.47%	0.97%	6	0.56%	R
	Eurema brigitta (Stoll, 1780)	0%	0%	1.21%	5	0.47%	R
	Appias phaola (Doubleday, 1847)	0%	0%	0.97%	4	0.38%	R
	Dixeia capricornus (Ward, 1871)	0%	0%	0.97%	4	0.38%	R
	Dixeia cebron (Ward, 1871)	0%	0%	0.48%	2	0.19%	VR
	Mylothris bernice (Hewitson, 1866)	0%	0%	0.48%	2	0.19%	VR
Saturniidae	*Micragone sp.* (Walker, 1855)	2.24%	0.94%	0.73%	12	1.13%	C
	Nudaurelia dione (Fabricius, 1793)	1.79%	1.41%	0%	10	0.94%	R
	Epiphora sp. (Wallengren, 1860)	0.90%	0.70%	0.73%	8	0.75%	R
Sphingidae	*Nephele maculosa* (Rothschild & Jordan, 1903)	2.24%	1.41%	0%	11	1.03%	C
	Nephele funebris (Fabricius, 1793)	1.35%	0.47%	0.73%	8	0.75%	R
	Hippotion sp. (Hübner, 1819)	1.35%	0%	0.73%	6	0.56%	R
	Nephele sp. (Hübner, 1819)	0%	0.47%	0.73%	5	0.47%	R
Total		100%	100%	100%	1063	100%	

N: Number of species; **Ls:** Local status; **TRA:** Total Relative Abundance.

The relative abundance analysis showed that among the 143 species recorded in the entire study area, 10 were very common, 13 were common, 79 were rare, and 40 were very rare (Table 2). The very common butterfly species found in the study area were: *Charaxes imperialis, Euphaedra ravola, Euphaedra medon, Sevenia amulia, Cymothoe lucasii, Euphaedra fulvofasciata, Euphaedra limbourgi, Eurema senegalensis, Appias sabina*, and *Leptosia sp*. Moreover, the common butterfly species in the study area were: *Papilio lormieri, Bicyclus dubia, Charaxes Cynthia, Euphaedra ruspina, Cynandra opis, Euphaedra uniformis, Catuna crithea*, *Charaxes brutus, Cymothoe caenis, Cymothoe hypatha, Euphaedra margaritifera, Micragone sp.,* and *Nephele maculosa*. For the two others categories, the name of species concerned is listed in the table 2.

Diversity indices and specific richness

The results of diversity indices and specific richness are presented in the Table 3. The study revealed that species diversity indices were higher at Cratere-Mikouka (H'=0.52; E=0.09), followed by Massoko (H'=0.49; E=0.08) (Table 3) and the least diversity were observed in Minkebe (H'=0.47; E=0.07) (Table 3). These low value of Pielou's index show the dominance of one butterfly species in the study sites.

However, the specific richness and the number of genera were higher at Minkebe (S=80; G=36), than at Massoko (S=75; G=27) and Cratere-Mikouka (S=61; G=27) (Table 3).

Table 3: Diversity indices and species richness of butterflies in the three study sites

Parameters	Cratere-Mikouka	Massoko	Minkebe
Shannon's index (H')	0.52	0.49	0.47
Pielou's Equitability index (E)	0.09	0.08	0.07
Specific richness (S)	61	75	80
Number of genera (G)	25	27	36

Discussion

This study is the first research focused on butterfly diversity in the Minkebe forest massif. The specific richness of butterfly populations in the study area accounts for about 13.02% of the total known species (1090 species) from Gabon (Vande Weghe, 2010) [24]. Comparing with other studies on butterfly diversity, the specific richness of butterflies in this study was lower than some other studies. Besides, Vande Weghe (2005) [22] identified 472 butterfly species in Ivindo National Park. This low diversity and richness of butterfly populations can be due to disturbances caused by human activities. Moreover, the short duration of the study (2 months) and the occurrence of rains (rainy season) may be the responsible factors for this situation because they reduce butterfly activity. Indeed, butterflies are ectothermic and their life pace and body functions are dependent on climatic factors (Roy *et al.,* 2001; Thomas, 2005) [16, 20].

Among the Lepidoptera, the Nymphalidae family was more diversified with about 104 species. According to Akoudjin (2017) [1], the Nymphalidae constitute a large family gathering more than 5000 worldwide species. As this author sees it, the presence of Nymphalidae denotes a more preserved environment through its diversity and density. The highest abundance of nymphalid butterflies among the total collected butterflies from the entire study area could be due to their ability to inhabit a variety of habitat types and their ability to feed on different plant species (Pollard and Yates, 1993; Koneri and Maabuat, 2016) [15, 7]. The lowest abundance of other butterfly families could be linked to the fact that some species have limited host plants.

Moreover, the Minkebe site had the highest number of butterfly species (n1=80) and genera (n2=36), followed by Massoko (n1=75; n2=27), while Cratere-Mikouka had the lowest number of species (n1=61; n2=25). This observation could be explained by the fact that this study site shared a lot of plants which are the larval food resources for many butterfly species. Besides, Koneri and Maabuat (2016) [7] reported that protected environments support more diversity of butterfly species, while unprotected and degraded sites support less diversity of Lepidoptera (Hamer *et al.,* 2003) [6].

Finally, this study conducted from April to May provided the first picture of butterfly abundance, specific richness, and diversity in the Minkebe forest massif. However, this study had some limitations in that trapping was not conducted in all seasons and there were limited traps used. Thus, future studies will include seasonal entomological surveys and trapping will be conducted using many traps. These studies will be conducted over a year in order to examine the effect of changes in habitat types on the dynamics and diversity of butterflies. The collected data will be necessary for generating all information useful for improving the conservation of the butterfly community in the study area (New, 1997; Bonebrake *et al.,* 2010) [13, 4].

Conclusion

This study is the primary investigation focused on the abundance and diversity of butterfly populations in the Minkebe forest massif. The results of the current study reveal that the study area is rich and diverse in butterfly species. A total of one hundred and forty-three species comprise the butterfly fauna of Minkebe forest massif. This list of butterfly species is not exhaustive because this survey covers only two months (April to May).

Furthermore, the study revealed the local status of different species of butterflies found in the study area. So, a particular attention must be paid to these insects in order to better understand the biology and the ecology of these insects.

Future investigations regarding the butterfly species should be completed to update the present butterfly checklist and to further understand the species abundance and their spatio-temporal distribution in the different sites of Minkebe forest massif.

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Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

Author contributions

AAK, CRZK and JFM conceived and supervised the study. AAK, CRZK and EAAL undertook collection of field data and species identification. AAK constructed all maps. CRZK conducted statistical analysis. AAK and CRZK interpreted the data and wrote initial manuscript while JFM, CRZK and RM revised the subsequent drafts. All authors read and approved the final manuscript for publication.

Data availability statement

The data presented in this study are available on request from the corresponding author.

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