Butterfly community (Lepidoptera: Papilionoidea) in a transition area of Atlantic Forest and *Cerrado* in Minas Gerais, Brazil

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Abstract

Fauna inventories function as a database to guide biota conservation policies, such as the creation of Conservation Units, especially in biomes that suffer from habitat loss. This work was developed to survey the butterfly fauna in a transition area of Atlantic Forest and *Cerrado* in the central-south of the state of Minas Gerais, Brazil, which has potential for the creation of a Conservation Unit. The study was carried out in three forest remnants in the municipalities of Barroso and Prados, from October 2020 to March 2021, using active search and attractive traps to collect specimens. A total of 555 individuals were collected comprising 164 species of butterflies, with Nymphalidae being the richest and most abundant family. Two endemic subspecies of the *Cerrado* were recorded, *Diaethria eluina eluina* and *Pseudoscada acilla quadrifasciata*. In conclusion, the place is home to a relevant butterfly fauna, which ratifies the need for the creation of a Conservation Unit in the region of the municipality of Barroso.

Keywords: Biodiversity; Conservation; Fauna; Insects; Inventory.

Introduction

In Brazil, the Atlantic Forest and the *Cerrado* are two important biodiversity hotspots since they have a high level of endemism and endangered species (MITTERMEIER et al., 2011; OLIVEIRA et al., 2021). The Atlantic Forest is one of the biomes that suffers the most from deforestation in Brazil, with less than 8 % of its original cover remaining (WWF BRASIL, 2023), which forms fragments smaller than 50 ha (about 85 %), resulting in a large edge effect, which can be harmful to the functioning of its ecosystems (SANTOS et al., 2018). The Cerrado is also subject to different anthropogenic pressures, such as wildfires and extraction of ornamental species (NEGREIROS et al., 2011; RODRIGUES et al., 2022) and habitat loss due to the expansion of agricultural areas (RAUSCH et al., 2019).

The reduction of natural environments is the main cause of biodiversity loss (ROSSETTI et al., 2017). This justifies inventory studies (an instrument that allows the implementation of effective conservation measures), since knowing the biota is one of the first steps to formulate environmental conservation policies (DOLIBAINA et al., 2011, GIRARDELLO et al., 2019) such as the creation of Conservation Units (CU), which is the main tool for the protection of the biota and of Brazilian natural resources (SALVIO, 2017).

Despite the accelerated reduction of habitats and loss of biodiversity, many areas in Brazil do not have information on the biodiversity of different taxa such as butterflies, insects of the order Lepidoptera, as observed in the state of Minas Gerais (BROWN JR., MIEKE, 1967a, 1967b, 1968; EBERT, 1969; HENRIQUES

et al., 2019; VIEIRA et al., 2022; SILVA et al., 2022). Despite this lack of information, about 1,600 species are known, of which 25 are at risk of extinction (CASAGRANDE et al., 1998; COPAM, 2010; ICMBIO/MMA, 2018).

These insects perform essential functions in ecosystems, such as pollination, herbivory, and nutrient cycling (LOMOV et al., 2006), in addition to acting as bioindicators of environmental quality since they are easy to sample, sensitive to environmental changes and have a short life cycle (FREITAS et al., 2006; UEHARA-PRADO et al., 2009; BOGIANI et al., 2012). Based on this, this work was developed to survey the butterfly fauna in a transition area of Atlantic Forest and *Cerrado*, in the central-south of the state of Minas Gerais, which is home to a relevant insect fauna and holds a potential for the creation of a CU.

Material and methods

The study was carried out in the municipalities of Barroso (21°11'13"S, 43°58'33"W), with an area of 8,172.6 ha, and Prados (21°13'33.20"S, 44°2'0.56"W, Figure 1), with an area of 2,641.5 ha, in the central-south of the state of Minas Gerais, in the Campo das Vertentes region. Both municipalities are in the transition area of the Atlantic Forest and *Cerrado* biomes (CARVALHO et al., 1994; MENINI-NETO et al., 2004), forming a vegetational mosaic. The climate is marked by dry winters and hot summers (Köppen classification: CWA), with average annual rainfall of 1,600 mm and average annual temperature of 21°C (REBOITA et al., 2015; MARTINS et al., 2018).

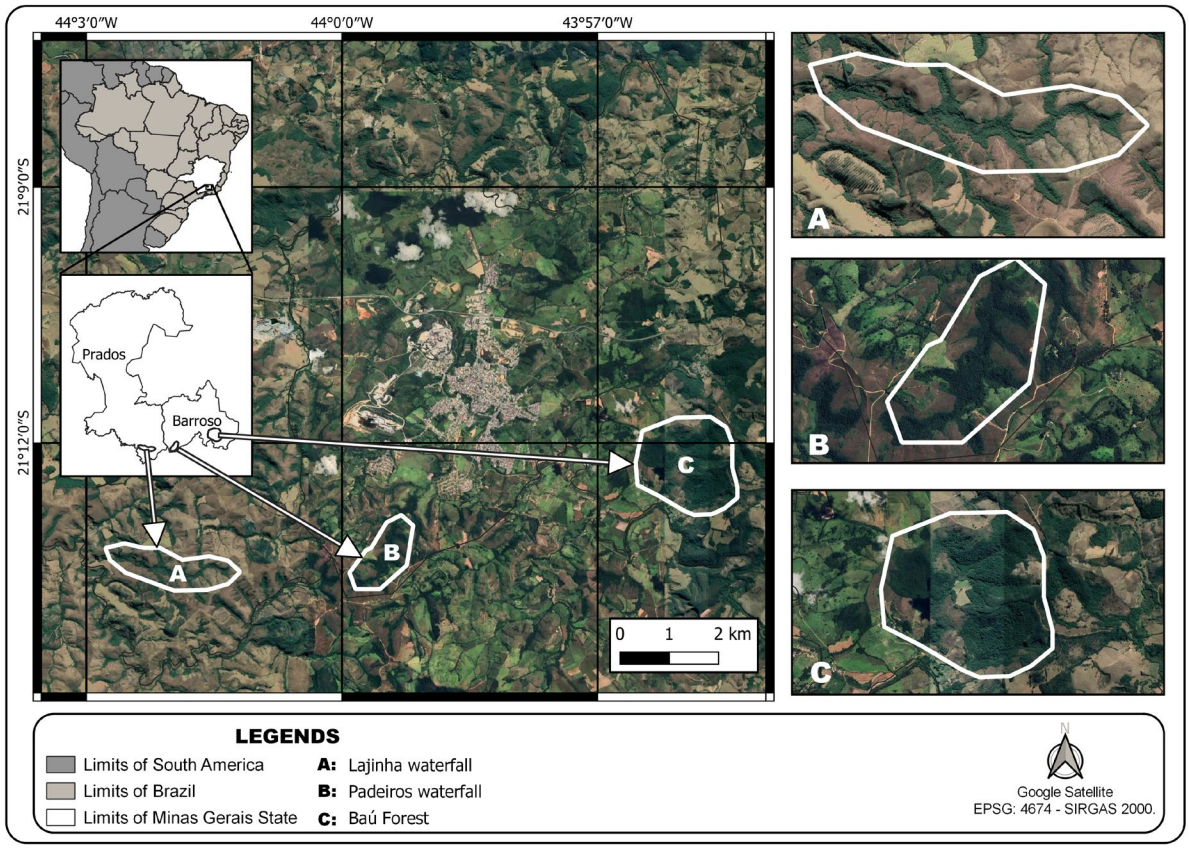
Samples were collected in three forest remnants: (A) Lajinha Waterfall, with 32.25 ha; (B) Padeiro Waterfall, with 26.43 ha; and (C) Baú Woods, with 384.9 ha (Figure 1). These remnants are formed by gallery forest, seasonal semi-deciduous forest and grassland, and are generally surrounded by pastures, associated with eucalyptus cultivation (A and C) or used for ecotourism activities (A and B). Wildfires were also recorded before and during the study, particularly at point C. The remnants are located between one and four kilometers from the urban perimeter, with A being the furthest (4 km), B the closest (1 km), and C the intermediate (2.5 km); fragments A and B are about 3.2 km apart, A and C are 7.8 km apart, and B and C are 4.5 km apart.

Butterfly sampling was carried out in four field campaigns, in a total period of six months (October–December 2020; January–March 2021) with 24 days of six hours of collection per day. Two attractive Van Someren-Rydon traps, baited with sugarcane juice with banana fermented for 48 hours (FREITAS et al., 2014), were placed for 72 h in each remainder, resulting in 288 h of sampling effort per trap and totaling 2,304 h. In the active search, with the use of a butterfly net on trails in forest areas and open fields, sampling took place in the morning and early afternoon, when the butterflies are most active: from 9 am to 2 pm (HENRIQUES et al., 2019), totaling 48 hours per fragment. Therefore, the total collection effort was of 2,448 h.

All sampled individuals were sacrificed in the field, stored into insect envelopes with labelling of date and place of collection, and sent for identification at the Laboratory of Systematics and Ecology of Butterflies (LABBOR), at the Institute of Biology of the State University of Campinas (UNICAMP). There, the material was deposited in the Zoological Collection of the Museum of Biological Diversity of the State University of Campinas (ZUEC), Campinas, São Paulo, Brazil.

The sampling effort was evaluated using the bootstrap 1 species estimator using the Estimates 9.1.0 software (COLWELL, ELSENSOHN, 2014), with 95 % confidence. To assess the sample sufficiency, a species rarefaction curve was constructed.

Figure 1. Forest remnants where butterfly community sampling was carried out in the municipalities of Barroso and Prados, central-south of the state of Minas Gerais, Brazil, 2020/2021.



Results

A total of 555 individuals were collected, distributed in 164 species of six butterfly families. The family Nymphalidae was the richest (82 species, 50 % of all species), followed by Hesperiidae (33 spp., 20.12 %), Riodinidae (21 spp., 12.81 %), Papilionidae and Pieridae (11 spp., 6.71 % each), and Lycaenidae (6 spp., 3.65 %). Regarding abundance, Nymphalidae remained the most abundant (N=313, 56.39 %), followed by Pieridae (N=73, 13.15 %), Hesperiidae (N=62, 11.17 %), Papilionidae (N=37, 6.69 %), Riodinidae (N=36, 6.48 %), and Lycaenidae (N=34, 6.12 %) (Table 1).

The most abundant species were *Hemiargus hanno hanno* (Lycaenidae: Polyommatinae, N=23), *Morpho helenor achillides* (Nymphalidae: Satyrinae, N=22), *Hamadryas epinome* (Nymphalidae: Biblidinae, N=17), and *Aeria olena* (Nymphalidae: Danainae, N=15), together representing 13.87 % of the sampled total. While only one individual (singletons) was collected for 67 species, two (doubletons) were recorded for 27. In addition, two subspecies are endemic to the *Cerrado* biome: *Diaethria eluina eluina* (Hewitson, 1855) Biblidinae) and *Pseudoscada acilla quadrifasciata* (Nymphalidae: Danainae).

The rarefaction curve shows that the richness of butterflies in the region can reach 195 species (Figure 2).

Discussion

The list of species generated is important, firstly, for providing information about the community of these insects, since little is known about the butterfly assemblage in the region (HENRIQUES et al., 2019); and, second, the richness is relevant to the butterfly fauna of the

Table 2. Families, subfamilies, abundance, and richness of butterflies in the municipalities of Barroso and Prados. Minas Gerais, 2020/2021.

Family/Subfamily	Species	Abundance
HESPERIIDAE (33)		
	Hesperiidae sp. 1	2
	Hesperiidae sp. 2	3
	Hesperiidae sp. 3	14
	Hesperiidae sp. 4	3
	Hesperiidae sp. 5	3
	Hesperiidae sp. 6	2
	Hesperiidae sp. 7	1
	Hesperiidae sp. 8	1
	Hesperiidae sp. 9	1
	Hesperiidae sp. 10	1
	Hesperiidae sp. 11	1
	Hesperiidae sp. 12	1
	Hesperiidae sp. 13	1
	Hesperiidae sp. 14	1
	Hesperiidae sp. 15	1
	Hesperiidae sp. 16	1
	Hesperiidae sp. 17	1
	Hesperiidae sp. 18	1
	Hesperiidae sp. 19	1
Eudaminae (1)		
	Cogia sp.	1
Hesperiinae (1)		
	Miltomiges cinnamomea (Herrich-Schäffer, 1869)	2
Pyrginae (12)		
	Achlyodes busirus rioja (Evans, 1953)	1
	Autochton sp. 1	1
	Autochton sp. 2	1
	Heliopetes alana (Reakirt, 1868)	1
	Heliopetes arsalte (Linnaeus, 1758)	1
	Heliopetes macaira orbigera (Mabille, 1888)	1
	Pyrgus orcus (Stoll, 1780)	3
	Pythonides lancea (Hewitson, 1868)	3
	Sostrata cronion (C. Felder & R. Felder, 1867)	1
	*Trina geometrina geometrina (*C. Felder & R. Felder, 1867)	3
	Urbanus dorantes dorantes (Stoll, 1790)	1
	Urbanus sp.	2

Family/Subfamily	Species	Abundance
LYCAENIDAE (6)		
Polyommatinae (3)		
	Hemiargus hanno hanno (Stoll, 1790)	23
	Leptotes cassius cassius (Cramer, 1775)	4
	Zizula cyna (W. H. Edwards, 1881)	4
Theclinae (3)		
	Arawacus separata (Lathy, 1926)	1
	Pseudolycaena marsyas (Linnaeus, 1758)	1
	Strymon astiocha (Prittwitz, 1865)	1
NYMPHALIDAE (82)		
Apaturinae (1)		
	Doxocopa laurentia laurentia (Godart, 1824)	2
Biblidinae (16)		
	Diaethria candrena candrena (Godart, 1824)	3
	Diaethria eluina eluina (Hewitson, 1855)	3
	Dynamine agacles agacles (Dalman, 1823)	2
	Dynamine postverta postverta (Cramer, 1779)	1
	Dynamine tithia tithia (Hübner, 1823)	1
	Ectima thecla thecla (Fabricius, 1796)	2
	Epiphile orea orea (Hübner, 1823)	3
	Episcada carcinia (Schaus, 1902)	2
	Eunica Margarita (Godart, 1824)	5
	Haematera pyrame pyrame (Hübner, 1819)	2
	Hamadryas chloe rhea (Fruhstorfer, 1907)	2
	Hamadryas epinome (C. Felder & R. Felder, 1867)	17
	Hamadryas februa februa (Hübner, 1823)	5
	Hamadryas feronia feronia (Linnaeus, 1758)	3
	Myscelia orsis (Drury, 1782)	1
	Temenis laothoe meridionalis (Ebert, 1965)	2
Charaxinae (8)		
	Archaeoprepona amphimachus amphimachus (Fabricius, 1775)	2
	Archaeoprepona chalciope (Hübner, 1823)	2
	Archaeoprepona demophon thalpius (Hübner, 1814)	3
	Archaeoprepona demophoon antimache (Hübner, 1819)	1
	Fountainea ryphea phidile (Geyer, 1837)	2
	Memphis acidalia victoria (H. Druce, 1877)	3
	Memphis moruus stheno (Prittwitz, 1865)	1
	Prepona eugenes laertides (Staudinger, 1898)	2
Cyrestinae (2)		
	Marpesia chiron marius (Cramer, 1779)	2
	Marpesia petreus petreus (Cramer, 1776)	2

Family/Subfamily	Species	Abundance
Danainae (12)		
	Aeria olena olena (Weymer, 1875)	15
	Brevioleria aelia plisthenes (R.F. d'Almeida, 1958)	4
	Danaus erippus (Cramer, 1775)	1
	Hypoleria alema proxima (Weymer, 1899)	7
	Hypothyris ninonia daeta (Boisduval, 1836)	2
	Ithomia agnosia zikani (R.F. d'Almeida, 1940)	4
	Ithomia drymo (Hübner, 1816)	8
	Mcclungia cymo salonina (Hewitson, 1855)	3
	Mechanitis lysimnia lysimnia (Fabricius, 1793)	9
	Mechanitis polymnia casabranca (Haensch, 1905)	14
	Pseudoscada acilla quadrifasciata (Talbot, 1928)	3
	Pteronymia carlia (Schaus, 1902)	1
Heliconiinae (9)		
	Actinote cf. pellenea pellenea	1
	Actinote mamita mitama (Schaus, 1902)	6
	Actinote pyrrha (Fabricius, 1775)	3
	Actinote sp.	10
	Actinote surima surima (Schaus, 1902)	2
	Agraulis vanillae maculosa (Stichel, 1908)	3
	Dryas iulia alcionea (Cramer, 1779)	3
	Heliconius erato phyllis (Fabricius, 1775)	5
	Heliconius ethilla narcaea (Godart, 1819)	3
Limenitidinae (2)		
	Adelpha syma (Godart, 1824)	6
	Adelpha thessalia indefecta (Fruhstorfer, 1913)	1
Nymphalinae (7)		
	Colobura dirce dirce (Linnaeus, 1758)	1
	Eresia lansdorfi (Godart, 1819)	4
	Junonia genoveva (Cramer, 1780)	4
	Ortilia orthia (Hewitson, 1864)	2
	Siproeta stelenes meridionalis (Fruhstorfer, 1909)	8
	Tegosa sp.	15
	Vanessa braziliensis (Moore, 1883)	5
Satyrinae (25)		
	Caligo arisbe fulgens (Rothschild, 1916)	1
	Caligo illioneus (Cramer, 1775)	3
	Cissia eous (A. Butler, 1867)	1
	Cissia phronius (Godart, 1824)	1
	Forsterinaria necys (Godart, 1824)	1
	Godartiana muscosa (A. Butler, 1870)	1

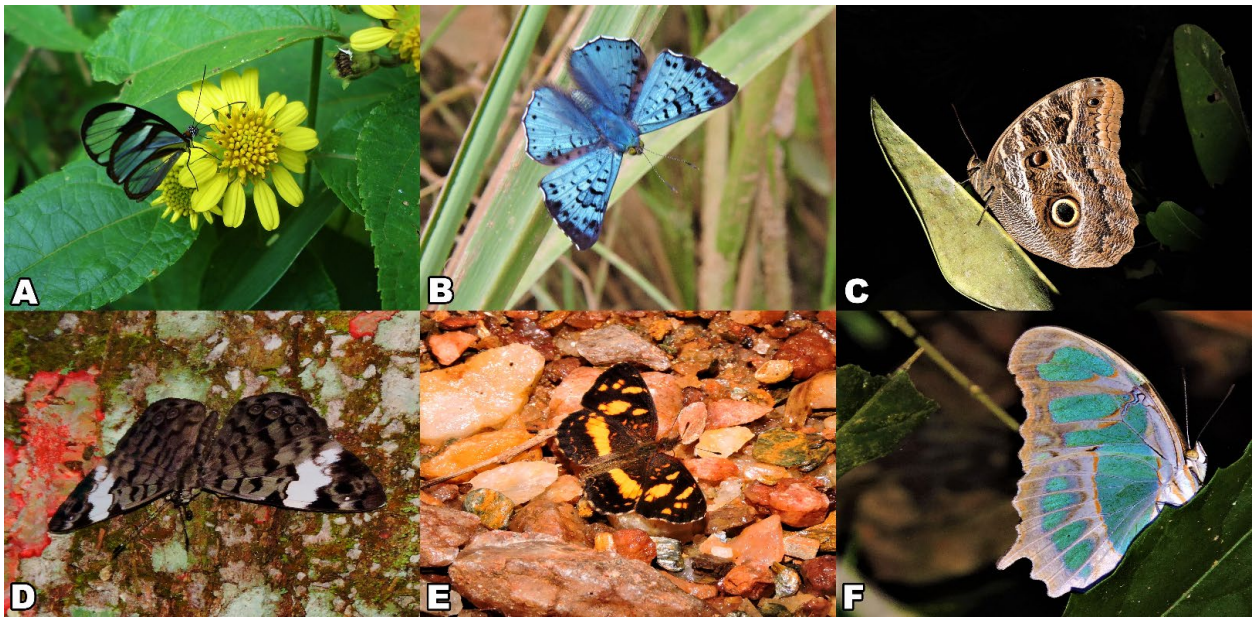
Family/Subfamily	Species	Abundance
	Hermeuptychia sp.	4
	Moneuptychia castrensis (Schaus, 1902)	1
	Morpho anaxibia (Esper, 1801)	1
	Morpho epistrophus epistrophus (Fabricius, 1796)	1
	Morpho helenor achillides (C. Felder & R. Felder, 1867)	22
	Morpho menelaus (Linnaeus, 1758)	6
	Opsiphanes invirae pseudophilon (Fruhstorfer, 1907)	1
	Opsiphanes quiteria meridionalis (Staudinger, 1887)	1
	Pareuptychia ocirrhoe interjecta (R.F. d'Almeida, 1952)	5
	Paryphthimoides poltys poltys (Prittwitz, 1865)	1
	Pharneuptychia innocentia (C. & R. Felder, 1867)	9
	Pseudodebis ypthima (Hübner, 1821)	3
	Satyrinae sp. 1	1
	Satyrinae sp. 2	1
	Taygetis sp. (laches complex)	4
	Yphthimoides angularis (A. Butler, 1867)	1
	Yphthimoides pacta (Weymer, 1911)	10
	Yphthimoides patricia (Hayward, 1957)	3
	Yphthimoides renata (Stoll, 1780)	1
PAPILIONIDAE (11)		
Papilioninae (11)		
	Battus crassus crassus (Cramer, 1777)	2
	Heraclides hectorides (Esper, 1794)	6
	Heraclides thoas brasiliensis (Rothschild & Jordan, 1906)	1
	Heraclides torquatus polybius (Swainson, 1823)	1
	Mimoides lysithous lysithous (Hübner, 1821)	7
	Neographium asius (Fabricius, 1781)	1
	Parides anchises nephalion (Godart, 1819)	4
	Parides bunichus bunichus (Hübner, 1821)	5
	Parides proneus (Hübner, 1831)	7
	Protesilaus sp.	2
	Pterourus scamander (Boisduval, 1836)	1
PIERIDAE (11)		
Coliadinae (7)		
	Eurema albula sinoe (Godart, 1819)	8
	Eurema elathea flavescens (Chavannes, 1850)	5
	Eurema phiale paula (Röber, 1909)	14
	Leucidia elvina (Godart, 1819)	5
	Phoebis neocypris (Hübner, 1823)	5
	Phoebis statira (Cramer, 1777)	3
	Pyrisitia nise tenella (Boisduval, 1836)	9

Family/Subfamily	Species	Abundance
Dismorphiinae (1)		
	Pseudopieris nehemia nehemia (Boisduval, 1836)	8
Pierinae (3)		
	Archonias brassolis tereas (Godart, 1819)	2
	Melete lycimnia paulista (Fruhstorfer, 1908)	11
	Pereute antodyca (Boisduval, 1836)	3
RIODINIDAE (21)		
Riodininae (21)		
	Amarynthis meneria (Cramer, 1776)	1
	Anteros lectabilis (Stichel, 1909)	2
	Aricoris tutana (Godart, 1824)	1
	Baeotis johannae johannae (Sharpe, 1890)	1
	Brachyglenis drymo (Godman & Salvin, 1886)	1
	Calephelis sp.	3
	Caria sp.	1
	Chalodeta sp.	5
	Chamaelimnas briola (H. Bates, 1868)	1
	Charis cadytis (Hewitson, 1866)	1
	Chorinea heliconides (Swainson, 1833)	2
	Emesis sp.	4
	Lasaia agesilas agesilas (Latreille, 1809)	1
	Lemonias stalachtioides (A. Butler, 1867)	1
	Lemonias zygia zygia (Hübner, 1807)	1
	Melanis electron auriferax (Stichel, 1910)	3
	Mesene sp.	1
	Metacharis sp.	1
	Panara soana bacana (Callaghan, 1997)	2
	Riodina lycisca (Hewitson, 1853)	2
	Synargis paulistina (Stichel, 1910)	1
	Richness	164
	Abundance	555

Cerrado and the Atlantic Forest, since it is similar or greater to other studies carried out in the state (PIRES et al., 2018; PIRES et al., 2020; VIEIRA et al., 2022) even if the studied area is fragmented and surrounded by pasture areas and eucalyptus cultivation, which has a negative impact on the butterfly fauna (UEHARA-PRADO et al., 2007; UEHARA-PRADO et al. 2009; DE BRITO et al., 2021).

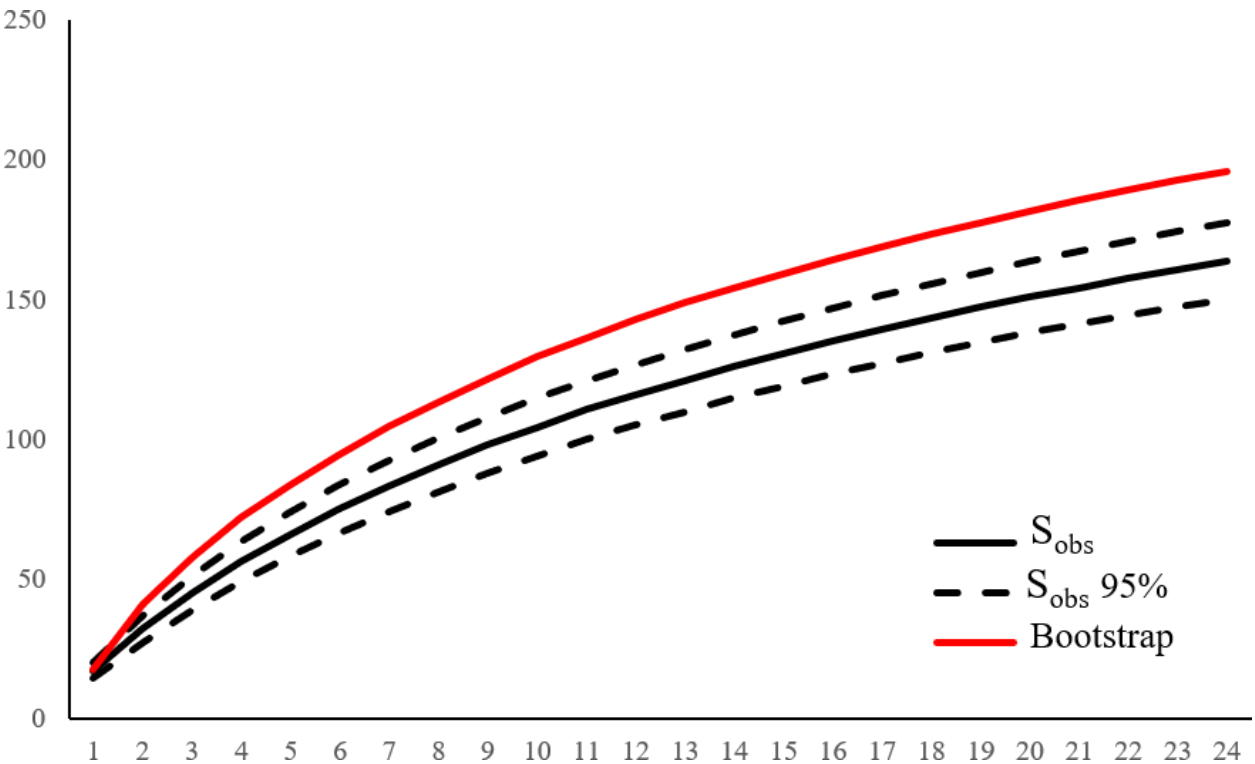
The presence of *Diaethria eluina eluina* and *Pseudoscada acilla quadrifasciata*, two subspecies endemics to the *Cerrado* (PINHEIRO et al., 2010) and also recorded in other studies in the biome (EMERY et al., 2006; SAMPAIO et al., 2014), further reinforces the importance of these remnants for the conservation of local biodiversity and highlights the need for conservation measures in the remaining areas of

Figure 2. Butterfly species recorded in forest remnants in the municipalities of Barroso and Prados, Minas Gerais, Brazil, 2020/2021.



Legend: *Ithomia* sp. (A); *Lasaia agesilas* (B); *Caligo illioneus* (C); *Ectima thecla thecla* (D); *Ortilia orthia* (E); *Siproeta stelenes meridionalis* (F). **Source:** Authors

Figura 3. Rarefaction curve based on the sampling period of butterfly species (*bootstrap* richness estimator) in the municipalities of Barroso and Prados, Minas Gerais, Brazil, 2020/2021.



Legend: The bootstrap line refers to the expected number of species, the S_{obs} line refers to the sampled number, whereas the dotted lines refer to the error intervals, with 95 % confidence.

Cerrado and Atlantic Forest, as already proposed in the area by Oliveira et al. (2021).

The high richness and abundance of the families Nymphalidae and Hesperiidae were expected, since they are among the families with the highest species richness in Brazil (BONFANTTI et al., 2009), a pattern also described in other studies carried out in Minas Gerais (MOTTA, 2002; OLIVEIRA et al., 2018; HENRIQUES et al., 2019; VIEIRA et al., 2022). Nymphalidae has occupational success, being present in several ecosystems (DEVRIES, 1987), having several feeding niches (BROWN JR., FREITAS, 1999), and being easily attracted and captured by attractive traps (FREITAS et al., 2003; UEHARA-PRADO et al., 2007; VIEIRA et al., 2020), which may explain its high richness and abundance in this study.

The abundance of the species shows the sampling relation with the local landscape and environmental conditions. *Hemiargus hanno hanno* and *Hamadryas epinome*, two of the most abundant species, are common in open, anthropized areas, forest edges, and gallery forests (BROWN JR., 1992; SOUZA et al., 2007; RIBEIRO et al., 2012; SAMPAIO et al., 2014). *Morpho helenor achillides*, a frugivorous and low-flying species (BROWN JR., 1992), has a behavior that favors its survival in areas that suffer fires (NASCIMENTO et al., 2020). *Aeria olena olena*, on the other hand, is a species found in Cerrado vegetation and near dewy soils (BROWN JR., 1992; BROWN JR., FREITAS, 2000), where its population tends to grow during the wet seasons (FONSECA et al., 2006). All these characteristics are present in the studied area since it is fragmented, with gallery forests and grassland that suffer anthropic action, in which fire outbreaks were observed before and during our work, in addition to the sampling effort having been concentrated in the rainy season and close to humid areas.

The number of species recorded is similar to other studies in the Atlantic Forest (BONFANTTI et al., 2011; VIEIRA et al., 2022) and Cerrado (PIRES et al., 2018). However, some groups were probably undersampled, which would explain the high number of singleton and doubleton species such as the genera *Pyrgus*, *Urbanus*, and *Hermeuptychia*, which have relatively common species in any environment but were poorly sampled in this study. Despite this, according to the Bootstrap species estimator, about 84 % of the butterfly community was sampled in the study area. New visits, at other times of the year, to record seasonal species (RIBEIRO, FREITAS, 2011), and periods known as high species richness (BROWN JR., 1972), would probably be sufficient for a more complete record of the butterfly community in the study area.

Conclusion

The municipalities of Barroso and Prados are home to a relevant butterfly fauna for the state of Minas Gerais, a condition evident by the presence of endemic species. This reinforces the need to create a Conservation Unit for the Barroso region, to ensure the different environmental services provided by these insects.

Acknowledgements

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