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Inventory

Butterflies of Amazon and Cerrado remnants of Maranhão, Northeast Brazil

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Abstract: Species inventories are important tools to evaluate biodiversity losses and contribute to the conservation of endangered areas. The Amazon and Cerrado are the largest Brazilian biomes and represent some of the most threatened regions of the country. Due to its location between these biomes, the state of Maranhão, Northeast Brazil, possesses a great variety of habitats and a high local diversity. Nonetheless, few faunistic inventories of diversified groups have been performed in the state. In the specific case of butterflies, a well-known biological indicator, no inventories have been published in the past years. This study aimed to expand the knowledge on the composition of butterflies in Amazon and Cerrado remnants of Maranhão. Butterflies were sampled between 2011 and 2015 across eight municipalities of the state. Captures were made through entomological nets and baited traps. In total, 189 species were sampled, of which 165 were captured in the Amazon, 65 in the Cerrado and 41 in both biomes. We sampled 167 species through entomological nets and 43 through baited traps, representing 12% of similarity in species composition between sampling methods. We estimate that the recorded species represent a small subset of the butterflies from Maranhão. Therefore, long-term researches in poorly studied areas of the state are recommended to identify novel and/or endemic taxa.

Keywords: *tropical forest, diversity, Lepidoptera, Neotropical region, savanna.*

Borboletas de remanescentes de Amazônia e Cerrado do Maranhão, nordeste do Brasil

Resumo: Inventários de espécies são ferramentas importantes para avaliar perdas de biodiversidade e contribuir para a conservação de áreas ameaçadas. A Amazônia e o Cerrado são os maiores biomas brasileiros e representam algumas das regiões mais ameaçadas do país. Devido à sua localização entre estes biomas, o estado do Maranhão, nordeste do Brasil, possui uma grande variedade de habitats e uma alta diversidade local. No entanto, poucos inventários faunísticos de grupos diversificados foram realizados no estado. No caso específico de borboletas, um indicador biológico bem conhecido, nenhum inventário foi publicado nos últimos anos. Este estudo objetivou expandir o conhecimento sobre a composição de borboletas de remanescentes de Amazônia e Cerrado do Maranhão. As borboletas foram amostradas entre 2011 e 2015 em oito municípios do estado. As capturas foram realizadas através de redes entomológicas e armadilhas com iscas. No total, 189 espécies foram amostradas, das quais 165 foram capturadas na Amazônia, 65 no Cerrado e 41 em ambos os biomas. Nós amostramos 167 espécies através de redes entomológicas e 43 através de armadilhas com iscas, representando 12% de similaridade na composição de espécies entre métodos de amostragem. Nós estimamos que as espécies registradas representam um pequeno subconjunto das borboletas do Maranhão. Deste modo, pesquisas de longa duração em áreas pouco estudadas do estado são recomendadas para identificar taxa novos e/ou endêmicos.

Palavras-chave: *floresta tropical, diversidade, Lepidoptera, região Neotropical, savana.*

Introduction

Species inventories contribute to the conservation of endangered areas by providing relevant data for conservation plans, such as occurrence, richness and diversity (Kremen et al. 1993, Santos et al. 2008, Santos et al. 2016). Unfortunately, conservation plans are usually restricted to studies focusing vertebrates and higher plants (Santos et al. 2008). The scarcity of basic knowledge studies on megadiverse groups, such as insects, increases the difficulty of cataloging all species present in a region (Santos et al. 2008). Despite that, insects are suggested as suitable biological indicators in studies of environmental monitoring and evaluations of natural landscape diversity and integrity. Thus, insect

inventories are important tools to biological evaluations in regions threatened by anthropic disturbances (Kim 1993, Brown Jr 1997, Uehara-Prado et al. 2007, Santos et al. 2016).

Among the insects, butterflies are considered excellent organisms to indicate the "health state" of ecosystems and an effective "umbrella group" for biodiversity conservation (Uehara-Prado et al. 2007, Bonebrake et al. 2010, Santos et al. 2016). There are about 3,300 species of butterflies in Brazil (Brown Jr 1996, Lewinsohn et al. 2005, Francini et al. 2011), but few inventories have been performed in large biomes of the country (Santos et al. 2008). The low number of researchers and difficult access to some sites partially explain the lack of information for many areas of Brazil, especially within the North and Northeast regions (Santos et al. 2008). As a consequence, relatively little is still known about the biodiversity of butterflies in the country considering its vast area, hindering the development of management and conservation strategies (Santos et al. 2008).

The Amazon is the largest biome in Brazil and possesses the world highest absolute rate of forest reduction (Laurance et al. 2000, Silva et al. 2005). Anthropogenic effects caused by the insertion of enterprises and the implementation of monocultures and livestock are the main causes of deforestation, especially in the Eastern portion, which is part of the "deforestation arch" (Silva et al. 2005, Vieira et al. 2008, Martins & Oliveira 2011). Considering the Amazonian high biodiversity, information on insect composition and distribution remains scarce (Santos et al. 2008). Butterfly inventories have been performed in the Amazon since the 19th century (Bates 1867, Santos et al. 2008), but many of these do not present a delimitation of the sampled area, reducing their scientific reliability (Santos et al. 2008, Casagrande et al. 2012).

The Cerrado is the second largest biome in Brazil and consists of a mosaic of vegetation types, varying from savannas to dense forests (Klink & Machado 2005). Human occupation has caused extensive habitat loss and transformed large areas of this domain into crops and pastures (Klink & Machado 2005, Diniz-Filho et al. 2009). Due to the increasing land-use and the high degree of endemism, the Cerrado is considered a biodiversity hotspot (Myers et al. 2000). However, despite the existence of previous butterfly lists performed in this biome, butterfly fauna is poorly understood especially in regions with insufficient number of research centers, such as the state of Maranhão, one of the poorest known areas in Brazil regarding butterflies (Santos et al. 2008).

The state of Maranhão, Northeast Brazil, contains portions of Amazon, Cerrado and Caatinga vegetation, contributing to the maintenance of a high local diversity. Patterns of habitat reduction are evident within the Amazon and Cerrado areas of Maranhão, and major deforestations are already assumed for the next years in these areas (Vieira et al. 2008, Diniz-Filho et al. 2009, Martins & Oliveira 2011, Barreto et al. 2012). For this reason, long-term butterfly inventories are crucial for the development and application of efficient conservation measures in the state. The present study aims to broaden the knowledge of the butterfly fauna in the state of Maranhão and provide perspectives for future researches.

Material and Methods

1. Study areas

Field work was performed in forest remnants of Amazon (six municipalities) and Cerrado (two municipalities) (Figure 1). The studied remnants of Amazon forest presented different vegetation types and degrees of human impact (Figure 2): (1) Maracanã, located in the municipality of São Luís (2º 36' S and 44º 17' W), possesses an area of 1,813 ha and vegetation characterized as open ombrophilous forest with high anthropic impacts in several points; (2) Sítio Aguahy, located in the municipality of São José de Ribamar (2° 38' S and 44° 08' W), possesses an area of 635 ha composed by portions of stacional semidecidous forest, being

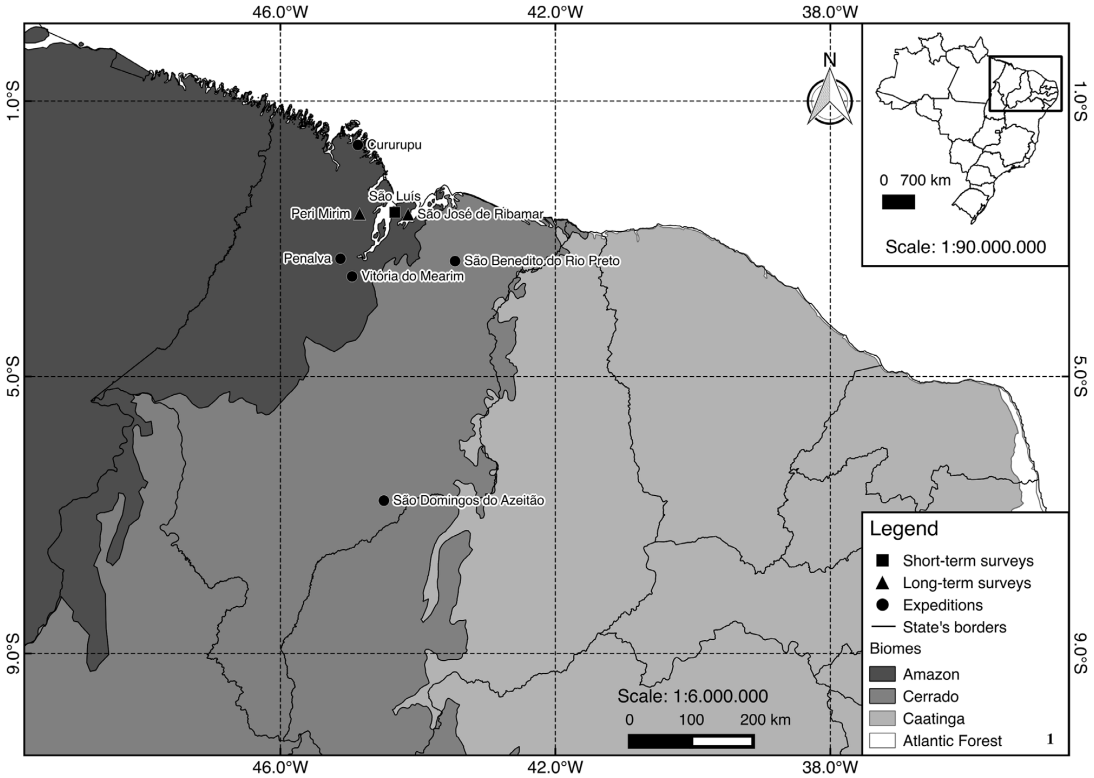

Figure 1. Map of the state of Maranhão, Northeast Brazil. Six study areas were selected in the Amazon and two study areas were selected in the Cerrado. Projection system: UTM. Datum: WGS 84.

Figure 2. Studied landscapes of the Amazon biome in the state of Maranhão, Northeast Brazil. A. Stacional semideciduous forest in São José de Ribamar. B. Transition zone between Amazon forest and coastal vegetation in Cururupu. C. Natural open fields in Peri Mirim. D. Amazon forest remnant in Vitória do Mearim.

surrounded by crops of *Manihot* sp. (Euphorbiaceae) and *Zea* sp. (Poaceae); (3) Cururupu (1° 49'S and 44° 51' W), located in a coastal region inside the Environmental Protection Area of "Reentrâncias Maranhenses", is characterized by the predominance of transition zones between Amazon forest and coastal vegetation, with anthropic impacts of the surrounding villages; (4) Parque Agroecológico de Buritirana, located in Peri Mirim (2° 38'S and 44° 50'W); (5) Fazenda Coque, located in Vitória do Mearim (3° 32'S and 44° 57'W); and (6) Fazenda Canadá & Boa Esperança, located in Penalva (3° 17'S and 45° 07'W), are situated in the region of "Baixada Maranhense" - 1,775,035 ha of Amazon forest remnants characterized by flooded areas and natural open fields inserted in a matrix of urban settlements and secondary forests.

The study areas of Cerrado were selected in two municipalities (Figure 3): (7) São Benedito do Rio Preto (3° 19' S and 43° 31' W), located in the Northeast of Maranhão, is characterized by tablelands and gallery forests following the Preto river; and (8) São Domingos do Azeitão (6º 47' S and 44º 29' W), located between the headwaters of Itapecuru and Alpercatas rivers, is characterized by open areas with sparse trees and gallery forests, being surrounded by soy crops.

2. Butterfly sampling and identification

Butterflies were sampled between 2011 and 2015 by two to four collectors in each locality. Field trips were classified into three categories according to the duration and sampling effort: (1) Short-term survey: two sampling days; (2) Long-term surveys: two sampling days per month during 24 months; and (3) Expeditions: one sampling week.

Using entomological nets, we surveyed for butterflies every sampling day. Butterflies were sampled along transects that varied in extension from 1 - 5 km. At least two collectors walked along transects collecting with entomological nets in a given amount of time (from 8 – 12 a.m. and from 2 – 5 p.m., totalling 7 hours*person/day). Cylindrical traps were also used to capture fruit-feeding butterflies (family Nymphalidae) (Uehara-Prado et al. 2007, Freitas et al. 2014). In each transect, at least five traps were disposed with minimum distances of 100 meters between traps. Five traps were used in our short-term survey and 10 traps were used in expeditions. For the long-term surveys, 10 traps were used monthly in Peri Mirim and 18 traps were used monthly in São José de Ribamar. In total, 707 traps were disposed in the Amazon biome and 20 in the Cerrado. Traps were placed 1.5 meters from the ground and baited with cat feces, rotting fish or fruits. The proportion of four traps baited with bananas or mango with sugarcane juice to one trap baited with cat feces or rotting fish was maintained for all transects in expeditions. On the other hand, only bananas with sugarcane juice were used as baits in short and long-term surveys. We inspected traps twice a day. For each collected specimen, date, time and habitat type was recorded.

Captured butterflies were taken to the Laboratório de Ecologia e Sistemática de Insetos Polinizadores e Predadores (LESPP/UFMA) and identified through comparison with specimens from the Museu de Zoologia da Universidade de São Paulo (MZUSP), Museu de Zoologia da Universidade Estadual de Campinas (ZUEC), Coleção Entomológica Pe. Jesus Santiago Moure (DZUP) and specialized catalogues (D'abrera 1995, Garwood et al. 2009). Taxonomy follows mostly Lamas (2004), Mielke

Figure 3. Studied landscapes of the Cerrado biome in the state of Maranhão, Northeast Brazil. A. Tablelands of Cerrado in the Northeast of the state. B. The Preto river and its gallery forest. C. Typical Cerrado vegetation in São Benedito do Rio Preto. D. Gallery forest following the Alpercatas river in São Domingos do Azeitão.

(2005) and Duarte & Robbins (2010). Vouchers were deposited in four collections: LESPP/UFMA, MZUSP, ZUEC and DZUP.

3. Data analysis

We used the Jaccard index (J) to evaluate quantitatively the similarity in species composition between sampling methods (entomological nets and baited traps). This index is based on presence-absence data and has been widely used in ecological studies (Magurran 2004, Jost et al. 2011). In order to compare our list to other lists performed in the state, we searched for papers in the Web of Science, Scopus and Google Scholar databases. Only papers that provided a list of butterfly species and a clear indication that the field work was performed in the state of Maranhão (e.g.: coordinates, region or municipality) were included in the analysis.

Results

We recorded 189 butterfly species, of which 165 were captured in the Amazon, 65 in the Cerrado and 41 in both biomes. Nymphalidae was the best represented family, with 41.3% of the total richness (n = 78), followed by Hesperiidae (n = 53), Riodinidae (n = 29), Lycaenidae (n = 16), Pieridae (n = 10) and Papilionidae (n = 3) (Table 1). The richest subfamilies were, respectively, Riodininae with 29 species (15.3% of the species collected), Satyrinae with 24 species (12.7%) and Hesperiinae with 23 species (12.2%). *Hamadryas februa* (Hübner, [1823]), an indicator of disturbed habitats (Brown Jr 1992), was the most widespread species, occurring in all municipalities. Regarding sampling effort, 146 species were captured in long-term surveys, 112 in expeditions and 15 in our short-term survey. Specifically, the municipality of Peri Mirim presented the greatest number of species (n = 101), followed by São José de Ribamar (n = 99). A total of 167 species were sampled through entomological nets and 43 through baited traps. Similarity in species composition between sampling methods was recorded in 12% (J = 0.12).

Four lists performed in the state of Maranhão that meet the established criteria were included in the analyzes (Table 2). Of these studies, three used exclusively entomological nets to collect butterflies (Bates 1867, Garcia et al. 1990, Garcia & Bergman 1994), and one used cylindrical traps baited with bananas and sugarcane juice (Ramos 2000). Additionally, all these studies were performed in the Amazon biome, being two of these at the state capital, São Luís (Garcia et al. 1990, Garcia & Bergman 1994).

Discussion

The butterfly fauna captured in this study represents approximately 6% of the species recorded for Brazil (Brown Jr 1996, Lewinsohn et al. 2005, Francini et al. 2011). It is known that species richness is strongly dependent on sampling effort, partially explaining the lowest richness in our short-term survey when compared to our expeditions and long-term surveys. The influence of sampling effort on species richness is also observed when we compare our total richness (189 species) to intensively sampled areas in the Amazon, such as Rondônia (843) (Emmel & Austin 1990), Parque Nacional del Manu, in Peru (1,300) (Robbins et al. 1996) and Parque Estadual do Chandless, Acre (482) (Mielke et al. 2010), and Cerrado sites, such as Distrito Federal (504) (Emery et al. 2006). Comparing our results with those from other biomes, such as the Atlantic forest, one of the most

Table 1. List of butterflies of Amazon and Cerrado remnants of the state of Maranhão, Northeast Brazil.

Taxa (Family, Subfamily, Species, Subspecies)	Amazon						Cerrado		Sampling method	
	CP	PV	PM	SJR	SL	VT	SBR	SDA	EN	BT
Nymphalidae (S=78)										
Biblidinae (S=14)										
Biblis hyperia (Cramer, 1779)				x						x
Callicore astarte astarte (Cramer 1779)				x						x
Catonephele acontius (Linnaeus 1771)				x						x
Dynamine agacles (Dalman, 1823)	x								x	
Dynamine myrson myrson (Doubleday, 1849)	x								x	
Dynamine paulina (Bates, 1865)				x					x	
Dynamine postverta postverta (Cramer, 1779)			x	x					x	
Ectima iona E. Doubleday, [1848]	x									x
Eunica maja (Fabricius, 1775)				x						x
Hamadryas amphinome (Linnaeus, 1767)	x		x	x		x	x		x	x
Hamadryas chloe (Stoll, 1787)	x		x	x			x		x	x
Hamadryas februa (Hübner, [1823])	x	x	x	x	x	x	x	x	x	x
Hamadryas feronia (Linnaeus, 1758)			x	x	x	x	x	x	x	x
Hamadryas laodamia (Cramer, 1777)				x						x
Charaxinae (S=10)										
Archaeoprepona demophon (Linnaeus, 1758)			x	x	x	x				x
Archaeoprepona demophoon (Hübner, [1814])			x							x
Fountainea ryphea (Cramer, 1775)			x	x	x	x			x	x
Hypna clytemnestra (Cramer, 1777)			x	x					x	x
Memphis acidalia (Hübner, [1819])				x						x
Memphis leonida (Stoll, 1782)				x						x
Prepona laertes (Hübner, [1811])			x	x		x				x
Prepona pheridamas (Cramer, 1777)			x	x					x	x
Prepona pseudomphale Le Moult, 1932			x							x
Zaretis isidora (Cramer, 1779)		x	x	x		x	x		x	x
Cyrestinae (S=2)										
Marpesia chiron (Fabricius, 1775)			x	x					x	
Marpesia petreus (Cramer, 1776)			x	x		x			x	
Danainae (S=5)										
Danaus eresimus (Cramer, 1777)			x						x	
Danaus gilippus (Cramer, 1775)			x					x	x	
Danaus sp Kluk, 1780			x						x	
Lycorea halia (Hübner, 1816)			x	x		x			x	
Methona sp Doubleday, 1847			x	x	x				x	
Heliconiinae (S=13)										
Agraulis vanillae (Linnaeus, 1758)			x						x	
Dryas iulia (Fabricius, 1775)	x		x	x	x			x	x	
Dryadula phaetusa (Linnaeus, 1758)			x	x		x			x	
Euptoieta hegesia (Cramer, 1779)			x	x		x	x		x	
Heliconius antiochus (Linnaeus, 1767)	x	x	x	x			x		x	
Heliconius erato phyllis (Fabricius, 1775)				x					x	
Heliconius melpomene melpomene (Linnaeus, 1758)	x	x	x	x		x			x	
Heliconius melpomene nanna Stichel, 1899			x	x	x			x	x	
Heliconius ricini (Linnaeus, 1758)			x	x		x			x	
Heliconius numata (Cramer, 1780)			x	x					x	
Heliconius sara sara (Fabricius, 1793)				x				x	x	
Neruda mentis Moreira & Mielke, 2010								x	x	
Philaethria dido (Linnaeus, 1763)	x		x	x		x			x	
Limenitidinae (S=2)										
Adelpha cytherea cytherea (Linnaeus, 1758)	x			x					x	
Adelpha iphiclus iphiclus (Linnaeus, 1758)	x		x	x		x			x	
Nymphalinae (S=8)										
Anartia amathea (Linnaeus, 1758)			x					x	x	
Anartia jatrophae (Linnaeus, 1763)	x		x	x		x		x	x	

CP = Cururupu; PV = Penalva; PM = Peri Mirim; SJR = São José de Ribamar; SL = São Luís; VT = Vitória do Mearim; SBR = São Benedito do Rio Preto; SDA = São Domingos do Azeitão; EN = Entomological net; BT = Baited trap.

Table 1. Continued...

Taxa (Family, Subfamily, Species, Subspecies)	Amazon						Cerrado		Sampling method	
	CP	PV	PM	SJR	SL	VT	SBR	SDA	EN	BT
Colobura dirce (Linnaeus, 1758)	x		x	x		x			x	x
Historis acheronta (Fabricius, 1775)			x	x						x
Historis odius (Fabricius, 1775)			x	x						x
Junonia evarete (Cramer, 1779)	x	x	x	x		x			x	x
Siproeta stelenes (Linnaeus, 1758)			x	x					x	
Tigridia acesta (Linnaeus, 1758)	x								x	
Satyrinae (S=24)										
Brassolis sophorae (Linnaeus, 1758)			x					x	x	
Catoblepia berecynthia (Cramer, 1777)	x		x	x			x	x	x	x
Cissia penelope (Fabricius, 1775)	x	x		x		x		x	x	x
Caligo teucer (Linnaeus, 1758)			x	x						x
Caligo illioneus (Cramer, 1775)			x		x	x			x	x
Hermeuptychia hermes (Fabricius, 1775)				x		x		x	x	x
Magneuptychia libye (Linnaeus, 1767)			x	x		x			x	x
Magneuptychia ocypete (Fabricius, 1776)				x						x
Magneuptychia pallema (Schaus, 1902)				x						x
Morpho helenor (Cramer, 1776)	x		x	x		x			x	x
Morpho menelaus terrestris (Butler, 1866)				x	x				x	x
Morpho rhetenor Butler, 1866				x					x	x
Narope panniculus Stichel, 1904							x			x
Opsiphanes invirae (Hübner, [1808])			x	x					x	x
Opsiphanes quiteria (Stoll, 1780)				x		x			x	x
Pierella hyalinus (Gmelin, [1790])	x			x					x	
Pierella lamia (Sulzer, 1776)				x				x	x	
Pharneuptychia innocentia (C. Felder & R. Felder, 1867)							x		x	
Selenophanes cassiope (Cramer, 1775)								x	x	
Taygetis echo (Cramer, 1775)			x							x
Taygetis laches Fabricius, 1793			x	x					x	x
Taeygetis sosis Hopffer, 1874			x							x
Yphthimoides renata (Stoll,1780)				x						x
Yphthimoides affinis (Butler, 1867)						x				x
Lycaenidae (S=16)										
Polyommatinae (S=2)										
Hemiargus hanno hanno (Stoll, 1790)			x	x			x	x	x	
Leptotes cassius (Cramer, 1775)							x	x	x	
Theclinae (S=14)										
Arawacus aetolus (Sulzer, 1776)	x			x				x	x	
Calycopis demonassa (Hewitson, 1868)				x					x	
Chlorostrymon telea (Hewitson, 1868)							x		x	
Evenus satyroides (Hewitson,1865)				x					x	
Iaspis castitas (H. H. Druce, 1907)			x						x	
Rekoa palegon (Cramer, 1780)							x		x	
Ministrymon megacles (Stoll, 1780)			x				x		x	
Ministrymon zilda (Hewitson, 1873)			x				x		x	
Nicolaea socia (Hewitson, 1868)							x		x	
Panthiades phaleros (Linnaeus, 1767)			x	x					x	
Pseudolycaena marsyas (Linnaeus, 1758)	x		x	x			x		x	
Strymon mulucha (Hewitson, 1867)			x				x		x	
Tmolus echion (Linnaeus, 1767)							x		x	
Ziegleria hesperitis (Butler & H. Druce, 1872)			x						x	
Pieridae (S=10)										
Coliadinae (S=8)										
Anteos menippe (Hübner, [1818])	x								x	
Aphrissa statira statira (Cramer, 1777)			x	x			x		x	
Eurema albula (Cramer, 1775)			x	x			x		x	

CP = Cururupu; PV = Penalva; PM = Peri Mirim; SJR = São José de Ribamar; SL = São Luís; VT = Vitória do Mearim; SBR = São Benedito do Rio Preto; SDA = São Domingos do Azeitão; EN = Entomological net; BT = Baited trap.

Table 1. Continued...

Taxa (Family, Subfamily, Species, Subspecies)	Amazon						Cerrado		Sampling method	
	CP	PV	PM	SJR	SL	VT	SBR	SDA	EN	BT
Eurema elathea (Cramer, 1777)				x		x	x	x	x	
Phoebis argante argante (Fabricius, 1775)			x			x			x	
Phoebis philea philea (Linnaeus, 1763)			x	x					x	
Phoebis sennae marcellina (Cramer, 1777)			x	x	x	x	x	x	x	
Pyrisitia nise (Cramer, 1775)				x			x	x	x	
Pierinae (S=2)										
Ascia monuste (Linnaeus, 1764)		x	x	x		x	x		x	
Itaballia demophile (Linnaeus, 1763)			x			x			x	
Papilionidae (S=3)										
Papilioninae (S=3)										
Battus polydamas (Linnaeus, 1758)	x	x	x	x		x	x	x	x	
Heraclides thoas (Linnaeus, 1771)		x		x				x	x	
Heraclides anchisiades (Esper, 1788)			x						x	
Riodinidae (S=29)										
Riodininae (S=29)										
Aricoris campestris (Bates, 1868)			x					x	x	
Aricoris propitia (Stichel, 1910)			x					x	x	
Baeotis euprepes (Bates, 1868)							x		x	
Calospila lucianus (Fabricius, 1793)							x		x	
Calospila sp Geyer, 1832			x	x				x	x	
Detritivora zama (Bates, 1868)	x								x	
Emesis diogenia Prittwitz, 1865							x		x	
Eurybia elvina Stichel,1910				x					x	
Eurybia patrona Weymer, 1875				x					x	
Helicopis cupido (Linnaeus, 1758)						x	x		x	
Isapis agyrtus (Cramer, 1777)							x		x	
Juditha odites odites (Cramer, 1775)							x		x	
Lemonias zygia Hübner, 1807			x	x			x		x	
Melanis smithiae (Westwood, 1851)								x	x	
Mesosemia steli Hewitson 1858			x						x	
Mesosemia sp Hübner, [1819]				x					x	
Napaea beltiana beltiana (Bates, 1867)			x	x					x	
Napaea eucharila (Bates, 1867)			x						x	
Mesene phareus (Cramer, 1777)	x								x	
Phaenochitonia cingulus (Stoll, 1790)			x	x					x	
Stalachtis phlegia (Cramer, 1779)			x	x	x		x		x	
Synargis axenus axenus (Hewitson, 1876)							x		x	
Synargis agle (Hewitson, [1853])			x						x	
Synargis calyce (C. Felder & R. Felder, 1862)			x				x		x	
Synargis galena (Bates, 1868)	x								x	
Synargis gela (Hewitson, [1853])	x								x	
Thisbe irenea (Stoll, 1780)	x								x	
Thisbe molela (Hewitson, 1865)	x								x	
Theope foliorum Bates, 1868							x		x	
Hesperiidae (S=53)										
Eudaminae (S=16)										
Astraptes fulgerator fulgerator (Walch, 1775)			x						x	
Aguna asander asander (Hewitson, 1867)								x	x	
Aguna metophis (Latreille, [1824])				x					x	
Autochton neis (Geyer, 1832)				x	x				x	
Chioides catillus catillus (Cramer, 1779)			x						x	
Epargyreus clavicornis clavicornis (Herrich-Schäffer, 1869)			x						x	
Euriphellus euribates (Stoll, 1782)				x					x	
Hyalothyrus leucomelas (Geyer, 1832)			x						x	
Phocides pigmalion hewitsonius (Mabille, 1883)				x					x	

CP = Cururupu; PV = Penalva; PM = Peri Mirim; SJR = São José de Ribamar; SL = São Luís; VT = Vitória do Mearim; SBR = São Benedito do Rio Preto; SDA = São Domingos do Azeitão; EN = Entomological net; BT = Baited trap.

Table 1. Continued...

Taxa (Family, Subfamily, Species, Subspecies)	Amazon						Cerrado		Sampling method	
	CP	PV	PM	SJR	SL	VT	SBR	SDA	EN	BT
Typhedanus crameri McHenry, 1960	x								x	
Udranomia orcinus (C. Felder & R. Felder, 1867)				x					x	
Urbanus chalco (Hübner, 1823)			x						x	
Urbanus dorantes dorantes (Stoll, 1790)		x	x	x		x	x		x	
Urbanus procne (Plötz, 1881)		x	x						x	
Urbanus proteus (Linnaeus, 1758)	x			x			x		x	
Urbanus simplicius (Stoll, 1790)		x	x	x					x	
Hesperiinae (S=23)										
Augiades crinisus (Cramer, 1780)			x						x	
Aides duma duma Evans, 1955			x						x	
Aides duma argyrina Cowan, 1970		x					x		x	
Aides aegita (Hewitson, 1866)					x				x	
Calpodes ethlius (Stoll, 1782)			x	x					x	
Carystoides basoches (Latreille, [1824])			x						x	
Carystoides maroma (Möschler, 1877)			x	x					x	
Carystus phorcus phorcus (Cramer, 1777)			x						x	
Cobalus calvina (Hewitson, 1866)			x						x	
Cymaenes tripunctus theogenis (Capronnier, 1874)			x						x	
Cynea irma (Möschler, 1879)		x							x	
Cynea robba robba Evans, 1955				x					x	
Enosis uza uza (Hewitson, 1877)			x						x	
Mnasicles hicetaon Godman, 1901			x						x	
Morys valerius (Möschler, 1879)								x	x	
Nyctelius nyctelius nyctelius (Latreille, [1824])			x						x	
Panoquina fusina fusina (Hewitson, 1868)				x					x	
Phanes aletes (Geyer, 1832)								x	x	
Panoquina ocola ocola (Edwards, 1863)			x						x	
Polites vibex (Geyer, 1832)					x				x	
Pompeius pompeius (Latreille, [1824])			x						x	
Pyrrhopygopsis socrates (Ménétriés, 1855)	x						x		x	
Saliana saladin Evans, 1955				x	x				x	
Synale hylaspes (Stoll, 1781)								x	x	
Pyrginae (S=14)										
Elbella sp Evans, 1951				x					x	
Grais stigmaticus stigmaticus (Mabille, 1883)			x						x	
Heliopetes arsalte (Linnaeus, 1758)	x	x	x	x				x	x	
Heliopetes omrina (Butler, 1870)	x					x			x	
Jemadia fallax fida Evans, 1951				x					x	
Mysoria barcastus antila Evans, 1951		x	x						x	
Pyrgus orcus (Stoll, 1780)			x	x		x	x	x	x	
Pyrgus veturius Plötz, 1884				x					x	
Pyrrhopyge phidias (Linnaeus, 1758)						x			x	
Pyrrhopyge sp Hübner, [1819]			x						x	
Timochares trifasciata (Hewitson, 1868)				x					x	
Timochreon satyrus (C. Felder & R. Felder, 1867)								x	x	
Viola violella (Mabille, 1898)							x		x	
Zopyrion evenor evenor Godman,1901								x	x	

CP = Cururupu; PV = Penalva; PM = Peri Mirim; SJR = São José de Ribamar; SL = São Luís; VT = Vitória do Mearim; SBR = São Benedito do Rio Preto; SDA = São Domingos do Azeitão; EN = Entomological net; BT = Baited trap.

Table 2. Butterfly inventories previously published in the state of Maranhão, Northeast Brazil.

Authors and year	Municipality	Coordinates	Sampling method	Species richness
Bates 1867	Maracaçumé	02º 02' S 45º57' W	Entomological net	364 *
Garcia et al. 1990	São Luís	02 º39' S 44 º15' W	Entomological net	39
Garcia & Bergman 1994	São Luís	02 º39' S 44 º15' W	Entomological net	19
Ramos 2000	Açailândia	5°01´S, 47°32´W	Baited traps	90

*There are 23 species mentioned in the paper, but the author states that 364 species were sampled and deposited in collections.

well inventoried biomes regarding butterflies in Brazil (Santos et al. 2008), we observe higher richness in several sites of the later, which shelter from 218 to 914 species (Brown Jr & Freitas 2000, Francini et al. 2011). On the other hand, the richness of 189 species that was recorded in the present study was greater than in three of the four butterfly lists previously performed in the state of Maranhão (Garcia et al. 1990, Garcia & Bergman 1994, Ramos 2000), highlighting the need for greater sampling effort towards butterflies in the state. Although not directly comparable, these data indicate that new records should be expected in our less sampled study areas with the inclusion of rare and inconspicuous taxa, which are usually only captured after extensive samplings (Magurran 2004).

Patterns of endemism to a specific biome have been proposed for different groups of butterflies in Brazil (Pinheiro et al. 2010), suggesting that some of the collected species could be endemic. However, the task of determining endemism has been hampered by the scarcity of available data, especially for transition zones (Silva et al. 2005, Pinheiro et al. 2010). From the collected species, we highlight *Nicolaea socia* (Hewitson, 1868), which has been proposed to be endemic of Cerrado (Pinheiro et al. 2010). Considering that *Nicolaea socia* (Hewitson, 1868) was only captured in São Benedito do Rio Preto, we reinforce its distribution as an endemic species of this biome. The high number of species that only occurred in the Amazon (124) is probably related to the greater sampling effort applied in our Amazonian sites. Since Bates (1867), Garcia et al. (1990), Garcia & Bergmann (1994) and Ramos (2000) field works were performed exclusively in the Amazon, we believe that new inventories in Maranhão's Cerrado are necessary to evaluate the distribution and endemism of butterflies from Maranhão.

The low similarity between species captured through entomological nets and cylindrical traps was expected. Entomological nets usually capture larger number of species, but its dependence on good weather and collector's abilities may limit the capture of inconspicuous groups (Sparrow et al. 1994). On the other hand, baited traps sample fewer species, but consistently yields species rarely observed by researchers (Sparrow et al. 1994, Freitas et al. 2014). Consequently, the low value of similarity obtained in this study reinforces that entomological nets and baited traps contribute with complementary data for butterfly inventories in the Neotropics (Sparrow et al. 1994, Caldas & Robbins 2003).

1. Taxonomic composition

The richest family in our list was Nymphalidae, following the same pattern of other butterfly lists performed in Brazil (Zacca et al. 2011, Morais et al. 2012). Most recorded species of this family are widespread throughout the country, such as *Hamadryas februa* (Hübner, [1823]), *Hamadryas feronia* (Linnaeus, 1758), *Hamadryas amphinome* (Linnaeus, 1767), *Junonia evarete* (Cramer, 1779) and *Agraulis vanillae* (Linnaeus, 1758). The fact that *Hamadryas februa* (Hübner, [1823]) was our most widespread species is concerning but expected, since this species is characteristic of modified habitats and secondary forests (Brown Jr 1992). Individuals of *Hamadryas februa* (Hübner, [1823]) were also captured by Garcia et al. (1990), Garcia & Bergmann (1994) and Ramos (2000), suggesting that this species is common in different regions of the state. Six species of the genus *Heliconius* Kluk, 1780, one of the most studied groups of butterflies regarding evolution and diversity patterns (Mallet 1993, Mavárez et al. 2006, Merrill et al. 2015), were sampled, including two races of *Heliconius melpomene* (Linnaeus, 1758): *Heliconius melpomene melpomene* (Linnaeus, 1758) and *Heliconius melpomene nanna* Stichel, 1899. Bates (1867) described different variations of *Heliconius* species captured in Maracaçumé, including intermediate varieties between *Heliconius melpomene melpomene* (Linnaeus, 1758) and *Heliconius melpomene thelxiope* Hübner [1806]. Considering the distribution of *Heliconius* butterflies and the suggested hybridization zones for this group in the Amazon (Mallet 1993, Merrill et al. 2015), new species and races of *Heliconius* are expected to be found in Maranhão.

The second richest family was Hesperiidae, including common species in the Neotropics, such as *Astraptes fulgerator fulgerator* (Walch, 1775), *Autochton neis* (Geyer, 1832) and *Heliopetes arsalte* (Linnaeus, 1758). Hesperiidae is considered, along with Nymphalidae, the richest families in the Neotropical region (Lamas 2004). Moreover, Francini et al. (2011) stated that Hesperiidae is expected to be the richest family in relatively complete inventories of Brazil, while Nymphalidae is the best represented butterfly group in short-term studies, probably because nymphalids are easily visualized and identified in the field. In this study, Nymphalidae was considerably richer than Hesperiidae, implying that additional records of hesperids should be expected with an increased sampling effort.

Riodinidae was the third family in species richness, followed by Lycaenidae. This result agrees with those from lists performed in other Amazonian sites (Emmel & Austin 1990, Brown Jr & Freitas 2002), although lists from other biomes frequently demonstrate Lycaenidae being richer than Riodinidae (Francini et al. 2011). Riodinidae richness has been correlated with the mean temperature of the study areas, explaining its greater number in tropical regions (Brown Jr 2005, Francini et al. 2011), such as Maranhão. From the captured riodinids, we highlight *Napaea beltiana beltiana* (Bates, 1867) and *Napaea eucharila* (Bates, 1867), species also captured and described by Bates (1867). Lycaenidae was the fourth family in number of species, but we expect the richness of Lycaenidae to increase, since this family include small and inconspicuous species, requiring longer temporal surveys for adequate samplings (Francini et al. 2011).

Pieridae and Papilionidae are the families with lowest species richness in Brazil (Emery et al. 2006, Francini et al. 2011), and our findings corroborate this pattern. Most captured species of Pieridae and Papilionidae are considered widely distributed throughout the country and characteristic of modified habitats (Emery et al. 2006, Zacca et al. 2011, Morais et al. 2012), suggesting that the study areas have been harmed by anthropic influences.

2. Perspectives for future research

Considering our sampling effort and the difficulties to sample a large Brazilian state, we estimate that the recorded species represent a small subset of the butterflies from Maranhão. Broader and longer samplings could result in much greater richness, especially for the families Hesperiidae, Riodinidae and Lycaenidae. Centuries of butterfly records from Maranhão in museum collections must also be analyzed in the future to achieve better understanding of butterflies' diversity and distribution in the state.

Two of the four lists previously performed in Maranhão were conducted at the state capital, São Luís. The proximity to the major research centers of the state and the easy access to study areas may be the main reason for this geographic bias. Consequently, little or no effort is applied for distant and complicated access areas, resulting in the current lack of information. Among the priority areas for butterfly inventories, the western region of Maranhão should be focused by researchers, since this portion of Amazon is still poorly studied and under human pressures (Silva et al. 2005, Martins & Oliveira 2011). Moreover, this region is part of the most threatened endemism center in Brazil, the Belém Center of Endemism (Silva et al. 2005). Only about one-third of its forest remains, and the increasing deforestations may represent the extinction of several species, including endemic butterflies (Hall & Harvey 2002, Silva et al. 2005). Therefore, inventories in this area are recommended to identify novel and/or endemic taxa. Long-term researches are also requested for Maranhão's Cerrado, since different butterfly species have been considered endemic of this endangered biome (Brown Jr & Gifford 2002, Pinheiro et al. 2010) and there are no previous butterfly lists published for this region.

Species inventories are important tools for a better understanding of the biodiversity. In this context, it is urgent to perform studies that generate lists

of species in poorly studied areas to evaluate the distribution and endemism of different taxa, such as megadiverse groups of insects. As previously mentioned, the richness of 189 butterfly species collected in the present study can be considered low when compared to intensively sampled areas in the Amazon and Cerrado. On the other hand, we presented the greatest number of species in butterfly inventories from Maranhão since Bates (1867). Furthermore, some of our study areas were sampled for the first time and may shelter a greater butterfly diversity, including species not yet known. Thus, we call attention to the urgent measures that should be taken to preserve Amazon and Cerrado remnants of Maranhão and their local biodiversity, since these areas have been increasingly threatened by anthropic disturbances.

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Author Contributions

Lucas Pereira Martins: substantial contribution in the concept and design of the study; contribution to manuscript preparation, data collection, interpretation and analysis.

Elias da Costa Araujo Junior: substantial contribution in the concept and design of the study; contribution to manuscript preparation, data collection and critical revision.

Ananda Regina Pereira Martins: substantial contribution in the concept and design of the study; contribution to manuscript preparation and critical revision.

Mairla Santos Colins: substantial contribution to manuscript preparation, data collection and critical revision.

Gabriela Cristina Fonseca Almeida: substantial contribution to manuscript preparation, data collection and critical revision.

Gisele Garcia Azevedo: substantial contribution in the concept and design of the study; contribution to manuscript preparation and critical revision.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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