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ARTICLE

Butterflies (Lepidoptera: Papilionoidea) of the urban park of Instituto Butantan, São Paulo, Southeastern Brazil

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Abstract. Green areas in urban landscapes are under strong anthropogenic pressure, and, at the same time are fundamental to maintaining biodiversity, as they provide resources for many animal and plant species. Knowing these species is fundamental for its maintenance and conservation, and inventories are extremely important for monitoring fauna and conserving it. Therefore, the goal of this research is to inventory the butterflies species in the park of the Instituto Butantan (Ibu), located in an urban area in the city of São Paulo, southeast Brazil. The surveys of butterflies were conducted through visual censuses from August 2017 to July 2019 and recorded a total of 324 butterfly species. The most speciose family was Hesperiidae, followed by Nymphalidae, Lycaenidae, Pieridae, Riodinidae, and Papilionidae. Among the sampled species, there is *Euselasia zara* which is a new record for the state of São Paulo. Neither the species accumulation nor the richness estimator curves tended to reach an asymptote, suggesting that additional butterflies' species will be recorded with more sampling effort on the site. Even with a flora composed mainly of exotic and ornamental plants, the park of Instituto Butantan exhibits a very rich butterfly community. This community exhibits a pattern of seasonally variation, with the peak of species richness related to the rainy season. When compared with Cidade Universitária Armando de Salles Oliveira (USP), another nearby urban green area, which is larger, more heterogeneous and sampled over a longer period, it is possible to notice that the Ibu butterfly community is a subsample of this larger one. These results highlight the potential that urban parks have for the maintenance and conservation of butterfly species.

Keywords. Butterfly community; Conservation; Inventory; Species richness, Urban fauna.

INTRODUCTION

In an era dominated by anthropogenic effects, Earth's land surface is more covered by human-dominated ecosystems than by undisturbed ecosystems (McCloskey & Spalding, 1989, Foley *et al.,* 2005). The results of this human interference include habitat fragmentation and isolation, changes in abiotic factors, such as nutrients flow, temperature, light and noise levels and atmospheric and aquatic chemical composition (Gaston, 2010). This can lead to changes in species composition and abundance, species dispersal and migration, shifts in trophic structure and food-web dynamics, loss of native species, introduction of exotic species and creation of new habitats (Lindenmayer & Fischer, 2006, Shochat *et al.,* 2006, McKinney, 2008). Variables such as spatial scale, taxonomic group and intensity of urbanization are related to the increase or decrease in species richness that urbanization can cause (Kowarik, 2011, Soga *et al.,* 2015). Nevertheless, green areas in urban landscapes, such as gardens and parks, are important for biodiversity conservation, since they represent a meaningful part of the planet's ecosystems and provide resources and refuge for several species of plants and animals (Brown & Freitas, 2002, Bryant, 2006, Goddard *et al.,* 2010).

To this extent, the interest in urban biodiversity conservation has increased (Dearborn & Kark,

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2010), and, for studies of conservation based on animal communities it is recommended the use of well-known taxa, since they provide faster assessment and a more direct response to changes in the environment (Iserhard & Romanowski, 2004). Butterflies are considered to be very effective as environmental bioindicators (Brown & Freitas, 2000a, Thomas, 2005), because of their rapid reproduction, ease of sampling and identification and sensitivity to different abiotic factors (Uehara-Prado *et al.,* 2009, Leviski *et al.,* 2016). In addition, butterflies work as an "umbrella group" for biodiversity conservation (New, 1997), and are also flagship species, since they attract the interest of amateurs and the public (New, 2013). In fact, Soga & Gaston (2016) have suggested that urban butterflies are a group with great potential to make people reconnect with nature.

The conservation of urban green areas depends to a great extent on the formulation of conservation policies for any species, including butterflies, and for this, the first and most critical step is the knowledge of biodiversity (Dolibaina *et al.,* 2011). This knowledge can be obtained through inventories with precise identification of organisms, since they provide basic data such as species richness, distribution and occurrence (Brown & Freitas, 2000a; Santos *et al.,* 2016). Therefore, besides being crucial for the development of preservation strategies, lists of species are important to provide baseline data for future studies, whether on a local or regional scale, as well as identify changes in time that can be correlated with abiotic or other biotic factors, including climate change, that might be important for the conservation of urban areas.

Ramírez-Restrepo & MacGregor-Fors (2017) carried out an extensive review work where they compiled 173 studies published between 1956 and 2015 focused on urban butterflies. This work showed that in the last two decades, information about urban butterflies has increased worldwide. Most studies involving urban butterflies were published in the Americas, followed by Europe, Asia, Oceania and Africa. Among these publications, more than half were carried out in Brazil, United States, Japan, India, France and England, with Brazil having the largest number of published works. The main general topics covered in these works are ecological patterns, species lists and conservation studies, respectively.

There are few published works about the butterfly community in the municipality of São Paulo, in southeastern Brazil, especially when we consider urban forest fragments. As far as we are concerned, there is only one species survey done in two green areas in the city of São Paulo, Ibirapuera Park and the University of São Paulo campus (Accacio, 1997). In addition, there are surveys carried out in the urban region of Campinas (Rodrigues *et al.,* 1993, Brown & Freitas, 2002), which is approximately 95 km from the metropolitan region of São Paulo. The present study aims to provide an inventory of the butterfly species registered in the park of the Instituto Butantan, located in an urban area in the city of São Paulo, Brazil. This is the first general study of the butterfly fauna in the park.

MATERIAL AND METHODS

Study area

The study was conducted in the park of the Instituto Butantan (IBu) (Fig. 1), located in the city of São Paulo (23°34′03.2″S, 46°43′06.2″W), the largest city in South America. Its climate is humid temperate (Cwa according to Köppen-Geiger classification), with hot and rainy summer and dry winter. The historical annual average (1933-2016) of temperature is 18.7°C and of rainfall is 1,409.5 mm (IAG-USP, 2016). The IBu park has regions of more concentrated human occupation, which allows for the presence of extensive green areas that cover about 80 ha. The process of deforestation and unplanned reforestation that took place at IBu generated a diversified vegetation pattern at this site. The vegetation varies from cultivated gardens for landscape purposes, being mostly exotic, in addition to two areas of forest in a state of secondary regeneration (Souza *et al.,* 2015), thus called a heterogeneous woodland (SVMA, 2018).

Sampling and identification

Sampling was carried out from August 2017 to July 2019 in the study area. The butterfly surveys were conducted through four transects per month, covering fixed routes. This method is similar to transect methods, which have been used successfully in butterfly community studies (Pollard & Yates, 1993, Collier *et al.,* 2006; Kral *et al.,* 2018) and have the main advantage of speed, practicality and lower survey costs in comparison to mark-recapture or trapping methods (Accacio, 1997, Kral *et al.,* 2018). In each census, an observer walked in a fixed route (Fig. 1) identifying and recording in lists all butterfly's species seen. Field inventory was carried out by observation, with only those individuals who raised doubts or who were considered important to integrate the pre-existing image bank being photographed. Most butterflies did not even need to be photographed to be identified in the field, given that almost all of them have unique characteristics evident by observation. In case of doubt, photos were taken and then compared with other photos in reference sites (*e.g.,* http://www.butterfliesofamerica.com/L/Neotropical.htm – BoA), specialized literature (Brown, 1992, Uehara-Prado *et al.,* 2004) or with an image bank of butterfly species observed in the city of São Paulo, today with more than 24,000 photos of identified species. In addition, there are vouchers from individuals collected in Cidade Universitária Armando de Salles Oliveira (USP), an urban green area very close to Ibu and with almost the same butterfly community, which can serve as a reference collection. About 350 species of butterflies collected between 1996 and 2002 at USP were deposited in the collection of the Instituto de Biociências at Universidade de São Paulo or in the zoological collection of the Museu de Diversidade Biológica at UNICAMP (MDBio). Nomenclature follows Lamas (2004) and was updated from Wahlberg *et al.* (2009) for Nymphalidae,

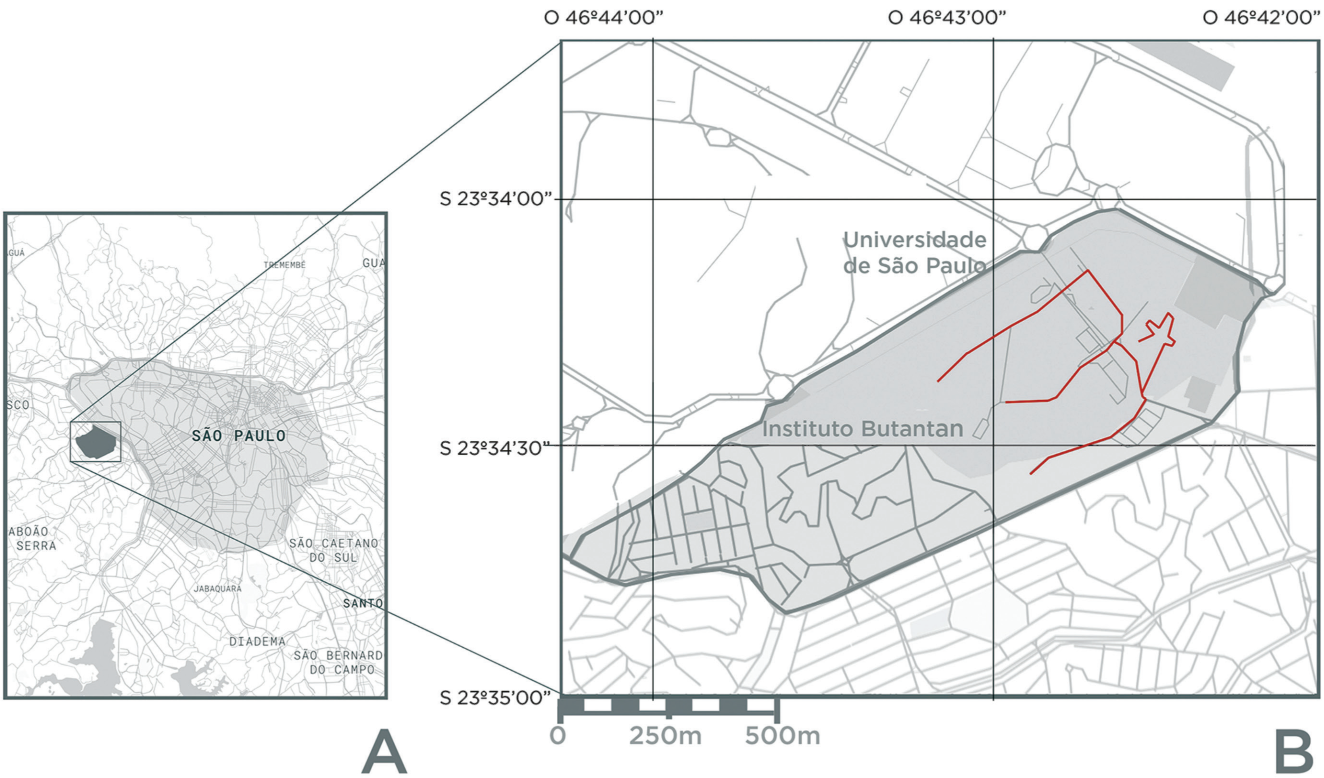

Figure 1. Map of the municipality of São Paulo, Brazil (A) showing the expanded center of the city (light gray). Park of Instituto Butantan (B), with the transect used to record the butterfly's species highlighted in red.

Seraphim *et al.* (2018) for Riodinidae and Warren *et al.* (2009) for Hesperiidae.

During the two years of sampling, 4 censuses were performed each month, except for August 2017, where only 2 censuses were completed. The transect covered in each census lasted about 3 hours and was conducted between 09:30 and 14:00, on sunny days with a maximum of 30% cloudiness. This totaled 282 hours of sampling effort. To maintain a standardization, censuses were preferably carried out during the first two weeks of each month if the weather conditions were favorable.

In addition to compiling the species list, we used the data obtained through the monthly censuses to plot the seasonal variation in the richness of each of the 6 butterfly families found in the IBu park.

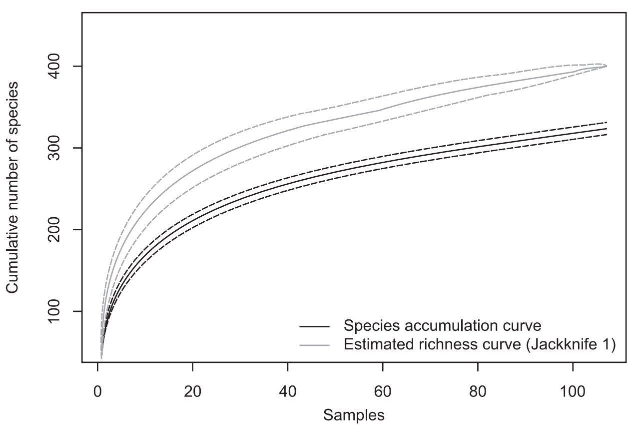

Figure 2. Species accumulation curve (black) and first order Jackknife estimator curve (gray) for butterfly species recorded in Instituto Butantan, São Paulo, Brazil, from August 2017 to July 2019. The dotted lines represent standard deviations.

Data analysis

To build the species accumulation curve, the specaccum function of the package Vegan (Oksanen *et al.*, 2015) in R (R Development Core Team, 2017) was used, with the Mao Tau resampling method with 95% confidence intervals (Colwell *et al.*, 2012). The poolaccum function of Vegan was used to estimate the extrapolated species richness, using the Jackknife 1 estimator.

RESULTS

Species richness

A total of 324 butterfly species belonging to 19 subfamilies were recorded (Table 1, some species in Fig. 3). The most speciose family was Hesperiidae (117 species, 36.1%), followed by Nymphalidae (102 spp., 31.5%), Lycaenidae (51 spp., 15.7%), Pieridae (23 spp., 7.1%), Riodinidae (22 spp., 6.8%), and Papilionidae (9 spp., 2.8%).

Of this total, two species, *Godartiana muscosa* (Nymphalidae) and *Pterourus scamander grayi* (Papilionidae), were not recorded during the work sampling period, but after the end of the study. As this work aims to carry out a complete inventory of the butterfly community of the Instituto Butantan park, we chose to

Figure 3. Some of the species of butterflies found in the park of Instituto Butantan, São Paulo, Brazil. Hesperiidae: (A) *Pythonides lancea,* (B) *Calpodes esperi,* (C) *Urbanus belli,* (D) *Cobalus virbius.* Lycaenidae: (E) *Elkalyce cogina,* (F) *Arawacus meliboeus.* Riodinidae: (G) *Euselasia zara,* (H) *Chadia cadytis.* Nymphalidae: (I) *Consul fabius,* (J) *Eunica margarita,* (K) *Heliconius sara apseudes,* (L) *Hypanartia lethe,* (M) *Carminda paeon,* (N) *Mechanitis lysimnia,* (O) *Marpesia petreus,* (P) *Adelpha zea.* Pieridae: (Q) *Melete lycimnia paulista,* (R) *Dismorphia amphione astynome,* (S) *Phoebis philea.* Papilionidae: (T) *Parides agavus.* Photos: Aline Vieira-Silva, Gustavo M. Accacio and Gabriel Banov.

Table 1. Butterflies (Lepidoptera: Papilionoidea) from the urban park of Instituto Butantan, São Paulo, Southeastern Brazil. Number of species are provided within parentheses for higher taxa.

PAPILIONOIDEA (324)
PAPILIONIDAE (9)
Papilioninae (9)
Battus polydamas (Linnaeus, 1758)
Parides proneus (Hübner, [1831])
Parides agavus (Drury, 1782)
Parides anchises nephalion (Godart, 1819)
Heraclides hectorides (Esper, 1794)
Heraclides anchisiades capys (Hübner, 1809)
Heraclides androgeus (Cramer, 1775)
Heraclides thoas brasiliensis (Rothschild & Jordan, 1906)
Pterourus scamander grayi (Boisduval, 1836)
PIERIDAE (23)
Dismorphiinae (4)
Enantia lina psamathe (Fabricius, 1793)
Dismorphia thermesia (Godart, 1819)
Dismorphia astyocha (Hübner, [1831])
Dismorphia amphione astynome (Dalman, 1823)
Pierinae (4)
Glutophrissa drusilla (Cramer, 1777)
Ascia monuste (Linnaeus, 1764)
Melete lycimnia paulista Fruhstorfer, 1908
Hesperocharis anguitea (Godart, 1819)
Coliadinae (15)
Leucidia elvina (Godart, 1819)
Anteos clorinde ([Godart, 1824])
Aphrissa statira (Cramer, 1777)
Phoebis neocypris (Hübner, [1823])
Phoebis sennae (Linnaeus, 1758)
Phoebis argante (Fabricius, 1775)
Phoebis philea (Linnaeus, 1763)
Abaeis arbela arbela (Geyer, 1832)
Abaeis albula sinoe (Godart, 1819)
Teriocolias deva deva (E. Doubleday, 1847)
Eurema phiale paula (Röber, 1909)
Eurema elathea (Cramer, 1777)
Pyrisitia nise tenella (Boisduval, 1836)
Pyrisitia leuce (Boisduval, 1836)
Colias lesbia mineira J. Zikán, 1940
LYCAENIDAE (51)
Theclinae (47)
Pseudolycaena marsyas (Linnaeus, 1758)
Contrafacia muattina (Schaus, 1902)
Arawacus ellida (Hewitson, 1867)
Arawacus meliboeus (Fabricius, 1793)
Rekoa palegon (Cramer, 1780)
Rekoa meton (Cramer, 1779)
Chlorostrymon simaethis (Drury, 1773)
Cyanophrys herodotus (Fabricius, 1793)
Parrhasius polibetes (Stoll, 1781)
Thepytus thyrea (Hewitson, 1867)
Michaelus ira (Hewitson, 1867)
Michaelus thordesa (Hewitson, 1867)
Panthiades hebraeus (Hewitson, 1867)
Arzecla arza (Hewitson, 1874)
Arzecla nubilum (H. Druce, 1907)
Hypostrymon asa (Hewitson, 1868)
Allosmaitia strophius (Godart, [1824])
Laothus phydela (Hewitson, 1867)
Janthecla flosculus (H. Druce, 1907)
Badecla badaca (Hewitson, 1868)
Lamprospilus orcidia (Hewitson, 1874)
Strymon bazochii (Godart, [1824])
Strymon astiocha (Prittwitz, 1865)
Strymon ziba (Hewitson, 1868)
Strymon megarus (Godart, [1824])
Strymon cestri (Reakirt, [1867])
Strymon rana (Schaus, 1902)
Calycopis bellera (Hewitson, 1877)
Calycopis caulonia (Hewitson, 1877)
Calycopis gentilla (Schaus, 1902)
Tmolus echion (Linnaeus, 1767)
Tmolus cydrara (Hewitson, 1868)
Aubergina vanessoides (Prittwitz, 1865)
Strephonota tephraeus (Geyer, 1837)
Strephonota elika (Hewitson, 1867)
Ostrinotes sophocles (Fabricius, 1793)
Nesiostrymon calchinia (Hewitson, 1868)
Nesiostrymon celona (Hewitson, 1874)
Ministrymon azia (Hewitson, 1873)
Nicolaea dolium (H. Druce, 1907)
Gargina thyesta (Hewitson, 1869)
Chalybs hassan (Stoll, 1790)
Celmia celmus (Cramer, 1775)
Dicya dicaea (Hewitson, 1874)
Rubroserrata ecbatana (Hewitson, 1868)
Ziegleria hesperitis (A. Butler & H. Druce, 1872)
Kisutam syllis (Godman & Salvin, 1887)
Polyommatinae (4)
Elkalyce cogina (Schaus, 1902)
Hemiargus hanno (Stoll, 1790)
Leptotes cassius (Cramer, 1775)
Zizula cyna (W.H. Edwards, 1881)
RIODINIDAE (22)
Euselasiinae (3)
Euselasia zara (Westwood, 1851)
Myselasia hygenius occulta (Stichel, 1919)
Methone euploea (Hewitson, [1855]
Riodininae (19)
Mesosemia icare matatha Hübner, [1819]
Mesosemia odice (Godart, [1824])
Eurybia pergaea (Geyer, 1832)
Panara soana soana Hewitson, 1875
Chadia cadytis (Hewitson, 1866)
Chalodeta theodora (C. Felder & R. Felder, 1862)
Detritivora zama (H. Bates, 1868)
Chorinea licursis (Fabricius, 1775)
Notheme erota (Cramer, 1780)
Monethe alphonsus (Fabricius, 1793)
Lasaia agesilas (Latreille, [1809])
Riodina lycisca (Hewitson, [1853])
Rhetus arcius amycus Stichel, 1909
Emesis russula Stichel, 1910
Emesis ocypore zelotes Hewitson, 1872
Aricoris signata (Stichel, 1910)
Lemonias zygia zygia Hübner, [1807]
Synargis calyce (C. Felder & R. Felder, 1862)
Nymphidium lisimon (Stoll, 1790)
NYMPHALIDAE (102)
Danainae (24)
Lycorea halia cleobaea (Godart, 1819)
Danaus erippus (Cramer, 1775)
Aeria olena Weymer, 1875
Methona themisto (Hübner, 1818)
Pagyris euryanassa (C. Felder & R. Felder, 1860)
Thyridia psidii (Linnaeus, 1758)
Mechanitis lysimnia (Fabricius, 1793)
Mechanitis polymnia casabranca Haensch, 1905
Epityches eupompe (Geyer, 1832)
Hypothyris ninonia daeta (Boisduval, 1836)
Hypothyris euclea laphria (E. Doubleday, 1847)
Ithomia drymo Hübner, 1816
Ithomia agnosia zikani R.F. d'Almeida, 1940
Dircenna dero celtina Burmeister, 1878
Episcada hymenaea (Prittwitz, 1865)
Episcada sylvo (Geyer, 1832)
Episcada striposis Haensch, 1909
Pteronymia carlia Schaus, 1902
Heterosais edessa (Hewitson, [1855])
Oleria aquata (Weymer, 1875)
Pseudoscada erruca (Hewitson, 1855)
Pseudoscada acilla quadrifasciata Talbot, 1928
Mcclungia cymo salonina (Hewitson, 1855)
Hypoleria alema proxima Weymer, 1899
Satyrinae (11)
Morpho helenor (Cramer, 1776)
Opsiphanes cassiae (Linnaeus, 1758)
Opsiphanes invirae (Hübner, [1808])
Taygetis laches Fabricius, 1793
Capronnieria galesus (Godart, [1824])
Pareuptychia ocirrhoe interjecta (R.F. d'Almeida, 1952)
Godartiana muscosa (A. Butler, 1870)
Hermeuptychia sp.
Moneuptychia soter (A. Butler, 1877)
Cissia phronius (Godart, [1824])
Carminda paeon (Godart, [1824])
Charaxinae (10)
Archaeoprepona demophon (Linnaeus, 1758)
Archaeoprepona amphimachus (Fabricius, 1775)
Consul fabius (Cramer, 1776)
Zaretis strigosus (Gmelin, [1790])
Hypna clytemnestra huebneri A. Butler, 1866
Fountainea ryphea phidile (Geyer, 1837)
Memphis appias (Hübner, [1825])
Memphis moruus stheno (Prittwitz, 1865)
Memphis acidalia victoria (H. Druce, 1877)
Memphis otrere (Hübner, [1825])
Limenitidinae (6)
Adelpha lycorias (Godart, [1824])
Adelpha serpa (Boisduval, 1836)
Adelpha mythra (Godart, [1824])
Adelpha syma (Godart, [1824])
Adelpha plesaure Hübner, 1823
Adelpha zea (Hewitson, 1850)
Cyrestinae (2)
Marpesia chiron (Fabricius, 1775)
Marpesia petreus (Cramer, 1776)
Biblidinae (24)
Biblis hyperia (Cramer, 1779)
Cybdelis phaesyla (Hübner, [1831])
Dynamine postverta (Cramer, 1779)
Dynamine tithia (Hübner, 1823)
Dynamine athemon (Linnaeus, 1758)
Dynamine agacles (Dalman, 1823)
Dynamine artemisia (Fabricius, 1793)
Myscelia orsis (Drury, 1782)
Catonephele numilia penthia (Hewitson, 1852)
Ectima thecla (Fabricius, 1796)
Hamadryas amphinome (Linnaeus, 1767)
Hamadryas epinome (C. Felder & R. Felder, 1867)
Hamadryas feronia (Linnaeus, 1758)
Hamadryas februa (Hübner, [1823])
Hamadryas fornax (Hübner, [1823])
Eunica margarita (Godart, [1824])
Eunica tatila bellaria Fruhstorfer, 1908
Temenis laothoe (Cramer, 1777)
Epiphile orea (Hübner, [1823])
Haematera pyrame (Hübner, [1819])
Catagramma pygas eucale Fruhstorfer, 1916
Catagramma pyracmon pyracmon (Godart, [1824])
Diaethria clymena meridionalis (H. Bates, 1864)
Diaethria candrena (Godart, [1824])
Nymphalinae (14)
Historis odius (Fabricius, 1775)
Colobura dirce (Linnaeus, 1758)
Hypanartia lethe (Fabricius, 1793)
Hypanartia bella (Fabricius, 1793)
Junonia genoveva (Cramer, 1779)
Vanessa brasiliensis (Moore, 1883)
Anartia jatrophae (Linnaeus, 1763)
Anartia amathea roeselia (Eschscholtz, 1821)
Siproeta stelenes meridionalis (Fruhstorfer, 1909)
Siproeta epaphus trayja Hübner, [1823]

Table 1. Continued.

Tegosa claudina (Eschscholtz, 1821)
Ortilia ithra (W.F. Kirby, 1900)
Eresia lansdorfi (Godart, 1819)
Chlosyne lacinia saundersi (E. Doubleday, [1847])
Heliconiinae (11)
Philaethria wernickei (Röber, 1906)
Agraulis vanillae maculosa (Stichel, [1908])
Dione juno (Cramer, 1779)
Dryas alcionea alcionea (Cramer, 1779)
Eueides isabella dianasa (Hübner, [1806])
Eueides aliphera (Godart, 1819)
Heliconius ethilla narcaea (Godart, 1819)
Heliconius erato phyllis (Fabricius, 1775)
Heliconius sara apseudes (Hübner, [1813])
Actinote carycina Jordan, 1913
Actinote pellenea Hübner, [1821]
HESPERIIDAE (117)
Eudaminae (26)
Augiades epimethea (Plötz, 1883)
Epargyreus pseudexadeus Westwood, 1852
Polygonus savigny (Latreille, [1824])
Aguna asander (Hewitson, 1867)
Aguna megaeles (Mabille, 1888)
Narcosius parisi (R. Williams, 1927)
Cogia crameri (McHenry, 1960)
Ectomis octomaculata (Sepp, [1844])
Urbanus proteus (Linnaeus, 1758)
Urbanus belli (Hayward, 1935)
Urbanus pronta Evans, 1952
Urbanus esmeraldus (A. Butler, 1877)
Urbanus esta Evans, 1952
Spicauda teleus (Hübner, 1821)
Spicauda simplicius (Stoll, 1790)
Spicauda procne (Plötz, 1881)
Cecropterus dorantes dorantes (Stoll, 1790)
Cecropterus doryssus (Swainson, 1831)
Cecropterus virescens (Mabille, 1877)
Cecropterus zarex (Hübner, 1818)
Telegonus fulgerator (Walch, 1775)
Telegonus alardus (Stoll, 1790)
Telegonus anaphus (Cramer, 1777)
Telegonus creteus siges (Mabille, 1903)
Astraptes enotrus (Stoll, 1781)
Spathilepia clonius (Cramer, 1775)
Pyrginae (31)
Celaenorrhinus similis Hayward, 1933
Nisoniades castolus (Hewitson, 1878)
Nisoniades macarius (Herrich-Schäffer, 1870)
Nisoniades bipuncta (Schaus, 1902)
Noctuana diurna (A. Butler, 1870)
Pellicia sp.
Bolla catharina (E. Bell, 1937)
Staphylus ascalon (Staudinger, 1876)
Gorgythion begga (Prittwitz, 1868)
Gorgythion beggina escalaphoides (Hayward, 1941)
Festivia cronion (C. Felder & R. Felder, 1867)
Sostrata bifasciata (Ménétriés, 1829)
Mylon maimon (Fabricius, 1775)
Echelatus sempiternus simplicior (Möschler, 1877)
Ebrietas anacreon (Staudinger, 1876)
Helias phalaenoides palpalis (Latreille, [1824])
Achlyodes busirus (Cramer, 1779)
Eantis thraso (Hübner, [1807])
Ouleus fridericus riona Evans, 1953
Zera hyacinthinus (Mabille, 1877)
Quadrus u-lucida (Plötz, 1884)
Pythonides lancea (Hewitson, 1868)
Milanion leucaspis (Mabille, 1878)
Trina geometrina (C. Felder & R. Felder, 1867)
Carrhenes canescens (R. Felder, 1869)
Xenophanes tryxus (Stoll, 1780)
Antigonus erosus (Hübner, [1812])
Burnsius orcynoides (Giacomelli, 1928)
Burnsius orcus (Stoll, 1780)
Heliopetes alana (Reakirt, 1868)
Heliopetes omrina (A. Butler, 1870)
Hesperiinae (60)
Perichares adela (Hewitson, 1867)
Lycas argentea (Hewitson, 1866)
Pyrrhopygopsis socrates (Ménétriés, 1855)
Lychnuchus celsus (Fabricius, 1793)
Talides alternata E. Bell, 1941
Cobalus virbius (Cramer, 1777)
Oz ozias ozias (Hewitson, 1878)
Panoquina lucas (Fabricius, 1793)
Panoquina fusina viola Evans, 1955
Calpodes esperi Evans, 1955
Calpodes triangularis (Kaye, 1914)
Rhinthon bajula (Schaus, 1902)
Anthoptus epictetus (Fabricius, 1793)
Anthoptus insignis (Plötz, 1882)
Corticea corticea (Plötz, 1882)
Corticea noctis (Plötz, 1882)
Corticea obscura O. Mielke, 1969
Corticea lysias potex Evans, 1955
Zariaspes mys (Hübner, [1808])
Vinius letis (Plötz, 1883)
Callimormus diaeses Schaus, 1902
Mnasicles remus (Fabricius, 1798)
Mnasinous ina (Plötz, 1882)
Mnasinous cinnamomea (Herrich-Schäffer, 1869)
Phanes almoda (Hewitson, 1866)
Artines aquilina (Plötz, 1882)
Cymaenes lepta (Hayward, 1939)
Cymaenes gisca Evans, 1955
Cymaenes tripunctus theogenis (Capronnier, 1874)
Tigasis perloides (Plötz, 1882)
Vehilius stictomenes (A. Butler, 1877)
Vehilius inca (Scudder, 1872)
Mnasalcas ritans (Schaus, 1902)
Papias phainis Godman, 1900
Cobalopsis valerius (Möschler, 1879)
Cobalopsis nero (Herrich-Schäffer, 1869)
Rectava vorgia (Schaus, 1902)
Troyus diversa diversa (Herrich-Schäffer, 1869)
Troyus phyllides (Röber, 1925)
Vettius lafrenaye (Latreille, [1824])
Artonia artona (Hewitson, 1868)
Koria kora (Hewitson, 1877)
Onophas columbaria (Herrich-Schäffer, 1870)
Lamponia elegantula (Herrich-Schäffer, 1869)
Naevolus orius (Mabille, 1883)
Mit schausi O. Mielke & Casagrande, 2002
Dion uza (Hewitson, 1877)
Mucia zygia (Plötz, 1886)
Hylephyla phyleus (Drury, 1773)
Hedone catilina (Plötz, 1886)
Pompeius pompeius (Latreille, [1824])
Pompeius amblyspila (Mabille, 1898)
Cynea cannae (Herrich-Schäffer, 1869)
Cynea trimaculata (Herrich-Schäffer, 1869)
Conga chydaea (A. Butler, 1877)
Tirynthia conflua (Herrich-Schäffer, 1869)
Nyctelius nyctelius (Latreille, [1824])
Thespieus xarippe (A. Butler, 1870)
Thespieus dalman (Latreille, [1824])
Xeniades orchamus (Cramer, 1777)

include this species in the final list. Regarding the sampling effort, neither the species accumulation nor the richness estimator curves (Fig. 2) tended to reach an asymptote, indicating that the butterflies' species list of the park has considerable potential to increase with more sampling effort following the visual censuses protocol. The Jackknife 1 estimated curve reached a maximum of 406 species (Fig. 2), meaning that about 80% of the estimated community at the end of the sampling was recorded.

Among the sampled species, a notable record was *Euselasia zara* (Westwood, 1851) (Fig. 3g), which is a new record for the state of São Paulo. In Brazil, this Riodinidae species has a known distribution in Espírito Santo (Brown & Freitas, 2000b), Distrito Federal (Emery *et al.,* 2006), Paraná (Dolibaina *et al.,* 2011), Rio Grande do Sul (Siewert *et al.,* 2014), Santa Catarina (Orlandin *et al.,* 2019) and Minas Gerais (Vieira *et al.,* 2020). Given this already known distribution, it was expected that *Euselasia zara* would also occur in São Paulo. The presence of this species indicates an especially rich environment (Brown & Freitas, 2000b), demonstrating the importance of conserving that area.

Seasonal variation

The number of butterfly species recorded in each month did not have a marked variation in the initial months of the study, ranging from 112 to 128 species recorded per month (mean = 117, SD = 4.78; Fig. 4). On the other hand, a more evident variation in the number of species occur in the second year of survey, ranging from 99 to 152 species (mean = 112, SD = 14.46; Fig. 4).

The low number of species registered in August 2017 is not due to seasonal changes, but rather to a smaller number of censuses carried out in that month (2 censuses instead of 4), which totaled only 6 hours of sampling, half of the sampling effort of the too many months. The peak of species richness occurred during the rainy

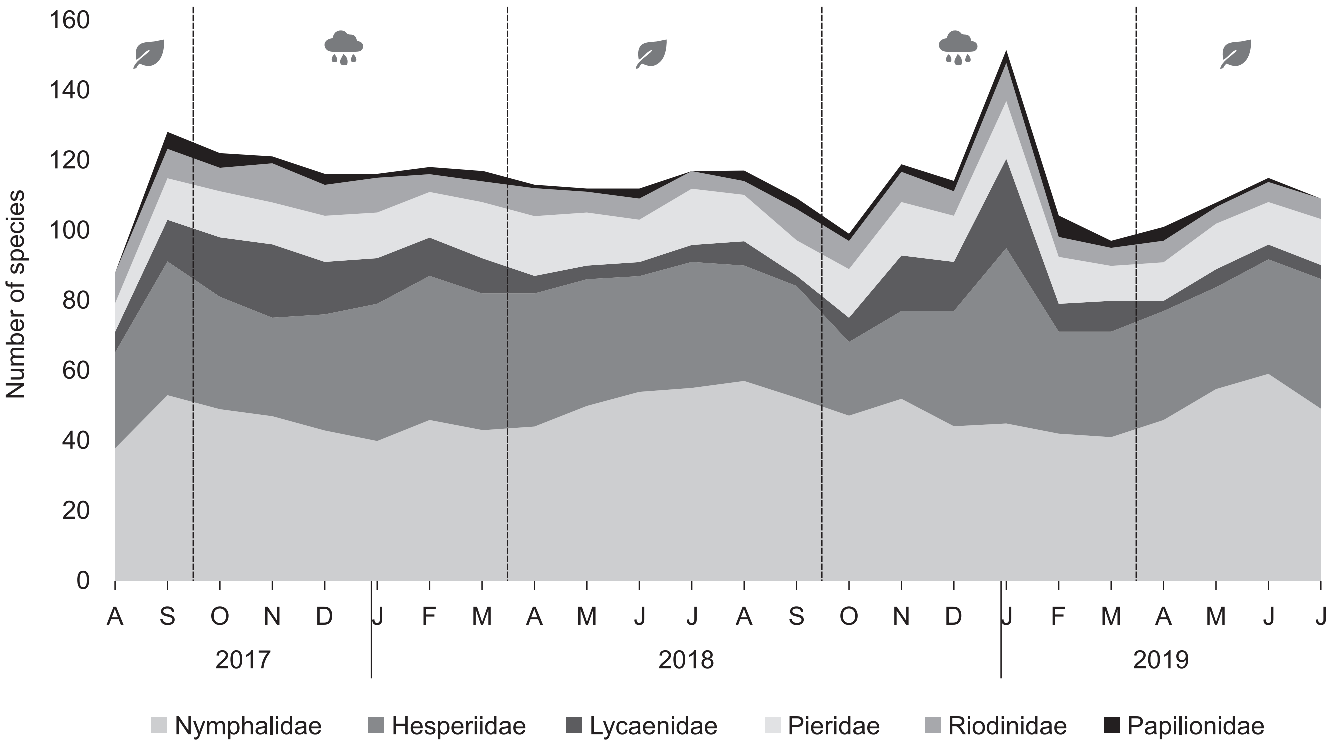

Figure 4. Seasonal variation in the number of species per family in each month in the butterfly community of Instituto Butantan. Regions with colored symbols represent wet (blue cloud) and dry (brown leaf) season.

season in January 2019, with a total of 152 species recorded. Comparing the richness of each month with the total richness of the sampled community (324 spp.), it is possible to notice that the percentage of butterfly species recorded varied between 30% (March 2019) and 47% (January 2019). This shows that even in the period with the highest number of species sampled, less than half of the total community richness was detected.

DISCUSSION

Species richness

The number of species recorded increased over the months of the study (Fig. 2), which illustrates the great richness of the area (Iserhard & Romanowski, 2004). Furthermore, the Jackknife estimator curve did not reach an asymptote, confirming the difficulty in sampling all species from a specific locality within a limited sampling time (Brown & Freitas, 2000a, Iserhard *et al.,* 2010, Fattorini, 2013). Some groups of butterflies were certainly under sampled due to their habits, habitat preferences and/or due to the sampling protocol used. Certain nymphalids (mainly from the subfamily Satyrinae) and hesperiids that exhibit a cryptic coloration on the ventral surface of the wings were more difficult to locate and also to identify when perched. In addition, given that the samplings were carried out between 10:00 and 14:00, some taxa that have species with twilight habits, such as Brassolini (Nymphalidae) and Hesperiidae, were possibly undersampled. Riodinidae, which is the third richest family of butterflies in the Atlantic Forest biome (Iserhard *et al.,* 2017), probably did not have a higher proportion of species recorded because they have the habit of landing under leaves, making them more difficult to locate visually. Therefore, to register the entire butterfly community of the Instituto Butantan, it would be necessary to extend the study for a longer period, and perhaps add other collection methods, such as attractive bait traps for the frugivorous butterfly guild. Despite these limitations in the sampling protocol adopted, the number of species already recorded is high when compared to other urban parks.

Hesperiidae had the highest proportion of species in relation to the other families. This is an indication that the area is being well sampled, and this data can be used as an estimate of sampling sufficiency (Iserhard *et al.,* 2017). Moreover, a greater number of species of Hesperiidae has not yet been recorded due to their difficulty in viewing and sampling, as mentioned above, resulting from their relatively small size and unflattering coloration (Vasconcelos *et al.,* 2009). Species richness per butterfly family found in the present work follows the pattern recorded for the total number of butterflies from Brazil and other well-sampled regions in the Neotropics, with Hesperiidae being the richest family, followed by Nymphalidae (Brown & Freitas, 1999, Brown & Freitas, 2000b).

Brown & Freitas (2002) carried out a study in 15 urban parks in the region of Campinas, which is about 80 km from São Paulo. The richness of butterflies found in these different fragments ranged from 80 to 702 species, with sampling effort ranging from 40 to 1,000 hours. According to the authors, more homogeneous or smaller fragments resulted in lower richness, while fragments located in semi-urban areas presented greater richness and more variable species composition than more urbanized locations (Brown & Freitas, 2002). In most parks, the proportion of species per family differed from that found in the Instituto Butantan, with Nymphalidae being the most abundant family. However, the lack of standardization of collection methods and sampling effort among studies makes it difficult to directly compare the richness found in the Instituto Butantan and in these urban parks.

There is not much published knowledge about the butterfly community from the São Paulo region, and only two studies surveying butterfly species in urban parks of the city were concluded. Accacio (1997), using a transect method modified of the "Pollard walk" method (Pollard, 1977), recorded 245 species of butterflies in the Universidade de São Paulo Campus (USP) with a sampling effort of 126 hours. The USP and the Instituto Butantan park have very similar vegetation, in addition to being separated by only a few kilometers apart, therefore, it would be expected that the richness of butterflies found in these two regions would be very close. The discrepancy in richness observed is due to the difference in the sampling method, since using the Pollard walk many species that are present are not recorded.

After carrying out single monthly censuses (about 3 hours) for the last 17 years with the same methodology used in the present work, Accacio added many more species to the USP butterfly assemblage. The current number of butterfly species recorded on campus is 481 (Accacio, personal communication), much higher than that of the Instituto Butantan park (324 species). Of this total, both sites share 318 species, almost all of which are found in Ibu and are also found in USP. Instituto Butantan has only 5 species that were not registered in USP, while USP has 163 unique species that do not occur in Ibu (gamma diversity = 486, alpha diversity = 402 and beta diversity = 1,208). In fact, in the same period of the Butantan study, the single monthly censuses carried out at USP (75 accumulated hours) resulted in the recording of 328 butterfly species, roughly the same number found in Butantan (gamma diversity = 390, alpha diversity = 325.5 and beta diversity = 1.198).

Brown & Freitas (2002) concluded that connectivity is the environmental factor that exerts the greatest influence on butterfly richness. Therefore, due to the great proximity and connectivity between the park of Instituto Butantan and USP, we believe the two locations share a very similar community. As the campus is much larger and far more heterogeneous than the Butantan park, even including remnants of native savannah (Cerrado), the greater species richness with only ¼ of the time effort is not a particular surprise. Also, because the forest/wood tracts of the two areas are very close and similar, we believe that, with greater sampling effort, the recorded forest butterfly richness of the Instituto Butantan still will increase and become very close to that of USP.

When comparing the butterfly community of IBu and USP, we noticed that the difference between the species composition is mainly due to the families Riodinidae, Lycaenidae and Hesperiidae, which respectively share only 58, 58 and 61% of the species. These families exhibit great variation both locally and temporally, with high turnover (Iserhard *et al.,* 2013), showing transient species that appear only in a few years and highly local species (Ebert, 1969, Callaghan, 1978, Robbins & Small, 1981, Brown, 1993). The other families, Papilionidae, Nymphalidae and Pieridae share two thirds or more of the species (70, 72% and 85% respectively). For Papilionidae and Pieridae, what explains this greater similarity between the species of the two communities is the proportionally lower richness values that they present (Iserhard *et al.,* 2013). The Nymphalidae family usually does not show a high turnover, with relatively constant species throughout the year (Iserhard *et al.,* 2013).

Seasonal variation

The IBu butterfly community exhibit a seasonal distribution mainly in the second year of the study, with the peak of species richness related to the rainy season. The increase in species number in the warmer and more humid season can be explained by the more favorable conditions of this period, since it provides new resources for butterflies, whether new leaves where the immatures can develop or floral resources for adults (Brown & Freitas, 2000). Another phenomenon associated with this rainy season is the migration of species from the Lycaenidae family (Accacio, 1997) which ranged from 13 to 26 species per month between November and January, compared to a variation of 3 to 12 in the other months (Fig. 4).

The results found in Ibu park are similar to those found by Pozo *et al.* (2008) in a study carried out in a seasonal region in Mexico, which also shows higher butterfly species richness during the rainy season. In the study by Pozo *et al.* (2008), the two richest families (Hesperiidae and Nymphalidae), as well as Lycaenidae (analyzed together with Riodinidae) recorded peaks of richness in the rainy season, whereas Papilionidae was more associated with the dry season, and Pieridae was constant throughout the year. Comparing with the pattern of richness of each family recorded in the IBu (which can be observed by comparing the area of the graph occupied by each family in Fig. 4), it is possible to notice that Hesperiidae and Lycaenidae also present the pattern of higher species richness in the season rainy season and Pieridae also remained constant throughout the year. However, in the present study, Nymphalidae does not seem to have a clear pattern of association with a specific season. Another difference is in relation to the family Papilionidae, associated with the transition between the dry season and the beginning of the rainy season in Mexico, but more numerous during the rainy season in the IBu. Thus, in general, the community of the two locations seems to exhibit a pattern of variation in climatic seasonality, which organisms from tropical environments tend to follow (Kishimoto-Yamada & Itioka, 2015).

Several communities of the Seasonal Atlantic Forest of southeastern Brazil show a bimodal pattern of species richness, with peak of richness normally occurring in the transition between seasons (Ribeiro *et al.,* 2010, Santos *et al.,* 2017, Lourenço *et al.,* 2020). This pattern was not recorded in the present study, and this may possibly be related to microclimatic factors and vegetation structure of this urban region (Checa *et al.,* 2014).

CONCLUSION

Although no threatened species were recorded in the present study, the butterfly fauna of the Instituto Butantan deserves attention. Even with a flora composed mainly of exotic and ornamental plants, with areas of secondary forest, the park exhibits a very rich butterfly community. This community exhibits a pattern of seasonally variation, which is common for many tropical insects' communities. Considering that the Instituto Butantan park is located in the most populous city in Brazil (IBGE, 2021), and one of the most populous cities in the world, suffering from various human disturbances, the species richness is even more surprising. This richness is an indication that even degraded areas, which have been suffering intense anthropic interference, can still sustain a significant part of their original species. Therefore, conserving this urban fragment becomes important for the maintenance of these butterfly species. In addition, another relevant factor that must also be considered for the conservation of these species is to create a connection between different urban fragments. This increases the chances of these butterflies being able to disperse and become more abundant in urban centers.

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