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Diversity of Papilionoidea in the Tamanduá Farm, Septentrional Sertaneja Depression Ecoregion, Caatinga, Semiarid, Santa Teresinha, Paraíba, Northeast, Brazil (Insecta: Lepidoptera)

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Abstract

The objective of this study was to know the composition, richness and abundance of Papilionoidea with entomological net, in different environments and distinct periods in the Caatinga biome or Semiarid region during 12 months in the Tamanduá Farm. A total of 5556 individuals were recorded, with 82 species of Papilionoidea in a systematic survey and subsequently 93 species. The estimators of richness or diversity extrapolated from 85.5 (Chao 1) to 121.75 (ChaoRichness - Incidence) and highlighted the ICE with 93.4 species. Hesperiidae and Nymphalidae were the most representative families, followed by others. An unprecedented record was found for Northeast and two for Semiarid-Caatinga, five new records were described to the state of Paraíba and 24 unpublished records for the ecoregion of the Septentrional Sertaneja Depression. The importance of the remaining of ciliary forest for the protection of Papilionoidea was evidenced, allowing the permanence of certain species in the area even in dry period, which has a strong influence on the conservation of this group in population dynamics and community resilience.
Keywords: Insecta, Lepidoptera, Papilionoidea, abundance, biodiversity, composition, richness, Brazil.

Diversidad de Papilionoidea en la Hacienda Tamanduá, Ecorregión de la Depresión Sertaneja Septentrional, Caatinga, Semiárido, Santa Teresinha, Paraíba, Nordeste, Brasil (Insecta: Lepidoptera)

Resumen

El objetivo de este estudio fue conocer la composición, riqueza y abundancia de Papilionoidea con red entomológica, en ambientes diferentes y períodos distintos en el bioma Caatinga o región Semiárida durante 12 meses en la Hacienda Tamanduá. Se registraron un total de 5.556 individuos, con 82 especies de Papilionoidea en un levantamiento sistematizado y posteriormente 93 especies. Los estimadores de riqueza o diversidad extrapolaron de 85.5 (Chao 1) hasta 121.75 (“ChaoRichness - Incidence”) y se destacó el ICE con 93.4 especies. Hesperiidae y Nymphalidae fueron las familias más representativas, seguidas de otras. Se encontró un registro inédito para el Nordeste y dos para el Semiárido-Caatinga, se describieron cinco nuevos registros para el estado de Paraíba y 24 registros sin precedentes para la ecorregión de la Depresión Sertaneja Septentrional. Se evidenció la importancia del remanente de bosque ciliar para la protección de los Papilionoidea, al permitir la permanencia de determinadas especies en el área incluso en período seco, lo que tiene una fuerte influencia en la conservación de este grupo en dinámicas poblacionales y resiliencia de la comunidad.
Palabras clave: Insecta, Lepidoptera, Papilionoidea, abundancia, biodiversidad, composición, riqueza, Brasil.

Diversidade de Papilionoidea na Fazenda Tamanduá, Ecorregião da Depressão Sertaneja Setentrional, Caatinga, Semiárido, Santa Teresinha, Paraíba, Nordeste, Brasil (Insecta: Lepidoptera)

Resumo

O objetivo deste estudo foi conhecer a composição, riqueza e abundância de Papilionoidea com rede entomológica, em diferentes ambientes e períodos distintos no bioma Caatinga ou região Semiárida durante 12 meses na Fazenda Tamanduá. Foram registrados 5556 indivíduos, com 82 espécies de Papilionoidea em um levantamento sistemático e posteriormente 93 espécies. Os estimadores de riqueza ou diversidade extrapolaram de 85,5 (Chao 1) para 121,75 (ChaoRichness - Incidência) e destacaram o ICE com 93,4 espécies. Hesperiidae e Nymphalidae foram as famílias mais representativas, seguidas de outras. Um registro inédito foi encontrado para o Nordeste e dois para o Semiárido-Caatinga, cinco novos registros foram descritos para o estado da Paraíba e 24 registros inéditos para a ecorregião da Depressão Sertaneja Setentrional. Foi evidenciada a importância dos remanescentes de mata ciliar para a proteção dos Papilionoidea, permitindo a permanência de determinadas espécies na área mesmo em período seco, o que tem forte influência na conservação desse grupo na dinâmica populacional e resiliência da comunidade.

Palavras-chave: Insecta, Lepidoptera, Papilionoidea, abundância, biodiversidade, composição, riqueza, Brasil.

Introduction

The order Lepidoptera, emphasizing Papilionoidea, as observed in annual compilations of Lamas (2024), is one of the most studied groups of hyperdiverse insects in the Neotropical region and world. However, in Brazil and specifically in the Northeast geopolitical region there is still no adequate characterization of diversity (Kerpel et al. 2014). Evidence that unfolds by the accentuated inequalities at spatial levels, where most studies and inventories with Papilionoidea converge to the Southeast and South regions in Atlantic Forest areas (Brandão & Yamamoto, 2003; Carneiro et al. 2008; Freitas & Marini-Filho, 2011), due to a higher concentration of researchers or zoological collections (Basílio et al. 2024), for example (https://collectory.sibbr.gov.br/collectory).

Various works on the Caatinga biome emphasized the importance of areas for biodiversity conservation, scarcity of studies and information on several groups with invertebrate species (Brandão et al. 2000; Tabarelli & Silva, 2003; Brandão & Yamamoto, 2003; Araújo et al. 2005; Silva et al. 2017; Joly et al. 2019). The Caatinga represents one of the biggest gaps in Brazilian knowledge about Lepidoptera (Brandão & Yamamoto, 2003; Carneiro et al. 2008; Freitas & Marini-Filho, 2011; Lewinsohn et al. 2022), even with the emerging mitigation promoted by projects supported through the Research Program on Biodiversity of the Semiarid (PPBio Semiárido in Portuguese for “Programa de Pesquisa em Biodiversidade do Semiárido”) (Kerpel et al. 2014; Kerpel et al. 2016), National Biodiversity Research System (SISBIOTA Brasil in Portuguese for “Sistema Nacional de Pesquisa em Biodiversidade”) (Oliveira et al. 2024) and others (Santos et al. 2023).

For the set of publications in the Northeast of Brazil, with exclusive application of entomological net or with net and trap, 24 lists of Papilionoidea species stand out (Table I), currently without publication for Sergipe of the nine states that constitute the Northeast region and for portion of the Caatinga in the north of Minas Gerais in the Southeast region. Of these inventories, considered hybrid areas, ecotones or different physiognomies in stricto sensu or lato sensu classifications in the Brazilian biomes, 15 were focused on areas of the Atlantic Forest in the states of Alagoas, Paraíba, Rio Grande do Norte, Bahia and Pernambuco (Cardoso, 1949; Kesselring & Ebert, 1979; Duarte-Júnior et al. 2001; Vasconcelos et al. 2009; Zacca et al. 2011; Paluch et al. 2011; Paluch et al. 2016; Melo et al. 2019; Vila-Verde et al. 2020; Vila-Verde & Paluch, 2020; Bezerra et al. 2021; Dantas et al. 2021; Medeiros et al. 2021; Gonçalves et al. 2021; Gualberto et al. 2024), seven other studies include areas of the Caatinga in the states of Pernambuco, Bahia, Ceará, Piauí and Paraíba (Nobre et al. 2008; Zacca & Bravo, 2012; Roque et al. 2014; Lima & Zacca, 2014; Kerpel et al. 2014; Câmara et al. 2017; Ferreira-Júnior, 2021), while two were described for areas of the Cerrado and Amazon in the state of Maranhão (Martins et al. 2017; Pereira et al. 2018).

Table I. Papilionoidea inventories published for the Northeast region of Brazil, exclusively with entomological net (N) or with mixed collection method (N/T), with periods that represent interposed quantities of collections per hours per day or days per month or months per year or years and do not express that the collection effort was applied at all the hours of days or on all the days of months or not necessarily in all months of the year. AL = Alagoas, PB = Paraíba, RN = Rio Grande do Norte, PE = Pernambuco, BA = Bahia, CE = Ceará, PI = Piauí, MA = Maranhão; FAT = Atlantic Forest, CAA = Caatinga, CER = Cerrado, AMA = Amazon; N = Entomological net, T = Van Someren-Rydon trap.

Work	State	Biome	Period	Method	Richness
Cardoso (1949)	AL	FAT	≈ 5 years	N	225
Kesselring & Ebert (1979)	PB	FAT	≈ 5 years	N	291
Duarte-Júnior et al. (2001)	RN	FAT	12 months	N	22
Nobre et al. (2008)	PE	CAA	12 months	N/T	121
Vasconcelos et al. (2009)	BA	FAT	6 months	N/T	70
Zacca et al. (2011)	BA	FAT	7 months	N	140
Paluch et al. (2011)	PE	FAT/CAA	12 months	N/T	197
Zacca & Bravo (2012)	BA	CAA	7 months	N/T	169
Roque et al. (2014)	CE	CAA	12 months	N	73
Lima & Zacca (2014)	BA	CAA	7 months	N/T	121
Kerpel et al. (2014)	PI, CE, PB, PE, BA	CAA	≈ 3 years	N/T	389
Paluch et al. (2016)	BA	FAT	12 months	N	260
Câmara et al. (2017)	CE	CAA	2 months	N/T	150
Martins et al. (2017)	MA	CER/AMA	24 months	N/T	189
Pereira et al. (2018)	MA	AMA	19 months	N/T	91
Melo et al. (2019)	PE	FAT	20 months	N	288
Vila-Verde et al. (2020)	BA	FAT	12 months	N/T	235
Vila-Verde & Paluch (2020)	BA	FAT	17 months	N/T	228
Ferreira-Júnior (2021)	PB	CAA	10 months	N	90
Bezerra et al. (2021)	AL	FAT	7 months	N	44
Dantas et al. (2021)	BA	FAT/CAA	9 months	N/T	114
Medeiros et al. (2021)	PB	FAT	7 months	N/T	89
Gonçalves et al. (2021)	BA	FAT	6 months	N/T	205
Gualberto et al. (2024)	PB	FAT	6 months	N/T	212

Recently, a study on regeneration in the Caatinga evaluated the successional stages through multitaxa, including fruit-feeding bPapilionoidea at Tamanduá Farm with 13 species and concluded that diversity was higher in the initial succession phases than in the late growth phases, but varied widely in the intermediate stages (Oliveira et al. 2024). Concerning Papilionboidea, the knowledge is still incipient in the state of Paraíba; aggravated not only in the semiarid portion, including herbaceous-shrubby-arboreal caatinga environments, ciliary forests and high-altitude wetlands, where studies are scarce or practically non-existent in certain indispensable localities (Ministério do Meio Ambiente e Mudança do Clima, 2023) and crucial to promote conservation (Cardoso et al. 2011; Hortal et al. 2015).

Furthermore, to achieve goals since the year 2000 for the Millennium Development Goals (MDGs) in Goal 7 (Ensure Environmental Sustainability) and until the year 2015 through of the 2030 Agenda (Agenda 2030 para o Desenvolvimento Sustentável, 2015) by Sustainable Development Goals (SDGs) (United Nations, 2023; Organização das Nações Unidas no Brasil, 2023), in the state of Paraíba (Objetivos de Desenvolvimento Sustentável na Paraíba, 2023a) in the geoadministrative region (GAR) of Patos (Objetivos de Desenvolvimento Sustentável na Paraíba, 2023b) and in the municipality of Santa Teresinha (Objetivos de Desenvolvimento Sustentável na Paraíba, 2023c; Índice de Desenvolvimento Sustentável das Cidades-Brasil, 2024), in Brazil and as an example for Goal 13 (Climate Action) or Goal 15 (Life on Land). Also to align with nature-based solutions for climate change, area protections and ecosystem restorations (UN Biodiversity Lab, 2024).

There were harmful situations in Brazil which have been and are still going through legal regulations for mitigation and adaptation actions, via diverse movements, such as environmental or socioenvironmental issues addressed by the Federal Supreme Court (STF in Portuguese for "Supremo Tribunal Federal") and that became known as STF green package or green agenda (#PacoteVerdeNoSTF, #PautaVerde), to the ecologically balanced environment in Brazil (https://portal.stf.jus.br/textos/verTexto.asp?servico=informativoSTF), highlight for Claim of Non-compliance with a Fundamental Precept (ADPF in Portuguese for "Arguição de Descumprimento de Preceito Fundamental") - ADPF 651/DF in defense of the democracy with participation of organized civil society groups (Informativo-STF, 2022). Moreover, other characteristics through the Constitution of the Federative Republic of Brazil, in chapter VI "Environment" and other parts, to the instances, for noting the expression of species in plural (Brasil, 1988; Brazil, 1988) to the context of Biological Sciences or Ecology ("The Economy of Nature"), until reflection on the unified concept of species and other aspects (Ferreira-Júnior, 2021), and to the context of Economic Sciences (Brasil, 1988; Brazil, 1988), splitter in English (species, specie) and lumper in Portuguese ("espécie", "espécies"), with representations, about translation and origin/etymology (probably metaplasm from Latin to Portuguese, possibly also in some other languages) or change/transformation and values, via species in singular/species in plural and specie in singular/specie in plural (paronymy and relationships with synonyms, two signifiers with different signifieds depending on the specific contexts), and for the integrated concept of "espécie" (singular)/"espécies" (plural) in Portuguese (homonymy and relationships with synonyms, one signifier with more than one signified depending on the specific contexts).

Thus, the aim was to generate data on the composition, richness and abundance of Papilionoidea taxocenosis at the Tamanduá Farm, Santa Teresinha, Paraíba, Brazil, contributing to a better representation and conservation of the Papilionoidea fauna in the Caatinga or Semiarid with species; in the "Patos-Santa Terezinha" demarcation area of high biological importance, with priority for the knowledge and conservation of invertebrates, in addition to the recommendation of integral protection for being considered a transition area between ecoregions in the Caatinga (Ministério do Meio Ambiente, 2002; Silva et al. 2002; Tabarelli & Silva, 2003; Brandão et al. 2003; Silva et al. 2003), with update (Ministério do Meio Ambiente e Mudança do Clima, 2023).

Material and Methods

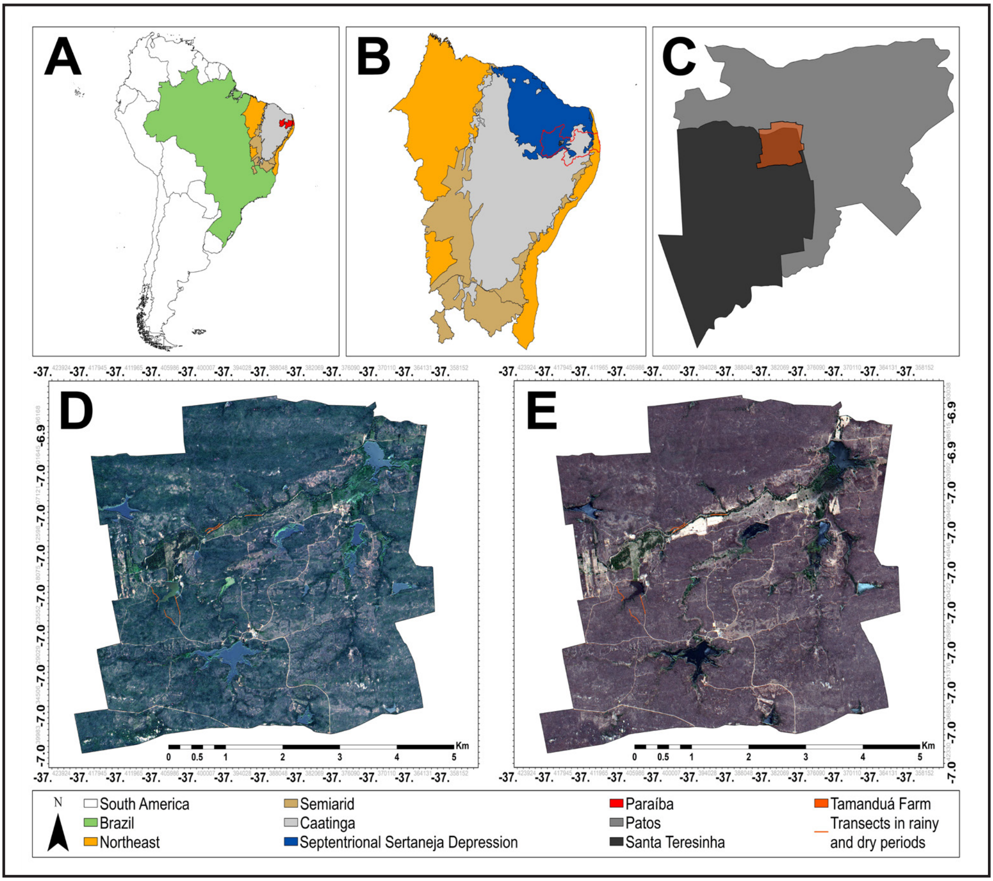
Study area

The Tamanduá Farm (FATA in Portuguese for "Fazenda Tamanduá"), property of "Mocó Agropecuária Ltda.", is located between the municipalities of Patos and Santa Teresinha (Leal et al. 2018), "Sertão" mesoregion in the state of Paraíba, Brazil (7º01'31" S and 37º23'31" W), inserted in the Semiarid region, Caatinga biome, Septentrional Sertaneja Depression ecoregion (Velloso et al. 2002), with other characterizations (Figure 1). It represents an important forest remnant with preserved or conserved vegetation in the Paraíba semiarid and has one of the relevant conservation units in the state (Sistema Informatizado de Monitoria de RPPN, 2023a; Superintendência de Administração do Meio Ambiente, 2023a, b; Unidades de Conservação Estaduais, 2023; Paraíba, 2023). It is approximately 400 km from the coast or littoral, with an average altitude of 240 m (Fazenda Tamanduá, 2023), typical vegetation of xerophytic caatinga and classified as Steppic-Savanna: Seasonal Deciduous Forest or Deciduous Tropical Forest (Instituto Brasileiro de Geografia e Estatística, 2012), Deciduous Stationary Forest or Tropical Deciduous Forest, susceptible to desertification (Figure 2).

The area has a remnant of riparian forest or ciliary forest, which is part of the Permanent Protection Area (PPA or APP in Portuguese for "Área de Proteção Permanente") and where part of the inventory was conducted, relief with deeper soil and intermittent river (Figure 2). The topography varies from plain, smooth to wavy and accentuated, mountainous by rocky outcrops, surface with soils of crystalline origin, predominantly Litholic Neosol and Luvisols, relatively shallows, with differences in hydric deficiency, stony, sandy and low to medium fertility, with deposition of litter that varies between months or periods (Alves et al. 2006; Andrade et al. 2008; Henriques et al. 2016; Santos et al. 2018).

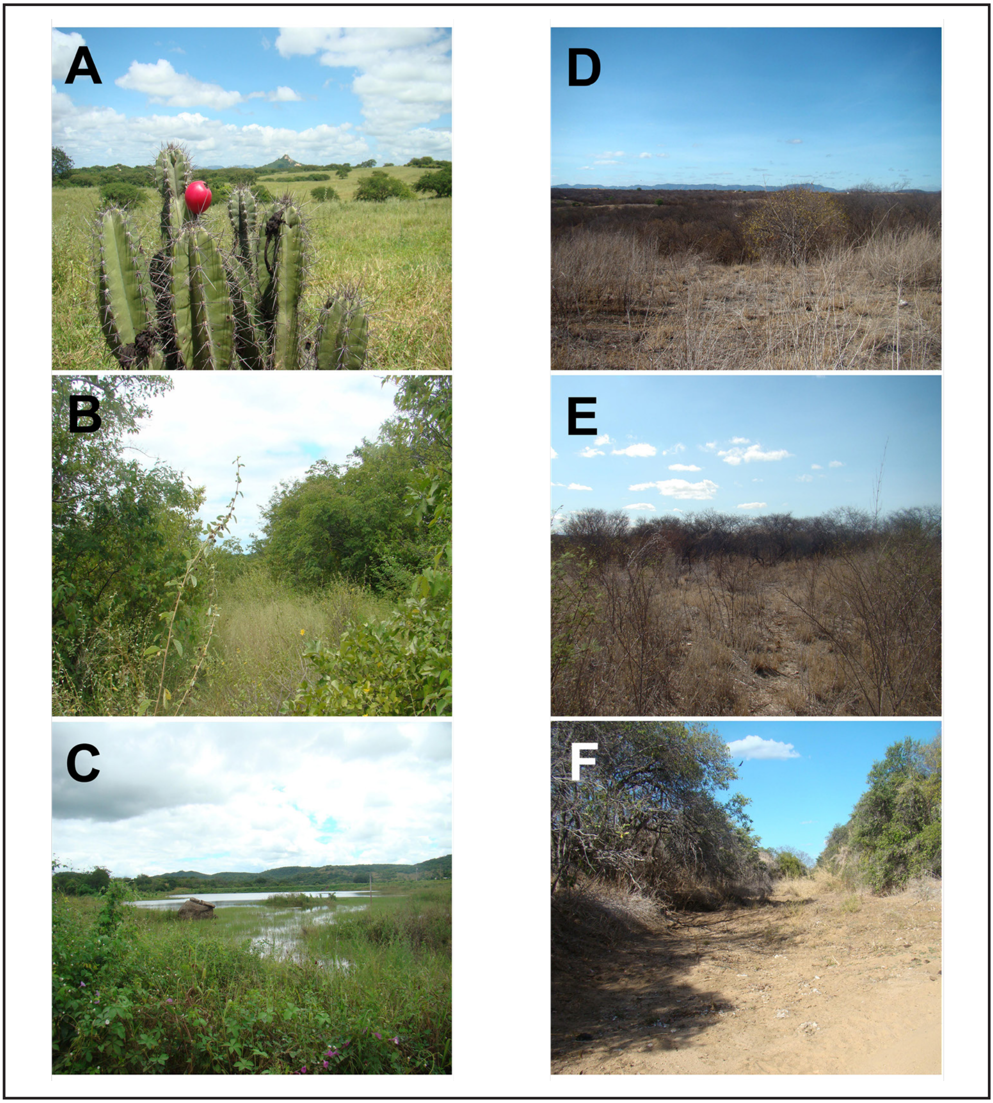
The area has historic of disturbances by livestock or agriculture of greater damage to the environment and from a given time until the present the production system has become organic. In addition to having primary forest area preserved for approximately 70 years and fragments of secondary forest conserved for approximately 25 or 47 years, representing different successional stages (Santos et al. 2014); covering 1344 ha or nearly onethird of the total area of 4135 ha (Figure 1, Figure 2), which contains a Legal Reserve (LR or RL in Portuguese for "Reserva Legal") of 1019 ha and where part of the inventory was conducted, still to include a Private Natural Heritage Reserve (PNHR or RPPN in Portuguese for "Reserva Particular do Patrimônio Natural") of 325 ha created in July 1998 (The Nature Conservancy do Brasil & Associação Caatinga, 2003; Sistema Informatizado de Monitoria de RPPN, 2023b; Oliveira et al. 2024). The RPPN is a quality or type of federal conservation unit of perennial character, irrevocable, designated for protection through preservation, also for educational and scientific activities or ecotourism (Fonseca et al. 2017).

Figure 1. Location of the Tamanduá Farm (FATA). **A)** South America subcontinent in white, Brazil country in green, Northeast geopolitical region in yellow, Caatinga biome in light gray, Paraíba state in red, Patos and Santa Teresinha municipalities in medium gray and dark gray respectively; **B)** Northeast geopolitical region in yellow by highlight, Semiarid climatic region in brown, Septentrional Sertaneja Depression ecoregion in blue, Paraíba state in red line, Patos and Santa Teresinha municipalities in medium gray and dark gray respectively; **C)** Patos and Santa Teresinha municipalities in medium gray and dark gray respectively, by highlight, delimitation of the Tamanduá Farm area in black line with orange fill between Patos and Santa Teresinha municipalities; **D)** Tamanduá Farm area during the rainy period and transects in orange lines; **E)** Tamanduá Farm area during the dry period and transects in orange lines.



Among the species of woody plants recorded the families Fabaceae, Euphorbiaceae, and Apocynaceae were most representative, along with other families of shrubby or arboreal habit (Guedes et al. 2012). With greater species richness in the late community and proportionally decrescent in the other stages of ecological succession (Cabral et al. 2013). Poaceae, Fabaceae, Malvaceae, Convolvulaceae, Asteraceae, Amaranthaceae, Boraginaceae, and Rubiaceae were highlighted as the most representative families in number of species with herbaceous habit, followed by others (Silva et al. 2012; Laine et al. 2017).

Figure 2. Different environments in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil. **A)** Open area with pasture and sparse trees in rainy period. **B)** Edge of the shrubby-arboreal caatinga with herbaceous plants in rainy period. **C)** Herbaceous vegetation at the weir edge in rainy period. **D)** Open area and secondary forest at the beginning of the dry period. **E)** Shrubby caatinga in dry period. **F)** Intermittent River with ciliary forest in dry period. Pictures by Solange M. Kerpel.



In the Caatinga the climate is mainly tropical(A)/dry(B)/semiarid(S) with two climatic qualities (As, BSh), dry (B) and semiarid (S) in hot of low latitude/altitude (h) in this portion of the state (BSh), according to the Köppen classification (Alvares et al. 2013), with drought regimes on distinct scales and variabilities recognized by historical series (Marengo et al. 2017). In addition to the climatic influence mainly by the Intertropical Convergence Zone (ITCZ) and El Niño-Southern Oscillation (ENSO) or other direct/indirect climatological phenomena, air masses not only from the Amazon that can reach the Semiarid or Caatinga, with variations in temperature and precipitation or for other variables (Ferreira & Mello, 2005; Marengo et al. 2011; Francisco & Santos, 2017;

Paraíba, 2017; Paraíba, 2023), during months or groups of months, seasons or periods, in years or groups of years. Combined with low precipitations and annual average of 500 to 800 mm, configuring a strongly seasonal environment, with rains concentrated in a short period of the year or approximately two to four months (Velloso et al. 2002; Santos et al. 2014), when streams and other intermittent bodies of water are formed, followed by a longer period of drought that results in xerophilia or deciduousness and possibility of extemporaneous rainfall. In the study area there were records of average annual temperatures of 27º C (Telino-Júnior et al. 2005) and 32.8° C (Silva et al. 2012).

Sampling and procedures

The sampling was standardized and adapted through of "Pollard walks" (Caldas & Robbins, 2003; Pellet et al. 2012; Freitas et al. 2021). Six transects of 300 m of length were established, three in shrubby-arboreal caatinga (CAA) and three in ciliary forest (CIL), which included areas of open vegetation, forest interiors and borders or weir margin. The Papilionoidea were captured with an entomological net, part of the counted individuals were collected and deposited in envelopes or marked with a non-toxic pen and released, visual counts of the individuals of species in population explosions were also made, with registration of transects, from May 2011 to April 2012 (12 months), one day per month, from 8 am to 4 pm, one hour and twenty minutes per transect, traversed alternately during the different months and times on sampling days, totaling a sampling effort of 96 hours/network/one collector plus another person to take notes in envelopes and spreadsheets. Authorization expedited via ICMBio nº 27173/SISBIO for capture or marking and collection/transport of Lepidoptera specimens from the wild fauna in situ as biological material through the activities with scientific purpose.

The rainy period was considered from May to June 2011 and plus January to April 2012 (six months), while the dry period was considered from July to December 2011 (six months), by relative alignment with meteorological or astronomical seasons in the Southern Hemisphere (National Oceanic and Atmospheric Administration, 2022). Average monthly precipitation data were obtained from the meteorological station of Tamanduá Farm and checked with public data from the Executive Agency for Water Management of the State of Paraíba (Agência Executiva de Gestão das Águas do Estado da Paraíba, 2021), while the public data on the monthly compensated average temperature were obtained through of the National Institute of Meteorology and to the nearest conventional station with code 82791 in the municipality of Patos (Instituto Nacional de Meteorologia, 2022).

The specimens were deposited in the Lepidoptera collection via the Laboratory of Ecology and Interactions of Insects of the Caatinga (LEIIC in Portuguese for "Laboratório de Ecologia e Interações de Insetos da Caatinga") at the Federal University of Campina Grande (UFCG in Portuguese for "Universidade Federal de Campina Grande"), Patos, Paraíba, Brazil and part in the Father Jesus Santiago Moure Entomological Collection (DZUP in Portuguese for "Departamento de Zoologia da UFPR" or "Coleção Entomológica Padre Jesus Santiago Moure") via the Laboratory of Studies of Neotropical Lepidoptera (LABLEPNEO in Portuguese for "Laboratório de Estudos de Lepidoptera Neotropical") at the Federal University of Paraná (UFPR in Portuguese for "Universidade Federal do Paraná"), Curitiba, Paraná, Brazil. To complement the composition or richness were added Lepidoptera specimens not collected during the sampling period or outside of the sample and coming from the Collection of the LEIIC (CLEIIC in Portuguese for "Coleção do Laboratório de Ecologia e Interações de Insetos da Caatinga").

Systematics and taxonomy in subsumptions and confluences follow for Lepidoptera with Kawahara & Breinholt (2014), Kawahara et al. (2019) and Rota et al. (2022), followed for the Papilionoidea with propositions by Lamas (2004, 2008), Wahlberg et al. (2005), Kim et al. (2010), Heikkilä et al. (2012), Espeland et al. (2018), Chazot et al. (2019), Wiemers et al. (2020), Kawahara et al. (2023), and Warren et al. (2024) with other references.

Data analysis

For ecological modeling of the diversity, Papilionoidea community structure, were used information on the compositions, richness and abundance of species, subfamilies and families, absolute frequencies and relative frequencies by percentage, presence and absence of species in rainy period (RAI) and dry period (DRY), also in the environments of shrubby-arboreal caatinga (CAA) and ciliary forest (CIL), as well other proportions, similarities and dissimilarities between taxocenoses, collection effort, species accumulation or sampling sufficiency, when were considered only the data in collection period of 12 months to the biostatistical analyses.

The constancy and dominance were obtained as in correspondence for Ferreira-Júnior (2021), with value modifications of the category of Friebe (1983) to the rarity qualification: eudominant > 10%, dominant > 5-10%, subdominant > 2-5%, recessive = 1-2% and rare < 1%, now rare < 1-0.2% and ultrarare < 0.2%.

The PAST 4.05 software (https://www.nhm.uio.no/english/research/resources/past) of January 2021 (Hammer et al. 2001) was used to obtain diversity indexes (Maurer & McGill, 2011; Mittelbach & McGill, 2019) by Dominance (DO)/ Equitability (J) in probabilities of the diversity permutation test (TPD*p*) and by Shannon (H')/ Gini-Simpson (1-D) in probabilities of the diversity *t* test (T*p*). Additionally, to the utilization of the EstimateS 9.1 software (https://www.robertkcolwell.org/pages/estimates) by version of May 2019 (Colwell, 2013) to obtain extrapolations through the richness estimators based on data of species abundance or incidence in Jackknife 1 and 2, Bootstrap, Chao 1 and 2, Incidence-based Coverage Estimator - ICE and Abundance-based Coverage Estimator - ACE (Dias, 2004; Gotelli & Colwell, 2011). The rest of the analyses and all the graphs were obtained using the R software (R Core Team, 2021), for Analysis of Similarities (ANOSIM) or Similarity Percentages (SIMPER) and the Non-metric Multidimensional Scaling (NMDS) (Melo & Hepp, 2008; Silva et al. 2022a) with function Fits an Environmental Vector or Factor onto an Ordination (envfit) via vegan 2.6-4 package (https://cran.r-project.org/web/packages/vegan/index.html and https://cran.r-project.org/web// packages/vegan/vignettes/intro-vegan.pdf) of October 2022 (Oksanen et al. 2022), in addition to the diversity estimators q0 (Richness)/ q1 (Shannon)/ q2 (Simpson) or curves of interpolation (rarefaction) and extrapolation (prediction) by abundance or incidence data in 1000 bootstrap replications via iNEXT 3.0.0 package (https:// cran.r-project.org/web/packages/iNEXT/index.html) of July 2022 (Hsieh et al. 2016; Hsieh et al. 2022a, b). With related parts for instance in probability theory and information theory or mathematical theory of communication (Martins & Santos, 1999; Dias, 2004; Melo, 2008; Lima et al. 2016), statistical theories of sampling, estimation or inference (Chao & Jost, 2012; Chao et al. 2014) and approximation theory.

Simple comparisons were also made to the composition or richness of species of the FATA with the available inventories for the Caatinga biome and other biomes in the Northeast of Brazil, to identify new records in the region based on Table I, in addition to finding simple relationships of the occurrence of (sub)species in common with other areas of biomes outside of the Northeast region.

Results

A total of 5556 individuals were recorded to the abundance (Table II), with 934 captured-collected individuals and none of the captured-marked-released individuals were recaptured; distributed in increasing representability to 3266 individuals of Pieridae (58.8%), 1329 of Nymphalidae (23.9%), 517 of Hesperiidae (9.3%), 390 of Lycaenidae (7%), 44 of Riodinidae (0.8%) and 10 individuals of Papilionidae (0.2%) (Table III, Figure 3).

Initially 82 Lepidoptera species were recorded in FATA during the sampling period to the richness (Table II); distributed in 28 species of Hesperiidae (34%), 25 species of Nymphalidae (31%), 12 species of Lycaenidae (15%), 11 species of Pieridae (13%), four species of Riodinidae (5%) and two species of Papilionidae (2%) (Table III, Figure 3).

Table II. List of the species of Papilionoidea in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil, with sampling effort of 96 hours/one collector plus assistant in 12 months, between May 2011 to April 2012. **N (*f_i*)** = abundance (absolute frequency); **% (*fp_i*)** = percentage (percent relative frequency); **D** = dominance, EU = eudominant, DO = dominant, SU = subdominant, RE = recessive, RA = rare, UL = ultrarare; **C** = constancy, CON = constant, ACE = accessory, ACI = accidental; **CAA** = species and abundances recorded in the shrubby-arboreal caatinga, **CIL** = species and abundances recorded in the ciliary forest; **RAI** = species and abundances recorded in rainy period (May-June 2011 and January-April 2012), **DRY** = species and abundances recorded in dry period (July-December 2011); species that were recorded at minimum in one of the works for the biomes and the presence or absence of apostrophe (') means records of different subspecies (with apostrophe) or the same subspecies (without apostrophe) in cases or just the same species (without apostrophe) for 1 = Caatinga (Nobre et al. 2008, Paluch et al. 2011, Zacca and Bravo 2012, Lima and Zacca 2014, Kerpel et al. 2014, Câmara et al. 2017, Ferreira-Júnior 2021, Dantas et al. 2021), 2 = Atlantic Forest (Cardoso 1949, Kesselring and Ebert 1979, Zacca et al. 2011, Paluch et al. 2016, Melo et al. 2019, Vila-Verde and Paluch 2020, Vila-Verde et al. 2020, Dantas et al. 2021, Medeiros et al. 2021, Gonçalves et al. 2021), 3 = Cerrado (Emery et al. 2006, Pinheiro and Emery 2006, Mielke et al. 2008, Martins et al. 2017, Silva et al. 2022b, Pinheiro and

Ribeiro 2022), 4 = Amazon (Emmel and Austin 1990, Mielke et al. 2010, Casagrande et al. 2012, Mielke et al. 2012, Martins et al. 2017, Pereira et al. 2018, Mota et al. 2022); [1] = Lepidoptera species outside of the sampling period and of the sample, [2] = Lepidoptera species outside of the sample, [3] = unprecedented record in the Northeast region of Brazil, [4] = unpublished records for Semiarid-Caatinga, [5] = unpublished records in Paraíba state, [6] = unpublished records in the Septentrional Sertaneja Depression ecoregion, [7] = singletons, [8] = doubletons, [9] = uniques, [10] = duplicates; x = presence in the environment or in period.

Taxon	N	%	D	C	Environment		Period		Biomes
	(f_i)	(fp_i)			CAA	CIL	RAI	DRY	
PAPILIONOIDEA (93)									
PAPILIONIDAE (2)									
Papilioninae (2)									
Troidini									
Battus polydamas (Linnaeus, 1758) [10]	9	0.16	UL	ACI	4	5	9		1’, 2’, 3’, 4’
Papilionini									
Heraclides thoas brasiliensis (Rothschild & Jordan, 1906) [7, 9]	1	0.02	UL	ACI	1			1	1, 2, 3, 4’
PIERIDAE (11)									
Coliadinae (8)									
Abaeis albula (Cramer, 1775)	81	1.46	RE	ACE	15	66	12	69	1’, 2’, 3’, 4’
Anteos clorinde (Godart, [1824]) [10]	3	0.05	UL	ACI		3	3		1, 2, 3
Aphrissa statira (Cramer, 1777) [6]	8	0.14	UL	ACE	7	1	6	2	1, 2, 3, 4
Eurema flavescens (Chavannes, 1850)	1822	32.79	EU	CON	509	1313	936	886	1, 2, 3’, 4’
Eurema phiale paula (Röber, 1909) [6]	5	0.09	UL	ACE	4	1	4	1	1, 2, 3
Phoebis marcellina (Cramer, 1777)	300	5.4	DO	CON	183	117	155	145	1, 2, 3’, 4
Pyrisitia leuce (Boisduval, 1836)	49	0.88	RA	CON	14	35	37	12	1’, 2’, 3’, 4’
Pyrisitia nise tenella (Boisduval, 1836)	115	2.07	SU	CON	33	82	72	43	1, 2, 3, 4’
Pierinae (3)									
Pierini									
Ascia monuste orseis (Godart, 1819)	824	14.83	EU	CON	176	648	421	403	1, 2, 3, 4’
Ganyra phaloe endeis (Godart, 1819)	46	0.83	RA	ACE		46	10	36	1, 2’, 4’
Glutophrissa drusilla (Cramer, 1777)	13	0.23	RA	ACE		13	7	6	1, 2’, 3’, 4’
LYCAENIDAE (14)									
Theclinae (12)									
Eumaeini									
Allosmaitia strophius (Godart, [1824]) [1]						x	x		1, 2, 3
Chlorostrymon simaethis (Drury, 1773) [7, 9]	1	0.02	UL	ACI		1	1		1
Electrostrymon endymion (Fabricius, 1775) [9]	3	0.05	UL	ACI		3	3		1, 2’, 3
Kisutam syllis (Godman & Salvin, 1887) [1]						x	x		1, 2, 3, 4
Ministrymon azia (Hewitson, 1873) [6, 7, 9]	1	0.02	UL	ACI		1	1		1, 3, 4
Pseudolycaena marsyas (Linnaeus, 1758) [8, 9]	2	0.04	UL	ACI		2		2	1, 2, 3, 4
Strephonota sp. [5, 6]	8	0.14	UL	ACE		8	3	5	
Strymon astiocha (Prittwitz, 1865)	21	0.38	RA	CON	7	14	13	8	1, 2, 3, 4
Strymon bubastus (Stoll, 1780) [10]	5	0.09	UL	ACI	2	3	5		1, 2, 3
Strymon crambusa (Hewitson, 1874) [7, 9]	1	0.02	UL	ACI	1		1		1, 3
Strymon rufofusca (Hewitson, 1877)	17	0.31	RA	CON	9	8	3	14	1, 2, 3
Tmolus echion (Linnaeus, 1767) [6, 9]	12	0.22	RA	ACI		12		12	1, 2, 3, 4
Polyommatinae (2)									
Polyommatini									
Hemiargus hanno (Stoll, 1790)	311	5.6	DO	CON	161	150	78	233	1’, 2’, 3, 4’
Leptotes cassius (Cramer, 1775)	8	0.14	UL	ACE	3	5	5	3	1’, 2’, 3’, 4

RIODINIDAE (4)									
Riodininae (4)									
Nymphidiini									
Aricoris campestris (H. Bates, 1868)	15	0.27	RA	CON	6	9	9	6	1, 2, 3, 4
Aricoris sp. [5, 6]	24	0.43	RA	CON	7	17	5	19	
Synargis calyce (C. Felder & R. Felder, 1862) [6, 10]	3	0.05	UL	ACI		3		3	1, 2, 3, 4
Riodinini									
Lasaia sp. [3, 4, 5, 6, 8, 10]	2	0.04	UL	ACI		2	1	1	
NYMPHALIDAE (27)									
Danainae (5)									
Danaini									
Danaus eresimus plexaure (Godart, 1819)	30	0.54	RA	ACE		30	23	7	1, 2, 3, 4’
Danaus erippus (Cramer, 1775)	31	0.56	RA	ACE	1	30	17	14	1, 2, 3
Danaus gilippus (Cramer, 1775)	138	2.48	SU	CON	11	127	107	31	1’, 2’, 3’, 4
Lycorea halia discreta Haensch, 1909 [7, 9]	1	0.02	UL	ACI		1	1		1, 2, 3, 4’
Ithomiini									
Mechanitis lysimnia nesaea Hübner, [1820][7, 9]	1	0.02	UL	ACI		1		1	1, 2, 3’, 4’
Heliconiinae (4)									
Argynnini									
Euptoieta hegesia meridiania Stichel, 1938	320	5.76	DO	CON	55	265	230	90	1, 2, 3, 4’
Heliconiini									
Dione maculosa Stichel, [1908]	127	2.29	SU	CON	89	38	64	63	1, 2, 3, 4’
Eueides isabella dianasa (Hübner, [1806])[8, 10]	2	0.04	UL	ACI		2	1	1	1, 2, 3, 4’
Heliconius erato phyllis (Fabricius, 1775)	45	0.81	RA	CON	1	44	18	27	1, 2, 3, 4’
Biblidinae (8)									
Biblidini									
Biblis hyperia nectanabis (Fruhstorfer, 1909)	11	0.2	RA	ACE	1	10	2	9	1, 2, 3, 4’
Mestra hersilia hypermestra Hübner, [1825] [6]	111	2	RE	CON	35	76	96	15	1, 2, 3’
Catonephelini									
Eunica tatila bellaria Fruhstorfer, 1908	22	0.4	RA	ACE	7	15	2	20	1, 2, 3, 4
Ageroniini									
Hamadryas februa (Hübner, [1823])	88	1.58	RE	CON	8	80	18	70	1’, 2’, 3, 4
Hamadryas feronia (Linnaeus, 1758) [10]	3	0.05	UL	ACI		3		3	1’, 2’, 3’, 4
Eubagini									
Dynamine arene Hübner, [1823] [6]						x			1, 2, 4
Dynamine postverta (Cramer, 1779) [6, 10]	3	0.05	UL	ACI		3	3		1, 2, 3, 4
Callicorini									
Callicore sorana (Godart, [1824])	23	0.41	RA	CON		23	4	19	1’, 2’, 3’
Nymphalinae (5)									
Victorinini									
Anartia jatrophae jatrophae (Linnaeus, 1763)	195	3.51	SU	CON	17	178	92	103	1’, 2’, 3’, 4’
Siproeta stelenes meridionalis (Fruhstorfer, 1909) [6]	3	0.05	UL	ACE		3	1	2	1, 2, 3’, 4’
Junoniini									
Junonia evarete (Cramer, 1779)	48	0.86	RA	CON	12	36	41	7	1, 3, 4’
Melitaeini									
Anthanassa hermas (Hewitson, 1864)	13	0.23	RA	ACE		13	8	5	1, 2, 3, 4’
Ithra ithra (W. F. Kirby, 1900)	23	0.41	RA	ACE	2	21	7	16	1, 2, 3, 4

Charaxinae (4)									
Anaeini									
Fountainea glycerium cratais (Hewitson, 1874) [6]	19	0.34	RA	ACE	8	11	7	12	1, 2, 3
Fountainea halice moretta (H. Druce, 1877)	58	1.04	RE	CON	33	25	19	39	1, 4’
Hypna clytemnestra forbesi Godman & Salvin, 1884	6	0.11	UL	ACE	3	3	5	1	1, 2, 3’, 4’
Preponini									
Prepona laertes (Hübner, [1811]) [6]					x		x		1, 2, 3, 4
Satyrinae (1)									
Satyrini									
Pharneuptychia phares (Godart, [1824])	8	0.14	UL	ACE	4	4	4	4	1, 2, 3, 4
HESPERIIDAE (35)									
Eudaminae (10)									
Eudamini									
Aguna asander (Hewitson, 1867) [6, 10]	4	0.07	UL	ACI		4	4		1, 2, 3, 4
Cecropterus dorantes (Stoll, 1790)	127	2.29	SU	CON	12	115	123	4	1’, 2’, 3’, 4’
Chioides catillus (Cramer, 1779)	10	0.18	UL	ACE	1	9	4	6	1’, 2’, 3’, 4’
Epargyreus exadeus (Cramer, 1779) [10]	6	0.11	UL	ACI	3	3	6		1, 2’, 3’, 4
Spicauda procne (Plötz, 1881) [8, 9]	2	0.04	UL	ACI		2		2	1, 2, 3, 4
Spicauda teleus (Hübner, 1821) [1, 6]						x	x		1, 2, 3, 4
Telegonus anaphus (Cramer, 1777) [9]	3	0.05	UL	ACI		3		3	1, 2’, 3’, 4’
Urbanus proteus (Linnaeus, 1758) [9]	6	0.11	UL	ACI		6	6		1’, 2’, 3’, 4’
Oileidini									
Cogia calchas (Herrich-Schäffer, 1869)	51	0.92	RA	CON	41	10	43	8	1, 2, 3, 4
Cogia undulatus (Hewitson, 1867)	3	0.05	UL	ACE	1	2	2	1	1, 2, 3, 4
Tagiadinae (1)									
Celaenorrhinini									
Celaenorrhinus sp. [6]	4	0.07	UL	ACE		4	1	3	
Pyrginae (12)									
Carcharodini									
Nisoniades macarius (Herrich-Schäffer, 1870)	4	0.07	UL	ACE	2	2	3	1	1, 2, 3, 4
Erynnini									
Chiothion asychis autander (Mabille, 1891) [6]	15	0.27	RA	ACE	4	11	14	1	1, 2, 3
Clito sompa Evans, 1953	6	0.11	UL	ACE		6	2	4	1, 3
Gesta gesta (Herrich-Schäffer, 1863)	21	0.38	RA	CON	2	19	14	7	1, 2, 3, 4
Hoodus cristata (Austin, 2000)	7	0.13	UL	ACE	4	3	7		1, 2, 3, 4
Pyrgini									
Burnsius orcus (Stoll, 1780)	68	1.22	RE	CON	25	43	52	16	1, 2, 3, 4
Chirgus veturius (Plötz, 1884) [10]	3	0.05	UL	ACI		3	3		1, 2, 4
Heliopetes arsalte (Linnaeus, 1758) [8, 9]	2	0.04	UL	ACI		2	2		1, 2, 3, 4
Heliopetes orbigera (Mabille, 1888) [7, 9]	1	0.02	UL	ACI		1	1		1, 2, 3, 4
Heliopetes willi (Plötz, 1884)	74	1.33	RE	CON	45	29	56	18	1, 3
Trina geometrina (C. Felder & R. Felder, 1867) [6, 7, 9]	1	0.02	UL	ACI		1	1		1, 2, 3, 4
Zopyrion evenor thania Evans, 1953	16	0.29	RA	ACE	11	5	15	1	1, 2, 3’, 4’
Hesperiinae (12)									
Hesperiini									
Callimormus saturnus (Herrich-Schäffer, 1869) [10]	11	0.2	RA	ACI		11	11		1, 3, 4

Cymaenes lepta (Hayward, 1939)[2, 4, 5, 6]						x	x		2, 3
Cymaenes tripunctus theogenis (Capronnier, 1874)	34	0.61	RA	CON		34	27	7	1, 2, 3, 4
Hylephila phyleus (Drury, 1773)	7	0.13	UL	ACE	6	1	2	5	1’, 2’, 3’, 4’
Lerema ancillaris (A. Butler, 1877)[2]						x	x		1, 2, 4’
Lerodea erythrostictus (Prittwitz, 1868)[2]						x		x	1, 2, 3
Lerodea eufala (W. H. Edwards, 1869)[2, 5, 6]						x	x	x	3’
Nyctelius nyctelius (Latreille, [1824])[1, 6]						x	x		1, 2, 3, 4
Panoquina hecebolus (Scudder, 1872)[2, 6]						x	x		1, 2, 3, 4
Panoquina lucas (Fabricius, 1793)[9]	27	0.49	RA	ACI		27	27		1, 2’, 3’, 4’
Pompeius pompeius (Latreille, [1824])[6, 8, 10]	2	0.04	UL	ACI		2	1	1	1, 2, 3, 4
Synapte malitiosa equa Evans, 1955[8, 10]	2	0.04	UL	ACI		2	1	1	1, 2, 4’
Total	**5556**	**100**	**82**	**82**	**47 1586**	**80 3970**	**74 2998**	**63 2558**	**87, 80, 82, 71 14’, 20’, 24’, 33’**

The richness estimators Jackknife 1 and 2 extrapolated 96.7 and 99.4 species, respectively, Bootstrap obtained 89.6, Chao 2 predicted 89.3, ICE expressed 93.4, results obtained equally through the distribution matrices by data of presence-absence and abundance, while Chao 1 and ACE obtained 85.5 and 86.2 species, with these last two estimators being exclusive to the abundance matrix and inoperative for the binary incidence matrix (Table IV). Values derived from eight singletons, one Papilionidae, three Lycaenidae, two Nymphalidae and two Hesperiidae, seven doubletons, one Lycaenidae, one Riodinidae, one Nymphalidae and four Hesperiidae, 16 uniques, one Papilionidae, six Lycaenidae, two Nymphalidae and seven Hesperiidae, 14 duplicates, one Papilionidae, one Pieridae, one Lycaenidae, two Riodinidae, three Nymphalidae and six Hesperiidae (Table II). With these parameters that quantify rarities the highest expressions were for Hesperiidae (19 species), Lycaenidae (11 species), Nymphalidae (eight species), Papilionidae and Riodinidae (three species each), Pieridae (one species).

Table IV. Richness, abundance and estimates of richness by abundance or incidence of the Lepidoptera species in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil, with sampling effort of 96 hours/one collector plus assistant in 12 months, between May 2011 to April 2012, through EstimateS software. S = richness; N = abundance; FATA = Tamanduá Farm, DRY = dry period, RAI = rainy period, CAA = shrubby-arboreal caatinga environment, CIL = ciliary forest environment.

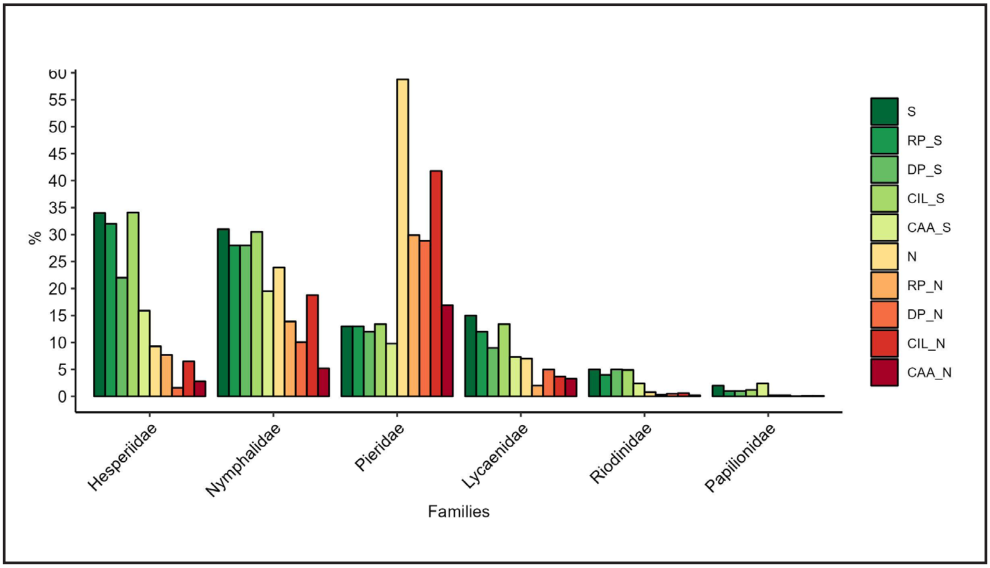
	S	N	Jackknife 1/ 2	Bootstrap	Chao 1/ 2	ICE	ACE
FATA	82	5556	96.7/ 99.4	89.6	85.5/ 89.3	93.4	86.2
DRY	63	2558	78/ 84.1	70.2	76.2/ 73.6	76.9	71.8
RAI	74	2998	90.7/ 90.7	82.9	83.4/ 80.1	90.5	80.7
CAA	47	1586	56.2/ 59.2	51.6	51.2/ 52.2	53.6	50.9
CIL	80	3970	96.5/ 97.1	88.7	83.6/ 87	94.6	85.7

Were added cumulatively to the richness and listing five species involved in cryptic pattern of Hesperiidae (Hesperiinae), *Cymaenes lepta* (Hayward, 1939), *Lerema ancillaris* (A. Butler, 1877), *Lerodea erythrostictus* (Prittwitz, 1868), *Lerodea eufala* (W. H. Edwards, 1869), *Panoquina hecebolus* (Scudder, 1872) (Table II), outside the sample; in addition to six species of Papilionoidea recorded by different collection methods outside of the sampling period and outside of the sample, four species via entomological net with *Nyctelius nyctelius* (Latreille, [1824]) and *Spicauda teleus* (Hübner, 1821), Hesperiidae, *Allosmaitia strophius* (Godart, [1824]) and *Kisutam syllis* (Godman & Salvin, 1887), Lycaenidae (Table II), plus two species of Nymphalidae by *Dynamine arene* Hübner, [1823] with one individual collected via Malaise trap in the ciliary forest and *Prepona laertes* (Hübner, [1811]) recorded in Oliveira et al. (2024) with one individual collected via Van Someren-Rydon trap of fruit-feeding Papilionoixdea in rainy season in the ecological stage of late succession of the caatinga. Species that were not considered in the sample for the calculations of richness or diversity estimators.

Table III. Richness and abundance in absolute numbers and relative proportions in percentages (**%**) of families and subfamilies by periods and environments in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil, with sampling effort of 96 hours/one collector plus assistant in 12 months, between May 2011 to April 2012. **S** = richness; **N** = abundance; **RAI** = months in the rainy period (May-June 2011 and January-April 2012), **DRY** = months in the dry period (July-December 2011); **CAA** = shrubby-arboreal caatinga, **CIL** = ciliary forest.

Families	S	%	Periods (S)				Environments (S)				N	%	Periods (N)				Environments (N)			
Subfamilies			**RAI**	%	**DRY**	%	**CAA**	%	**CIL**	%			**RAI**	%	**DRY**	%	**CAA**	%	**CIL**	%
Papilionidae	**2**	**2**	**1**	**1**	**1**	**1**	**2**	**2.4**	**1**	**1.2**	**10**	**0.2**	**9**	**0.2**	**1**	**0.02**	**5**	**0.1**	**5**	**0.1**
Papilioninae	2	2	1	1	1	1	2	2	1	1	10	0.2	9	0.16	1	0.02	5	0.09	5	0.09
Pieridae	**11**	**13**	**11**	**13**	**10**	**12**	**8**	**9.8**	**11**	**13.4**	**3266**	**58.8**	**1663**	**29.9**	**1603**	**28.85**	**941**	**16.9**	**2325**	**41.8**
Coliadinae	8	10	8	10	7	9	7	9	8	10	2383	42.9	1225	22.05	1158	20.84	765	13.77	1618	29.12
Pierinae	3	4	3	4	3	4	1	1	3	4	883	15.9	438	7.88	445	8.01	176	3.17	707	12.72
Lycaenidae	**12**	**15**	**10**	**12**	**7**	**9**	**6**	**7.3**	**11**	**13.4**	**390**	**7**	**113**	**2**	**277**	**4.99**	**183**	**3.3**	**207**	**3.7**
Theclinae	10	12	8	10	5	6	4	5	9	11	71	1.3	30	0.54	41	0.74	19	0.34	52	0.94
Polyommatinae	2	2	2	2	2	2	2	2	2	2	319	5.7	83	1.49	236	4.25	164	2.95	155	2.79
Riodinidae	**4**	**5**	**3**	**4**	**4**	**5**	**2**	**2.4**	**4**	**4.9**	**44**	**0.8**	**15**	**0.3**	**29**	**0.52**	**13**	**0.2**	**31**	**0.6**
Riodininae	4	5	3	4	4	5	2	2	4	5	44	0.8	15	0.27	29	0.52	13	0.23	31	0.56
Nymphalidae	**25**	**31**	**23**	**28**	**23**	**28**	**16**	**19.5**	**25**	**30.5**	**1329**	**23.9**	**770**	**13.9**	**559**	**10.06**	**287**	**5.2**	**1042**	**18.8**
Danainae	5	6	4	5	4	5	2	2	5	6	201	3.6	148	2.66	53	0.95	12	0.22	189	3.4
Heliconiinae	4	5	4	5	4	5	3	4	4	5	494	8.9	313	5.63	181	3.26	145	2.61	349	6.28
Biblidinae	7	9	6	7	6	7	4	5	7	9	261	4.7	125	2.25	136	2.45	51	0.92	210	3.78
Nymphalinae	5	6	5	6	5	6	3	4	5	6	282	5.1	149	2.68	133	2.39	31	0.56	251	4.52
Charaxinae	3	4	3	4	3	4	3	4	3	4	83	1.5	31	0.56	52	0.94	44	0.79	39	0.7
Satyrinae	1	1	1	1	1	1	1	1	1	1	8	0.1	4	0.07	4	0.07	4	0.07	4	0.07
Hesperiidae	**28**	**34**	**26**	**32**	**18**	**22**	**13**	**15.9**	**28**	**34.1**	**517**	**9.3**	**428**	**7.7**	**89**	**1.6**	**157**	**2.8**	**360**	**6.5**
Eudaminae	8	10	6	7	5	6	5	6	8	10	208	3.7	187	3.37	21	0.38	58	1.04	150	2.7
Tagiadinae	1	1	1	1	1	1	0	0	1	1	4	0.1	1	0.02	3	0.05	0	0	4	0.07
Pyrginae	13	16	13	16	8	10	7	9	13	16	222	4	171	3.08	51	0.92	93	1.67	129	2.32
Hesperiinae	6	7	6	7	4	5	1	1	6	7	83	1.5	69	1.24	14	0.25	6	0.11	77	1.39
Total	**82**	**100**	**74**	**90**	**63**	**77**	**47**	**57**	**80**	**98**	**5556**	**100**	**2998**	**54**	**2558**	**46**	**1586**	**28.5**	**3970**	**71.5**

Figure 3. Percentage relative frequencies of richness and abundance of the Lepidoptera families by general metric, periods and environments, in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil, with sampling effort of 96 hours/one collector plus assistant in 12 months, between May 2011 to April 2012. S = richness; RP_S = rainy period richness, DP_S = dry period richness; CIL_S = ciliary forest richness, CAA_S = arboreal shrubby caatinga richness; N = abundance; RP_N = rainy period abundance, DP_N = dry period abundance; CIL_N = ciliary forest abundance, CAA_N = arboreal shrubby caatinga abundance.



With the additional records of 11 species outside the sample, 93 Papilionoidea species in the FATA were totalized and equal to the prediction of 93 species by the ICE richness estimator for horizontal asymptote (Table IV). Presenting the following proportions in ascending order of families for Hesperiidae with 35 species and 38%, Nymphalidae with 27 species and 29%, Lycaenidae with 14 species and 15%, Pieridae with 11 species and 12%, Riodinidae with four species and 4%, Papilionidae with two species and 2%.

The most representative subfamilies in abundance were Coliadinae (2383 individuals, 42.9%), Pierinae (883 individuals, 15.9%), Heliconiinae (494 individuals, 8.9%), Polyommatinae (319 individuals, 5.7%), Nymphalinae (282 individuals, 5.1%), Biblidinae (261 individuals, 4.7%), Pyrginae (222 individuals, 4%), Eudaminae (208 individuals, 3.7%), Danainae (201 individuals, 3.6%), among others with smaller representations (Table III, Figure 4).

The most representative subfamilies in richness were Pyrginae (13 species, 16%), Theclinae (10 species, 12%), Eudaminae and Coliadinae (eight species, each, 10%), Biblidinae (seven species, 9%), Hesperiinae (six species, 7%), Danainae and Nymphalinae (five species, each, 6%), among the others (Table III, Figure 4). With 11 additional species the most representative subfamilies became Pyrginae (13 species, 13.98%), Hesperiinae and Theclinae (12 species, each, 12.9%), Eudaminae (nine species, 9.68%), Coliadinae and Biblidinae (eight species, each, 8.6%), Danainae and Nymphalinae (five species, each, 5.38%), Riodininae, Heliconiinae and Charaxinae (four species, each, 4.3%), Pierinae (three species, 3.23%), Papilioninae and Polyommatinae (two species, each, 2.15%), Satyrinae and Tagiadinae (one species each, 1.08%).

Among the months were registered 37 species and 173 individuals in May, 48 species and 419 individuals in June (addition of 18 different species), 38 species and 491 individuals in July (addition of two different species), 42 species and 425 individuals in August (addition of nine different species), 36 species and 493 individuals in September (addition of four different species), 22 species and 250 individuals in October (without addition of different species), 31 species and 581 individuals in November (addition of two different species), 26 species and 318 individuals in December (without addition of different species), for the year 2011, 26 species and 292 individuals in January (addition of one different species), 20 species and 164 individuals in February (addition of one different species), 39 species and 711 individuals in March (addition of four different species), 44 species and 1239 individuals in April (addition of four different species), for the year 2012. With relative percentage of abundance and richness of families and subfamilies by months presented in Figure 5 and Figure 6, Figure 7 and Figure 8.

Figure 4. Percentage relative frequencies of richness and abundance of the Lepidoptera subfamilies by general metric, periods and environments, in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil, with sampling effort of 96 hours/ one collector plus assistant in 12 months, between May 2011 to April 2012. S = richness; RP_S = rainy period richness, DP_S = dry period richness; CIL_S = ciliary forest richness, CAA_S = arboreal shrubby caatinga richness; N = abundance; RP_N = rainy period abundance, DP_N = dry period abundance; CIL_N = ciliary forest abundance, CAA_N = arboreal shrubby caatinga abundance.

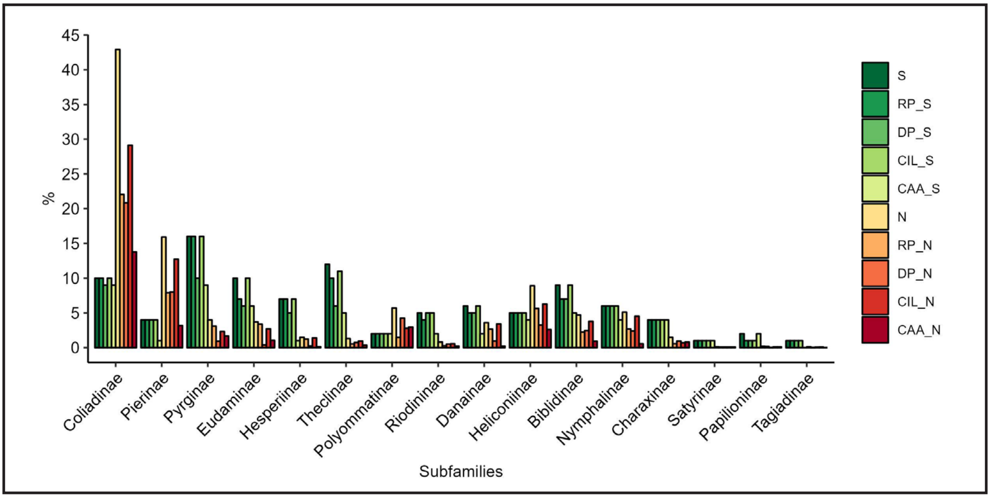
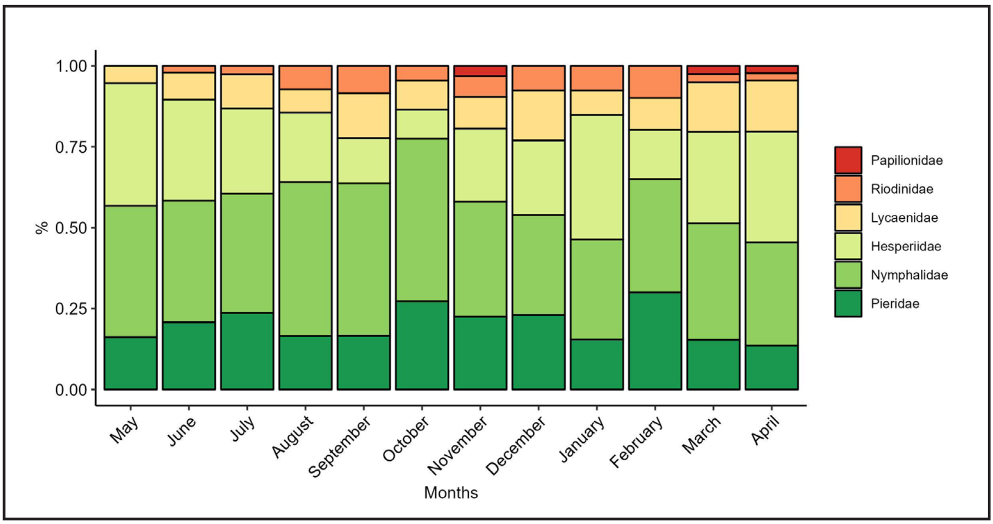


Figure 5. Relative frequencies in percentages of the abundance of Lepidoptera families by months in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil, with sampling effort of 96 hours/one collector plus assistant in 12 months, between May 2011 to April 2012.



In total abundance there was a division of 2998 individuals (54%) for the rainy period (RAI) and 2558 individuals (46%) for the dry period (DRY), while the distribution of 1586 individuals (28.5%) in shrubby-arboreal caatinga (CAA) and 3970 individuals (71.5%) in ciliary forest (CIL) (Table III). When examining the environments (CAA and CIL) in rainy period (RAI) and dry period (DRY), it was evidenced shrubby-arboreal caatinga environment with 837 individuals in rainy period (52.8%) and 749 individuals in dry period (47.2%), while it was demonstrated to ciliary forest environment with 2161 individuals in rainy period (54.4%) and 1809 individuals in dry period (45.6%).

Figure 6. Relative frequencies in percentages of the abundance of Lepidoptera subfamilies by months in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil, with sampling effort of 96 hours/one collector plus assistant in 12 months, between May 2011 to April 2012.

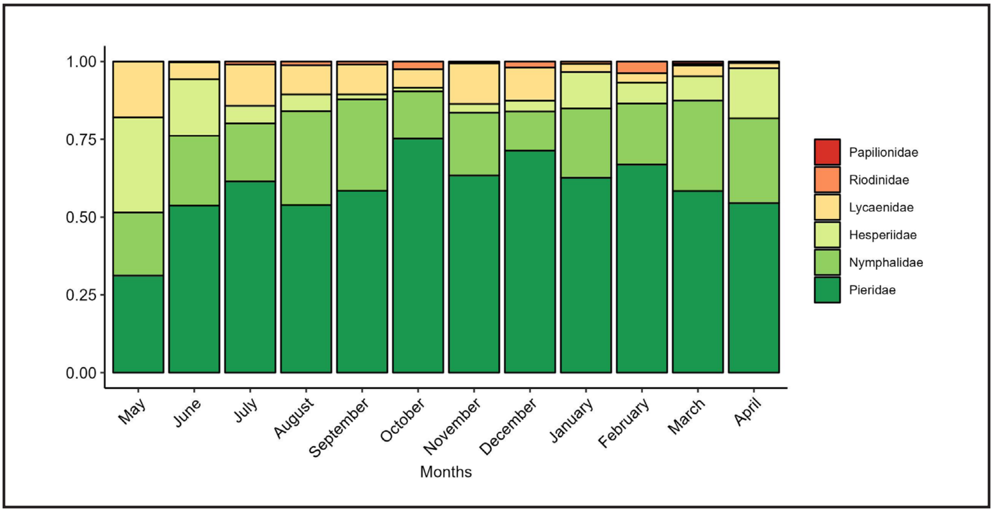


Figure 7. Relative frequencies in percentages of the richness of Lepidoptera families by months in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil, with sampling effort of 96 hours/one collector plus assistant in 12 months, between May 2011 to April 2012.

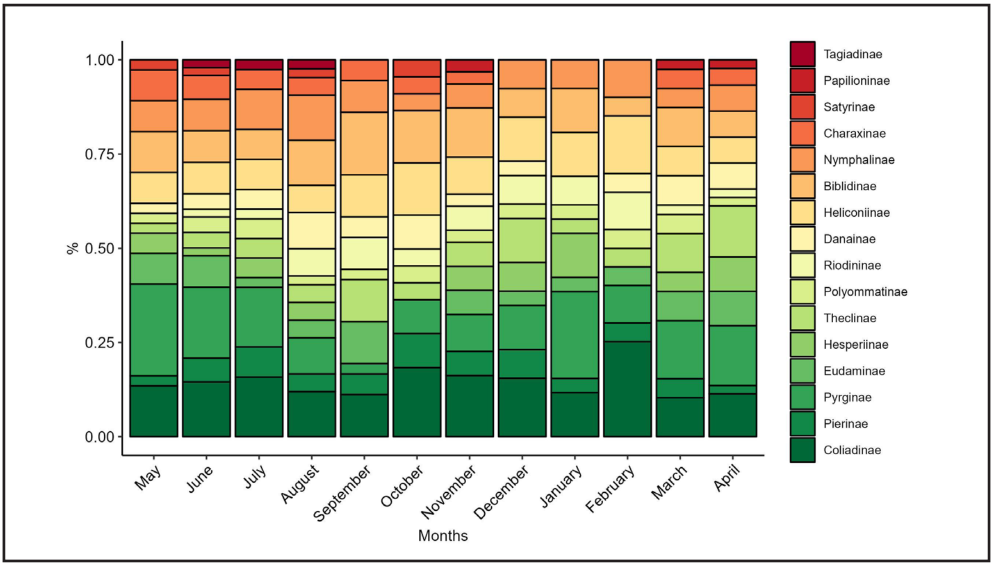
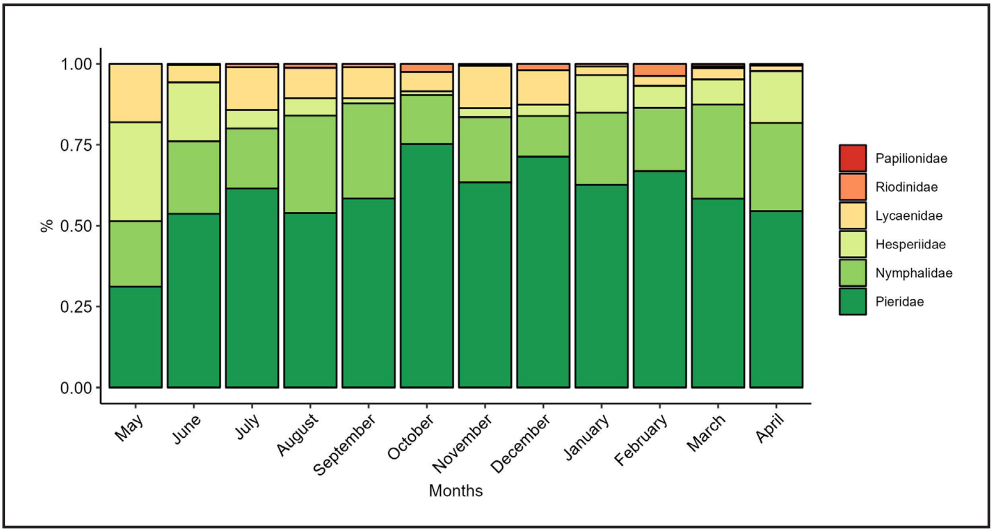


Figure 8. Relative frequencies in percentages of the richness of Lepidoptera subfamilies by months in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil, with sampling effort of 96 hours/one collector plus assistant in 12 months, between May 2011 to April 2012.



Considering the sample, 74 species (90%) were recorded in rainy period (RAI) and 63 species (77%) in dry period (DRY) (Table III), with 19 exclusive species for the rainy period (23%) and eight exclusive species for the dry period (10%), a total of 55 species shared for both periods or more than half (67%).

The similarity and distance indexes resulted in 0.76 (76%) and 0.24 (24%) of the total of one (100%) with Bray-Curtis, very significant probability through bifactorial ANOSIM test for the factor of periods ($p = 0.0039$) and for expressing a difference between rainy period (RAI) and dry period (DRY) assemblies, meanwhile 0.67 (67%) and 0.33 (33%) for Jaccard, non-significant probabilities by the monofactorial and bifactorial ANOSIM tests ($p > 0.05$), via PAST. Richness extrapolations follow for the dry period (DRY) in Bootstrap with 70.2 species, Chao 1 and 2 with 76.2 and 73.6 species, Jackknife 1 and 2 with 78 and 84.1 species, ICE and ACE with 76.9 and 71.8 species; while estimates for the rainy period (RAI) in Bootstrap with 82.9 species, Chao 1 and 2 with 83.4 and 80.1 species, Jackknife 1 and 2 with 90.7 species for both estimators, ICE and ACE with 90.5 and 80.7 species, via EstimateS (Table IV).

About the differences and similarities between the environments (CAA and CIL) it was recorded 47 species (57%) in shrubby-arboreal caatinga (CAA) and two exclusive species (2%), 80 species (98%) in ciliary forest (FCI) and 35 exclusive species (43%) (Table III), with a total of 45 shared species in both environments and by just over half (55%). According to the indexes of similarity and distance that resulted in 0.5 (50%) for Bray-Curtis, very significant probability through monofactorial ANOSIM test ($p = 0.0017$) and highly significant by the bifactorial ($p < 0.001$), then in 0.55 (55%) and 0.45 (45%) for Jaccard, extremely significant probability by monofactorial ANOSIM ($p < 0.001$) and very significant by the bifactorial ($p = 0.0014$), confirming difference between these taxocenoses (CAA and CIL), via PAST. Richness estimates for the shrubby-arboreal caatinga environment (CAA) follow in Bootstrap with 51.6, Chao 1 and 2 with 51.2 and 52.2, Jackknife 1 and 2 with 56.2 and 59.2, ICE and ACE with 53.6 and 50.9, while for the ciliary forest environment (CIL) in Bootstrap with 88.7, Chao 1 and 2 with 83.6 and 87, Jackknife 1 and 2 with 96.5 and 97.1, ICE and ACE with 94.6 and 85.7, via EstimateS (Table IV).

Table V. Diversity indexes in two localities in Brazil, Semiarid, Caatinga, Septentrional Sertaneja Depression, Paraíba, through PAST software. CSTR = Health Center and Rural Technology ("Centro de Saúde e Tecnologia Rural"), Patos, sampling effort of 80 hours/one collector plus assistant in 10 months; FATA = Tamanduá Farm ("Fazenda Tamanduá"), Santa Teresinha, sampling effort of 96 hours/one collector plus assistant in 12 months, DRY = dry period, RAI = rainy period, CAA = shrubby-arboreal caatinga environment, CIL = ciliary forest environment; **S** = richness; **N** = abundance; **DO** = Dominance; **J** = Equitability; **H'** = Shannon; **1-D** = Gini-Simpson; **D** = Simpson; **TPD*p*** = probabilities of the diversity permutation test; **T*p*** = probabilities of the diversity *t* test.

	S	N	DO	J	H'	1-D	TPD*p*	T*p*
CSTR	81	2531	0.06	0.76	3.33	0.94	< 0.001 (DO) < 0.001 (J)	< 0.001 (H') < 0.001 (D)
FATA	82	5556	0.14	0.63	2.77	0.86		
DRY	63	2558	0.16	0.62	2.57	0.84	< 0.001 (DO) = 0.01 (J)	< 0.001 (H') < 0.001 (D)
RAI	74	2998	0.13	0.65	2.79	0.87		
CAA	47	1586	0.147	0.66	2.55	0.853	> 0.05 (DO) > 0.05 (J)	< 0.001 (H') > 0.05 (D)
CIL	80	3970	0.149	0.63	2.74	0.851		

Table VI. Diversity estimators q0 (Richness), q1 (Shannon) and q2 (Simpson) by rarefaction and extrapolation of the Lepidoptera species in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil, with sampling effort of 96 hours/one collector plus assistant in 12 months, between May 2011 to April 2012, through R software and iNEXT package in 99% confidence limits. FATA = Tamanduá Farm, CAA = shrubby-arboreal caatinga environment, CIL = ciliary forest environment; SC = sample coverage estimate, CI = confidence interval; **N/ NSU** = Abundance/ Number of sampling units; **O** = Observed; **E** = Estimator; **L/ U** = Lower and Upper confidence limits through functions ChaoRichness(), ChaoShannon() and ChaoSimpson(); * = by applications see Hsieh et al. (2022b) for explanations of the standardization and of the possibility of variations, to the numbers obtained by the bootstrap method in randomly regenerated samples and by replications with the same data, probable differences via distinct versions or configurations in activations or not of determinate functions and parameters with arguments (syntax).

Site	N/ NSU	*Diversity	Abundance			Incidence		
			O	E	L/ U	O	E	L/ U
FATA	5556/ 12	Richness	82	86.57	82.6/ 116.82	82	90.38	83.77/ 121.75
		Shannon	15.89	16.02	15.89/ 16.89	62.04	67.15	62.04/ 72.78
		Simpson	6.93	6.94	6.93/ 7.41	52.26	54.87	52.26/ 59.49
			SC = 0.9986		CI = 0.99	SC = 0.9662		CI = 0.99
CAA	1586/ 12	Richness	47	53.12	47.73/ 98.65	47	53.55	48.01/ 89.56
		Shannon	12.81	13.03	12.81/ 14.24	36.08	39.92	36.08/ 44.66
		Simpson	6.80	6.82	6.80/ 7.53	30.01	32.13	30.01/ 35.95
			SC = 0.9956		CI = 0.99	SC = 0.9569		CI = 0.99
CIL	3970/ 12	Richness	80	84.50	80.64/ 111.74	80	87.82	81.75/ 114.98
		Shannon	15.47	15.64	15.47/ 16.65	59.27	65.14	59.43/ 70.85
		Simpson	6.70	6.71	6.70/ 7.21	48.78	51.76	48.78/ 56.82
			SC = 0.9977		CI = 0.99	SC = 0.9576		CI = 0.99

The diversity of the Papilionoidea community in the FATA, with assemblages or taxocenoses on temporal or spatial scales, in different periods or environments, evidenced greater abundance and richness for the rainy period and ciliary forest environment, detainers of diversities (relationship between richness and equitability or evenness) more expressive, mainly by the Shannon index (H') with individuals more evenly distributed among the species in rainy period (H' = 2.79) and in the ciliary forest environment (H' = 2.74), followed by a bigger accumulation of individuals belonging to few species in dry period (H' = 2.57) and in the shrubby-arboreal caatinga environment (H' = 2.55), in convergence by relationship with the greater equitability of Pielou (J) as greater homogeneity for the rainy period (J = 0.65) than to the dry period (J = 0.62) and lower dominance (DO) in rainy period (DO = 0.13) than in dry period (DO = 0.16), while the relative confluence for results of the Gini-Simpson index (1-D) by higher in rainy period (1-D = 0.87) and lower in dry period (1-D = 0.84) due to having more dominant species with greater average relative abundance or smaller equitability in dry period (Table V). Results were reinforced by the observation of highly significant probabilities ($p < 0.001$) for the indexes between the different periods and environments through the diversity tests, especially Shannon, in addition to the very significant index of J ($p = 0.01$) between the dry and rainy periods; except with the non-significant indexes (> 0.05) of D, J and 1-D for the shrubby-arboreal caatinga and ciliary forest environments (Table VI).

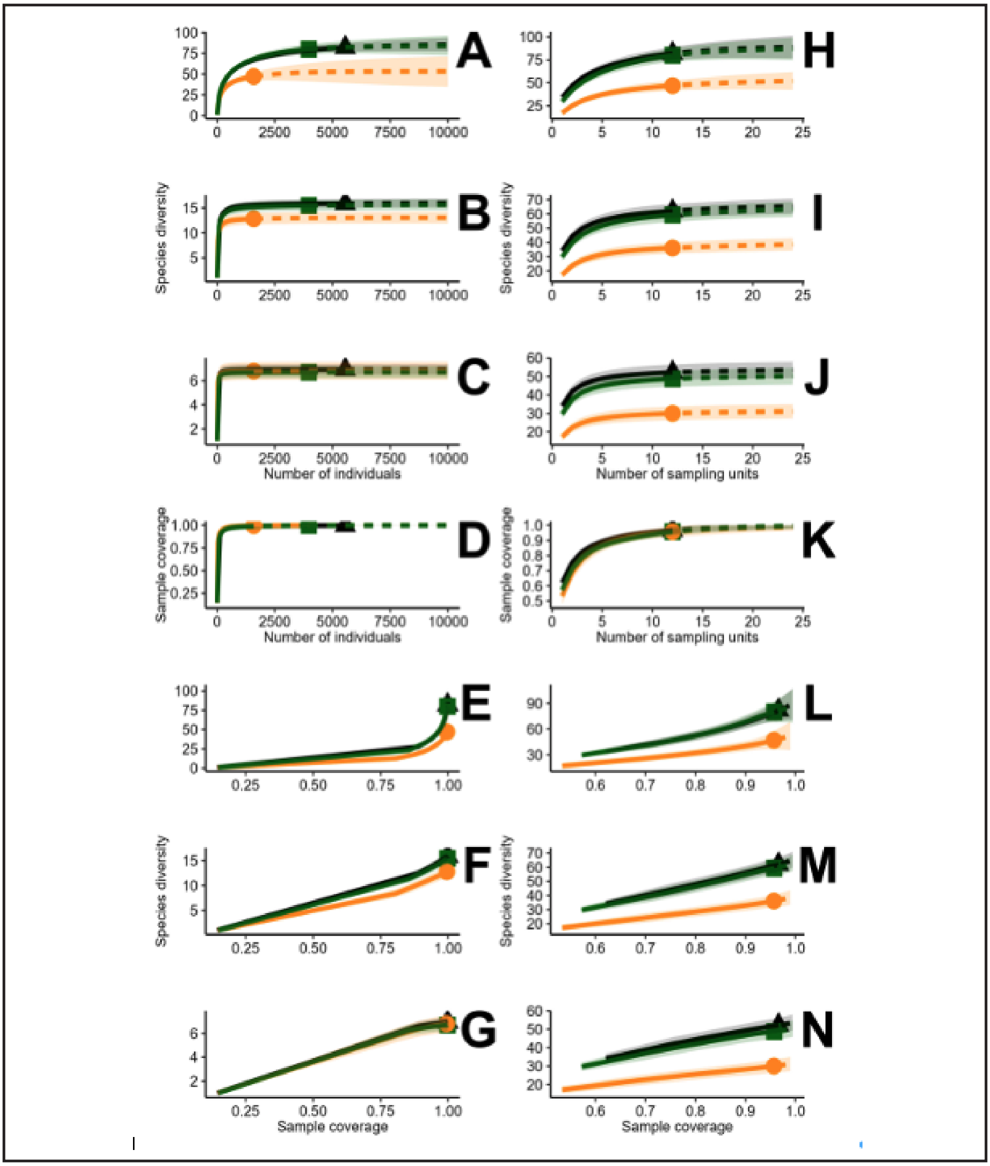
The dominance expressed two species of Pieridae as eudominants (2.4% of the total richness), *Eurema flavescens* (Chavannes, 1850) with 1822 individuals (32.79%) and *Ascia monuste orseis* (Godart, 1819) with 824 individuals (14.83%), accounted in 2646 individuals (47.62%) of the total abundance of 5556 registered individuals (Table II); reflected in population explosions of some Pieridae species involved in migrations and recorded for the months with the highest precipitations during the rainy period (Table III); following in the dominant category with three species (3.7%) and encompassing 931 individuals (16.76% of the total abundance), *Phoebis marcellina* (Cramer, 1777) with 300 individuals (5.4%), *Hemiargus hanno* (Stoll, 1790) with 311 individuals (5.6%) and *Euptoieta hegesia meridiania* Stichel, 1938 with 320 individuals (5.76%) (Table II); subdominant with five species (6.1%) and 702 individuals (12.64%) (Table II); recessive with six species (7.3%) and 480 individuals (8.63%) (Table II); rare with 25 species (30.5%) and 637 individuals (11.47%), most Nymphalidae (10 species) and Hesperiidae (seven species), followed by Pieridae and Lycaenidae (three species each), Riodinidae (two species) (Table II); ultrarare with 41 species (50% of the total richness) and 160 individuals (2.88% of the total abundance), most Hesperiidae (18 species), Nymphalidae and Lycaenidae (eight species each), followed by Pieridae (three species), Papilionidae and Riodinidae (two species each) (Table II).

The constancy resulted in 26 constant species (32%), most Nymphalidae (10 spp.), Hesperiidae (six spp.), Pieridae (five spp.), followed by Lycaenidae (three spp.) and Riodinidae (two spp.) (Table II), with 10 species present throughout the entire sampling period of 12 months, *E. flavescens*, *P. marcellina*, *Pyrisitia nise tenella* (Boisduval, 1836), *A. monuste orseis*, *H. hanno*, *E. hegesia meridiania*, *Dione maculosa* Stichel, [1908], *Heliconius erato phyllis* (Fabricius, 1775), *Hamadryas februa* (Hübner, [1823]), *Anartia jatrophae jatrophae* (Linnaeus, 1763); 26 accessory species (32%), most Nymphalidae (10 spp.), Hesperiidae (nine spp.), followed by Pieridae (five spp.) and Lycaenidae (two spp.) (Table II); 30 accidental species (36%), most Hesperiidae (13 spp.), Lycaenidae (seven spp.) and Nymphalidae (five spp.), followed by Papilionidae and Riodinidae (two spp. each), Pieridae (one sp.) (Table II). Only three constant species were present in both shrubby-arboreal caatinga and ciliary forest environments throughout the entire sampling period, *E. flavescens*, *P. marcellina* and *H. hanno*.

Interpolation and extrapolation analyses for species diversity by Hill numbers through iNEXT showed promising results (Table VI, Figure 9), with relative comparative correspondence to the results contained in Table IV and Table V, as well as transposing some limitations of given tools or other statistical resources, for example, by increasing estimate intervals or giving others for important differences. Due to probabilities involved in the dynamics of fluctuations of populations and communities to the possible human records as representations for formal documentation, with potentialities for approximate or exact validations of computational simulations (evidence, proof). See, for instance, estimates of richness order (q0) to FATA at 116.82 species (upper confidence limit) by abundance and 121.75 species (upper confidence limit) by incidence (Table VI); with replications by functions in specific configurations, as other examples, to the result for past and recent versions of iNEXT in the R return with q0 orders by 103.43 species in abundance (UCL 95% and 95% Upper in ChaoRichness) or for the recent version by 103.03 species in incidence (UCL 99%), even by the recent version of iNEXT Online (http://chao.stat.nthu.edu.tw/wordpress and https://chao.shinyapps.io/iNEXTOnline) with q0 orders in extrapolations by 102.77 species in abundance (qD.UCL 99% Level of confidence interval) or by 103.06 species in incidence (qD.UCL 99% Level of confidence interval), as some of the intervals.

Other analyses, through the R software with vegan package and auxiliaries, such as those that can precede the NMDS ordination or after for the provenance, by ANOSIM function resulted in a significant difference ($p < 0.05$) between the rainy period (RAI) and dry period (DRY) in the FATA; followed by the dissimilarity level in configuration of the SIMPER function with 0.45 (45%) of the total of one (100%) and in another configuration with contributions to the significance levels for some of the species by *Junonia evarete* (Cramer, 1779), *Heliopetes willi* (Plötz, 1884), *Burnsius orcus* (Stoll, 1780), *Zopyrion evenor thania* Evans, 1953, *H. hanno*, *Strymon rufofusca* (Hewitson, 1877) and *Aricoris* sp. Then, by the dimensioning via NMDS in a stress of 0.072, by random departures to the dissimilarity calculations, for ordination with the formation in significance of two different groups by the lines of distinct polygons at different points and overlapping parts or not for the set of the months of rainy period or the set of the months of dry period, with adjustment qualities by sequences in centroids for approximations and distances between points (Figure 10).

Figure 9. Interpolation and extrapolation curves of the abundance (A-G) and incidence (H-N) of Papilionoidea in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil, with sampling effort of 96 hours/one collector plus assistant in 12 months, between May 2011 to April 2012, through R software and iNEXT package in 99% Lower and Upper Confidence Limits (LCL and UCL). Continuous line = Rarefaction; Dashed line = Extrapolation; Triangle and black color = Tamanduá Farm; Circle and orange color = Shrubby-arboreal caatinga; Square and green color = Ciliary forest; A, E and H, L = order q0 (Richness); B, F and I, M = order q1 (Shannon); C, G and J, N = order q2 (Simpson); A, B, C and H, I, J = Sample-size-based R/E curves; D and K = Sample completeness curves in orders q0, q1, q2; E, F, G and L, M, N = Coverage-based R/E curves.



The NMDS data of the FATA for rainy (RAI) and dry (DRY) periods, through envfit function for dissimilarity of the communities in periods and other variables that could or could not drive the distribution pattern, resulted in contributions by significance levels for species *E. flavescens*, *A. monuste orseis*, *P. nise tenella*, *Pyrisitia leuce* (Boisduval, 1836), *Eurema phiale paula* (Röber, 1909), *Cogia calchas* (Herrich-Schäffer, 1869), *Epargyreus exadeus* (Cramer, 1779), *Nisoniades macarius* (Herrich-Schäffer, 1870), *H. willi*, *E. hegesia meridiania*, *Danaus gilippus* (Cramer, 1775), *Danaus eresimus plexaure* (Godart, 1819), *Danaus erippus* (Cramer, 1775), *D. maculosa*, *Mestra hersilia hypermestra* Hübner, [1825], *Dynamine postverta* (Cramer, 1779), *Anthanassa hermas* (Hewitson, 1864), *Hypna clytemnestra forbesi* Godman & Salvin, 1884 and with little variation, continuing by envfit in another configuration with output of the relative contribution of isolated environmental variables and only for temperature as significant ($p < 0.05$); along with the possibility of using different functions and distinct configurations or other tests, for correlations or not with ordination axes, also to evaluate the influence of variables separately or jointly to verify the conduction or not of observed differences in distributions, perhaps to reinforce or not, such as a different function in a configuration that returned significance for correlation with the variable set of precipitation plus temperature in the FATA and for disposition in periods (RAI and DRY) by species.

Data arrangement for the environments of shrubby-arboreal caatinga (CAA) and ciliary forest (CIL), in the FATA, resulted in relationships by environments (CAA and CIL) and periods (RAI and DRY) to the dimensioning. The disposition of environments by periods showed ANOSIM result in non-significance, with another result in distinction for significance due to a different function and configuration; then by SIMPER in a configuration between the periods with 0.54 (54%) and significance levels for few species compared to the results of the anterior and posterior SIMPER. In an analytical disposition only by environments (CAA and CIL) resulted in ANOSIM as very significant ($p = 0.001$); followed by SIMPER in configurations between the environments with 0.57 (57%) and significance levels for slightly more than half of the species registered in the FATA. The data of the NMDS from FATA by environments of shrubby-arboreal caatinga (CAA) and ciliary forest (CIL), with general stress of 0.096, resulted in directional points with lines to the formation of polygons with overlapping parts or not by degrees of differentiation for the months by periods (DRY and RAI) in distribution (Figure 11) and for the months by environments (CAA and CIL) in approximation or distancing (Figure 12).

Figure 10. NMDS of the abundance of Lepidoptera species by rainy period (RAI) and dry period (DRY) in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil, with sampling effort of 96 hours/one collector plus assistant in 12 months, between May 2011 to April 2012, through R software and vegan package, 0.072 stress. Square and green color = rainy period (May-June 2011 and January-April 2012); Triangle and orange color = dry period (July-December 2011).

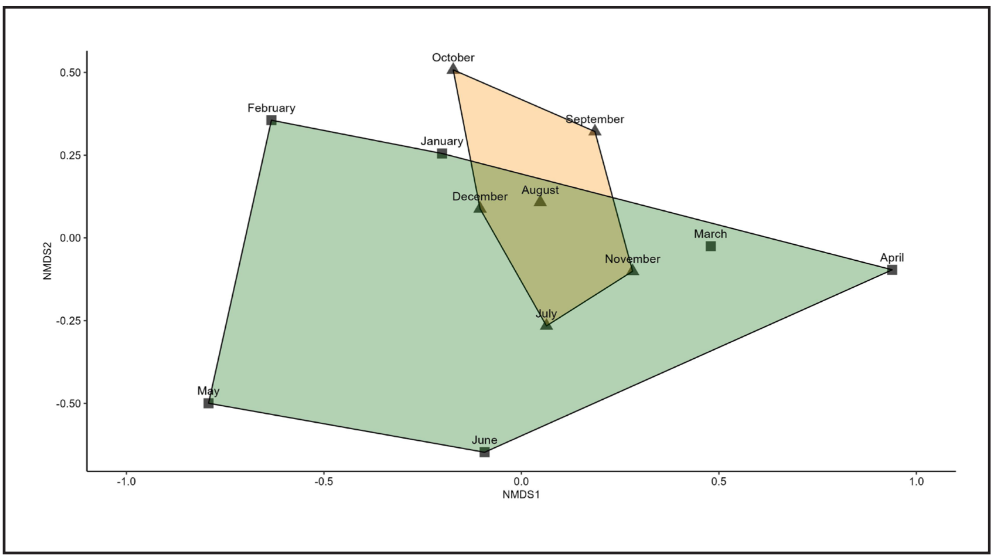


Figure 11. NMDS of the abundance of Lepidoptera species by environments of shrubby-arboreal caatinga (_Caa) and ciliary forest (_Cil) in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil, with sampling effort of 96 hours/one collector plus assistant in 12 months, between May 2011 to April 2012, through R software and vegan package, 0.096 stress, for the environments in months by periods. Square and green color = rainy period (May-June 2011 and January-April 2012); Triangle and orange color = dry period (July-December 2011).

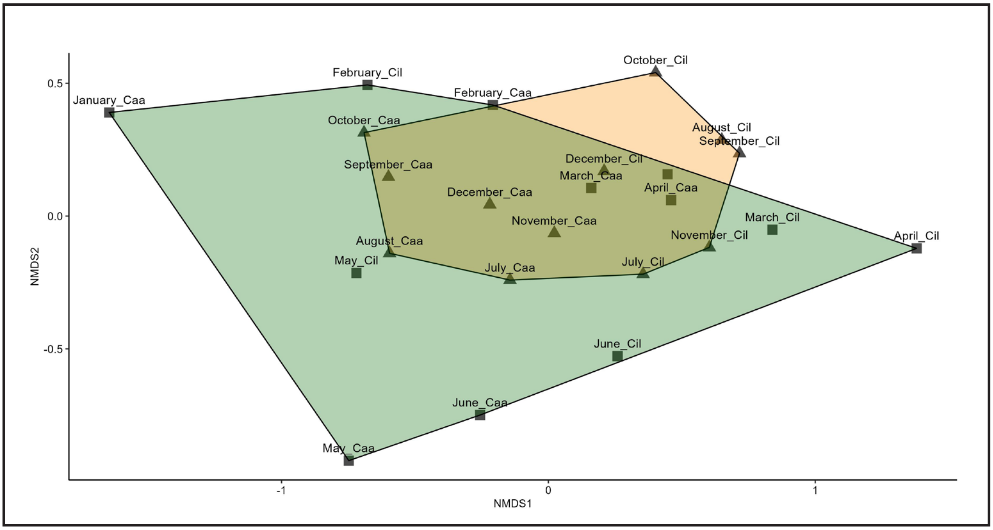
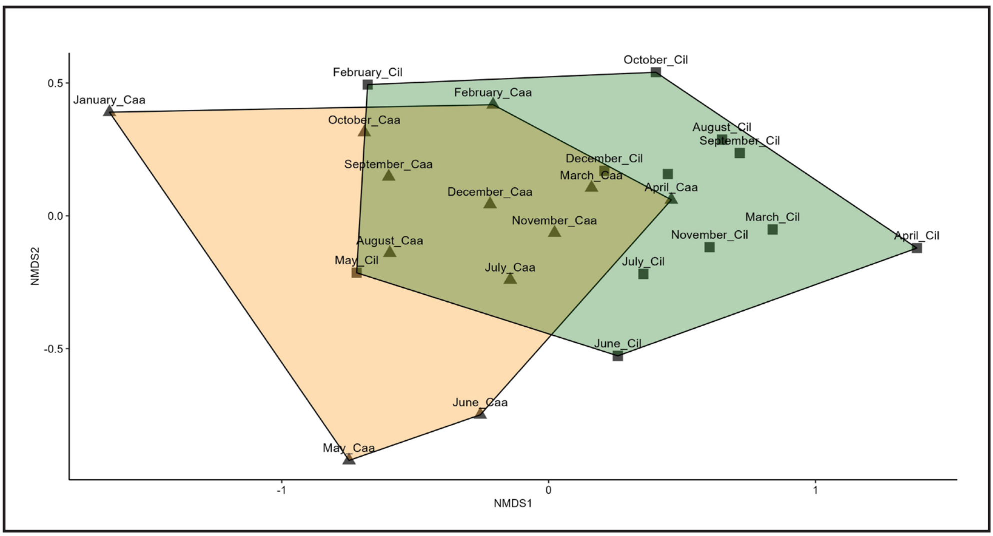


Figure 12. NMDS of the abundance of Lepidoptera species by environments of shrubby-arboreal caatinga (_Caa) and ciliary forest (_Cil) in the Tamanduá Farm (FATA), Santa Teresinha, Paraíba, Brazil, with sampling effort of 96 hours/one collector plus assistant in 12 months, between May 2011 to April 2012, through R software and vegan package, 0.096 stress, for the months by environments. Square and green color = ciliary forest (_Cil); Triangle and orange color = shrubby-arboreal caatinga (_Caa).



The envfit function via the NMDS result, through the dissimilarity of communities to spaces and species as driving variables of the distribution pattern, resulted in contributions by significance levels for *E. flavescens*, *E. phiale paula*, *P. leuce*, *P. nise tenella*, *A. monuste orseis*, *Strephonota* sp., *Leptotes cassius* (Cramer, 1775), *D. eresimus plexaure*, *D. erippus*, *D. gilippus*, *E. hegesia meridiania*, *H. erato phyllis*, *M. hersilia hypermestra*, *Callicore sorana* (Godart, [1824]), *A. jatrophae*, *Siproeta stelenes meridionalis* (Fruhstorfer, 1909), *C. calchas*, *E. exadeus*, *N. macarius*, *Hoodus cristata* (Austin, 2000), *H. willi* and with little variation, species in the multidimensional space with center and greater proximities to the centroids; followed by envfit in another configuration to return relative contribution of isolated variables and only to the environment (CAA and CIL) as very significant ($p = 0.003$), with reinforcement for previous correlation by different functions and distinct configurations or different tests.

Discussion

The majority of species at FATA are common in forest edges, open or ruderal areas; generalists by polyphagy with approximately 41 species, among 71 recognized species that also include specialists by monophagy with 12 species and by oligophagy with 18 species, via connected information or cross-data (Trigo et al. 2000; Beccaloni et al. 2008; Guedes et al. 2012; Silva et al. 2012; Cabral et al. 2013; Laine et al. 2017); extensively distributed in Brazil because many are shared in different environments of Caatinga (87 species), Cerrado (82 species), Atlantic Forest (80 species) and Amazon (71 species), as observed in comparison described for these biomes (Table II), while sharing more than half of their species (84 species) with the largest inventory in the northeastern Semiarid region (Kerpel et al. 2014) and representation around 21.6% (Table VII). Descriptions of possible new species included in the FATA are still in development, such as *Aricoris* sp. (Riodinidae) and *Celaenorrhinus* sp., in addition to the probable definitions of endemism's for the Caatinga biome or Semiarid region which are under evaluation.

Table VII. Synthesis of the Lepidoptera inventories developed in the Caatinga biome and published, including the present study in the Tamanduá Farm (FATA) in Santa Teresinha municipality and Paraíba state. DSS = Septentrional Sertaneja Depression ("Depressão Sertaneja Setentrional"), DSM = Meridional Sertaneja Depression ("Depressão Sertaneja Meridional"), PBO = Borborema Plateau ("Planalto da Borborema"), CCD = Chapada Diamantina Complex ("Complexo da Chapada Diamantina"), CCM = Campo Maior Complex ("Complexo de Campo Maior"), CIA = Ibiapaba/Araripe Complex ("Complexo Ibiapaba/Araripe"); N = Entomological net, T = Van Someren-Rydon trap.

Work	Locality	State	Caatinga Ecoregion	Sampling effort	Richness	Shared species
Present study FATA	Fazenda Tamanduá	PB	DSS	96 h/ one collector N	82 (93)	–
Nobre et al. (2008)	PARNA do Catimbau	PE	PBO, DSM	360 h/ one collector N(T)	121	66
Paluch et al. (2011)	Parque Municipal João V. Sobrinho	PE	PBO	216 h/ two collectors N(T)	197	57
Zacca & Bravo (2012)	Chapada Diamantina	BA	CCD	392 h/ one collector N(T)	169	60
Lima & Zacca (2014)	Serra da Fumaça	BA	CCD	97 h/ one collector N(T)	121	47
Kerpel et al. (2014)	11 localities	PI, CE, PB, PE, BA	DSM, PBO, CCD, CIA	N(T)	389	84
Kerpel et al. (2014)	Milagres	BA	DSM	32 h/ two collectors N(T)	65	43
Kerpel et al. (2014)	Maracás	BA	DSM	32 h/ two collectors N(T)	84	40
Câmara et al. (2017)	PARNA de Sete Cidades and Ubajara	CE	CCM, CIA	98 h/ one collector N(T)	150	45

Ferreira-Júnior (2021)	UFCG-CSTR, Patos	PB	DSS	80 h/ one collector N	81 (92)	60 (69)
Dantas et al. (2021)	UEFS, Feira de Santana	BA	DSM	180 h/ one collector N(T)	96 (114)	61

The richness found in the FATA is considerably lower compared to five studies described for areas in Caatinga ecoregions (Nobre et al. 2008; Paluch et al. 2011; Zacca & Bravo, 2012; Lima & Zacca, 2014; Câmara et al. 2017), while the richness is close to two localities with Maracás in Bahia (Kerpel et al. 2014) or Patos in Paraíba (Ferreira-Júnior, 2021) and having greater richness than that recorded for Milagres in Bahia (Kerpel et al. 2014), considering distinct phytophysiognomies, environmental heterogeneities, collection methods and different sampling efforts, in contrast to the difference of species composition between the cited works (Table VII). The richness of the FATA is also considered low when compared with the richness in areas of Atlantic Forest, Cerrado and Amazon in the Northeast region, except for the works of Duarte-Júnior et al. (2001), Vasconcelos et al. (2009), Pereira et al. (2018) and Medeiros et al. (2021) (Table I). The relatively low richness is expected for a hyperxerophilous region that is under strong influence of seasonality, has a very irregular rainfall regime and high levels of insolation, with relatively scarce forest and litter cover, where most of the trees are deciduous (Nobre et al. 2008). So far, the richness in the FATA represents 21.78% of the Lepidoptera richness in Paraíba, with the possibility of changes in conformity to future studies.

The greater abundance for the rainy period in the FATA is in agreement with the baseline result by Malaise trap for Lepidoptera in “RPPN Fazenda Almas” in the semiarid of the Paraíba with preserved caatinga vegetation and approximately 108 km of distance, defining the rainy period from February to July and dry period from August to January (Vasconcellos et al. 2010); as findings of relative accuracy or precision of the standards; then also by abundance and richness of fruit-feeding Papilionoidea collected with Van Someren-Rydon traps in the semiarid or caatinga of Pernambuco as more expressive during the rainy period in “PARNA Catimbau” with approximately 255 km away from FATA, defining the rainy period from March to August and dry period from September to February (Nobre et al. 2012).

A new record of Lepidoptera for the Northeast region is cited, *Lasaia* sp. (Riodininae, Riodinidae), with a single individual collected during the rainy period while ingesting mineral salts in a seasonal water body in the stream or another recorded by sighting during the dry period and both in the ciliary forest (Table I, Table II); meanwhile *Lasaia* sp. and *C. lepta* represent two previously unrecorded for the Semiarid-Caatinga; including when added with *Strephonota* sp. (Lycaenidae, Theclinae), *Aricoris* sp. (Riodinidae, Riodininae) and *L. eufala* (Hesperiidae, Hesperiinae) to form five unpublished records to the Paraíba state (Table I, Table II). For the ecoregion of the Septentrional Sertaneja Depression 24 unprecedented records were included, which is equivalent to the number of exclusive species of the FATA by comparison with the Health Center and Rural Technology (CSTR in Portuguese for “Centro de Saúde e Tecnologia Rural”) in Patos (Ferreira-Júnior, 2021), also adding the Papilionoidea *D. arene* and *P. laertes* (Table I, Table II, Table VII). It is noteworthy that *L. eufala* was not recorded through works contained in Table I and this species was documented via specimen collected in Pernambuco state as reported by Evans (1955). To date and through the free or open platform of the citizen science iNaturalist (https://www.inaturalist.org) no unprecedented Lepidoptera records have been observed in the intermediations of the Santa Teresinha municipality (https://www.inaturalist.org/observations?place_id=22813) or when covering the area of the Tamanduá Farm (iNaturalist 2023).

It is emphasized that most species of Nymphalidae, Pieridae and Papilionidae, are relatively easier to record; while many species of Riodinidae and especially Hesperiidae or Lycaenidae often small in size, exhibit fast or erratic flight, may present slight coloration on two sides or one, may occur spatiotemporally of mode more punctual and with few individuals of transient or infrequent species, most of the time (Iserhard et al. 2013), requiring greater collection effort to be adequately sampled; as well as evidenced by relationships with the FATA through expressions of rarities, like via singletons or doubletons and uniques or duplicates, in dominance or constancy and species recorded outside the sampling period or sample, belonging more to Hesperiidae and Lycaenidae (Table II). Moreover, samples can have cryptic species complexes that make identification difficult. It is noteworthy that given identifications may vary by synonymies or change by non-synonymies (redetermination or not) and depending on who observed or how it was observed, relatively, due to limitations involved in the field or laboratory, lack or scarcity of resources, level of knowledge or experience, new studies or systematictaxonomic reviews, for the observer effect applied in this scope which can be mitigated by the integration with other methods or more analyzes to deepen and such as genetic analyzes in objectivity to reinforce hypotheses/results or not.

Only one (sub)species of Ithomiini, *Mechanitis lysimnia nesaea* Hübner, [1820], was registered in the FATA and in ciliary forest, a Lepidoptera indicative of more disturbed environments in the Atlantic Forest (Brown-Junior, 1992) and without record for its host plants of Solanaceae (Beccaloni et al. 2008) in the area (Guedes et al. 2012; Silva et al. 2012; Cabral et al. 2013; Laine et al. 2017), besides Satyrini also with a single species recorded for *Pharneuptychia phares* (Godart, [1824]) in the FATA. The low representation of Ithomiini or Satyrini found in the FATA and for a semi-urban environment surrounding the city of Patos, at 250 m of average altitude and approximately 20 km away (Ferreira-Júnior, 2021), demonstrates in agreement with the works of Nobre et al. (2008, 2012) and Melo et al. (2023) that the richness of these specialized groups is considered low in typical areas of xerophilic caatinga of low altitude or due to environmental filters, with the possibility to extending in localities at (Septentrional) Sertaneja Depression and see works in Table VII. Limiting factors include climatic conditions, lack of suitable habitats, level of preservation or conservation, absence or scarcity of resources for larvae or adults, which are ideal for the survival and distribution of other representatives of these groups.

Among the species that showed potentiality for future studies of natural history, bionomy, migration, clinal variation (cline), polyphenism and others, highlighted *E. flavescens flavescens* by the evident observations of the difference in size between individuals in rainy and dry periods, with possible overlap of forms in variation, changes to the dimorphism or dichromatism, probably due to differences that involve seasonal conditions or food resources (Vanini et al. 1999; Ruszczyk et al. 2004).

Through samples of the 82 species registered in the FATA and 81 species recorded in the CSTR, 103 species of a total were obtained, by the intersection of 60 shared species (58%) between these localities (Table VII), with 22 exclusive species to FATA and 21 exclusive species to CSTR, correction of part in Ferreira-Júnior (2021); these or some of these exclusive species can occur, be registered or not, eventually for each locality in which were not recorded or collected. In general, when including species from the samples and outside them, there are a total of 116 species for the FATA set (93 spp.) plus the CSTR set (92 spp.) and in intersection with 69 shared species (59%) between these areas (Table VII). With probable species to the turnover (rotativity), establishment or not through colonization, in conformity with the habitat preferences and by conditions or resources, totaling 47 exclusive species between the localities of the FATA (24 spp.) and CSTR (23 spp.), then, by expressions of Hesperiidae (19 spp.), Nymphalidae (12 spp.), Pieridae (seven spp.), Riodinidae (five spp.), Lycaenidae (three spp.) and Papilionidae (one sp.), via flows in cycles of fluctuations due to dispersions by the emigrations or immigrations in (meta)populations or (meta)communities.

The Shannon (H') and Gini-Simpson (1-D) diversity indexes, with emphasis on rare species or intermediary relative abundances (H') and more common or dominant species (1-D), revealed that the Lepidoptera community in the less anthropogenic environment of the FATA (H' = 2.77 and 1-D = 0.85) is less diverse and more heterogeneous than in the more anthropogenic environment of the CSTR (H' = 3.33 and 1-D = 0.94), proportionally due to decreased uniformity in the FATA and not necessarily by a difference of richness for just one species, in convergence with the greater equitability of Pielou (J) in the CSTR and with the greater dominance (DO) in the FATA, reinforced by the extremely significant probabilities ($p < 0.001$) in diversity tests (Table V). Dispositions are possibly influenced by the contribution of the edge effect and not exclusively. Along with the evidence of greater abundance in the FATA (5556 individuals) in distribution among species to the example by rarities with 80.5% which corresponds to only 14.35% of the total abundance and comparison with the smaller abundance in the CSTR (2531 individuals) in distribution of species by rarities with 72% which corresponds to only 13% of the total abundance.

It is necessary to emphasize that there was the prediction of a greater number of species in the CSTR, Chao 1 equal to 105 species (Ferreira-Júnior, 2021), than in the FATA, Jackknife 2 equal to 99 species (Table IV), considered the highest value obtained through richness estimators in both localities, with proximity to the evidential cumulative computation of 103 or 117 registered species, for probable fluctuations, while assessment of interval by the iNEXT in order of the richness q0 by abundance with 103.43 species (UCL 95% and 95% Upper in ChaoRichness) or 116.82 species (99% Upper in ChaoRichness) and other details in Table VI.

It is noted through the set in evidence of the current record of 116 species, resulting from the combination FATA plus CSTR, that in the FATA over time can approach (for less or more) or exactly reach (equality) the

116.82 species by estimate of abundance q0 (Table VI), for a given space of time (period) and cumulatively; even exceed and observe the extrapolation of 121.75 species by the q0 incidence estimate (Table VI) or by comparison if species are considered as elements inside and outside of the intersection between sets of recorded Papilionoidea in the interconnected spaces by levels of natural to artificial gradients between the FATA with CSTR at an approximate distance of 20 km (Ferreira-Júnior, 2021) and the former State Park Peak of Jabre (PEPJ in Portuguese for "Parque Estadual Pico do Jabre") at an approximate distance of 65 km from the FATA, in landscapes with characteristics and aiming the indispensable ecological corridors. Situations that are plausible or reasonable, for possibilities, probable by variables to the future in comparison with the documented past and through the present.

The populations of species in communities for a given space and time may or may not exhibit the same concentration of abundance or richness, due to environmental differences, distinct natural histories, methodological variations, besides compositions that can be the same or different, presenting population dynamics through (bio)ecological phenomena in biocenosis or biota of the biotope or ecotope in the ecosystem. In an analysis of the natural regeneration of tropical dry forests (TDFs), which includes Tamanduá Farm, fruit-feeding Papilionoidea had higher Hill-Simpson diversity in the early succession phase than in the late growth phase and varied widely in the intermediate stages; with evidence that Hill-Simpson diversity and changes in species composition, provided by β^2-diversity, are better indicators of forest natural regeneration than raw species richness (Oliveira et al. 2024).

It is important to highlight that in years 2011 and 2012 were recorded with the occurrence of La Niña phenomenon (National Oceanic and Atmospheric Administration, 2023), moderate La Niña between 2010-2011 (Centro de Previsão de Tempo e Estudos Climáticos, 2016), in 2011 that there were flash floods in Brazil (National Oceanic and Atmospheric Administration, 2012) and in 2012 was one of the warmest La Niña years (Osborne & Blunden, 2013), with drought in first semester in the Northeast region of Brazil (National Oceanic and Atmospheric Administration, 2013) and permanence for years, with further elucidations of the phenomena involved in Marengo et al. (2018), Pontes-Filho et al. (2020) and Barbosa (2023). Historically in area that covers the FATA was recorded rainiest quarter for November-December-January (Empresa Brasileira de Pesquisa Agropecuária, 2016).

Probably, due to habitat specificities or seasonality, some of the species found only in the ciliary forest are less tolerant to the microclimatic conditions of temperature or humidity in the shrubby-arboreal caatinga environment. See findings in statistical significance to the differences and distributive directions. Possibly, the milder environment and the greater availability of resources throughout the year in the ciliary forest favor these incidences, also functioning as a mesic refuge for these Papilionoidea and others in periods of greater adversity (Anselmo et al. 2014). It was observed that of the 35 exclusive species of the ciliary forest, which were not recorded in the transects of shrubby-arboreal caatinga in the FATA, 24 were recorded in the herbaceous-shrubby or shrubby-arboreal caatinga in the CSTR, three Pieridae, three Lycaenidae, seven Nymphalidae and 11 Hesperiidae (Ferreira-Júnior, 2021), filtering 11 remaining species in exclusivity in the ciliary forest for *Ministrymon azia* (Hewitson, 1873), *Strephonota* sp. and *Tmolus echion* (Linnaeus, 1767) (Lycaenidae), *Lasaia* sp. and *Synargis calyce* (C. Felder & R. Felder, 1862) (Riodinidae), *D. postverta postverta* and *S. stelenes meridionalis* (Nymphalidae), *Aguna asander* (Hewitson, 1867), *Celaenorrhinus* sp., *Trina geometrina* (C. Felder & R. Felder, 1867) and *Pompeius pompeius* (Latreille, [1824]) (Hesperiidae).

Some measures of biological or ecological diversity with attributes by characteristics, qualifications for quantifications or quantifications for qualifications, can be indifferent to certain qualitative particularities of compositions, thus still with preponderance of abundances to the definitions of balances/imbalances or environmental health level and risks of extirpation or extinction of species. Such as possible incidences of certain species or groups of Papilionoidea, indicator species (Freitas et al. 2003, 2006), endangered species, endemic species, and new species, with value by the conservation biology or conservation ecology. For example, some of the species that were recorded exclusively in the FATA in comparison with the CSTR stand out or some of the 11 species that by the filter represented exclusive records in the ciliary forest as probable indicators of this environment, probably, also by constituting bioindicator Papilionoidea of the environmental quality or of the conservation in levels in the Tamanduá Farm with parts mainly via fruit-feeding Papilionoidea for *D. arene* and *P. laertes* (Nymphalidae), *M. azia*, *Strephonota* sp. and *T. echion* (Lycaenidae), *Aricoris* sp., *Lasaia* sp. and *S. calyce* (Riodinidae), *Celaenorrhinus* sp. (Hesperiidae), or even other species, which can or cannot continue in these conditions in the Septentrional Sertaneja Depression and Caatinga or Semiarid with localities.

With the probable interchangeabilities or turnover of Lepidoptera species in spaces and times, time spaces (intervals), which can be segmented to evaluate differences, conditionalities, via qualifications or quantifications, specifications or generalizations, biogeographical or environmental details, up to geographical or political characteristics with social and human practices can influence in ambits through actions that contribute to the involvement of protections through fields of sociopolitical, socioenvironmental, sociobiodiversity, bioeconomy, biosocioeconomic or sociobioeconomic, ecosocioeconomic, ecodevelopment, and sustainable development (Agenda 2030 para o Desenvolvimento Sustentável, 2015), besides other scopes.

The continuity of the monitoring and development of other studies, such as the description of the survival strategies of Papilionoidea in the FATA, are necessary to better understand the natural history of many species or groups in the Caatinga or Semiarid, as well as, given the spatial or temporal heterogeneity and by the interperiod variability tendency, in order to evaluate possible alterations due to environmental or climatic changes, by being able to designate or corroborate patterns or parameters, reinforcing the importance of conservation of the ciliary forests and which provide resources for Papilionoidea not exclusively in periods with unfavorable conditions.

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Conflict of Interest

The authors declare that there is known financial interest or personal relationship that could have influence the work presented in this article.

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