Butterflies (Lepidoptera: Papilionoidea) of the Restinga de Cabedelo National Forest, Paraíba State, Brazil

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Abstract. Restinga forests are plant formations that occur on plains of quaternary sandy deposits along the Brazilian coast. Despite historical reduction of the Restinga forests, little effort has been made to know the butterfly fauna. In the Brazilian Restinga forests, the butterfly fauna is dominated by species widely distributed and commonly found in open or forested areas in Brazil. The Restinga de Cabedelo National Forest (FLONA de Cabedelo, following the Portuguese abbreviation) is a Federal Conservation created by Decree s/n of June 2, 2004). It is located in the metropolitan region of João Pessoa, municipality of Cabedelo (7°03’43” S and 34°51’09” W), Paraíba state, Northeast of Brazil (Figures 1-4). With an extension of 103.3 ha, the FLONA de Cabedelo is included in an area of sandy soil and heterogeneous vegetation, composed mainly of mangrove and Restinga forest (Figures 5-6) (ICMBio 2016). According to Köppen classification, the climate is tropical warm and humid (As), with annual average temperatures between 25°C and 28°C.
temperature and humidity of 26 °C and 80%, respectively (Governo do Estado da Paraíba 1985). Precipitation reaches around 1,800 mm per year, with the rain concentrated between May and September and the driest period between October and December (Freire 1996).

The FLONA de Cabedelo is largely delimited by anthropized areas, which makes it vulnerable to human activity that often invades the forest for resource exploitation and garbage disposal, this latter being one of the factors responsible for eventual fire occurrences (ICMBio 2016). In addition, the forest is cut by a road that gives access to the Conservation Unit's administrative center and by a railway through which passengers are transported daily between the municipalities of João Pessoa and Cabedelo (Figures 7-8). In its West portion, the FLONA de Cabedelo is crossed by the Mandacaru River, which flows to the Paraíba River on the West edge of the Conservation Unit (Figure 4). This area is daily inundated and
contains dense mangrove vegetation which makes some areas inaccessible (for a better characterization of the area, see ICMBio 2016).

Butterflies were sampled with entomological net and Van Someren-Rydon bait traps, in six transects (from approximately 250 to 450 m each) established on pre-existing trails in the East portion of FLONA de Cabedelo (Figure 4). The transects were selected to contemplate the most varied environments, including open areas, mangrove edge, forest interior, and forest edge. Due to the presence of dense mangrove vegetation, it was not possible to establish transects in the West portion of FLONA de Cabedelo. The sampling with net was made by a single collector (with an alternation between two collectors), between 9:00 am and 4:00 pm, for three consecutive days every two months, between March 2013 and April 2014, totaling 108 hours of sampling effort. Five traps were used on each trail, arranged at about 100 m from each other and suspended between 1.5 and 3 m from the ground, and remaining active during the three days of each expedition, totaling 432 hours of sampling effort. Traps were baited with a mix of banana and sugarcane juice fermented for 48 hours to attract the butterflies (Devries et al. 1997). The traps were inspected daily to renew the baits and remove the captured individuals. On average, three captured specimens of each species were collected on each expedition, the others were identified, marked not to count again the same individual, and released in the same collection site.

The species identification was based on specialized literature, consults to specialists (see acknowledgments), and comparison with specimens from "Laboratório de Ecologia e Interações de Insetos da Caatinga" collection (CLEIIC). The confirmation of the new records for Paraíba state was based on the following lists: Kesselring & Eberl (1982), Kerpel et al. (2014), and Ferreira-Junior (2021). The nomenclature follows Lamass (2004) updated with the modifications from Wahlberg et al. (2009) for Nymphalidae, Seraphin et al. (2018) for Riodinidae and Li et al. (2019), and Cong et al. (2019) for Hesperiidae. The collected material is deposited in the CLEIIC of the Centro de Saúde e Tecnologia Rural of the Universidade Federal de Campina Grande, Patos, Paraíba, Brazil.

The species accumulation curve was performed with presence and absence data (the sum of the records made with net and traps were considered), using the EstimateS 9.1.0 software (Colwell 2019) with the non-parametric richness estimates Bootstrap and CHAO 2, based on singletons and doubletons and other criteria (Magurran 2013).

**RESULTS AND DISCUSSION**

A total of 89 butterfly species and 1,503 individuals were recorded at the FLONA de Cabedelo (Table 1). Hesperidae was the richest family (34 species), followed by Nymphalidae (33), Pieridae (eight), Lycaenidae (seven), Riodinidae (five),...
Table 1. Butterflies species collected between March 2013 and April 2014 at the Restinga de Cabedelo National Forest, Cabedelo, Paraíba state, Brazil, per sampled methods: entomological net (EN) and Van Someren-Rydon bait traps (BT). The number of species for each major taxa is noted within parenthesis. The asterisk represents new record for Paraíba state.

| TAXON            | EN | BT |
|------------------|----|----|
| PAPILIONOIDEA (89) |    |    |
| Papilionidae (2) |    |    |
| Papilioninae (2) |    |    |
| Battus polydamas polydamas (Linnaeus) | x |    |
| Heraclides thoas brasiensis (Rothschild & Jordan) | x |    |
| Riodinidae (5) |    |    |
| Riodininae (5) |    |    |
| Calydnini (1) |    |    |
| Calydna sturnula (Geyer)* | x |    |
| Nymphidini (3) |    |    |
| Lemoniadiina (1) |    |    |
| Aricoris campestris (Bates) | x |    |
| Nymphidiina (1) |    |    |
| Nymphidium mantus (Cramer) | x |    |
| Theopina (1) |    |    |
| Theope foliorum (Bates)* | x |    |
| Symmachini (1) |    |    |
| Mesene florus (Fabricius) | x |    |
| Lycaenidae (7) |    |    |
| Polymommatinae (2) |    |    |
| Hemiarus hanno hanno (Stoll) | x |    |
| Leptotes cassius cassius (Cremer) | x |    |
| Theclinae (5) |    |    |
| Calycopis cissusa (Hewitson) | x |    |
| Electrostrymon endymion (Fabricius) | x |    |
| Oenomaus ortygnus (Cramer) | x |    |
| Pseudolycaena marsyas (Linnaeus) | x |    |
| Strymon bubastus bubastus (Stoll) | x |    |
| Pieridae (8) |    |    |
| Coliadinae (5) |    |    |
| Anteos menippe (Hübner) | x |    |
| Eurema elatea flavescens (Chavannes) | x |    |
| Phoebis marcellina (Linnaeus) | x |    |
| Pyrisitia leuce leuce (Boisdual) | x |    |
| Pyrisitia nise tenella (Boisdual) | x |    |
| Nymphalidae (33) |    |    |
| Biblidinae (5) |    |    |
| Ageronini (3) |    |    |
| Hamadryas amphinome amphinome (Linnaeus) | x | x |
| Hamadryas februa februa (Hübner) | x | x |
| Hamadryas feronia feronia (Linnaeus) | x | x |
| Eubagini (1) |    |    |
| Dynamine postverta postverta (Cramer) | x |    |
| Hesperiidae (34) |    |    |
| Eudamalinae (10) |    |    |

| TAXON            | EN | BT |
|------------------|----|----|
| Catonephelini (1) |    |    |
| Eunica tatila bellaria Fruhstorfer, | x |    |
| Charaxinae (4) |    |    |
| Anaenini (2) |    |    |
| Fountainea glycerium cratais (Hewitson) | x |    |
| Fountainea rypea phidile (Geyer) | x |    |
| Preponini (2) |    |    |
| Archaeoprepona demophon thalpius (Hübner) | x | x |
| Archaeoprepona demophon antimaque (Hübner) | x |    |
| Danainae (3) |    |    |
| Ithomini (2) |    |    |
| Methona singularis (Staudinger) | x |    |
| Scada reckia reckia (Hübner) | x |    |
| Danaini (1) |    |    |
| Danaus erippus (Cramer) | x |    |
| Helconinae (8) |    |    |
| Agraulis vanillae maculosa (Stichel) | x |    |
| Dryas iulia alcionea (Cramer) | x |    |
| Eueides isabella diana (Hübner) | x |    |
| Euptoieta hegesia meridiana (Stichel) | x |    |
| Heliconius erato phyllis (Fabricius) | x |    |
| Heliconius ethilla flavomaculatus Weymer | x |    |
| Heliconius melpomene nanna (Stichel) | x |    |
| Philaethria dido dido (Linnaeus) | x |    |
| Nymphalinae (6) |    |    |
| Nymphalini (1) |    |    |
| Colobura dirce dirce (Linnaeus) | x | x |
| Coeini (2) |    |    |
| Historis acheronta acheronta (Fabricius) | x |    |
| Historis odius dios Lamas | x | x |
| Kallimini (3) |    |    |
| Anartia jatrophae jatrophae (Linnaeus) | x |    |
| Junonia evarete evarete (Cramer) | x |    |
| Siproeta stelenes meridionalis (Fruhstorfer) | x | x |
| Satyrinae (7) |    |    |
| Brassolini (3) |    |    |
| Caligo teucer (Linnaeus) | x |    |
| Opsiphanes cassiae (Linnaeus) | x |    |
| Opsiphanes invirae (Hübner) | x |    |
| Morphini (1) |    |    |
| Morpho helenor (Cramer) | x | x |
| Satyrini (3) |    |    |
| Margueptychia libye (Linnaeus) | x | x |
| Taygetis laches laches (Fabricius) | x |    |
| Taygetis thamyras (Cramer) | x |    |

To be continue...
and Papilionidae (two). Out of the total species recorded, 79 were captured with entomological net, 19 with bait traps, and nine with both methods (Table 1). The species accumulation curve did not reach an asymptote, indicating that the number of the local butterfly species can increase with the intensity of the sampling effort. The estimators returned a richness ranging from 98 to 105 species per Bootstrap and CHAO 2, respectively (Figure 9).

The richness of the FLONA de Cabedelo butterflies is considered high when compared to inventors carried out in another Restinga forest along the Brazilian coast. Using only the entomological net as sampling method, for example, Monteiro et al. (2004) recorded 59 species for the Restinga de Jurubatiba National Park in Rio de Janeiro. Marchiori & Romanowski (2006), using the same sampling method, recorded 41 species in the Itapuã State Park, Rio Grande do Sul state. On the other hand, Bellaver et al. (2012) recorded 146 species in a Restinga forest of the Rio Grande do Sul state, of which 103 were collected with entomological net, 19 with bait traps, and 9 with both methods (Table 1). The species accumulation curve did not reach an asymptote, indicating the number of species can increase with the intensity of sampling efforts. The estimators returned a richness ranging from 98 to 105 species per Bootstrap and CHAO 2, respectively (Figure 9).

Although all these studies also applied entomological nets and bait traps as sampling methods (except for Keselring & Ebert [1982] that used only entomological net), it should be considered that they present different sampling efforts. Furthermore, it is largely known that seasonality and climate variation between different years effectively influences the presence of most butterfly species (Shapiro et al. 2003). Only long-term surveys can detect such variations and it should be explored in future studies in this region.

Studying the effect of forest fragmentation on the butterfly community, Ŭehara-Prado et al. (2007) found a positive correlation between fragment size and species richness. Considering that FLONA de Cabedelo is a reduced and fragmented area, such factors may influence its relatively low richness. However, future studies considering the composition of butterflies and the size area of the FLONA de Cabedelo are needed to test this hypothesis.

The richest family in our list was Hesperiidae, followed by Nymphalidae. This result was also found by Francini et al. (2011), Brown Jr & Freitas (1999), Keselring & Ebert (1982), and Dolubaina et al. (2011) in studies contemplated with several years of sampling. Brown Jr & Freitas (2000) present a compilation of surveys from several Brazilian sites where Hesperidae shows the highest number of species. According to Francini et al. (2011), the dominance of Hesperidae is the expected pattern for most studies relatively well sampled in the neotropical region, as shown in all above-mentioned studies, in which Hesperidae is considerably richer than Nymphalidae. In the FLONA de Cabedelo, however, the richness of these two families was quite similar, implying that...
Hesperiidae may have been one of the most underestimated families and additional records should be expected with an increased sampling effort.

Variations of this pattern were observed in studies carried out in Southern and in the Northeastern semi-arid regions of Brazil (Bonfanti et al. 2011; Morais et al. 2012; Bellerter et al. 2012; Nobre et al. 2008; Zacca et al. 2011; Zacca & Bravo 2012; Lima & Zacca 2014; Kerpel et al. 2014) in which Nymphalidae shows the highest number of species. This fact indicates a heterogeneous spatial distribution of butterfly families, probably due to the different environmental factors (Brown Jr & Freitas 2000) and host plants present in each studied site.

Although not considerably different, the higher richness of Pieridae concerning Lycaenidae and Riodinidae in the present study is an uncommon result in most butterfly surveys conducted in other regions of the country. This proportion differs from those recorded by Palluch et al. (2016) and Kesselring & Ebert (1982) for Atlantic Forest, in which Lycaenidae and Riodinidae were richer than Pieridae. In the Caatinga biome, Lima & Zacca (2014) recorded a higher richness of Riodinidae, followed by Pieridae and Lycaenidae and Zacca & Bravo (2012) recorded a higher richness of Lycaenidae, followed by Pieridae and Riodinidae. The variation in this proportion may be related to the challenge faced in sampling these groups in the field. While several pierids flight very high, the small size of the Lycaenidae and Riodinidae species associated with their behavior and seasonality makes them a little difficult to be captured, requiring more effort to be adequately sampled (Franchin et al. 2011). In the case of FLONA de Cabedelo, the higher richness of Pieridae draws attention to the fact that most species of this family are indicative of disturbed environments (Brown Jr 1992). On the other hand, Lycaenidae and Riodinidae are negatively correlated to disturbance, with a decrease in richness in these environments (Brown Jr & Freitas 2000).

In general, the butterfly composition of the FLONA de Cabedelo is dominated by species widely distributed and commonly found in open or forested areas in Brazil. Some of them are easily seen flying in the FLONA de Cabedelo, firstly due to their relatively large abundance, large body size, and flashy wing colors (Figures 10-15). It’s important to highlight that some species, such as Heracleides thoas brasilienis (Rothschild & Jordan), Battus polydamas polydamas (Linnaeus), Pyrisitia leuce leuce (Boisduval), Phoebis marcellina (Cramer), Ascia monuste orses (Godart) and Eurema elathea flavescens (Chavannes), are often associated with open, anthropic environments with a high degree of disturbance (Brown Jr 1992; Palluch et al. 2016). Additionally, the Lycaenidae Denoamaus ortygynus (Cramer) is considered the only species, among the six of the genus, associated with extremely degraded environments (Fainel 2012). In fact, although the FLONA de Cabedelo has some conserved environments, with dense forest, it also has open areas with intense anthropic pressure and the presence of ornamental plants which contributes to the dominance of these species.

Although almost all species recorded in the FLONA de Cabedelo are relatively common, five of them are new records for Paraíba state: Calydna sturnula (Geyer), Theope foliorum (Bates), Cogia hassan (Butler), Vehilius inca (Scudder), and Chiathion asychis (Stoll). These new records draw attention to the need for more studies, which will significantly increase the number of species recorded for the state. In the case of FLONA de Cabedelo, it is suggested to carry out monthly samplings which will certainly increase the list of species here presented. The species list here provided was made available for the elaboration of the management plan of the Unit Conservation (see ICMBio 2016).

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