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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 of these areas. This paper is an important contribution to the butterfly's knowledge, being the second inventory in the Restinga forest of northeastern Brazil. The survey was conducted in the Restinga de Cabedelo National Forest (FLONA de Cabedelo, following the Portuguese abbreviation) and aimed to provide preliminary information on the butterflies richness in this region. A total of 89 butterfly species and 1,503 individuals were recorded at FLONA de Cabedelo. Hesperiidae was the richest family (34 species), followed by Nymphalidae (33) Pieridae (eight), Lycaenidae (seven), Riodinidae (five), and Papilionidae (two). In general, the butterfly fauna of the FLONA de Cabedelo is dominated by species widely distributed and commonly found in open or forested areas in Brazil. Five species are new records in Paraíba state: *Calydna sturnula* (Geyer), *Theope foliorum* (Bates), *Cogia hassan* (Butler), *Vehilius inca* (Scudder), and *Chiothion asychis* (Stoll). We suggest carrying out monthly samplings which will certainly increase the list of species herein presented.

Keywords: Atlantic Forest; checklist; inventory; mangrove; northeastern.

The Brazilian Atlantic Forest is a heterogenic biome that includes different types of vegetation, such as mangroves and Restinga forests (Tabarelli *et al*. 2005). Despite being considered one of the most diverse hotspots of the world, the Atlantic Forest is currently threatened, with only 11.4 to 16% of its original coverage remaining intact (Ribeiro *et al*. 2009). According to Morellato & Haddad (2000) the historical exploitation of wood, the use of land for agriculture and livestock, and the construction of cities are the main factors of its degradation.

The Restinga forests are plant formations that occur on plains of quaternary sand deposits along the Brazilian coast. Their physiognomy varies from open herbaceous to a closed dense forest (Oliveira-Filho & Carvalho 1993). Although the Restinga forest is known for having elements from several Brazilian biomes, several endemic species are frequently found in these areas, especially plants and insects (Oliveira-Filho & Carvalho 1993; Vasconcellos *et al*. 2005). However, due to the long history of degradation, it is likely that many endemic or threatened species have disappeared before they were known (Rocha *et al*. 2007).

Inventorying species from a given locality is the first step towards their conservation (Freitas *et al*. 2006). However, knowing all the species from an ecosystem can take a long time (Santos 2006) which becomes an important problem considering the current rate of degradation of the tropical forests (Brown Jr & Brown 1992). Thus, many authors have focused on taxa that function as diversity and environmental quality indicators, and insects are frequently used for this purpose (Kremen 1992; Brown Jr 1997; Freitas *et al*. 2006). Among the insects, butterflies (Lepidoptera: Papilionoidea) are especially important for environmental assessment and monitoring due to their high diversity, specialization for specific resources, and rapid response to habitat changes. In addition, they are large, colorful, and have a relatively well-known taxonomy compared to other groups of invertebrates (Brown Jr 1991, 1992; Brown Jr & Freitas 1999).

Despite historical reduction of the Brazilian Restinga forests, little effort has been made to know about the butterfly fauna of these areas. The few studies carried out in Restinga forests are concentrated in the South and Southeast regions of the country (Monteiro *et al*. 2004; Marchiori & Romanowski 2006; Bellaver *et al*. 2012; Leviski *et al*. 2016). In the Northeast region, which is considered by Santos *et al*. (2008) as a gap in the knowledge of butterfly fauna, there is a single inventory conducted in an area of Restinga forest, with 11 species of fruit-feeding butterflies (Nymphalidae) recorded from Paraiba state (Lima-Verde & Hernández 2007).

Therefore, this study constitutes an important contribution to the knowledge on butterflies, being the second and so far, the most complete inventory about Restinga forest the northeastern Brazil. The inventory was conducted in the Restinga de Cabedelo National Forest, Paraíba State, and aimed to provide preliminary information on the butterflies richness in this region.

MATERIAL AND METHODS

The Restinga de Cabedelo National Forest (FLONA de Cabedelo, following the Portuguese abbreviation) is a Federal Conservation Unit created by Decree s/n of June 2, 2004 (Brasil 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

Figures 1-4. Localization of the study area. (1) Map of Brazil with emphasis on the state of Paraiba. (2) Map of the Paraíba with emphasis to the municipality of Cabedelo. (3) Map of the municipality of Cabedelo with the Restinga de Cabedelo National Forest highlighted in green. Source: the authors. (4) Expanded image of FLONA de Cabedelo, showing its boundaries (yellow line) and the location of the transects demarcated for butterflies collection (red lines). Image modified from Google Earth.

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

Figures 5-8. Landscapes of the Restinga de Cabedelo National Forest, Paraiba state, Brazil. (5) mangroves. (6) Restinga forest. (7) Road that gives access to the administrative center. (8) Railroad through which is made daily passenger transport between the municipalities of João Pessoa and Cabedelo. Source: the authors.

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, totalizing 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, totalizing 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 & Ebert ([1982]), Kerpel *et al.* (2014), and Ferreira-Junior (2021). The nomenclature follows Lamas (2004) updated with the modifications from Wahlberg *et al*. (2009) for Nymphalidae, Seraphim *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). Hesperiidae 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 brasiliensis (Rothschild & Jordan)	x	
Riodinidae (5)		
Riodininae (5)		
Calydnini (1)		
Calydna sturnula (Geyer)*	x	
Nymphidiini (3)		
Lemoniadina (1)		
Aricoris campestris (Bates)	x	
Nymphidiina (1)		
Nymphidium mantus (Cramer)	x	
Theopina (1)		
Theope foliorum (Bates)*	x	
Symmachiini (1)		
Mesene florus (Fabricius)	x	
Lycaenidae (7)		
Polyommatinae (2)		
Hemiargus 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 elathea flavecens (Chavannes)	x	
Phoebis marcellina (Linnaeus)	x	
Pyrisitia leuce leuce (Boisduval)	x	
Pyrisitia nise tenella (Boisduval)	x	
Pierinae (3)		
Ascia monuste orseis (Godart)	x	
Ganyra phaloe (Godart)	x	
Glutophrissa drusilla (Cramer)	x	
Nymphalidae (33)		
Biblidinae (5)		
Ageroniini (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	
Catonephelini (1)		
Eunica tatila bellaria Fruhstorfer,		x
Charaxinae (4)		
Anaeini (2)		
Fountainea glycerium cratais (Hewitson)		x
Fountainea ryphea phidile (Geyer)		x
Preponini (2)		
Archaeoprepona demophon thalpius (Hübner)	x	x
Archaeoprepona demophoon antimache (Hübner)		x
Danainae (3)		
Ithomiini (2)		
Methona singularis (Staudinger)	x	
Scada reckia reckia (Hübner)	x	
Danaini (1)		
Danaus erippus (Cramer)	x	
Heliconiinae (8)		
Agraulis vanillae maculosa (Stichel)	x	
Dryas iulia alcionea (Cramer)	x	
Eueides isabella dianasa (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 dious 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)		
Magneuptychia libye (Linnaeus)	x	x
Taygetis laches laches (Fabricius)		x
Taygetis thamyra (Cramer)		x
Hesperiidae (34)		
Eudaminae (10)		

to be continue...

Table 1. Continue...

TAXON	EN	BT
Eudamini (7)		
Eudamina (5)		
Cecropterus dorantes dorantes (Stoll)	x	
Chioides catillus (Cramer)	x	
Spicauda procne (Plöts)	x	
Spicauda teleus (Hübner)	x	
Urbanus proteus proteus (Linnaeus)	x	
Telemiadina (2)		
Ectomis octomaculata (Sepp)	x	
Ectomis sp. (Mabille)	x	
Oileidini (2)		
Typhedanina (2)		
Cogia hassan (Butler)*	x	
Cogia undulatus (Hewitson)	x	
Phocidini (1)		
Phocides polibius (Cramer)	x	
Hesperiinae (13)		
Hesperiini (13)		
Calpodina (4)		
Panoquina lucas (Fabricius)	x	
Panoquina ocola ocola (Edwards)	x	
Panoquina panoquinoides (Skinner)	x	
Saliana longirostris (Sepp)	x	
Hesperiina (4)		
Hylephila phyleus phyleus (Drury)	x	
Polites vibex (Geyer)	x	
Pompeius pompeius (Latreille)	x	
Wallengrenia otho (Smith)	x	
Moncina (5)		
Cymaenes alumna (Butler)	x	
Cymaenes tripunctus theogenis (Capronnier)	x	
Lerodea erithrostictus (Prittwitz)	x	
Morys compta (A. Butler)	x	
Vehilius inca (Scudder)*	x	
Pyrginae (11)		
Erynnini (6)		
Erynnina (6)		
Anaxas obliqua (Plöts)	x	
Chiothion asychis (Stoll)*	x	
Chiothion basigutta (Plötz)	x	
Echelatus sempiternus (Butler & H. Druce)	x	
Gorgythion begga (Prittwit)	x	
Timochares trifasciata (Hewitson)	x	
Pyrgini (5)		
Bunrsius orcus (Stoll)	x	
Chirgus veturius (Plöts)	x	
Heliopetes arsalte (Linnaeus)	x	
Heliopetes orbigera (Mabille)	x	
Zopyrion evenor (Godman)	x	
TOTAL	**79**	**19**

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. This value is higher than the richness of the areas above considered, however, the large coverage area with different environments and the greater sampling effort used in the study of Bellaver *et al*. (2012) should be highlighted.

Except for the survey carried out by Vasconcelos *et al*. (2009) in an urban park of the Atlantic Forest in the state of Bahia with a record of 70 species of butterflies, the low richness of the FLONA de Cabedelo is evident when compared to other inventories performed in Northeast Atlantic Forest and Caatinga biomes (Kesselring & Ebert [1982]; Paluch *et al*. 2011, 2016; Zacca & Bravo 2012; Melo *et al*. 2019; Dantas *et al*. 2021). Although all these studies also applied entomological nets and bait traps as sampling methods (except for Kesselring & 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-time 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, Uehara-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), Kesselring & Ebert ([1982]), and Dolibaina *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 Hesperiidae shows the highest number of species. According to Francini *et al*. (2011), the dominance of Hesperiidae is the expected pattern for most studies relatively well sampled in the neotropical region, as shown in all above-mentioned studies, in which Hesperiidae was considerably richer than Nymphalidae. In the FLONA de Cabedelo, however, the richness of these two families was quite similar, implying that

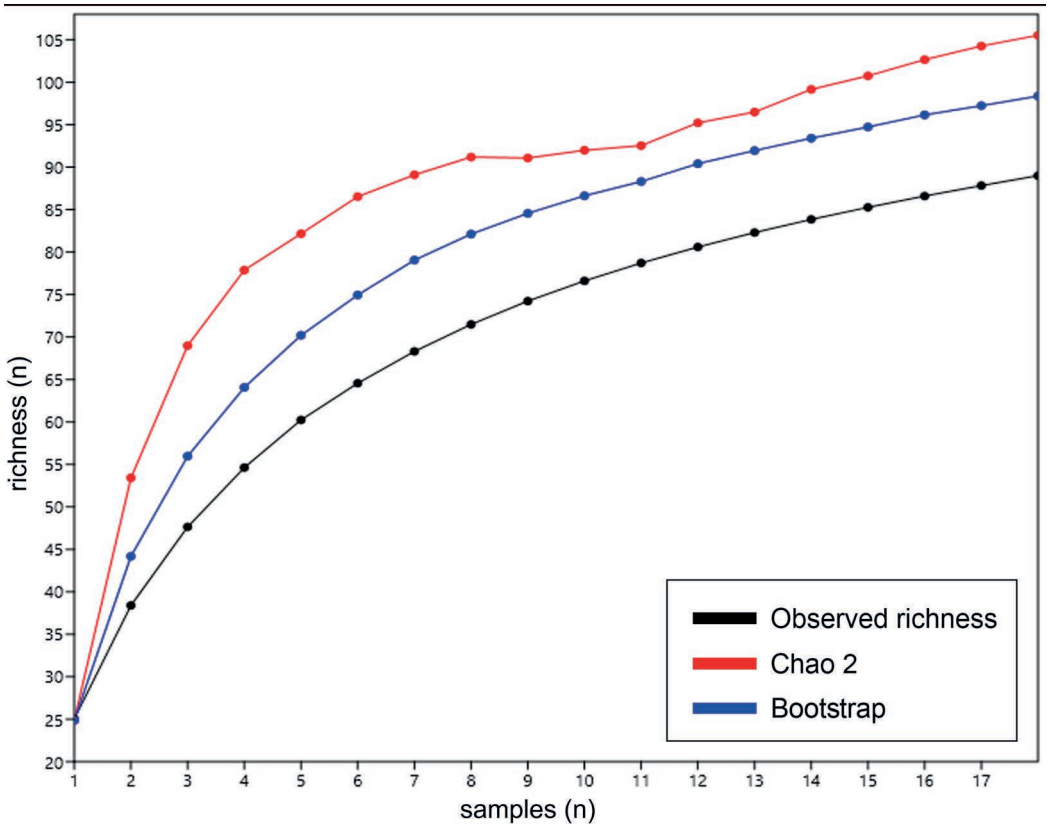

Figure 9. Species accumulation curve for the butterflies species collected between March 2013 and April 2014 at the Restinga de Cabedelo National Forest, Cabedelo, Paraíba state, Brazil, with the expected number of species by CHAO 2 and Bootstrap estimators. Source: the authors.

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 semiarid regions of Brazil (Bonfantti *et al*. 2011; Morais *et al*. 2012; Bellaver *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 Paluch *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 (Francini *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 *Heraclides thoas brasiliensis* (Rothschild & Jordan), *Battus polydamas polydamas* (Linnaeus), *Pyrisitia leuce leuce* (Boisduval), *Phoebis marcellina* (Cramer), *Ascia monuste orseis* (Godart) and *Eurema elathea flavecens* (Chavannes), are often associated with open, anthropic environments with a high degree of disturbance (Brown Jr 1992; Paluch *et al*. 2016). Additionally, the Lycaenidae *Oenomaus ortygnus* (Cramer) is considered the only species, among the six of the genus, associated with extremely degraded environments (Faynel 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 *Chiothion 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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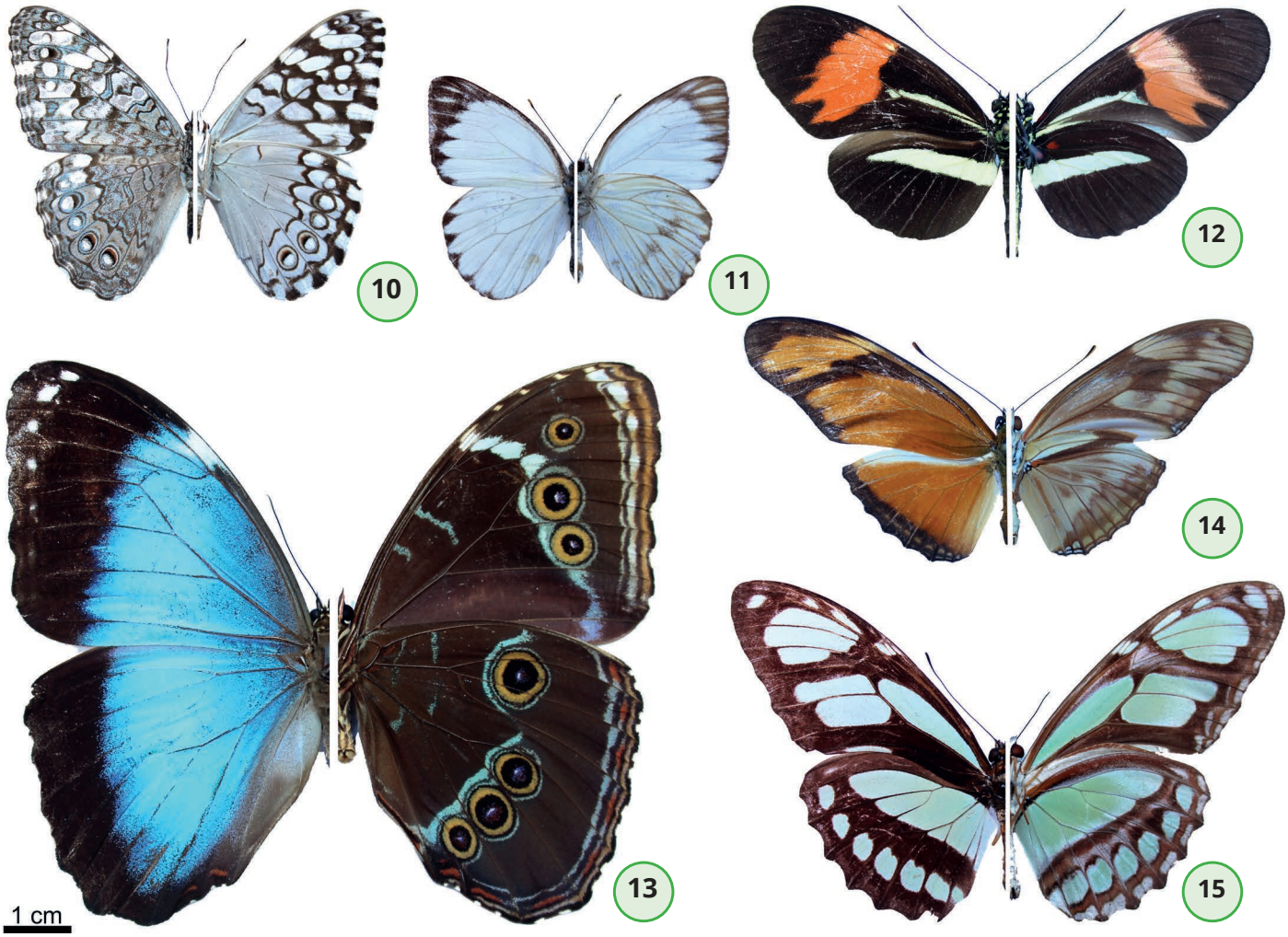

Figures 10-15. Dorsal (left) and ventral (right) views of the most common butterflies' species in the Restinga de Cabedelo national forest, Cabedelo, Paraíba state, Brazil: (10) *Hamadryas februa februa* (Hübner); (11) *Ascia monuste orseis* (Godart); (12) *Heliconius melpomene nanna* (Stichel); (13) *Morpho helenor* (Cramer); (14) *Dryas iulia alcionea* (Cramer); (15) *Philaethria dido dido* (Linnaeus). Source: the authors.

help in the identifications of several species of Hesperiidae and Satyrinae, respectively. To the Universidade Federal de Campina Grande for providing transport for the collection expedition. To Orione Álvares, environmental analyst for the support and invitation to participate in the Extreme Oriental of the Americas Project, and to Fabiano Gumier Costa of Instituto Chico Mendes de Conservação (ICMBio), Head of Conservation Unit. Finally, we thank the two anonymous reviewers for the valuable comments that have improved the quality of the manuscript.

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