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SYSTEMATICS, MORPHOLOGY AND PHYSIOLOGY

Euptychia bouletti (Le Cerf) n. comb. (Lepidoptera: Nymphalidae: Satyrinae), a Rare and Endangered Butterfly from Southeastern Brazil

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Introduction

Satyrinae (Nymphalidae) is one of the most diverse groups of butterflies, with more than 2,500 species occurring on all continents except Antarctica (Ackery *et al* 1998, Marín *et al* 2011). The group is particularly diverse in the Neotropical region where the species rich subtribe Euptychiina is represented by over 400 described species (Lamas 2004). This clade, however, is one of the least known groups of Satyrinae concerning its biology, ecology, and systematics (Marín *et al* 2011). There are few phylogenetic studies on this group, a large number of undescribed species and several polyphyletic genera waiting to be revised (Viloria 2003, Murray & Prowell 2005, Peña *et al* 2010, Marín *et al* 2011). Additionally, there are a number of genera that are still enigmatic in relation to their affinities within Satyrinae, including the monotypic genus *Caenoptychia* Le Cerf.

Caenoptychia bouletti Le Cerf (Fig 1) is an odd and rare species of Euptychiina known from a few sites of montane

Abstract

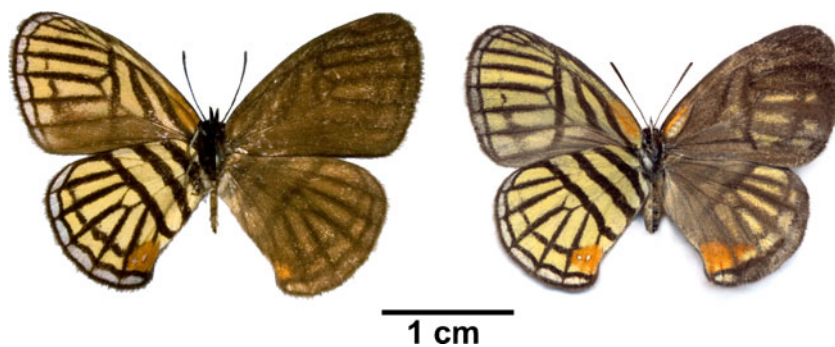
This paper discusses the systematic position of the rare and endangered satyrine butterfly *Caenoptychia bouletti* Le Cerf, the only included species in *Caenoptychia* (type species), based on adult morphology and molecular data. The results showed that *Caenoptychia* Le Cerf belongs to the *Euptychia* Hübner clade, and the genus is synonymized with *Euptychia*, new synonymy. *Euptychia bouletti* (Le Cerf) is a new combination. The male genitalia of *E. bouletti* showed at least one important synapomorphy with the other species of *Euptychia*, which is the presence of a posterior projection of the tegumen above the uncus. Molecular data reinforces the position of *Caenoptychia* within the genus *Euptychia*.

Atlantic Forest in Southeastern Brazil, from Espírito Santo to São Paulo (Freitas & Brown 2008). The species is considered endangered, and the main threats are the destruction and degradation of its habitats in recent years (Freitas & Brown 2008, Freitas 2010). The ventral wing pattern of this species is so distinctive from all other known satyrines that it was compared with some members of the family Lycaenidae by Le Cerf (1919) in its original description. This unique wing pattern probably made this species very conspicuous in early butterfly collections, resulting in three independent descriptions of this taxon in the first half of the twentieth century (Le Cerf 1919, Joicey & Talbot 1924, Gagarin 1936).

Since its description, the systematic position of *C. bouletti* remained enigmatic, and this taxon has not been treated either in the classic morphological work of Miller (1968) nor in the recent molecular phylogeny of Peña *et al* (2010).

In the present paper, the systematic position of *C. bouletti* is discussed based on morphological and molecular characters, as well as the taxonomic implications of its position within the Euptychiina.

Fig 1 *Euptychia bouletti*, ventral on the left and dorsal on the right. Left, male from Independência, Petrópolis, Rio de Janeiro (lectotype of *Ristia tigrina*); DZUP 615. Right, female from Maromba, Parque Nacional de Itatiaia, Rio de Janeiro; ZUEC.



Material and Methods

Specimens of *Caenoptychia bouletti* were studied in six collections. The acronyms for the collections are: DZUP, “Departamento de Zoologia, Universidade Federal do Paraná, Curitiba, Paraná, Brazil”; DZUP-OM, “Coleção Olaf H. H. Mielke, Curitiba, Paraná, Brazil”; MNHN, “Muséum National d’Histoire Naturelle, Paris, France”; MNRJ, “Museu Nacional da Universidade Federal do Rio de Janeiro, Rio de Janeiro, Rio de Janeiro, Brazil”; MZSP, “Museu de Zoologia, Universidade de São Paulo, São Paulo, São Paulo, Brazil”; USNM, “National Museum of Natural History, Smithsonian Institution, Washington, DC, USA”; ZUEC, “Museu de Zoologia da Universidade Estadual de Campinas, Unicamp, Campinas, São Paulo, Brazil” (Table 1).

Dissections were made using standard techniques. The abdomens were soaked in hot 10% KOH for 10 min before dissection, and dissected parts were stored in glycerol. Taxonomic nomenclature follows Lamas (2004), modified after Peña et al (2006).

DNA sequences of cytochrome c oxidase subunit I, elongation factor-1 alpha, glyceraldehyde-3-phosphate dehydrogenase, ribosomal protein S5, and wingless were sequenced for one individual (4,447 bp total; DNA voucher PM17-01), as described in Wahlberg & Wheat (2008) (GenBank accession numbers: JQ639284, JQ639285, JQ639286, JQ639287, and JQ639288). These sequences were analyzed together with the dataset compiled by Peña et al (2010) and included sequences of *Euptychia* species from Murray & Prowell (2005), using Bayesian Inference. Bayesian analyses (Huelsenbeck et al 2001, Huelsenbeck et al 2002) were carried out for the combined data set under the model GTR + Γ , using the program MrBayes 3.2 (Ronquist & Huelsenbeck 2003). Analysis of combined data by Bayesian methods permits partition-specific substitution models and parameters (Nylander et al 2004). For that reason, all substitution model parameters (gamma shape, character state frequencies, and substitution rates of GTR model) were allowed to vary across partitions (=genes). Two simultaneous chains were run for

10.0×10^6 generations, sampling trees every 1,000 cycles. The first 4,000 trees were discarded as “burn in” based on when the runs had converged and reached equilibrium. Additionally, Bayesian analyses were performed on separate gene datasets under the same settings as described above.

Results

Euptychia Hübner

Euptychia Hübner (1818, p. 20). Type-species *Euptychia mollina* Hübner (1818), designated by Hemming (1937, p. 150).

Caenoptychia Le Cerf (1919, p. 328). Type species *C. bouletti* by original designation. Syn. n.

Euptychia bouletti (Le Cerf) n. comb. (Figs 1, 2, and 3)

Caenoptychia bouletti Le Cerf (1919, p. 328). Holotype male, São Leopoldo, Rio Grande do Sul, Brazil, October, 1905; MNHN (examined).

Euptychia virgata Joicey & Talbot (1924, p. 570). One male (Holotype), Leopoldina, (unknown state), Brazil; BMNH.

Ristia tigrina Gagarin (1936, p. 8), Figs 2 and 3. Holotype (not designated in the collection) and specimens from October and November 1934, Independência, Petrópolis, Rio de Janeiro State, Brazil. Lectotype male (designed by Mielke & Casagrande 1986), Independência, Petrópolis, Brazil, 8 November 1934; DZUP.

Diagnosis

Body predominantly brown—wings rounded, brown dorsally (females usually present some yellow discal patches between main veins and with a unique ventral pattern of black stripes pattern over a light yellow background, with a marginal white stripe bordered with black. In both sexes, ventral forewing with a patch of orange scales in basal SC vein, and ventral hindwing with a patch of orange scales in

Table 1 Data for studied individuals of *Euptychia bouletti* from seven Museum collections (see text for museum acronyms) and field observations.

Code	Sex	Date	State	Municipality	Site	Altitude (m)
DZUP	1 male	13 Sept 1928	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 male	17 Mar 1935	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 male	5 Nov 1936	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 male ^a	15 Nov 1936	Rio de Janeiro	Petrópolis	Independência	900
DZUP	3 males	15 Nov 1936	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 male	17 Nov 1936	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 female ^a	29 Nov 1936	Rio de Janeiro	Petrópolis	Independência	900
DZUP	2 males	30 Nov 1936	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 male	26 Feb 1937	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 male	28 Feb 1937	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 male	4 Mar 1939	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 male	20 Mar 1939	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 male	21 Mar 1939	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 male	18 Oct 1939	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 male ^a	19 Oct 1939	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 male	20 Oct 1939	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 male	19 Nov 1939	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 male ^a	1 Jan 1960	Rio de Janeiro	Petrópolis	Parque São Vicente	930
DZUP	1 male	16 Nov 1960	Rio de Janeiro	Petrópolis	Independência	900
DZUP	1 female ^a	21 Jan 1966	Rio de Janeiro	Petrópolis	–	1,100
DZUP	1 male ^a	11 Apr 1968	Rio de Janeiro	Petrópolis	–	1,200
DZUP-OM	1 male	31 Oct 1964	Rio de Janeiro	Itatiaia	PNI-Maromba	1,100
DZUP-OM	1 male, 1 female	8 Dec 1936	Rio de Janeiro	Petrópolis	Independência	900
DZUP-OM	1 female	15 Nov 1936	Rio de Janeiro	Petrópolis	Independência	900
MNHN	1 male (holotype)	Oct 1905	Rio Grande do Sul ^b	São Leopoldo ^b	–	–
MNRJ	1 male	15 Nov 1936	Rio de Janeiro	Petrópolis	Alto da Independência	900
MNRJ	3 males	–	Rio de Janeiro	Petrópolis	–	–
MNRJ	1 male	29 Jan 1936	Rio de Janeiro	Itatiaia	–	900
MNRJ	2 males	8 Dec 1934	Rio de Janeiro	Petrópolis	Alto da Independência	900
MNRJ	2 males	8 Oct 1934	Rio de Janeiro	Petrópolis	–	–
MNRJ	1 male	29 Jan 1935	Rio de Janeiro	Itatiaia	–	–
MNRJ	1 male	29 Apr 1935	Rio de Janeiro	Itatiaia	–	–
MNRJ	1 male	–	Rio de Janeiro	Petrópolis	–	–
MNRJ	1 male	10 Apr 1936	Rio de Janeiro	Petrópolis	Alto da Independência	900
MNRJ	1 male	15 Oct 1936	Rio de Janeiro	Petrópolis	Alto da Independência	900
MZSP	1 male	Mar 1932	Rio de Janeiro	Teresópolis	–	1300
USNM	2 males, 1 female	24 Feb 1995	Rio de Janeiro	Itatiaia	PNI-Três Picos	1650
ZUEC	1 female	8 Feb 2011	Rio de Janeiro	Itatiaia	PNI-Maromba	1100
ZUEC	1 male ^a	30 Nov 1969	Rio de Janeiro	Petrópolis	Independência	900
KS Brown	1 male seen	16 Oct 1987	Espírito Santo	Santa Leopoldina	Cachoeira da Fumaça	300
JMS Bizarro	3 males seen	8 Jan 2012	Rio de Janeiro	Cachoeiras de Macacu	REG-Trilha Vermelha	1000

PNI Parque Nacional do Itatiaia, REG Reserva Ecológica de Guapiaçu.

^a Genitalia examined.

^b Probably wrong data (see text).

the tornus (partially present dorsally in males and larger in females). Both sexes are easily distinguished from all other

known Neotropical Euptychiina by its unique ventral wing pattern.

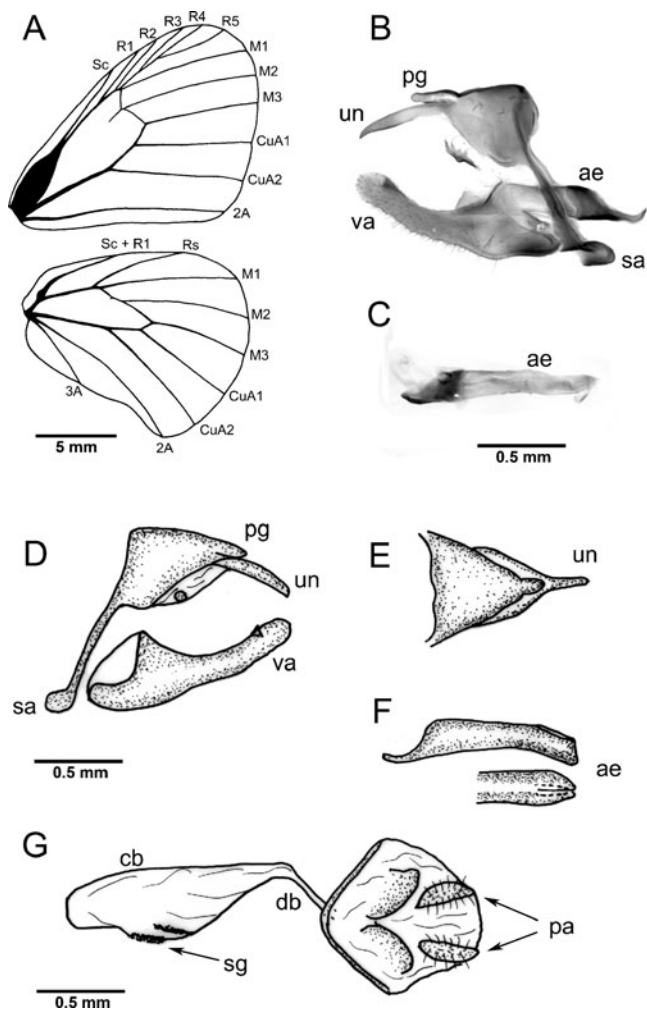


Fig 2 *Euptychia bouletti*. **a** Male wing venation. **b** Right view of entire male genitalia (photograph). **c** Left view of aedeagus (photograph). **d** Left view of male genitalia showing the internal view of right valva (drawing). **e** Dorsal view of tegumen (drawing). **f** Left view of aedeagus showing below a ventral view of aedeagus tip (drawing). **g** Female genitalia (drawing); male genitalia: *sa* saccus, *va* valva, *ae* aedeagus, *un* uncus, *pg* posterior projection of the tegumen; female genitalia: *cb* corpus bursae, *db* ductus bursae, *pa* papillae anales, *sg* genitalium.

The wing patterns of both sexes are very similar, with the main differences being that in females the wing profile is more rounded, general coloration is

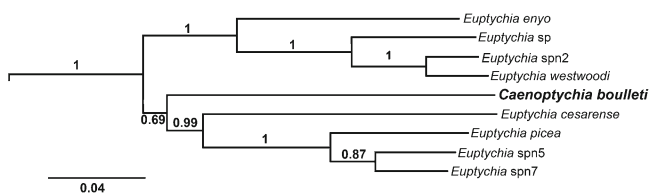


Fig 3 Relationships within the *Euptychia* clade based on DNA sequences from five gene regions and the dataset from Peña *et al* (2010) and Murray & Prowell (2005), analyzed using Bayesian inference. Posterior probabilities of nodes are given near the branches. The rest of Euptychiina are not shown for clarity.

paler than in males, and there are large patches of yellow and orange scales on the dorsal wings (males are uniformly dark brown dorsally) (Fig 1). The male wing venation and male and female genitalia are presented in Fig 2.

Male genitalia (Fig 2b–f). Saccus short and rounded; valvae elongated ending in a rounded bump with small irregular teeth; uncus elongated and pointed; tegumen with a developed pointed posterior projection; gnathos and appendices angulares absent; aedeagus short and broad, with a bifid tip in ventral view. The male genitalia is very similar to those of other *Euptychia* species, and quite distinctive in comparison with all other Euptychiina genera, because of the presence of a conspicuous posterior projection of the tegumen above the uncus (Fig 2b, d, e).

Female genitalia (Fig 2g). Similar to *Euptychia cesarense* Pulido, Andrade, Peña & Lamas (Pulido *et al* 2011), with papillae anales long and hairy adorned with setae, ductus bursae not sclerotized and corpus bursae rounded with two sclerotized linear signa longer than broader.

Systematic position

The Bayesian trees showed that *C. bouletti* is a member of the clade *Euptychia* (*sensu* Peña *et al* 2010), inside the genus *Euptychia* Hübner (Fig 3). *Euptychia* is divided into two well-supported clades, one with *E. cesarense* (= *Euptychia* sp. six of Peña *et al* 2010), *Euptychia picea* Butler and two undescribed species, and the other with *Euptychia westwoodi* Butler, and *Euptychia enyo* Butler and two undescribed species. The combined dataset tree placed *Caenoptychia* sister to the first clade, although with very low support, while the separate gene trees (not shown) weakly resolved the relations between the two clades and *Caenoptychia* as in the combined tree. Thus based on the total evidence, *Caenoptychia* Le Cerf is a new synonym of *Euptychia* Hübner, and *E. bouletti* (Le Cerf) is a new combination.

Geographic distribution

The species is only known from the Brazilian states of Espírito Santo (Santa Leopoldina), Rio de Janeiro (Itatiaia, Petrópolis, Teresópolis and Cachoeiras de Macacu), and São Paulo (Campos do Jordão) (Freitas & Brown 2008 and present study), usually in altitudes from 900 to 1,650 m asl (Table 1, Fig 4). The locality of São Leopoldo, Rio Grande do Sul, Brasil, mentioned for the holotype of *E. bouletti* is most likely a mistake; it should refer more likely

to Santa Leopoldina, Espírito Santo, where many Lepidoptera were collected by Michaelis in the beginning of the 20th century. The data from Campos do Jordão, in the state of São Paulo, comes from a personal communication of P. Gagarin, who observed the species in this locality. Unfortunately, the voucher specimen has not been found in all collections examined, and the presence in São Paulo needs confirmation. The citation of *E. bouletii* from Pará (Barlow *et al* 2008, Appendix), is wrong, and resulted from the identification of butterflies using D’Abrera (1988), where the name *E. bouletii* has been misplaced under an Amazonian *Magneuptychia* Forster (D’Abrera 1988, p. 762). Based on the known distribution (Fig 4), *E. bouletii* could be present in several high altitude areas in the mountains in southeastern Brazil and is expected to occur in several sites along the Mantiqueira Mountain range, including the southeastern region of the state of Minas Gerais.

Conservation status

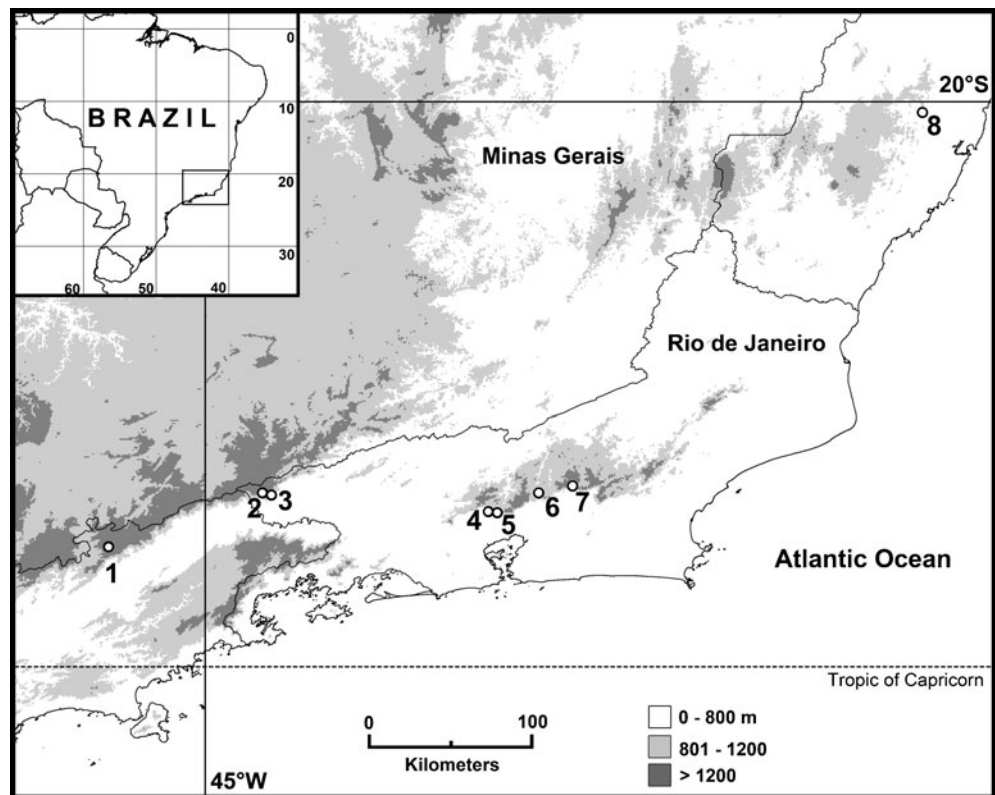
Based on the last official evaluation, *E. bouletii* has been considered “endangered” based on distribution criteria (Freitas & Brown 2008), especially taking into account that a well-established population has been destroyed by urbanization in the last decades (Freitas 2010). Fortunately, at least four known populations are

inside two National Parks and one Ecological Reserve, and are consequently protected. Future efforts should focus on discovering additional populations of this species through its extension of occurrence (Freitas & Marini-Filho 2011).

Discussion

In spite of its odd superficial appearance, both morphology and molecular data indicate that *E. bouletii* belongs to the clade *Euptychia* (*sensu* Peña *et al* 2010). The main morphological character corroborating this position is the presence of a conspicuous posterior projection of the tegumen above the uncus in *E. bouletii*, a structure present in all known *Euptychia* (including the type species—*E. mollina* (Hübner 1813) and absent from all other species of Euptychiina (see Forster 1964, Miller 1968, Freitas 2003, 2004, 2007, Freitas *et al* 2010, 2011, Peña & Lamas 2005, Pulido *et al* 2011; with the last article wrongly referring to this structure as a “superuncus”). Although the species of *Zischkaia* Forster have a similar structure in the male genitalia (Forster 1964), this is morphologically very distinct from that present in *Euptychia* and not considered homologous (Marin *et al*, in prep). Even considering the lack of consensus concerning the diagnostic characters of the genus *Euptychia* (Pulido *et al* 2011), the posterior projection of the tegumen appears to be restricted

Fig 4 Map showing the seven known localities for *Euptychia bouletii* in Southeastern Brazil (see Table 1 for further details). 1, Campos do Jordão, Estado de São Paulo; 2, Maromba, Parque Nacional do Itatiaia, Itatiaia, Estado do Rio de Janeiro; 3, Três Picos, Parque Nacional do Itatiaia, Itatiaia, Estado do Rio de Janeiro; 4, Parque São Vicente, Petrópolis, Estado do Rio de Janeiro; 5, Independência, Petrópolis, Estado do Rio de Janeiro; 6, Teresópolis, Estado do Rio de Janeiro; 7, Reserva Ecológica de Guapiaçu, Cachoeiras de Macacu, Estado do Rio de Janeiro; 8, Cachoeira da Fumaça, Santa Leopoldina, Estado do Espírito Santo.



to this clade, and could be considered a good synapomorphy shared by all taxa in the *Euptychia* clade. Additional non-exclusive characters for *E. bouletti*+*Euptychia* species are the absence of a gnathos and the presence of a recurrent vein in the forewing. Finally, the reduced humeral vein in the hindwing is an autapomorphy of *E. bouletti*.

There is very little available information about the habits of *E. bouletti* in nature. The species is apparently restricted to a few montane sites in southeastern Brazil (Freitas & Brown 2008) in the states of Espírito Santo, Rio de Janeiro, and São Paulo, and most of them above 900 m of altitude. The species is always rare and apparently very local, with usually no more than one or two individuals observed during a whole week of field work. A notable exception to this pattern was observed in a place known as “Independência” (type location for the synonym *R. tigrina* Gagarin), a suburb of the city of Petrópolis (state of Rio de Janeiro); in this site, the species was apparently common over many years on the top of a small hill until the region became mostly converted into an urban residential area (Freitas 2010), but there are many other unexplored hilltops close to this place. In this site, in Santa Leopoldina and in Cachoeiras do Macacu, males are apparently territorial and were observed exhibiting hill-topping behavior around 12:00 h to 13:00 h (K. S. Brown and J. M. S. Bizarro, pers. comm.), a relatively unusual behavior within Euptychiina. Based on its affinities, it is likely that *E. bouletti* uses a lycopsid as larval host plant, as reported for most other known *Euptychia* species (Singer et al 1971, DeVries 1987, Santin 2004, Beccaloni et al 2008).

The present results are of potential high significance for studies on the evolution and biogeography of Euptychiina. Since *E. bouletti* is endemic to SE Brazil (there is only one additional species of *Euptychia* that occurs also in SE Brazil), and *Euptychia* species are otherwise sister to all other Euptychiina (Marín et al 2011), or possibly even lying outside this group as currently defined (Peña et al 2010), its position within the tree could have a great influence on the definition of the ancestral area for Euptychiina. In this study, *E. bouletti* appeared within the genus *Euptychia*, based on informative shared morphological characters and well-supported molecular phylogenetic inferences.

Future work with more species of *Euptychia* and additional data may show the correct position of this taxon within the genus, and may resolve the relations between *E. bouletti* and the other *Euptychia* species. Clearly, more comprehensive work, including broad taxonomic sampling within this clade, is needed to help understand the evolutionary history of this enigmatic group of butterflies.

Checklist of the species of *Euptychia* Hübner

Euptychia bouletti (Le Cerf), *E. cesareense cesareense* Pulido, Andrade, Peña & Lamas, *E. cesareense viloriai* Andrade, Pulido, Pena & Lamas, *E. enyo* Butler, 1867

Euptychia fetna Butler, *Euptychia hannemanni* Forster, *Euptychia hilara* (C. Felder & R. Felder), *Euptychia insolata* Butler & H. Druce, *Euptychia jesia* Butler, *Euptychia meta* Weymer, *E. mollina* (Hübner), *E. picea* Butler, *Euptychia rubrofasciata* L. D. & J. Y. Miller, *Euptychia rufocincta* Weymer, *E. westwoodi* Butler.

Euptychia ernestina Weymer, mentioned in the “Checklist” by Lamas (2004) is excluded from the genus *Euptychia* by morphological and molecular reasons. The posterior projection of the tegumen is absent in this species, and the upperside of the hindwing bears a hairpencil at the anal margin. A new genus will be described for this species in a forthcoming paper (Freitas et al in prep.).

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