A new subspecies and validation of the enigmatic species *Adelpha herbita* Weymer endemic to the Brazilian Atlantic forest (Nymphalidae: Limenitidinae)

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Abstract: *Adelpha herbita* was described and illustrated by Weymer in 1907 from Santa Catarina in southern Brazil, but no specimens of the species were known in world collections and its taxonomic status has remained uncertain until now. Seven specimens of an apparently undescribed taxon were recently located in three collections, and examination of those specimens suggests that they represent a new subspecies of *A. herbita*, described here as *Adelpha herbita perdita* **n. ssp.** This discovery not only confirms the taxonomic validity of *A. herbita*, but also extends the range of the species within Brazil to Espírito Santo. A revised cladistic analysis of the *A. serpa* group was conducted using morphological data, but the relationships of this highly distinctive Atlantic forest endemic species remain obscure.

Key words: Atlantic forest, *A. serpa* group, cladistic analysis, rediscovery.

INTRODUCTION

Willmott (2003a) examined 20,796 specimens of *Adelpha* Hübner, [1819] while revising this genus of *c*. 90 species of Neotropical butterflies (see also Lamas, 2004; Willmott & Hall, 2013). While some *Adelpha* species are abundant and were represented by many specimens in collections, 14 species were represented by fewer than 25 specimens, and for one species, *Adelpha herbita* Weymer, 1907, not a single specimen could be located. *Adelpha herbita* was described in great detail from a single female specimen in Weymer's collection, collected in Santa Catarina, Brazil, but this specimen has not been located in any collections (including several German collections where other Weymer types are deposited) and is presumed lost. Nevertheless, both wing surfaces of the holotype were carefully illustrated with a color drawing (Weymer, 1907), which showed a highly distinctive taxon with an unusual grayish ventral surface lacking the reddish bands typical of *Adelpha* (Fig. 1A,B). This peculiar wing pattern and the absence of any known specimens, even in several Brazilian collections with extensive material from Santa Catarina, led to speculation that the holotype might be an aberration of a known species (several researchers, pers. comm. to KRW). Nevertheless, Willmott (2003a) noted several wing pattern characters that placed the species unequivocally in the *A. serpa* (Boisduval, 1836) group (Willmott, 2003a,b) but suggested that it was distinct from all other known species. Until now, however, this taxonomic hypothesis has been impossible to confirm, and the distribution and conservation status of the species has remained a mystery.

During recent curation of unsorted *Adelpha* material at the MGCL as part of a study of latitudinal gradients in *Adelpha* species richness, KRW discovered an unusual female *Adelpha* specimen from Espírito Santo, Brazil. Although this specimen has a ventral wing pattern that very closely matches the illustration of *A. herbita*, the dorsal pattern is quite different, instead being similar to many other co-occurring *Adelpha*, explaining why this specimen remained overlooked in the *pro tem* section of the collection. Circulation of an image of this specimen to AVLF and OHHM resulted in the discovery of six additional individuals in two Brazilian collections. The female in the DZUP had been identified as a probable new taxon awaiting further material, while those in the ZUEC were among previously unsorted, papered material. We therefore describe this new taxon as a subspecies of *A. herbita* and discuss the relationships of this very rare species to other members of the *A. serpa* group.

MATERIALS AND METHODS

Adelpha specimens were examined in major public and private collections in Europe, North and South America, as listed in Willmott (2003a), to record distributional data, study morphological variation, assess taxonomic diversity and locate type specimens. Acronyms used here include: **DZUP:** Departamento de Zoologia, Universidade Federal do Paraná, Curitiba, Paraná, Brazil; **MGCL**: Florida Museum of Natural History, Gainesville, USA; **ZUEC:** Museu de Zoologia da Universidade Estadual de Campinas, Unicamp, Campinas, São Paulo, Brazil. Morphology was studied using standard techniques, with adult abdomens being soaked in hot 10% KOH for 10–15 minutes, dissected and subsequently stored in glycerin. Body morphology and dissections were studied using a binocular microscope at 50× magnification. The terminology for morphology and wing pattern follows Willmott (2003a). We

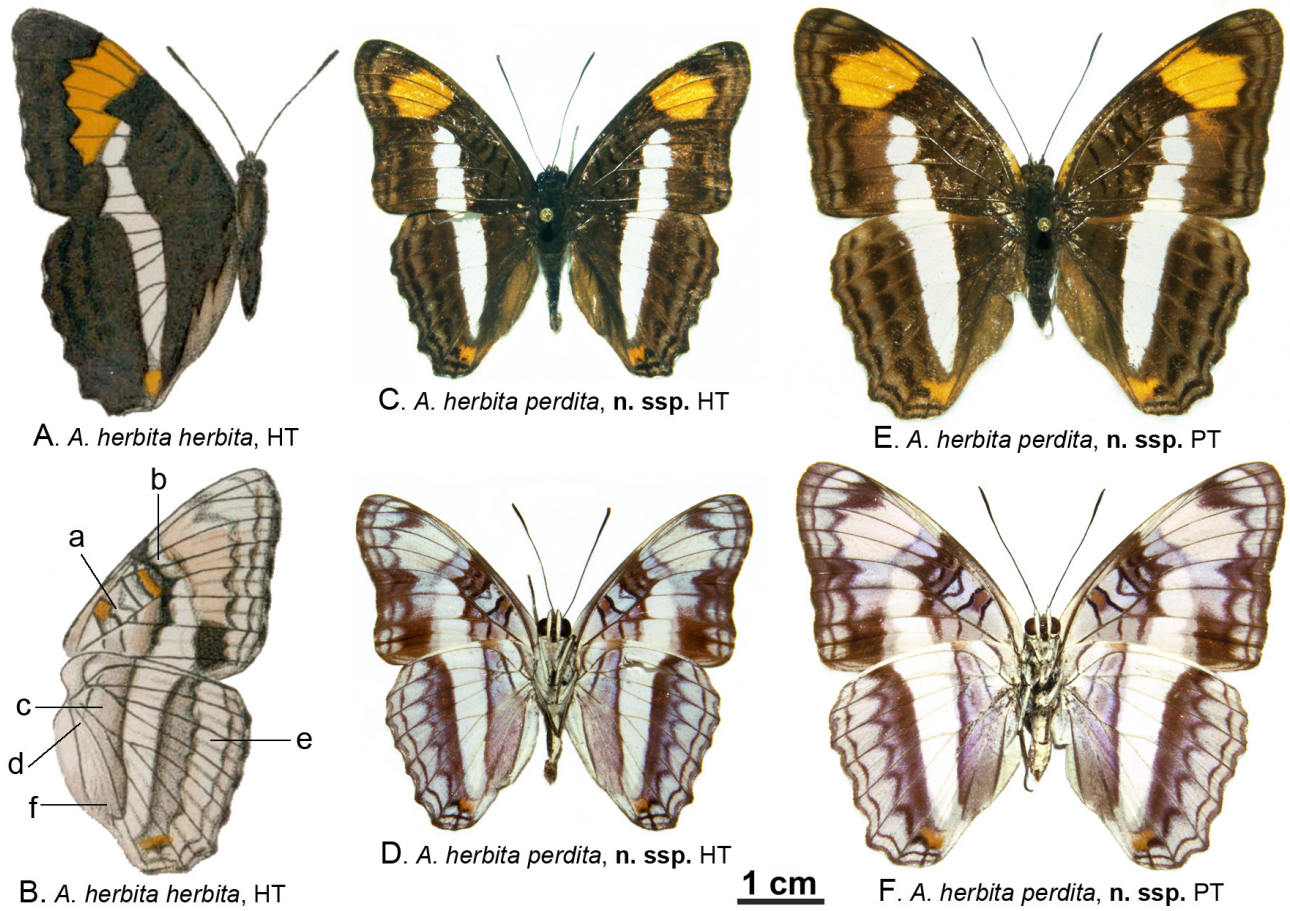

Fig. 1. A,B. *Adelpha herbita*, HT ♀, original illustration from Weymer (1907), dorsal (A) and ventral (B) surfaces. Lines with lower-case letters indicate characters referred to in the text. **C,D.** *Adelpha herbita perdita* **n. ssp.**, HT ♂, dorsal (C) and ventral (D) surfaces. **E,F**. *Adelpha herbita perdita* **n. ssp.**, PT ♀ (ZUEC LEP 9244), dorsal (E) and ventral (F) surfaces.

use the abbreviations DFW, VFW, DHW and VHW for dorsal and ventral forewing and hind wing.

We attempted to reassess the relationships of *A. herbita* by coding morphological characters described in Willmott (2003b) that were hitherto unknown for the species, omitting characters that were based on immature stages because these are unknown for *A. herbita* and many *A. serpa* group species. The analysis was restricted to the *A. serpa* group, and we included four *A. serpa* group species not coded by Willmott (2003b) which have recently been recognized by Prudic *et al.* (2008) and Willmott & Hall (2013), namely *A. eulalia* (Doubleday, [1848]), *A. californica* (Butler, 1865), *A. godmani* Fruhstorfer, 1913, and *A. margarita* Willmott & Hall, 2013. We included three additional basal *Adelpha* species with relatively unmodified wing patterns to help polarize characters, *A. alala* (Hewitson, 1847), *A gelania* (Godart, [1824]) and *A. fessonia* (Hewitson, 1847). Because the last two of these species and the *A. serpa* group are part of the same clade (Ebel *et al*., 2015), we used *A. alala* to root trees. We searched for maximum parsimony trees using a traditional heuristic search in TNT 1.5-beta (Goloboff *et al*., 2008) with 1000 replicate searches with a TBR swapping algorithm retaining no more than 10 trees in each search. All characters were unordered and equally weighted, and a strict consensus tree is used to summarize shortest tree topologies. To estimate the support for clades based on this character matrix, decay indices (Bremer, 1994) were calculated in TNT.

RESULTS

Adelpha herbita perdita Willmott & Freitas, **new subspecies**
Figs. 1-5

Description and diagnosis: Numerous characters place this new taxon within the *A. serpa* group, including, notably, the "V"-shaped third cell bar in the VFW discal cell and the absence of the clunicula (the spinose, dorsally projecting process from the middle of the inner, basal edge of the valva that is also absent in most other *A. serpa* group species) in the male genitalia. Other characters are indicated on Fig. 5. This new taxon is treated as conspecific with *A. herbita* based on a number of distinctive shared wing pattern characters (indicated on Fig. 1B), including on the ventral surface: a) the "V"-shaped third FW discal cell bar not touching the second discal cell bar; b) the FW upper postdiscal band being unbroken and even, touching the inner postdiscal series; c) lack of reddish shading in the HW discal cell; d) HW first discal cell bar not continuing to vein 3A; e) HW with very broad, undivided inner submarginal series; f) uniformly colored cell 3A-2A (unique in the *A. serpa* group).

The new subspecies differs from the nominate subspecies by the shape of the orange DFW subapical marking, which extends from the costa to terminate at vein M_3 or extend as diffuse scaling into cell Cu_1-M_3 (Fig. 1C,E); in the nominate subspecies (Fig. 1A) this orange marking extends to vein Cu_2 and closely borders the white markings in cells Cu_2-M_3. The illustration of the holotype of *A. h. herbita* also suggests that the inner submarginal series on the VFW may be broader in that subspecies, closely bordering the distal edge of the dorsal orange subapical markings anterior of vein M_1. In comparison with other similar species in southeastern Brazil, *A. h. perdita* may be distinguished by the combination of the "V"-shaped third VFW discal cell bar ('a' in Fig. 1B), overall lack of orange markings on the ventral surface, and complete upper postdiscal band on the VFW ('b' in Fig. 1B).

The male genitalia (Fig. 2) are notable for the absence of a clunicula, and the unusually elongate valva, which is somewhat similar to *A. nea* (Hewitson, 1847). The female genitalia (Fig. 3) are unique in *Adelpha* in having the seventh sternite partly recessed behind the sixth sternite, with the intersegmental membrane being slightly sclerotized and wrinkled, and unusual in the anterior ventral edge of the terminal tergite being weakly sclerotized. The sclerotized signa on the corpus bursae form a slightly elongated oval that is similar to that of *A. paroeca* (Bates, 1864).

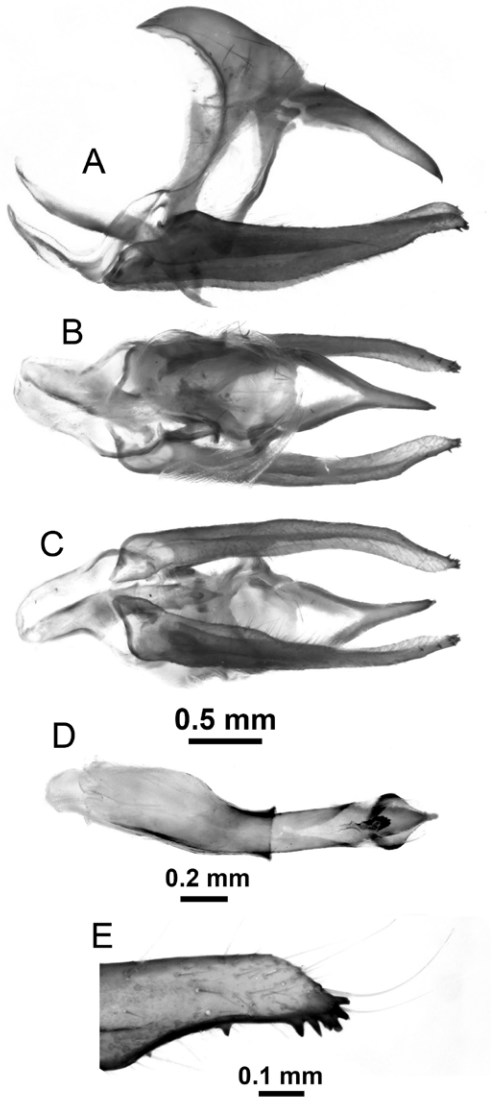

Fig. 2. Male genitalia of *A. herbita perdita* **n. ssp.** (holotype). **A.** lateral view; **B**. dorsal view; **C**. ventral view; **D**. dorsal view aedeagus; **E**. lateral view valva posterior tip.

Types: HOLOTYPE ♂ (Fig. 1C,D): **BRAZIL**: with the following labels (four labels separated by transverse bars): HOLOTYPUS / Floresta Nacional de Goytacazes, Linhares, Espírito Santo: Brazil, 19°26'11.47"S 40°4'52.79"W, 31.VIII.1973, 25-35 m, K. S. Brown leg. / Holotypus *Adelpha herbita perdita* Willmott & Freitas det. 2015 / ZUEC LEP 9238. Deposited in the ZUEC.
PARATYPES: **BRAZIL**: Espírito Santo: Linhares, 26-31-VIII-1974, 1 ♀, Claudionor Elias *leg*., DZ 33.435 (DZUP); Linhares, VIII.1973, 1 ♀, Paulo C. Elias *leg.*, (MGCL); Linhares, Floresta Nacional de Goytacazes, 25-35 m, 19°26'11.47"S, 40°4'52.79"W, 1 ♀, 31.VIII.1973, Keith S. Brown *leg*., ZUEC LEP 9239 (ZUEC); 2 ♀, VIII.1973, Paulo C. Elias *leg.*, ZUEC LEP 9244, ZUEC LEP 9245 (ZUEC); Linhares, Reserva Natural da Vale do Rio Doce, Torre de Observação, 60 m, 19°9'10.46"S, 40°1'8.12"W, 31.III.1995, 1 ♀, Keith S. Brown *leg.* (DNA voucher BLU 762), ZUEC LEP 9240 (ZUEC).

Etymology: The specific epithet, *perdita*, is a Latin feminine adjective meaning 'lost', alluding to the hitherto lack of knowledge of any specimens of this species.

Taxonomy and variation: As discussed above, several very distinctive wing pattern characters are shared by *A. h. perdita* and the illustration of the holotype of *A. herbita herbita*, strongly suggesting a close relationship between these taxa. The only substantial differences thus far known are in the dorsal wing pattern, which frequently varies intraspecifically in *Adelpha*. Indeed, analogous variation is seen in several sympatric *Adelpha* species, as discussed further below. It thus seems most appropriate to treat this new taxon as a subspecies of *A. herbita*. The seven known individuals are very similar in wing pattern, with only slight variation in pattern on both ventral and dorsal wings. The most conspicuous observed variation was in the thickness and darkness of the submarginal dark red lunules in cell Cu_1-M_3 on the ventral forewing.

Distribution: This subspecies is known from only two forest remnants close to the town of Linhares, Espírito Santo (Fig. 4).

Habitat and adult ecology: The two areas where this new subspecies has been collected are covered by tableland forest (known locally as "tabuleiro" forests), a formation associated with oligotrophic soils on flat land (20-60 m above sea level), presenting high floristic diversity (Peixoto *et al.*, 1995, 2008). These forest formations (also known as "Hiléia Bahiana", see Andrade-Lima, 1966) extend from Espírito Santo, north of the mouth of Rio Doce river, to south Bahia, presenting warm annual temperatures with little fluctuation and deciduousness in some tree species (Peixoto *et al.*, 2008).

The dorsal wing patterns of *A. herbita herbita* and *A. herbita perdita* match those of a number of sympatric *Adelpha*, and in particular the subspecies pairs *A. radiata radiata* Fruhstorfer, 1915/*A. r. myrlea* Fruhstorfer, 1915, and *A. e. epizygis* Fruhstorfer, 1915/*A. epizygis epona* Fruhstorfer, 1915, which show similar geographic variation in wing pattern between Santa Catarina and Espírito Santo (Willmott, 2003a). These species are therefore likely involved in mimicry, and the

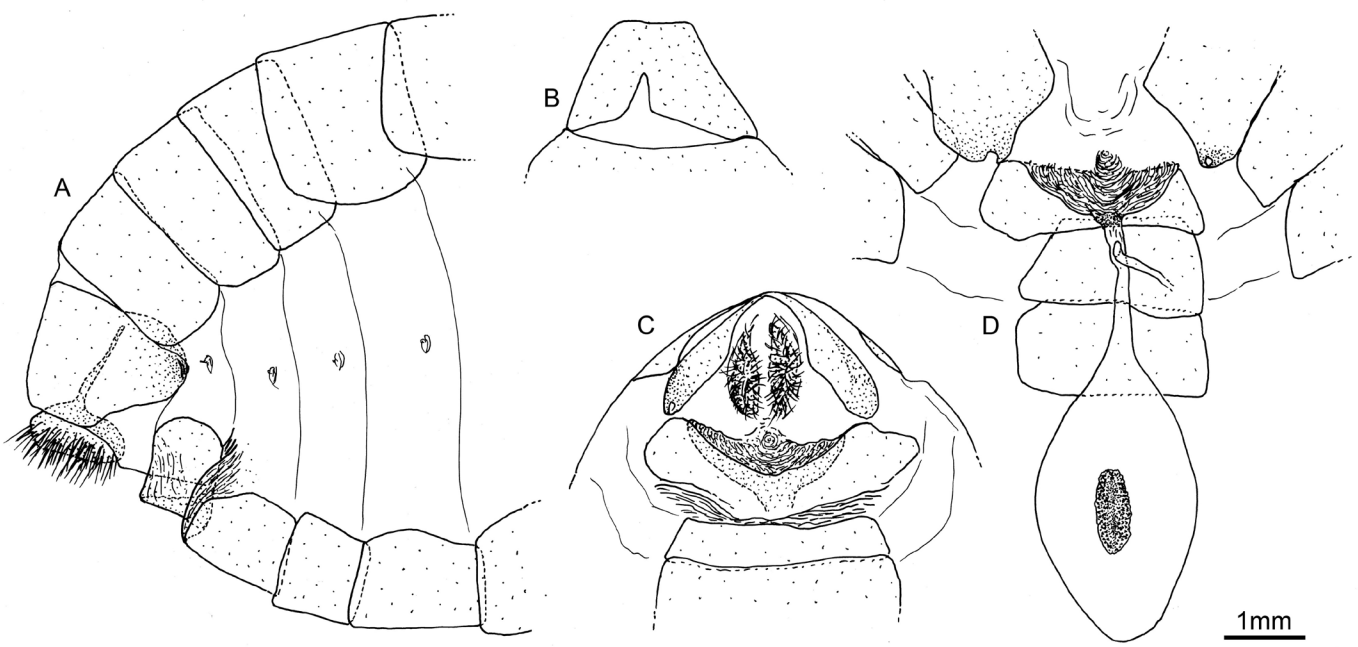

Fig. 3. Female genitalia of *A. herbita perdita* **n. ssp.** (paratype in MGCL). **A**. lateral view of posterior half of abdomen; **B**. dorsal view of terminal tergite; **C**. posterior view of abdomen posterior tip; **D**. dorsal view of genitalia.

presence of *A. radiata* and/or *A. epizygis* might indicate habitats suitable for *A. herbita.*

Relationships: The cladistic analysis found a total of 13 trees of length 111 (CI=0.68), whose strict consensus is shown in Fig. 5. The *A. serpa* group was strongly supported, as was a clade comprising the three species formerly treated as subspecies of *A. bredowii* and a clade containing all other *A. serpa* group species except *A. diocles*, which appeared as sister to this last clade. The relationships of *A. herbita* were not resolved, with the species forming a polytomy with *A. paroeca*, *A. zea*, *A. nea* and a clade containing *A. serpa*, *A. radiata*, *A. paraena* (Bates, 1865), *A. hyas* (Doyère, [1840]), *A. margarita*, *A. godmani*, and *A. seriphia* (C. & R. Felder, 1867).

DISCUSSION

The discovery of a population of *Adelpha herbita* is noteworthy because this is one of the rarest known species of *Adelpha* in the Brazilian Atlantic forest. Since the original description of *A. herbita*, whose holotype is missing, no individuals were collected for a period of 64 years. Accordingly, the seven individuals from this new population represent the only known specimens of *Adelpha herbita*.

Due to differences in dorsal wing pattern and because the seven known individuals are all from Espírito Santo (about 1,100 km northeast of Santa Catarina state, the alleged type locality of *A. herbita herbita*), this population is described as a new subspecies. However, the nominate subspecies, *A. herbita herbita*, remains an enigma; no populations are known, and the probable location of the type locality in Santa Catarina remains mysterious.

From a conservation perspective, *A. herbita perdita* deserves concern since it is known from only two localities in

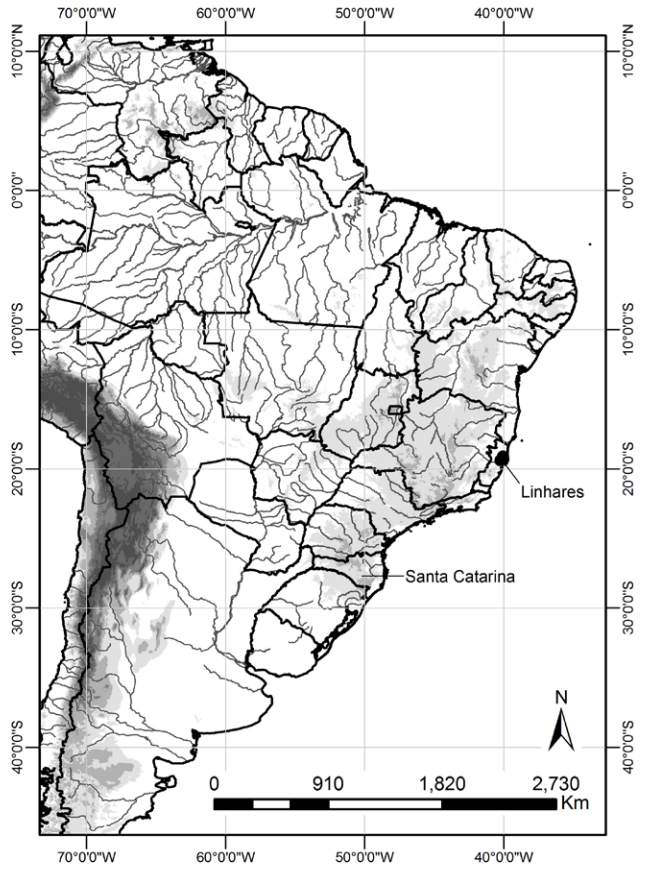

Fig. 4. Eastern and southern Brazil showing known distribution of *Adelpha herbita*: Santa Catarina state, the type locality for the nominate subspecies, and Linhares, Espírito Santo state, where all known specimens of *A. herbita perdita* **n. ssp.** were collected.

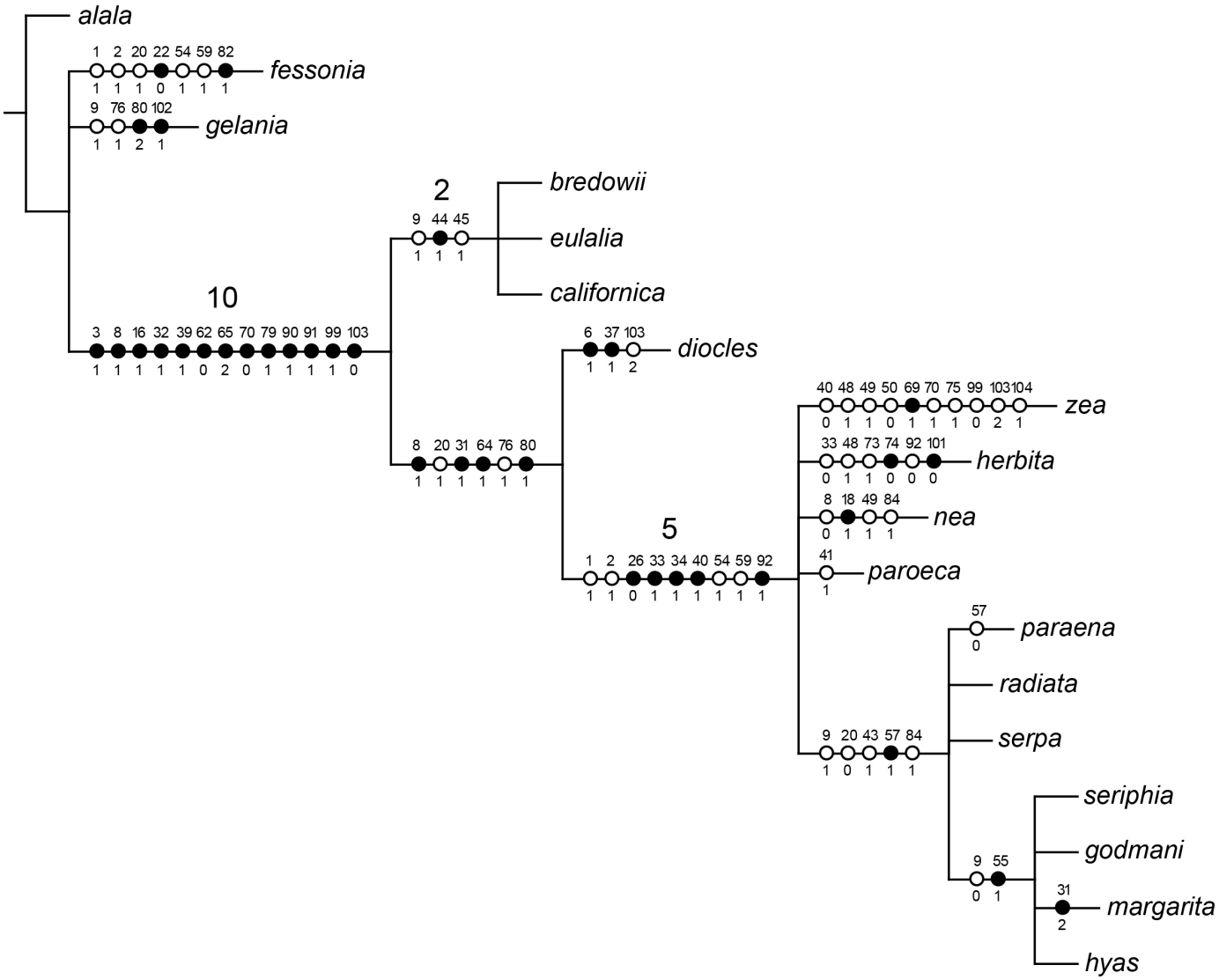

Fig. 5. Cladogram for *Adelpha serpa* group inferred from morphological characters described in Willmott (2003b). Circles represent optimized unambiguous characters, numbers above correspond to character numbers in Willmott (2003b), numbers below are character states. Solid circles indicate non-homoplasious character states, larger font numbers above nodes indicate Bremer support (> 1).

Espírito Santo. Although both known localities are preserved areas, there are few large continuous forest remnants in the tableland forests of North Espírito Santo and South Bahia (Ministério do Meio Ambiente, 2000), limiting other opportunities for the conservation of this subspecies. Candidate large continuous areas to be searched for *A. herbita perdita* include the Sooretama Biological Reserve in Espírito Santo, the Una Biological Reserve, the Monte Pascoal Historic National Park and the Descobrimento National Park, all in Bahia. Unfortunately, it is difficult to suggest optimal methods for sampling this species, if its biology is similar to that of other rare *A. serpa* group species. For example, despite several decades of intensive collecting in eastern Ecuador, *A. nea* is known from that region from just two specimens, and *A. radiata* Fruhstorfer, 1915 from just a single specimen. The hostplants and immature stages of *A. herbita* obviously remain unknown.

The cladistic analysis failed to clarify the relationships of *A. herbita* to other *A. serpa* group members. *Adelpha herbita* is a highly distinctive species that appears to share different morphological characters with *A. diocles* Godman & Salvin, 1878, *A. zea* (Hewitson, 1850), *A. nea* and *A. paroeca*, leading to a polytomy in the inferred tree (Fig. 5). Resolution of this cluster of species will hopefully be achieved once fresh tissue samples are available for molecular study, providing insights into how this group of mostly narrowly endemic species came to be widely scattered from the mountains of Central America to the southeast Brazilian Atlantic forests.

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Appendix 1.
Matrix of morphological character states used in the cladistic analysis. Characters correspond to those described in Willmott (2003b).

	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-106
alala	000000000?	0?00000000	05(01)102000(01)	0000000000	1000000000	0(05)00000000	0100001101	2101101000	0?00000000	000110?000	101010
fessonia	110100000?	1000000?01	0011020001	0000000020	0000000000	001100001(01)	1100111101	0001101000	010(01)000000	00010???00	101010
gelania	0001000010	1000000?00	???020001	0000000020	1????0??0?	????000000	1100111101	0001111002	?0001?0000	00010???00	11??10
bredowii	0011000110	1000010?0	0511020001	0100000010	(01)01110?00?	?510000000	100(02)211100	0?11001010	0000100001	101110?11?	100110
eulalia	0011000110	1000010?0	0511020001	0100000010	(01)01110?00?	?510000000	100(02)211100	0?11001010	0000100001	101110?11?	100110
californica	0011000110	1000010?0	0511020001	0100000010	(01)01110?00?	?510000000	100(02)(12)11100	0?11001010	0000100001	101110?11?	100110
diocles	00110101(01)1	1000010001	0(67)11020001	1100001?10	001000000?	1510000000	1001211100	0?11111011	??001?0001	101110?11?	102110
zea	111100010?	0?001?00?(01)	?7110?0001	1111000210	??00001110	1511000010	1001211111	0001111011	??001?0001	110110?101	102110
herbita	111100010?	0?001?0(02)01	?711000001	1101000211	0000001101	151100(01)0(01)0	1001211100	0?10?11011	??001?0001	100110?11?	000010
nea	111100000?	0?001?01?1	?7110?0001	1111000211	??0??01?1?	?51100001(01)	1011211100	1?01011011	??011?0001	110110?11?	100010
paroeca	111100010?	1000010001	?7110?0001	1111000211	1000000001	151100001(01)	1011211100	1?01011011	??001?0001	110110?11?	100010
paraena	1111000111	100001?00(01)	0(27)110?0001	1111000211	001(01)(01)0??0?	?51100001(01)	1011211100	1?01011011	??011?0001	110110?11?	100010
radiata	1111000111	100001?000	?7110?0001	1111000211	00(01)(01)(01)00(01)01	151100101(01)	1011211100	1?01011011	??011?0001	110110?11?	100010
serpa	1111000111	100001000(01)	?7110?0001	1111000211	0010(01)0?00?	151100101(01)	1011211100	1?01011011	??011?0001	110110?11?	100010
seriphia	111100010?	1000010000	?7110?0001	1111000211	001010??0?	?51110101(01)	1011211100	1?01011011	??0(01)1?0001	110110?11?	100010
godmani	111100010?	1000010000	?711000001	1111000211	001010??0?	?5111010(01)0	1011211100	1?01011011	??011?0001	110110?11?	100010
margarita	111100010?	1000010000	?711000001	2111000211	001010??0?	?511101010	1011211100	1?01011011	??011?0001	110110?11?	100010
hyas	111100(01)10?	1000010000	?7110?0001	1111000211	00?(01)?0??0?	?51110101(01)	1011211100	1?01011011	??011?0001	110110?11?	100010