



Redescription of *Paracles vulpina* (Hübner, [1825]) (Lepidoptera: Erebidae), with comments of the aquatic habit of larval instars

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Abstract

The genus *Paracles* Walker, 1855 is one of the most diverse genera present in Arctiinae and some species have larvae with aquatic habits. Several larvae were found swimming in flooded areas in different grasslands and were bred to adults to identify the species: *Paracles vulpina* (Hübner, [1825]). The current knowledge of immature stages of this species is not useful to identify and discriminate from other species of *Paracles*. For this reason, we proposed to redescribe adults of *P. vulpina*, showing for the first time the male and female genitalia, and improve the information on the immature stages and their habits. The adults can be recognized by the whitish paler brown band in the costal area in the forewing and whitish paler brown antenna. The final larval stage of *P. vulpina* can be differentiated from other species because it shows a body with a black pubescence except for a ferruginous subventral pubescence, blue dorsal verrucae, red lateral verrucae, and dorsal plastron with longest white setae. Because of its polyphagous feeding habit on aquatic and non aquatic plants we consider the aquatic larval habit is not a necessary strategy and could depend on the ground topography or weather of the locality.

Key words: Arctiinae, Arctiini, Spilosomina, tiger moth, larval morphology, genitalia, chaetotaxy

Introduction

Tiger moths (Lepidoptera: Erebidae: Arctiinae) are one of the most speciose group of Lepidoptera with almost 11,000 species and about 700 genera worldwide, of which at least half are present in the Neotropical region (Watson & Goodger 1986; Heppner 1991). In this subfamily *Paracles* Walker, 1855 is one of the most diverse genera with 77 species and 4 subspecies mostly distributed in South America with only one species in Central America (Vincent & Laguerre 2014).

Adults of *Paracles* have long and dense hairs in all their body, and the coloration pattern is dull, generally brownish, grayish, blackish, or yellowish. The males are smaller than females and some species have brachypterous females (Becker & Miller [1991]). The male and female genitalia of most species are unknown, therefore this makes their identification difficult. The classification for some species has been confusing because they were firstly included in other families such as Megalopygidae, Bombycidae, and Saturniidae, due to the hairy body and the similar coloration pattern of adults with these families (Becker & Miller [1991]). However, these peculiar characteristics are useful to identify them from most of the genera of tiger moths.

To our knowledge, *Paracles* is the genus of macrolepidoptera which have the more species with aquatic habits larvae (Heckman 2018; Morelli *et al.* 2018; Bentancur-Viglione *et al.* 2020). They can swim in stagnant or slow-

flowing waters such as lakes, lagoons, streams, and rivers (Bar 1873; Berg 1877a, b, c, d; Burmeister 1878; Adis 1983; Mey & Speidel 2008; Meneses *et al.* 2013; Drechsel 2014; Heckman 2018). These larvae lack tracheal gills and the respiration is mediated by air-holding hairs forming a plastron on the dorsal side (Mey & Speidel 2008; Morelli *et al.* 2018). The larvae of this genus have been studied as potential biological control agents of aquatic plants such as the weed *Cabomba caroliniana* Gray, an aquatic plant from South America which is becoming a serious pest worldwide (Schooler *et al.* 2009). Nevertheless, the authors could not identify the species due to the lack of information regarding life-cycles. There is a limited knowledge of the larvae and habits, which are unknown in most species (Mey & Speidel 2008; Heckman 2018).

Currently, seven species of *Paracles* have been reported to have aquatic habits: *Paracles laboulbeni* (Bar, 1873), *Paracles tenuis* (Berg, 1877a), *Paracles azollae* (Berg, 1877a), *Paracles burmeisteri* (Berg, 1877b), *Paracles argentina* (Berg, 1877b), *Paracles palustris* (Jørgensen, 1935), and *Paracles klagesi* (Rothschild, 1910). These species can feed on different species of aquatic plants such as *Eichhornia*, *Hydrocotyle*, *Mayaca*, *Potamogeton*, and *Tonina* (Bar 1873; Berg 1877a, b; Romero & Navarro 2009; Meneses *et al.* 2013; Drechsel 2014; Heckman 2018), and *P. laboulbeni* can also feed on species of algae such as *Melosira* and *Oedogonium* (Adis 1983).

In Argentina and Uruguay several larvae of *Paracles* were observed in different natural grasslands. From the adults collected and larvae reared to adults identified as *Paracles vulpina* (Hübner, [1825]), we could redescribe the species, showing for the first time their male and female genitalia. Additionally, the morphology of the immature stages was also described as well as the aquatic habits of larvae.

Material and Methods

Several larvae were found in native grassland of the Flooded Pampa, Buenos Aires, Argentina (Figs. 1a–b and Table 1). Some of the larvae found were sacrificed and conserved in ethanol 70% for study and others (n=30 in their last instar) were bred to adults individually in transparent plastic containers closed with a lid in a growth chamber with constant temperature (23°C [±1], photoperiod L16:D8 h). The larvae were fed with fresh leaves of the grazing brome *Bromus catharticus*, a palatable common native grass. These containers were daily visited to record the number of days from pupation to moth emergence. On the other hand, a single larva was found in the spring of 2016 in Santa Lucía, Montevideo, Uruguay (Figs. 1a, c, and Table 1), and it was maintained in an aquarium after being collected and bred to adult. Both localities where the larvae were found belong to the Rio de la Plata grasslands ecoregion (Soriano 1991; Paruelo *et al.* 2007). The eggs were not studied here because the life-cycle was not followed completely, only the mass of eggs was photographed. Only the cocoon and pupa from Santa Lucía were described and photographed. The larva was reared to adult stage and then deposited at FCEL. Additionally, adults were collected in Pampa de Achala, Córdoba, Argentina (Figs. 1a, d, and Table 1), a high plateau and flooded plain area. This area belongs to the Chacoan ecoregion (Oyarzabal *et al.* 2018). The maps here presented, were made with Simplemappr (Shorthouse 2010).

TABLE 1 Localities where adults and larvae were found including type of habitat and host plants where the larvae were found.

Locality	Latitude (decimal)	Longitude (decimal)	Habitat	Feeding on
“Las Chilcas” Farm, Buenos Aires Province, Argentina	-36.2667	-58.25	Flooded grassland	- <i>Schenodorus arundinaceus</i> (=Festuca arundinacea) (exotic grass) - <i>Lolium multiflorum</i> (exotic grass) - <i>Paspalum dilatatum</i> (native grass) - <i>Paspalum paludivagum</i> (native grass) - <i>Bromus catharticus</i> (native grass)
Humedales de Santa Lucía, Montevideo Department, Uruguay	-34.7924	-56.3481	Grassland and Caragüatales	- <i>Azollae</i> sp.
Quebrada del Condorito National Park, Córdoba Province, Argentina	-31.7096	-64.8481	High grassland	-No larvae collected

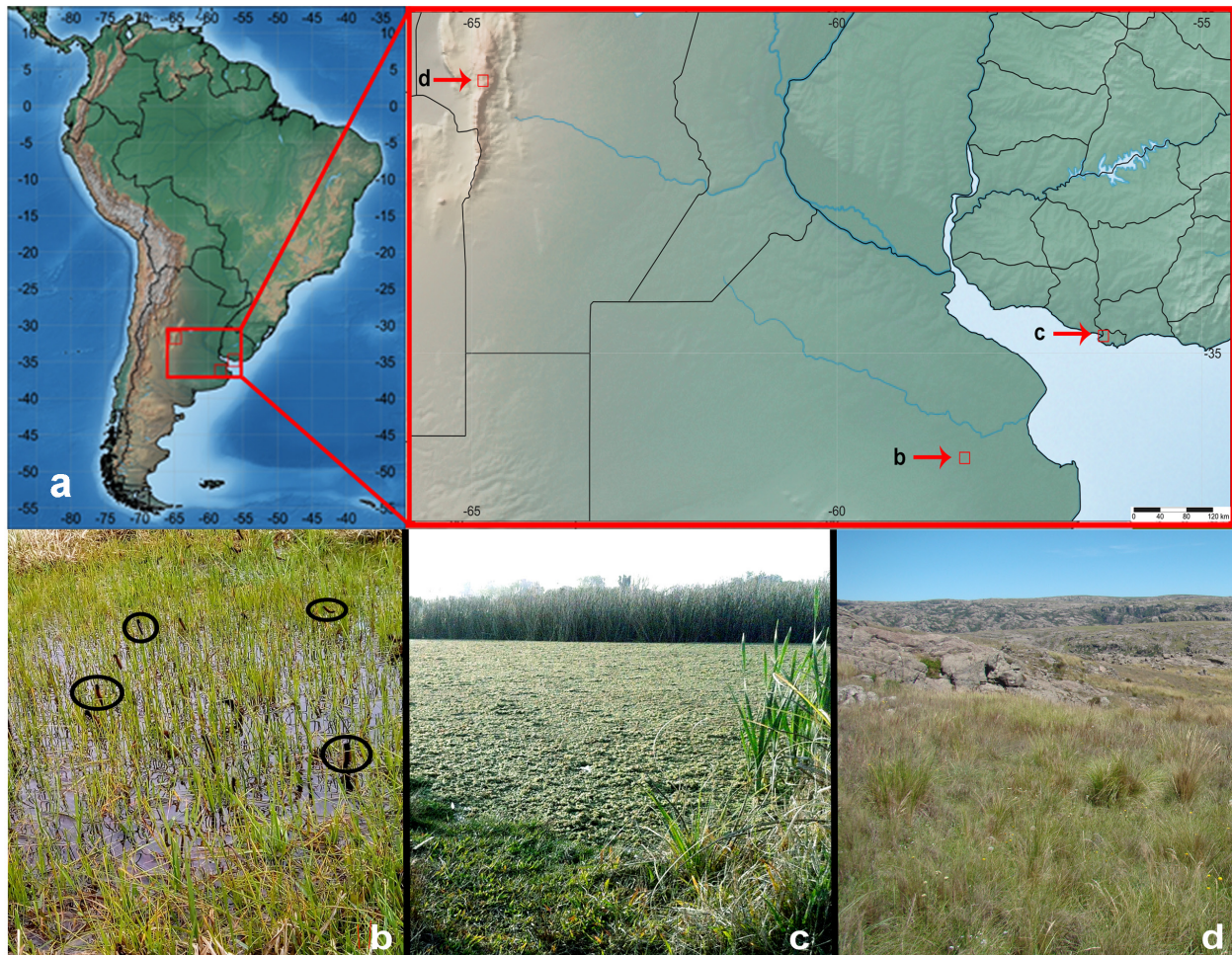


FIGURE 1 Localities and environments where larvae and adults of *Paracles vulpina* were found. **a** Map of South America and a closer view of the localities. Red squares = Localities, **b** Flooded Pampa, Buenos Aires, Argentina. Black circles: larvae eating grass, **c** Grassland and Caragüatales of Santa Lucía, Montevideo Department, Uruguay, **d** High grassland, Quebrada del Condorito National Park, Córdoba, Argentina.

Abdomens of the adults from Buenos Aires and Córdoba were removed and genitalia was dissected and prepared using a hot KOH (10%) solution to be compared (Beccacece 2017). Illustration images of male and female genitalia were taken with a camera attached to a ZeissStemi 2000-C stereomicroscope. The genital terminology followed Schmidt & Freina (2011).

Repository abbreviations

FCEL Facultad de Ciencias, Universidad de la República, Montevideo, Uruguay;
 MZUC Museo de Zoología de la Universidad Nacional de Córdoba, Córdoba, Argentina.

Results

Paracles vulpina (Hübner, [1825])
Antarctia vulpina Hübner, [1825]: pl. [193], figs. 1-4
Purius? vulpinus Walker, 1856: 1782 [new combination proposed]
Arctia pallicosta Boisduval, 1859: 158 [synonymized by Berg, 1899: 377]
Paracles vulpina (Hübner); Watson & Goodger, 1986: 32 [new combination proposed]

Type material. Undisclosed number of syntypes. These specimens could be lost or destroyed (Vincent & Laguerre 2014).

Redescription (Fig. 2a–f). **Male** (Fig. 2a–b): body completely covered with a great density of long hairs. Head: brown dorsally and dark brown ventrally. Posterior margin of the scape and eye edge light brown-orange. Antenna strongly bipectinate, whitish, and rami light brown. Palpi dark brown, erect, and directed to the ventral area. Proboscis reduced, no longer than the head, possibly not functional. Thorax: brown dorsally and dark brown ventrally. Legs: brown except the dorsal side of coxa, trochanter, and femur light brown-orange. Forewing – length 17–18 mm: shining brown dorsally with paler costa. Ventrally white except outer margin and apex darker and coastal area brownish. Hindwing – length 14–15 mm: dorsal and ventral white except the coastal and basal areas light brown-orange. Abdomen: brownish-orange dorsally and dark brown ventrally except the last segment the same as dorsal. There are darker specimens with same pattern. **Male genitalia** (Fig. 2d): genital capsule rhomboid. Uncus subtriangular with base rounded and apex finger-shape, curved ventrally; tegumen slightly rounded with an invagination at middle; juxta wide and trapezoidal; vinculum slightly rounded; saccus wide and broadly rounded; valvae shorter than uncus, with sacculus and costa fused, flattened and slightly directed towards the internal region; **aedeagus** (Fig. 2e) curved and slightly shorter than the genital capsule, caecum present and vesica membranous. **Female** (Fig. 2c): Externally similar to males except for the following features: larger and more robust, antennae with smaller rami. Forewing – length 24–20 mm: Brown dorsally with paler costa. Ventrally dark except base which is white and first part of costa which is brownish. Hindwing – length 14–15 mm: dorsally paler brown than forewing and inner margin whitish brown. Ventrally darker and base whitish brown. There are darker specimens with same pattern. **Female genitalia** (Fig. 2f): Papillae anales subquadrangular and setose. Pheromone gland tube-like, short, reaching the apophyses posteriores. Apophyses anteriores shorter than posteriores. Ductus bursae short, flattened, and sclerotized, tube-like. Corpus bursae oval, membranous with a circular striated band. Two rounded signa, sclerotized and present at the base of the corpus. Appendix bursae globose, membranous and similar in dimension to corpus bursae.

Immature stages (Figs. 3a–d, Fig. 4). **Eggs** (Fig. 3a): whitish, disposed in a mass and covered with pale scales. **Larvae** (Figs. 3b–c, Fig. 4): eruciform, very pubescent with a dark general color, with a very compact dorsal line of yellow silks. Body length up to 39 mm. \pm 3 mm. Aeriferous plastron present in T2–A9. Thoracic plastron with tufts of crisscrossed silks tightly packed and abdominal plastron airframe formed by plumes of tight white silks. **Head**: shiny black and rounded. **Thorax** (Fig. 4a): T1 plastron absent, dorsal, subdorsal and lateral verrucae blue; T2–3 plastron gray and verrucae same as T1 (Fig. 3d). **Abdomen** (Fig. 4b): A1 plastron gray and verrucae same as T1; A2 plastron white, dorsal and subdorsal verrucae blue, and lateral and subventral verrucae red; A3–8 plastron white, dorsal verrucae blue, and sublateral, lateral and subventral verrucae red; A9 plastron white, and dorsal, subdorsal, and lateral same as T1. **Cocoon** (Fig. 3d): cocoon elliptical, tapered at both ends, with circular emergency area. Maximum length 38 mm. All the cocoon wrapped in a loose weaving of light gray silks, compact cocoon with an interweaving of parchment-like appearance. The cocoon is made of grey soft silk, the long black hairs of the caterpillar are woven into the outer layer and with the white hairs the inner. **Pupa male** (Fig. 3d): Smooth tegument, caramel brown color, length 21 mm, and maximum width 8 mm. General elliptic shape, quadrangular broad front with slightly sinuous edges. Clipeus broadened, continuing the front edges with a slight lateral notch on each side, continuing in a rounded labyrinth. Labial palps with a wide base, tapering towards the end. Mouthpieces and antennae reach the edge of the metathorax. The meso and metathoracic podothecs visible, wide and with sinuous edges, tapering towards the apex. Antennae with visible external segmentation, somewhat shorter than the metathoracic podothec. Ceratothecas hardly visible accompanied the lateral edge of the pterothec. Pupae with seven free segments in the ventral area. Cremaster formed by a compact group of short and thick silks of bright amber color. Metathoracic spiracle visible, seven abdominal spiracles, from second to eighth segment. Anal slit transversely elongated framed in a pair of anal pads. Transverse short gonopore over a small blister in the ninth abdominal segment.

Biology. Females put the egg masses on the underside of the grass and cover them with a dense tuft of scales of the anal area. The caterpillar from Uruguay was found on aquatic plants in a lentic system and only ate *Azolla* at night. The pupae stage lasted for 21 days. On the other hand, hundreds of larvae (e.g.: 274 larvae in 12 m²) from the Flooding Pampa grassland in Buenos Aires (Argentina) were found feeding on different grasses such as *Schenodorus arundinaceus* (= *Festuca arundinacea*, tall fescue), *Lolium multiflorum* (annual ryegrass), *Paspalum dilatatum*, and *P. paludivagum* (native grasses). They were observed swimming and looking for new food resources but feeding out of the water (Fig. 1b; https://youtu.be/_cbyrf7-cDo). A total of 18 larvae of the 30 individuals collected and feeded with *Bromus catharticus* pupated. This stage lasted 22.33 days (\pm 0.43 S.E.) before developing a moth.

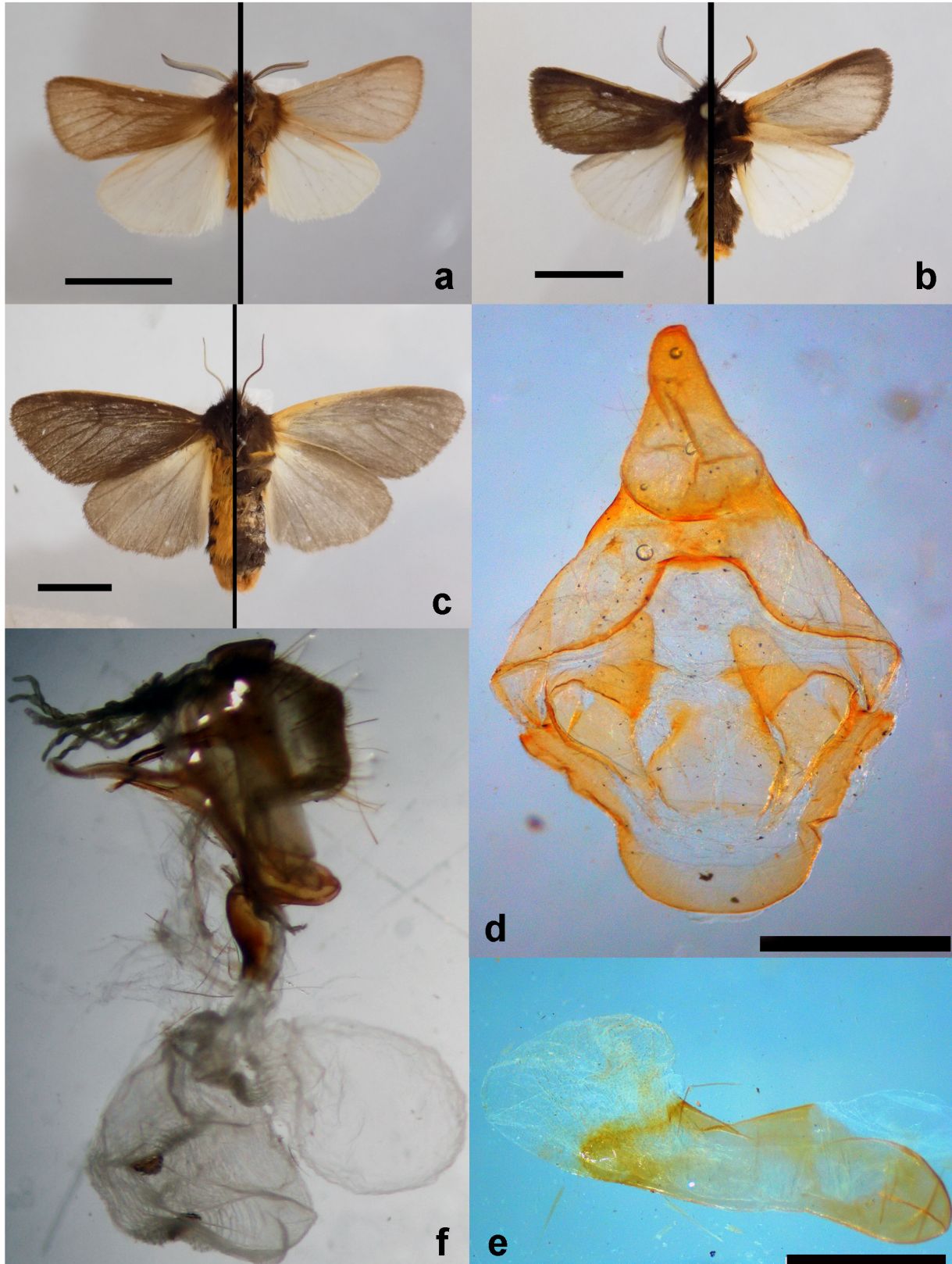


FIGURE 2 Habitus and genitalia of *Paracles vulpina* (Hübner, [1825]). **a** Dorsal (left) and ventral (right) view of adult male, **b** Dorsal (left) and ventral (right) view of darker adult male, **c** Dorsal (left) and ventral (right) view of adult female, **d** Male genitalia, **e** Aedeagus, **f** Female genitalia. Scale bar: 10 mm.

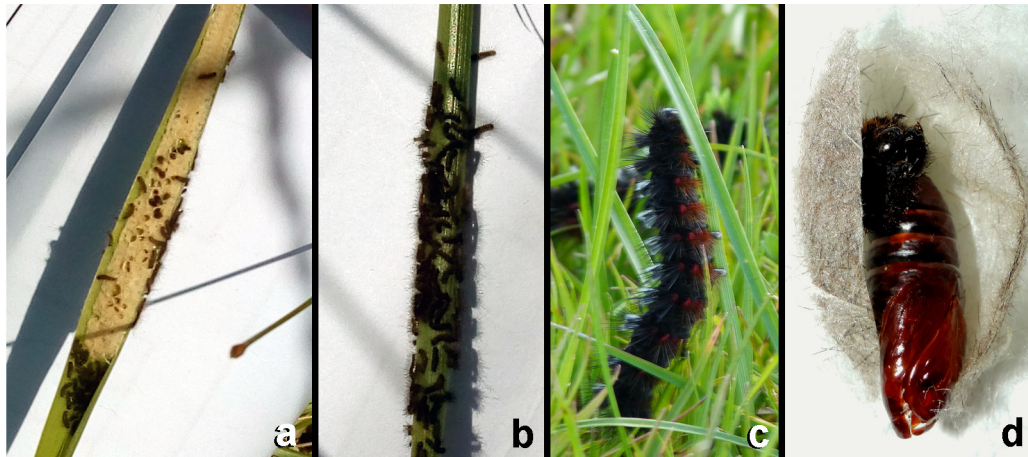


FIGURE 3 Immature stages of *Paracles vulpina* (Hübner, [1825]). **a** Egg masses on grass leaves and emergence of the first instar stage, **b** First instar stage, **c** Last instar stage, **d** Cocoon and pupa.

Distribution. Eastern Brazil, Uruguay, and central and eastern Argentina (Burmeister 1878; Köhler 1926; Breyer 1930; Pastrana 2004; Teston & Corseuil 2004; Ferro & Teston 2009; Formentini *et al.* 2015).

Material examined (adults). 5 males and 1 female: Buenos Aires (locality information in Table 1, all dissected), MZUC. 10 males and 2 females: Córdoba (locality information in Table 1, 2 males dissected and 1 female dissected), MZUC. 1 male: Santa Lucia, FCEL (locality information in Table 1).

Discussion

The adults of *P. vulpina* can be differentiated from other species of *Paracles* by the presence of a whitish paler brown band in costal area of forewing and whitish paler brown antenna in both sexes. These are the main diagnosis to identify the species. The habitus is similar to the type species of the genus: *Paracles contraria* Walker 1855 (Vincent & Laguerre 2014; Drechsel & Drechsel García 2016b) except for the ground color of this latter. Previous studies did not agree with some taxonomic rearrangement proposed concerning *P. vulpina* (Burmeister 1878; Hampson 1920; Strand 1919). These disagreements are because the type material of some species is lost, the type locality was not correctly specified in the original description and the original illustration representing the species is not enough detailed, e.g. *P. vulpina* (Type locality: South America) and *Paracles brunnea* (Hübner, [1831; Type locality: Montevideo [Uruguay]). Concerning these two species, Burmeister (1878) was the first to consider *P. brunnea* as a variation of *P. vulpina*. However, Hampson (1901) and Köhler (1926) omitted this synonymy and they commented that these two species can be differentiated on account of the larger pectination of the antenna, costal margin of forewing without a pale color band, and hindwing darker in *P. brunnea*. The habitus description used by these authors for *P. brunnea* is very different from *P. vulpina* and even, it is more similar to *Paracles severa* (Berg 1875). Strand (1919) also considered *P. brunnea* as a valid species in his catalogue. We found darker specimens in PN Condorito (Córdoba, Argentina), as Burmeister (1878) observed, and the genitalia is exactly the same as brownish specimens. A more careful study is needed using material from different localities or new collects to confirm if *P. brunnea* is or not a synonym of *P. vulpina*. On the other hand, it is necessary to discuss the status of *Paracles felderi* (Rothschild, 1910) because the habitus is very similar to *P. vulpina*. In fact, Hampson (1920) was the first to propose this species as a junior synonym of *P. vulpina* and later omitted. In this article, we show for the first time the male and female genitalia of *P. vulpina* and this will contribute to clarify the status of these species in further studies.

In the present study, the life cycle was not studied completely because we could not follow all stages. For this reason, more studies are necessary to know the number and differences of instars and development times for each stages. The female oviposits masses of eggs on the hostplant and cover them with a tuft of whitish scales from the anal area. This particular habit is a common behaviour in different species of *Paracles* (Köhler 1926) and other Lepidoptera and it seems to act as an egg protection against predator or weather climate (Floater 1998). Regarding the larvae of *P. vulpina*, we improved the previous information of Köhler (1926). He only provided superficial

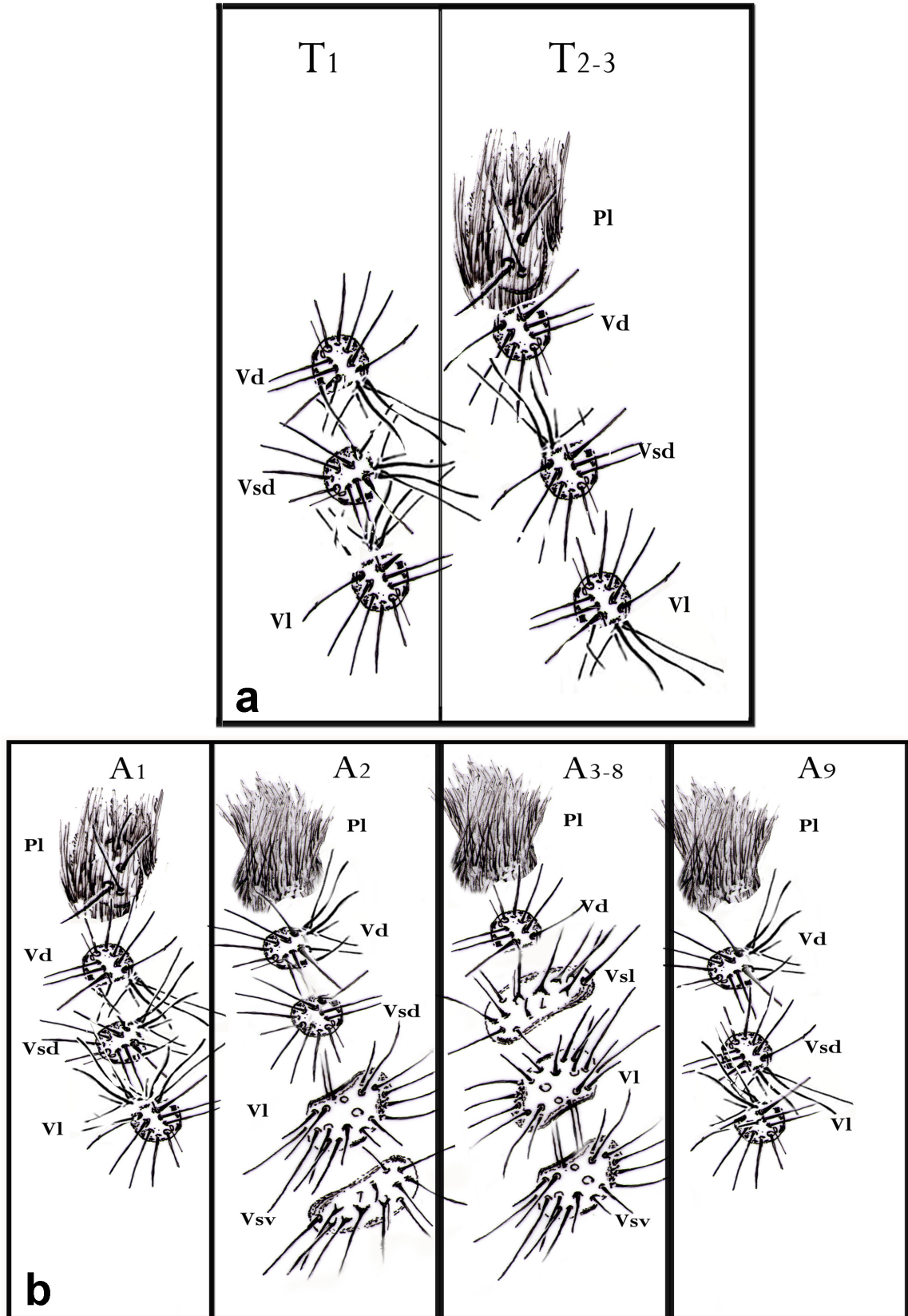


FIGURE 4 Chaetotaxy of the last instar of *Paracles vulpina* (Hübner, [1825]). **a** Thorax, **b** Abdomen. T1 (prothorax) Vd (dorsal verruca), Vsd (subdorsal verruca), VI (lateral Verruca), T2-3 (meso and metathorax), Pl (Plastron), A1-9 (abdominal segments 1 to 9), Vsv (subventral verruca).

characteristics of the coloration pattern and the number of verrucae and their disposition. We agree with this author about the characteristics of the larvae provided by Seitz (1920) are not from *P. vulpina* but correspond to *Paracles fusca* (Walker, 1856). This last species has a general brown greyish coloration, verrucae are red pinkish and the white yellowish dorsal band is visible because the setae of the plastron are shorts (Laplanche 2016). Rothschild (1911) also presents a lateral view illustration of *P. vulpina* larva. However, this is not useful because some important details to recognize this species are not visible. The last instar of *Paracles vulpina* can be differentiated from other species such as *P. contraria* and *P. azollae* because *P. vulpina* shows body with a black pubescence except for a ferruginous subventral pubescence, blue dorsal verrucae, red lateral verrucae, and dorsal plastron with longest white setae. *P. contraria* shows blue greyish marbled localized pubescent area, black lateral verrucae, and dorsal plastron with ocher yellowish shorter setae in well-defined areas. Finally, *P. azollae* shows a body with jet black pubescence, reddish lateral verrucae, and dorsal plastron with white well-compacted setae (Laplanche 2018; Morelli *et al.* 2018). About the pupa, this is here the first time this stage is described and shown. Köhler (1926) briefly described the cocoon. This stage has the same common characteristics than other Arctiinae.

Larvae of *P. vulpina* have been previously reported feeding on several plants from different families such as *Cucurbita maxima* (Fam. Cucurbitaceae), *Medicago sativa*, and *Glycine max* (alfalfa and soybean; Fam. Fabaceae), *Quercus robur* (oak; Fam. Fagaceae), *Juglans regia* (walnut; Fam. Juglandaceae), *Dactylis glomerata* (Orchardgrass; Fam. Poaceae), *Populus nigra* and *Salix humboldtiana* (poplar and willow; Fam. Salicaceae), *Cupania vernalis* (camboatá; Fam. Sapindaceae), and *Tilia cordata* (linden; Fam. Malvaceae; Hayward 1969; Pastrana 2004; Formentini *et al.* 2015). However, this information should be corroborated because an incorrect identification of the larvae could have happened. On the other hand, Köhler (1926) also commented that the larvae can feed on different herbaceous plants species. As shown previously, we observed several larvae feeding on different Poaceae such as the invasive grass *Schenodorus arundinaceus* (= *Festuca arundinacea*, tall fescue) (Graff *et al.* 2020), and *Lolium multiflorum* (annual ryegrass), both endophyte-infected plants with alkaloid compounds. The larvae were also observed on native grasses species such as *Paspalum dilatatum* and *Paspalidium paludivagum*, and they accepted *Bromus catharticus* as foodplant. A single larva was registered feeding of the aquatic plant *Azolla* in Uruguay. The evidence of the polyphagia and the possibility to consume toxic plants can be related to supplementing endogenous defenses by sequestering compounds from their host plants (Zaspel *et al.* 2014). Regarding the biology of caterpillars observed in the field, the aquatic larval habit is not a necessary strategy and it could be used depending on the ground topography or weather of the place.

Despite similar dull coloration of the *Paracles* adults, this speciose genus is maybe not a monophyletic group because there are important differences on the habitus, genitalia and immature stages of several species (Becker & Miller [1991]; Meneses *et al.* 2013; Drechsel 2014; Drechsel & Drechsel García 2016a, b, 2017). For this reason, it is necessary to make a full review of *Paracles*. The aquatic habits of larvae instars could be a character to consider. However, more studies of life-cycles and natural history of the *Paracles* species are needed.

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Author contributions

All authors contributed to the study conception and design. All authors read and approved the final manuscript.

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