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RESEARCH

Life history, first host plant record and distribution of the Neotropical tiger moth *Cosmosoma thoracicum* Schaus 1905 (Lepidoptera: Erebidae: Arctiinae: Euchromiina) in Peru

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Abstract

We describe for the first time the complete life cycle of the Neotropical tiger moth *Cosmosoma thoracicum* Schaus 1905, based on three individuals, one male and two females, reared at the Finca Las Piedras field station (Madre de Dios, Peru), as well as the first record of this species' host plant. Three eggs collected in their natural habitat went through seven larval stages (male) and five and seven larval stages (females). All individuals fed on *Lasiacis ligulata* Hitchcock & Chase, 1917 (Poaceae: Panicoideae: Panaceae), which is the first Poaceae recorded as a host plant for the genus *Cosmosoma* Hübner, [1823]. We also propose *Poecilosoma mapirense* Strand, 1915 as a **new synonym** for *C. thoracicum* and document both the species' previously undescribed female genitalia and geographical distribution in Peru. Finally, we provide genetic sequence information for the DNA barcode region (COI) derived from two individuals of *C. thoracicum*.

Keywords Amazonia · Lasiacis ligulata · Larval morphology · Madre de Dios · Natural history · Poaceae

Resumen

Se describe por primera vez el ciclo completo de la polilla tigre *Cosmosoma thoracicum* Schaus 1905, basado en tres individuos, un macho y dos hembras. Los especímenes fueron criados en la estación de campo Finca Las Piedras (Madre de Dios, Perú), así como el primer registro de la planta hospedera de esta especie. Tres huevos fueron recolectados en su hábitat natural pasando por siete estadios larvales (macho) y 5 o 7 estadios larvales (hembras). La planta hospedera fue identificada como *Lasiacis ligulata* Hitchcock and Chase, 1917 (Poaceae: Panicoideae: Panaceae), siendo la primera planta de la familia Poaceae registrada como planta hospedera para el género *Cosmosoma* Hübner, [1823]. Así mismo, se propone *Poecilosoma mapirense* Strand, 1915 como una nueva sinonimia para *C. thoracicum,* documentando tanto la genitalia femenina, no descrita previamente para la especie, como la distribución geográfica de la especie en Perú. Finalmente, proporcionamos información de la secuencia genética para la región de código de barras de ADN (COI) derivada de dos individuos de *C. thoracicum*.

Palabras Clave Amazonía · Historia natural · *Lasiacis ligulata* · Morfología de larvas · Madre de Dios · Poaceae

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Introduction

The genus *Cosmosoma* Hübner, [1823] (Lepidoptera: Erebidae: Arctiinae) occurs throughout much of the Americas, from the southeastern United States and Mexico through Central and South America to southern Brazil and northern Argentina (Lara-Pérez and Mora-Aguilar 2021). It is also very diverse: the genus contains more than 120 species (Draudt 1913–1916), making it the most speciose of all the genera in the arctiine subtribe Euchromiina. Although major revision is required – *Cosmosoma* does not appear to be monophyletic (Grados and Ramírez 2021), multiple synonymies almost certainly exist, and various species likely belong within other genera – the genus, or the closely-related groups that comprise it, represents a significant portion of arctiine diversity in the Americas, especially in the Neotropics. Peru, a megadiverse country located at the intersection of the Andes mountains and Amazon basin, appears to be a hotspot for diversity of Arctiinae and *Cosmosoma* in particular: at least 40 species of *Cosmosoma* are known to occur throughout the country, with 12 species identified from the department of Loreto, in the northern Peruvian Amazon, alone (Grados and Ramírez 2021).

Unfortunately, our knowledge of *Cosmosoma* life history, natural history, and ecology lags even further behind our patchy understanding of its taxonomy and systematics. For example, only two species' host plants in nature have been documented to date: *Cosmosoma auge* (Linnaeus, 1767) in Cuba and Florida (USA) feeds on *Mikania micrantha* Kunth, [1818] (Asteraceae) (Dyar 1896a; León-Finale and Barro 2014), and *C. myrodora* Dyar 1907 feeds on *M. cordifolia* (L. f.) Willd., 1803 (Asteraceae) in Puerto Rico (Torres 1992) and *M. scandens* (L.) Willd., 1803 (Asteraceae) in Florida (USA; Moscoso et al. 2013). Furthermore, few studies have documented the morphological characteristics of the larvae of any *Cosmosoma* species (i.e., Dyar 1896b, 1907; Conner et al. 2000). Such life and natural history observations, as well as information regarding other ecological interactions, hold great potential for illuminating our understanding of other poorly known aspects of arctiine biology. For instance, synapomorphic characters of the larvae and pupae might suggest or lend support to new taxonomic arrangements, as can information regarding host plant use across putative cryptic taxa (*e.g.*, Hebert et al. 2004). Therefore, more work should be done to examine the basic biology of *Cosmosoma* and other poorly-known groups of arctiine moths and other Lepidoptera throughout the Neotropics.

In the present study, we fill in major gaps in our knowledge of the biology of *Cosmosoma thoracicum* Schaus 1905 by describing, for the first time, the species' complete life cycle and natural host plant, in the southern Peruvian Amazon. We also report a new synonym, *Poecilosoma mapirense* Strand, 1915, for *C. thoracicum,* provide the first description of the female genitalia, and document the species' geographical distribution in Peru. Finally, we provide genetic sequence information for the mitochondrial cytochrome c oxidase subunit I (COI) DNA barcode region derived from two individuals of *C. thoracicum*, to aid in future research on this group.

Materials and methods

Study site and fieldwork

The study was conducted at Finca Las Piedras (FLP), a biological field research station spanning 74 ha of "terra firme" or upland rainforest, wetlands dominated by the palm *Mauritia flexuosa* L. f., [1782] (Arecaecae), and both active and abandoned agricultural fields and regenerating, secondary forest. The site is located approximately 48 km north of the regional capital of Puerto Maldonado in the department of Madre de Dios, Peru (−12.22789, −69.11119; ca. 240 m a.s.l.); for more information about this site, see Baine et al. (2019) and See et al. (2018). Fieldwork was carried out between Jan-Jun 2021 and Jan-Jun 2023 as part of the long term "Lepidoptera Diversity and Biology Project" led in partnership by the Alliance for a Sustainable Amazon and the Pontifical Catholic University of Peru, which aims to improve our knowledge of Amazonian biodiversity in southeastern Peru with a focus on Lepidoptera as a model group.

Rearing and morphological study

Three specimens were collected as eggs from natural host plants at FLP and taken to the field laboratory, where they were reared to adulthood inside 1 L plastic containers covered with a nylon mesh fabric secured with an elastic band. The containers were cleaned or changed daily to avoid contamination by fungi or other pathogens. Each specimen was assigned a unique code (male: 2021-FLP-IMM-0133 and females: 2021-FLP-IMM-0134, 2023-FLP-IMM-0315) and were reared on leaves of the host plant they were collected from. Leaves were changed regularly to maintain a fresh food supply and kept hydrated using floral water tubes. The immatures were inspected daily for morphological changes and photographed using a Nikon D7100 digital camera with Tokina Macro 100 F2.8 D AT-X Pro lens. All photographs included a scale in millimeters to allow for measurements by size-calibrated pixel counting. We follow the terminology of Peterson (1964) for the description of the eggs and Stehr (1987) for the description of the larvae. Genital dissections

were made following standard procedures. Terminal parts of male and female abdomens were removed and soaked in 10% KOH solution for 5–10 min in a water bath. The soft tissue from each abdomen was cleaned by immersion in water and subsequently placed in glycerol. Chlorazole black was used as a staining medium to improve observation of characters (Cannon 1937, 1941; Carayon 1969). Genital terminology follows Klots (1956).

Species identification and distribution

Arctiine moth species identification was made on the basis of comparisons with specimens in the following collections: Deutsches Entomologisches Institut Müncheberg, Germany (DEIM); Museo de Historia Natural, Universidad Nacional Mayor de San Marcos, Lima, Peru (MUSM); National Museum of Natural History—Smithsonian Institution, Washington D.C., USA (NMNH). The host plant was identified using the dichotomous key for the subfamily Panicoideae and subsequently for the genus *Lasiacis* developed by Tovar (1993).

All specimens used to generate the species occurrence records were collected during numerous field expeditions conducted over a span of three decades. Localities of the specimens were georeferenced and mapped using ESRI ArcMap 10.8. Only specimens with precise location data were included. Elevation data were obtained as raster data from the Geospatial Information Authority of Japan and categorized into intervals for visualization. Subsequently, the graphical output was edited in Adobe Photoshop 2025 to improve the positioning and visualization of the map elements.

Molecular work

We sequenced the DNA barcoding region of the mitochondrial cytochrome c oxidase 1 (COI) gene for two individuals captured in Tambopata, Peru. The tissue was obtained from the femur of the forelegs. Molecular work was performed at the Biodiversity Institute of Ontario, University of Guelph, Canada, following a standardized protocol (de Waard et al. 2008). This work was conducted as part of the Wired Amazon/Discovering New Species project in Tambopata.

Results

Cosmosoma thoracicum individuals were collected on 16 Feb. 2021 (two specimens; 1 male and 1 female) and 24 Mar. 2023 (1 female) and reared to adulthood. The single male passed through seven larval instars while the two female individuals passed through five and seven instars (see Table 1 for dates of collection and key life history events).

Description of immature stages

Life stages of male C. thoracicum (2021-FLP-IMM-133) (n = 1 throughout)

Duration from egg collection to adult eclosion: 38 days.

Egg (Fig. 1a, b**).** Chorion smooth, translucent, light-yellow and slightly shiny, hemispherical with a flattened base. No changes were observed in the egg between field collection and hatching. Diameter: approximately 0.8 mm. Duration: 2 days from collection.

First instar (Fig. 1c, d**).** Head capsule semitranslucent yellow with black stemmata, width = 0.23 mm. Primary setae A1, A2, A3, S1, S2, L1, P1, P2, F1, AF1, AF2, C1 and C2 present, Fa and La pores present. Smooth, ivory-colored translucent body that turns green along the abdomen and thorax after feeding. Numerous, mostly similarly-sized black setae with white tips arranged in tufts and arising from verrucae are present on T2 to A9: two dorsal, two lateral and two latero-ventral tufts. Some setae of the tufts are significantly longer on segments T2-T3 and A8-A9 and doubled on T2-T3 forming pinaculae. T1 and A10 are covered in a row of numerous short setae. Body length: 3 mm. Duration: 3 days.

Table 1 Information regarding the timing of key life history events, including egg hatching, larval molts, and adult eclosion of each reared *Cosmosoma thoracicum* individual at Finca Las Piedras. Abbreviations: L1, first larval instar; L2, second larval instar; L3, third larval instar; L4, fourth larval instar; L5, fifth larval instar; L6, sixth larval instar; L7, seventh larval instar. Dates are given in DD/MMM/YYYY format

Voucher	Sex	Date of coll	Egg hatch	L1 to L2	L2 to L3	L3 to L4	L4 to L5	L5 to L6	L6 to L7	Pupation	Adult
2021-FLP-IMM-0133	male	16-Feb-2021	18-Feb-2021	21-Feb-2021	24-Feb-2021	27-Feb-2021	2-Mar-2021	7-Mar-2021	12-Mar-2021	17-Mar-2021	26-Mar-2021
2021-FLP-IMM-0134	female	16-Feb-2021	19-Feb-2021	25-Feb-2021	28-Feb-2021	3-Mar-2021	7-Mar-2021	-	-	12-Mar-2021	21-Mar-2021
2023-FLP-IMM-0315	female	24-Mar-2023	29-Mar-2023	3-Apr-2023	7-Apr-2023	11-Apr-2023	17-Apr-2023	23-Apr-2023	27-Apr-2023	3-May-2023	14-May-2023

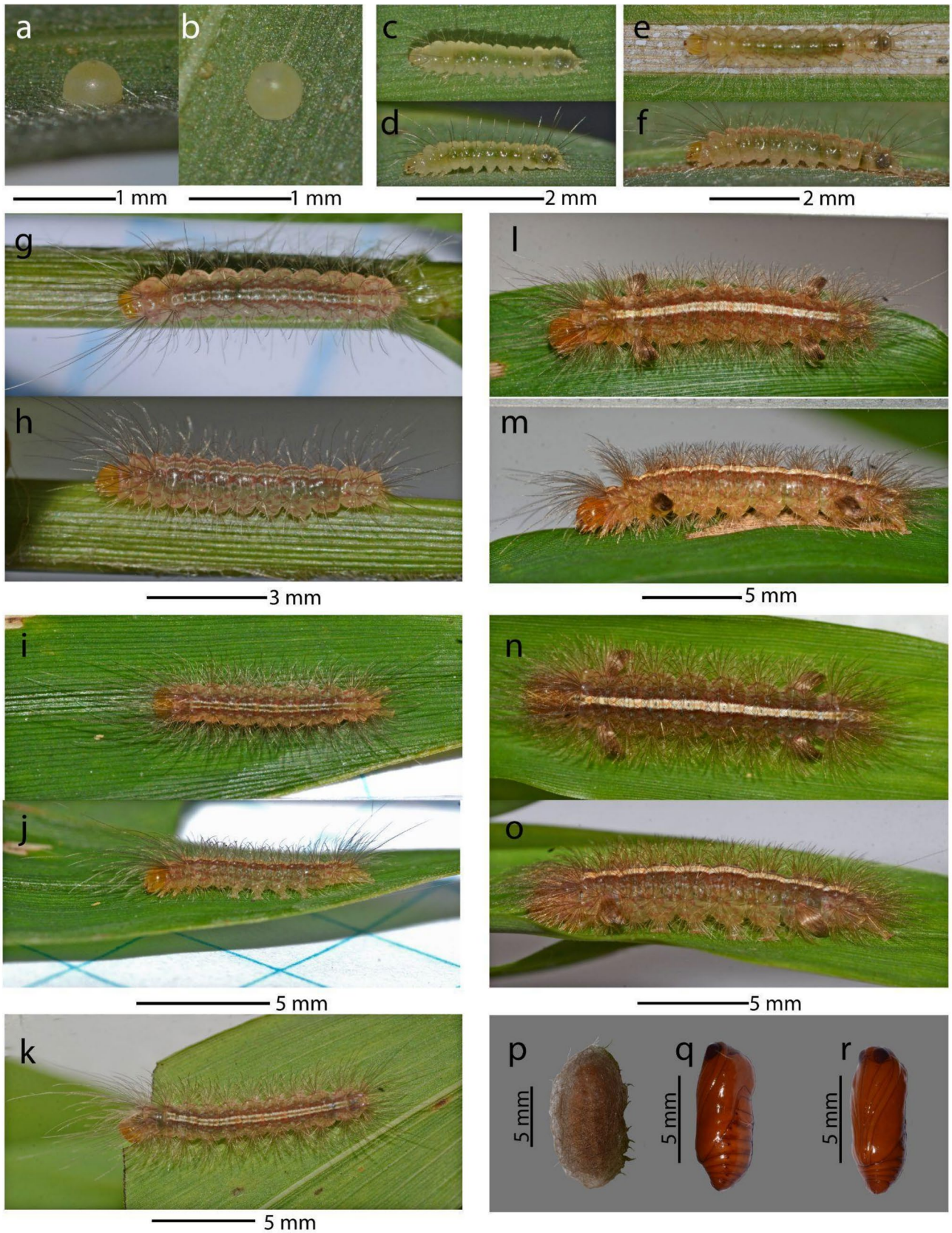

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Fig. 1 Life stages of *Cosmosoma thoracicum*, male, voucher 2021-FLP-IMM-0133. (**a**) lateral view of the egg; (**b**) dorsal view of the egg; (**c**) dorsal view of first instar; (**d**) lateral view of first instar; (**e**) dorsal view of the second instar; (**f**) lateral view of the second instar; (**g**) dorsal view of the third instar; (**h**) lateral view of the third instar; (**i**) dorsal view of the fourth instar; (**j**) lateral view of the fourth instar; (**k**) dorsal view of the fifth instar; (**l**) dorsal view of the sixth instar; (**m**) lateral view of the sixth instar; (**n**) dorsal view of the seventh instar; (**o**) lateral view of the seventh instar; (**p**) cocoon; (**q**) lateral view of the pupa; **(r)** ventro-lateral view of pupa

Second instar (Fig. 1e, f**).** Head capsule similar to the previous instar, but slightly darker and light orange. Body is olive green with T1, prolegs, and the base of the verrucae ivory-colored. Dorsal verrucae conspicuous, T2-T3 and A8-A9 present numerous hypertrophied setae that are directed outwards and extend well beyond the head and tail, respectively. Towards the end of the instar, two subdorsal red stripes start forming and the body takes on a slightly reddish hue. Body length: 6 mm. Duration: 3 days.

Third instar (Fig. 1g, h**).** Head capsule is yellow to pale orange. Body is pale yellow with longitudinal reddish and white stripes visible dorsally and becomes obscure towards terminal segments (T1-T2, A8-A9). Numerous red spots are distributed along the lateral side. Verrucae have formed, now covering the whole body with white setae. Verrucae remain longer and more numerous in segments T2-T3 and A8-A9 as previously instar. Body length: 7 mm. Duration: 3 days.

Fourth instar (Fig. 1i, j**).** Head capsule similar to the previous instar. Body reddish, with two mid-dorsal longitudinal bands with yellow patches between them in the intersegmental areas of abdominal segments A1-A5; a green–brown pattern between mid-dorsal bands that turns pale yellow on T1-T3 before molt to L5, scattered reddish spots in the supra- and subspiracular region. Verrucae are more numerous dorsally and have replaced ventral setae as well. Numerous white setae, slightly golden. Prolegs have tiny white setae. Body length: 7 mm. Duration: 3 days.

Fifth instar (Fig. 1k**).** Head capsule similar to the previous two instars. Body similar in shape and color to the previous instar, but the color pattern on the body is more prominent, slightly more yellowish and the anterior setae longer. Body length: 1.3 cm. Duration: 5 days.

Sixth instar (penultimate) (Fig. 1l, m**).** Head capsule similar to previous instars. Body similar to the previous instar, but with more prominent and slightly wider mid-dorsal bands which merge to form with yellow patches; body slightly more reddish than the previous instar, with irregular scattered gray spots. Two pairs of brown setal tufts have formed on lateral segments A1 and A7. Body length: 1.6 cm. Duration: 5 days.

Seventh instar (ultimate) (Fig. 1n, o**).** Head capsule is pale orange, similar in shape to the previous instar. Dark brown body with whitish, dark brown, and some golden setae. Dark brown setal tufts on A1 and A7, similar to the previous instar of the male individual. Lateral side of body greenish with scattered reddish spots. Verrucae with multiple dark brown circular spots. Body length: 1.7 cm. Duration: 4 days.

Prepupa (Fig. 2p**).** The larva stopped feeding and turned bright yellow. Afterward it shrank and detached setae from its body, constructing a cocoon by mixing these with silk.

Pupa (Fig. 1q, r**).** Obtect, light orange and enclosed in a thin, light brown ellipsoidal cocoon. Eyes and spiracles brown. Length: approx. 9 mm. Duration: 10 days.

Adult (Fig. 3a, b**).**

Life stages of female C. thoracicum (2021-FLP-IMM-0134; 2023-FLP-IMM-0315) ($n=2$)

Duration from egg collection to adult emergence: For specimen 2021-FLP-IMM-0134, the life cycle lasted 33 days, whereas for specimen 2023-FLP-IMM-0315, it lasted 51 days.

The female immature stages are overall very similar in appearance to those of the male from egg to fourth instar, with notable differences only in the last instars; the pupa is also very similar. It is worth mentioning that differences are also observed in the number of instars and the development time of structures among specimens. Only those characteristics which are significantly different from the male and between specimens are detailed below. Egg and instar duration times are reported for individuals 2021-FLP-IMM-0134 and 2023-FLP-IMM-0315, respectively, below.

Egg (Fig. 2a, b**).** Duration: 3 and 5 days from collection.

First instar (Fig. 2c, d**).** Duration: 6 and 5 days.

Second instar (Fig. 2e, f**).** Duration: 3 and 4 days.

Third instar (Fig. 2g, h**).** Duration: 4 days for both individuals.

Fourth instar (Fig. 2i, j**).** Duration: 4 and 7 days.

Fifth instar (Fig. 2k**).** This is the ultimate instar prior to pupa registered for voucher 2021-FLP-IMM-0134 which, unlike the other studied individuals that present setal tufts in A1 and A7 in this final instar, has only protuberances. For individual 2023-FLP-IMM-0315, this is the antepenultimate instar, and is similar to the fifth instar of the male.

Sixth instar (penultimate) (Fig. 2l, m**).** In 2023-FLP-IMM-0315, setal tufts do not develop. Before molting, the larva takes on a dark brown dorsal coloration, the head capsule turns slightly brown, especially in the stemmata area and the mid-dorsal white band turns creamy

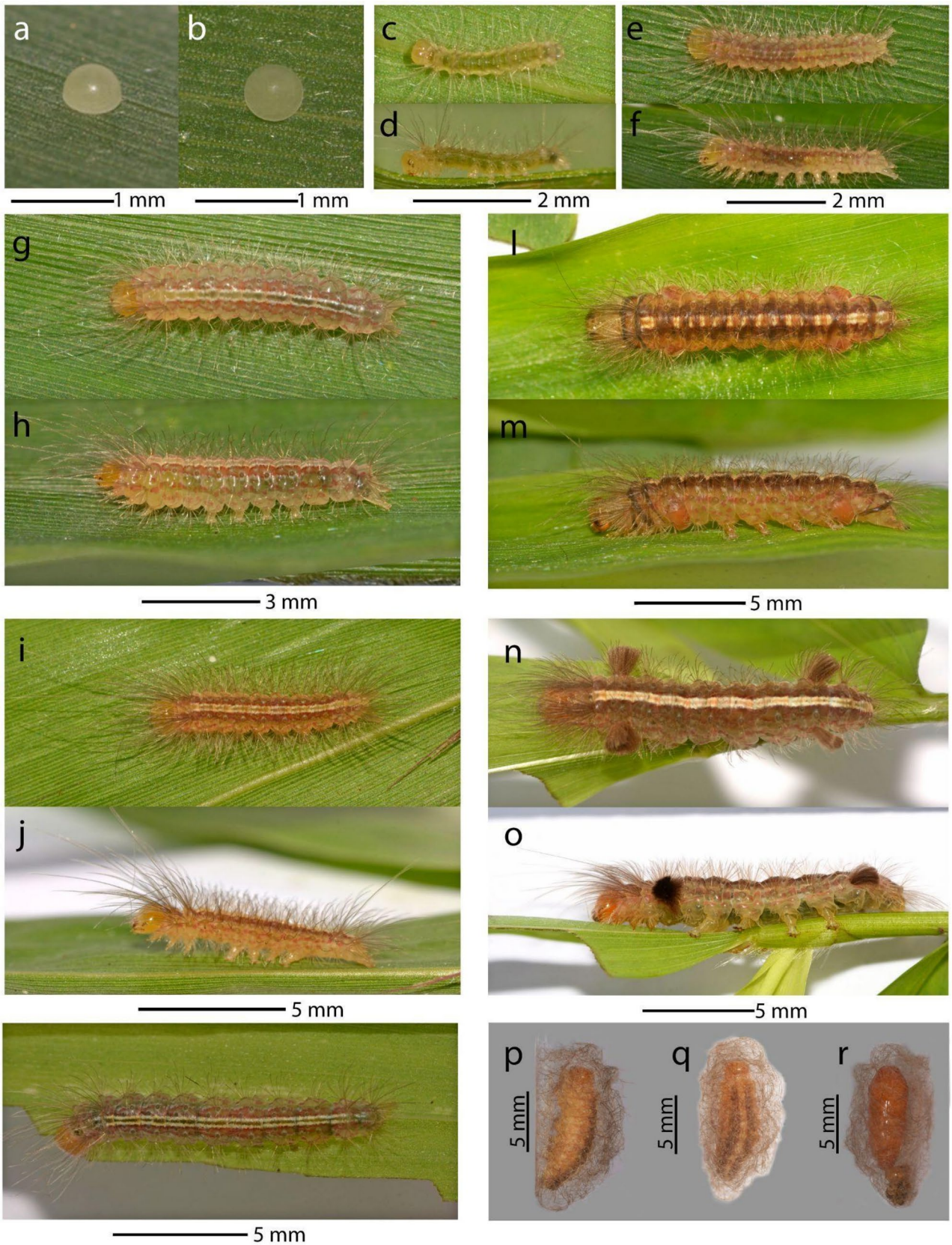

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Fig. 2 Life stages of *Cosmosoma thoracicum*, female, voucher 2023-FLP-IMM-0315. (**a**) lateral view of the egg; (**b**) dorsal view of the egg; (**c**) dorsal view of first instar; (**d**) lateral view of first instar; (**e**) dorsal view of the second instar; (**f**) lateral view of the second instar; (**g**) dorsal view of the third instar; (**h**) lateral view of the third instar; (**i**) dorsal view of the fourth instar; (**j**) lateral view of the fourth instar; (**k**) dorsal view of the fifth instar; (**l**) dorsal view of the sixth instar; (**m**) lateral view of the sixth instar; (**n**) dorsal view of the seventh instar; (**o**) lateral view of the seventh instar; (**p**) ventro-lateral view of the prepupa in cocoon; (**q**) dorsal view of the prepupa in cocoon; (**r**) pupa in cocoon

and discontinuous and segments A1 and A7 swell laterally, acquiring a pinkish color, similar to 2021-FLP-IMM-0134 in fifth instar. Duration: 4 days.

Seventh (ultimate) instar (Fig. 2n, o**).** Duration: 6 days. Similar to ultimate instar of male, but setal tuft in lateral view dark brown, with a slightly light-orange mid-dorsal line. Duration: 6 days.

Prepupa (Fig. 2p, q**).** Larva decreases in size and loses all setae. Body cream-colored, with two dark brown mid-dorsal lines. Cocoon constructed from setae and silk, with the larva clearly visible through it. Duration: 1 day.

Pupa (Fig. 2r**).** Duration: 10 and 11 days.

Adult (Fig. 3c, d**).** The species exhibits sexual dimorphism. Females differ from males in having shorter antennal rami, lacking the retinaculum, and lacking the spot between Cu1 and Cu2 on the forewings.

Hostplant

The host plant was identified as *Lasiacis ligulata* Hitchcock and Chase, 1917 (Poaceae: Panicoideae: Panaceae) (Fig. 4), a species of perennial grass distributed widely throughout northern South America and the Caribbean (Tovar 1993). *Lasiascis ligulata* has lignified culms extending from the base of the plant and forming tufts, and has glabrous, lanceolate leaves. The inflorescence is a panicle with 2–3 spikelets that contain one sterile and one fertile floret (Hitchcock and Chase 1971). According to previous work conducted at FLP, the species flowers in late June and fruits are present in July (Baine et al. 2019). At FLP this species is commonly associated with forest edges, light gaps, disturbed areas and patches of regenerating secondary forest, where it grows in small to large clumps up to several meters in height.

The three eggs were found on two different individuals of the same species. All individuals were found on different leaves, the 2021 individuals on the same plant and the 2023 individual on a different plant. All eggs were located in the middle third of the abaxial leaf surface, between approximately 1.2 and 0.6 m from the ground. The leaves where the individuals were found had medium to heavy damage and were mature. Upon discovery of the eggs, each plant was photographed, georeferenced, and given a unique code. Both plants were located at the forest edge with abundant light where this and other Poaceae species were abundant.

Description of the female genitalia of *C. thoracicum*

The description of the male genitalia can be found in Cerda (2008).

In the female, anal papillae as long as they are wide; diaphanous in the center and meso-ventrally; covered by setae throughout. Posterior processes almost twice as long as anterior processes. Lamella postvaginalis sclerotized, wide and concave in the center. Lamella antevaginalis sclerotized and concave. Antrum sclerotized, somewhat elongated and wider at the back. Ductus bursae divided into two parts: the first membranous, short and flattened; the second membranous, wide and cylindrical. Bursa copulatrix oval-shaped with small star-shaped signa throughout. Ductus seminalis wide (Fig. 5).

New synonym

Cosmosoma thoracicum Schaus 1905

= *Poecilosoma mapirense* Strand, 1915. **New synonym**.

The types of the male *C. thoracicum* and the female *P. mapirense* were examined directly. The species *C. thoracicum* was described from French Guiana; the male holotype is in the USNM (Type No. 8490), and no mention is made of females (Schaus 1905). Years later, Strand (1915) described the species *P. mapirense* based on only one female specimen (Holotype in DEIM) (Fig. 6), although the specimen is mentioned as male in the original description. The specimen was collected in Mapiri (Bolivia) by W. Schnuse.

Comparison of the male and female specimens reared in this study and the specimens deposited at MUSM and the holotype at DEIM confirms that both belong to the same species: *Cosmosoma thoracicum*. The species is sexually dimorphic in wing color pattern (Fig. 3), similar to closely related species, *e.g.*, *C. achemon* (Fabricius, 1781) and *C. remota* (Walker, 1854). Our females *C. thoracicum* specimens have the same characteristics (external morphology and color pattern) as the female of *P. mapirense*, but this was not recognized earlier, presumably due to a lack of knowledge of sexual dimorphism in *Cosmosoma*. According to our findings, therefore, the species *P. mapirense* is a junior synonym of *C. thoracicum* (ICZN 1999: Art.23.1).

Geographical distribution

Cosmosoma thoracicum has a wide distribution in South America, with known occurrences in French Guyana (type locality), Brazil (Teston and Ferro 2019), Bolivia (Strand

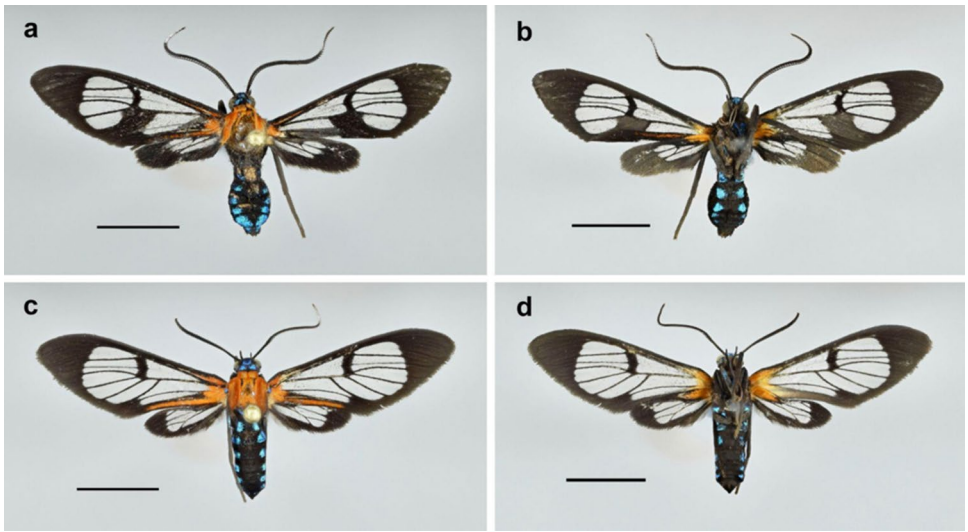


Fig. 3 Adult of *Cosmosoma thoracicum*. (**a**, **b**) male specimen with voucher 2021-FLP-IMM-0133; (**a**) dorsal view of male specimen; (**b**) ventral view of male specimen; (**c**, **d**) female specimen with voucher 2021-FLP-IMM-0134; (**c**) dorsal view of female specimen; (**d**) ventral view of the female specimen. Scale bars: 5 mm

1915), and Peru (see below). In Peru, it is common in Amazonia and in premontane forests of the eastern slopes of the Andes, having been recorded in the departments of Loreto, Amazonas, Huánuco, Ucayali, Junín, Ayacucho, Cusco, and Madre de Dios, between 195 and 800 m a.s.l. (Fig. 7).

Adult phenology, including seasonal abundance, has not been documented, and adults have been collected in all months of the year. Based on this, it is reasonable to consider the species as multivoltine.

Peruvian material examined (23 male, 4 female) All specimens listed below are deposited at MUSM. **LORETO**. 1 male, Qda. Rumiyacu, Campamento Dorado 5, 01°48′09"s, 75° 29′ 14″ W, 19.xi.2007, 230 m, J.J. Ramírez leg. **AMAZONAS**. 1 male, Imacita,05°04'S, 78°20'W, 12.xi.96, 300 m, J. Grados; 1, male, Cordillera del Cóndor, Qda. Chinganasa (Qda. Ponce), 03°47'S, 78°20'W, 15.xi.2003, 850–1160 m, J. Grados & A. Asenjo. Huánuco. **HUÁNUCO**. 1, male, Estación Biológica Panguana, 09° 38′ 36″ S, 74° 54′ 55″ W, 17–18.vii.2008, 260 m, J. Grados; 1, male, Los Angeles, 08°54′08.11"S, 75°02′55.86", 08–06.iv.2009, 227 m, C. Carranza. **UCAYALI**. 1 female, 3.5 km SSO de Nueva Galicia, Río Abujao, 08° 22′ 25″ S, 73° 48′ 50″ W, 22–25.ix.2011, 213 m; 1 male, 12.5 km. E Puerto Venus/Río Tapiche, 06° 27′ 21″ S, 74°01′27", 09–11.x.2008, 195 m, C. Espinoza; 1 male, Alexander von Humbolt, 08°48′47.59"S, 75°04′19.92"W, 03–04.iv.2009, 233 m, C. Carranza. **JUNÍN**; 1 female, Aldea,10°54'S, 74°55'W, 27.vi.2004, 600–700 m, J.J. Ramírez (DIURNAL COLLECTION); 1 male, Satipo, 11°16'S, 74°37'W, 22.ix.67, 630 m, P. Hocking; 1 male, Coriviali, 11°19'S, 74°47'W, 03–15.v.2008, 600 m, V.V. Izersky. **AYACUCHO**. 1 male, La Mar, Chungui, Chinete, 13° 07′ 45″ S, 73° 26′ 38″ W, 12.viii.2023, 863 m, R. Curo & E.Romani. **CUSCO**. 1 male, San Martín C, 11°47'S, 72°41'W, 26.iii.97, 480 m, J. Grados; 2 males, Segakiato, Río Camisea, 11°48'S,72°52'W, 29.ix.97, 330 m, J. Grados (LIGHT TRAP MV); 1 male, Cashiriari, 11°52'S, 72°39'W, 04.xii.97, 690 m, J. Grados (6:00—7:00); 1 male, Las Malvinas, RÍo Urubamba, 11°52'S, 72°55'W, 22.ix.97, 480 m, J. Grados (LIGHT TRAP MV). **MADRE DE DIOS**. 1 male, Finca Las Piedras, 12° 13′ 32″ S, 69° 06′ 52″ W, 14.x.2021, 256 m, S. Martínez & J. Grados; 1 female, Río Los Amigos, CICRA, 12°33'S, 70°06'W, 23.viii-15.ix.2008, 280 m, S. Carbonel (HELIOTROPIUM BAIT DAY); idem except, 28.x.2006, 280 m, A. Asenjo (HELIOTROPIUM BAIT-NIGHT); 1 male, Lago Sandoval, 12°36'S, 69°02'W, 02.v.1997, 200 m, J. Grados; idem except, 07.v.97; 1 male, Reserva de Tambopata, 12°50'S, 69°17'W, 13.xii.96, 250 m, J. Grados (MV/UV LIGHT TRAP); 1 male, Albergue Refugio Amazonas, 12° 52′ 30″ S, 69° 24′ 35″ W, 01.v.2017, 231 m, D. Couceiro (Voucher DNA-Artc#00 262-JGA MUSM/ARTC-000599 JGA COLLECTION); 1 male, idem except, 12.xii.2017 (Voucher DNA-Artc#00 655-JGA MUSM/ARTC-000992 JGA COLLECTION); 1 male, Río Alto Madre de Dios, ca. Atalaya, 12°53'S, 71°22'W, 21.vi.2006, 587 m, P. Centeno (MV LIGHT TRAP) (11:00 pm-0:00 am); 1 male, idem except, 17.ii.2007 (1:00–2:00 am); 1 male and 1 female, Tambopata Research Center, 13° 08′ 03″ S, 69° 36′ 39″ W, 01.iii-31.x.2021, 239 m, A. Avellaneda, G. Serrano & J. Grados.

COI sequencing

Two 658 bp COI sequences were obtained from vouchers MUSM-Arctiinae RFEWA655-18 (Tambopata Research Center) and RFEWA262-17 (Refugio Amazonas Lodge) (BOLD: ACF1839). Both COI sequences are identical.

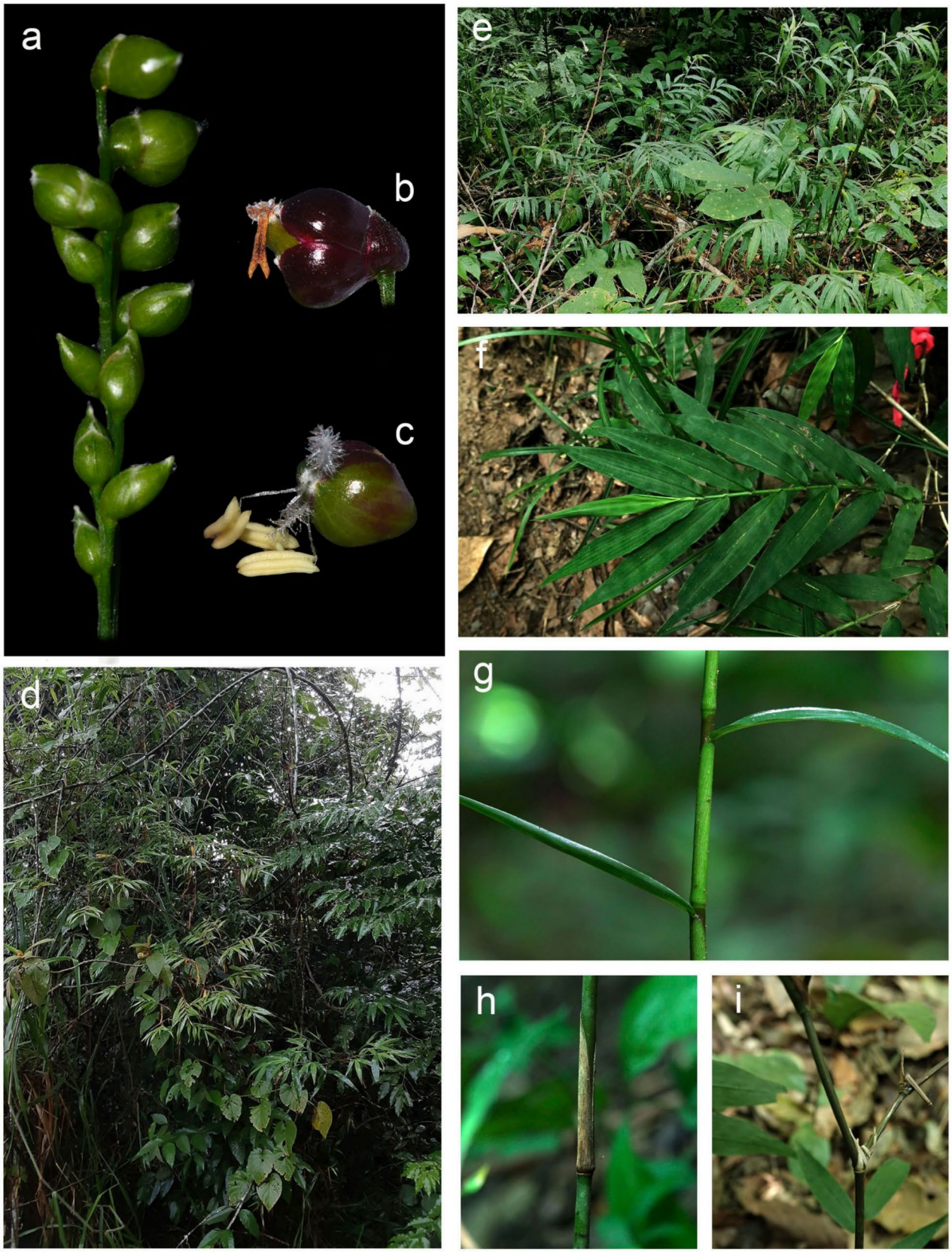


Fig. 4 Host plant of *Cosmosoma thoracicum* at Finca Las Piedras, *Lasiacis ligulata* Hitchcock & Chase, 1917 (Poaceae: Panicoideae: Panaceae). (**a**) immature inflorescence; (**b**) glume; (**c**) glume with stigma, anther and filament; (**d**, **e**) plant habitat; (**f**, **g**) phyllotaxis; (**g**) stem; (**h**) node of the stem; (**i**) branching pattern

These sequences do not correspond to individuals reared in this study; the identifications of our individuals were established through morphological review and comparison. The following sequence is from the voucher MUSM-Arctiinae RFEWA655-18:

AACATTATATTTTATTTTTGGTATTTGAGCAGGTA
TAGTAGGAACCTCATTAAGATTGTTAATTCGAGCT
GAATTAGGAAACCCAGGTTCTTTAATTGGAGATGA
TCAAATTTATAATACTATTGTAACAGCTCATGCTTT
CATTATAATTTTTTTTATAGTTATACCAATTATAATTG
GAGGATTTGGTAATTGATTAGTTCCCTTAATATTAG
GAGCCCCTGATATAGCTTTCCCTCGAATAAATAATA
TAAGTTTTTGACTTTTACCCCCATCCTTAACTTTATT
AATTTCAAGAAGAATTGTAGAAAATGGTGCAGGA
ACAGGATGAACAGTTTACCCCCCACTTTCATCCAA
TATTGCCCATGGAGGTAGTTCAGTTGATTTAGCTAT
TTTTTCCCTTCATTTAGCTGGAATCTCTTCAATTTT
AGGAGCAATCAATTTTATTACTACAATTATTAATATA
CGATTAAATAATCTATCATTTGATCAAATACCTTTAT
TTGTTTGAGCAGTAGGAATTACAGCATTTTTATTAT
TACTTTCTTTACCAGTATTAGCAGGAGCTATTACTA
TATTATTAACTGATCGAAATTTAAATACATCTTTCTT
TGACCCTGCTGGGGGAGGAGATCCTATTCTTTACC
AACATTTATTT.

Fig. 7 Geographical distribution of *Cosmosoma thoracicum* based on collection material in Peru

Discussion

Despite extensive searching, few *Cosmosoma thoracicum* eggs were found on the host plant species at FLP, which is consistent with reports of *C. auge* and *C. myrodora*, possibly indicating a solitary or semi-solitary larval strategy, as has been confirmed for *C. auge* on *Mikania micrantha* (León-Finalé and Barro 2014). Among Lepidoptera, low density of larvae has been associated with a decreased risk of parasitism and predation as well as decreased competition for food (Stamp 1980; Pérez-Contreras and Soler 2004; De-Silva et al. 2011, Freitas and Kaminski 2014; León-Finalé and Barro 2014). However, Thompson and Pellmyr (1991) noted that clutch size varies widely between and within arctiine species and depends on multiple factors such as host plant density. More field data are needed in order to understand the interplay between larval strategy and environmental factors in *C. thoracicum*.

Overall, the larval morphology of *C. thoracicum* is similar to that of *C. auge* (León-Finalé and Barro 2014) and, in general, to other arctiine species (Stehr 1987). Notably, the female larvae of *C. thoracicum* passed through five and

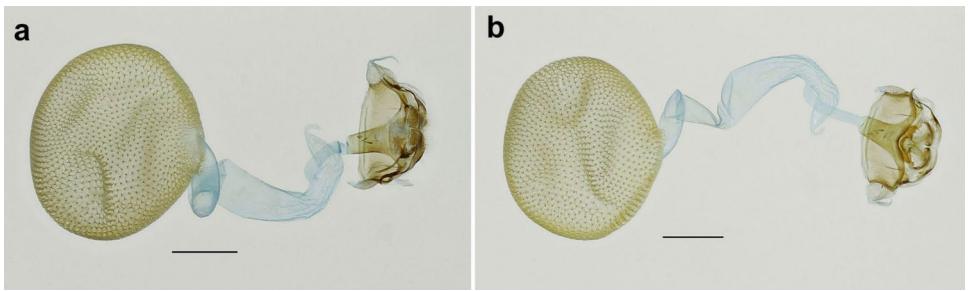


Fig. 5 Female genitalia of *Cosmosoma thoracicum* (Schaus) (based on 2021-FLP-IMM-0134) (genitalia JGA # 1298-MUSM). (**a**) dorsal view; (**b**) ventral view. Scale bars: 5 mm



Fig. 6 Female holotype of *Poecilosoma mapirense* Strand, 1915. (**a**) dorsal view; (**b**) ventral view

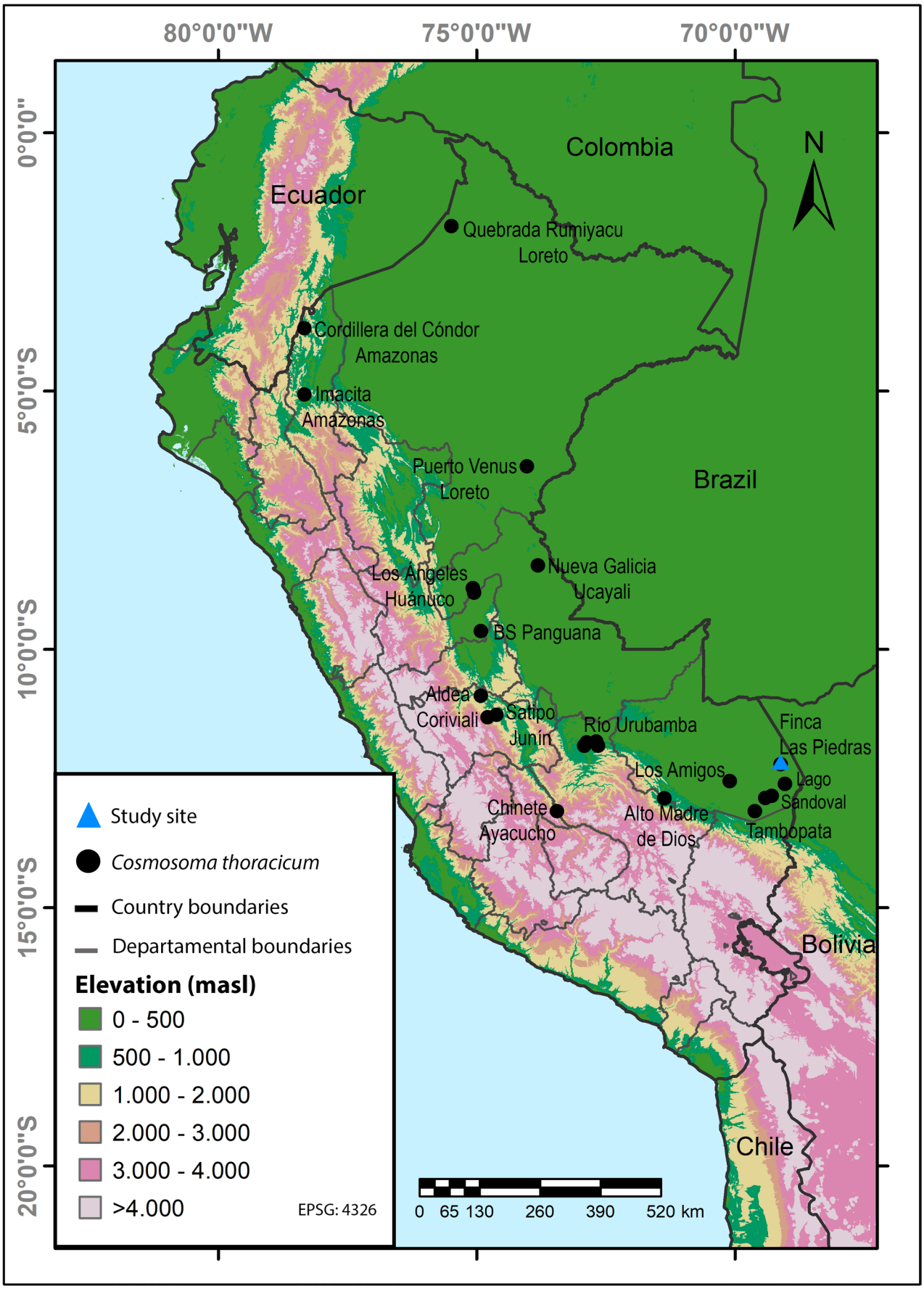

80°0'0"W
75°0'0"W
70°0'0"W
0°0'0"
5°0'0"S
10°0'0"S
15°0'0"S
20°0'0"S
N
Colombia
Ecuador
Brazil
Bolivia
Chile
Quebrada Rumiyacu
Loreto
Cordillera del Cóndor
Amazonas
Imacita
Amazonas
Puerto Venus
Loreto
Nueva Galicia
Ucayali
Los Angeles
Huanuco
BS Panguana
Aldea
Coriviali
Satipo
Junín
Río Urubamba
Finca
Las Piedras
Los Amigos
Lago
Sandoval
Tambopata
Chinete
Ayacucho
Alto Madre
de Dios
Study site
Cosmosoma thoracicum
Country boundaries
Departamental boundaries
Elevation (masl)
0 - 500
500 - 1.000
1.000 - 2.000
2.000 - 3.000
3.000 - 4.000
>4.000
EPSG: 4326
0 65 130 260 390 520 km

Table 2 Temperature (Celsius) and precipitation (mm) data measured daily at the FLP during the rearing period

Year	Month	Min_temp. (°C)	Max_temp. (°C)	Current_ temp. (°C)	Current_time	Min_Precip. (ml)	Max_Precip. (ml)	Avg. Precip. (ml)	Total Precip. (ml)
2021	Feb	21.00	31.50	23.96	7:59	0.00	95.00	13.82	387.00
	Mar	20.50	29.00	23.39	8:01	0.00	52.00	11.95	370.50
2023	Mar	20.50	29.00	23.50	8:00	0.00	52.00	11.95	150.50
	Apr	20.50	29.00	23.20	7:56	0.00	27.00	4.27	128.00
	May	20.00	29.00	22.60	7:54	0.00	33.70	4.09	126.70

seven instars while the male passed through seven instars, contrary to *C. auge* that appears to develop in six instars (León-Finale and Barro 2014). Arctiinae species are reported to pass through 6 or 7 instars in normal conditions and up to 12 instars in adverse conditions (Wagner 2009). Considering this, as well as the fact that there are over 11,000 species in the subfamily Arctiinae (Scherrer et al. 2013; Hilt and Fiedler 2005), it may not be surprising to find inter- and even intra-specific differences in the number of instars.

It is possible that temperature and precipitation conditions during the study periods may have played a role in the variation in numbers of instars across individuals. The three individuals were affected in their egg and larval stages by cold air surges known in Peru as "friajes", which originate during austral winter at extreme southern latitudes and bring abrupt decreases in temperature, and often heavy cloud cover, rainfall, and/or wind, to the study site in southeastern Peru (Marengo Orsini 1983). The individuals reared in parallel in 2021 were exposed to three friaje events with temperatures dropping to between 21.5 to 20.5 °C; these three events occurred on 23–24 Feb 2021, 10 Mar 2021, and 13–14 Mar 2021. The individual raised in 2023 was exposed to four friajes with temperatures ranging from 21.5 to 20.5 °C for a total of nine days on the dates: 25 Mar 2023, 28 Mar 2023, 10–11 Apr 2023, and 20–24 Apr 2023. The minimum temperature recorded for both years of rearing was 20.5 °C, significantly lower than the monthly average temperature which ranges from 22 to 24 °C in the months of rearing. In addition, in 2023 precipitation was considerably lower compared to the study period in 2021 (see Table 2). This could have influenced larval development via physiological or ecological (*i.e.*, dietary quality) effects in the female in 2023 compared to the female in 2021. Esperk et al. (2007), for instance, point out that environmental and physical conditions, as well as the quality and quantity of food, can influence the interspecific variation in instar number, usually with higher quality or quantity of food resulting in a larger number of instars. Consequently, the variable number of instars documented for *C. thoracicum* individuals reared at FLP may be linked to the recorded fluctuations in weather during the study periods. Variation in the number of instars has been documented in other species of Arctiinae and other groups within the family Erebidae (*e.g.*, *C. auge* and *Pantydia capistrada*, León-Finalé and Barro 2014; Rodríguez-Loeches and Barro 2008), although the causes in these cases were not studied.

We documented further variation across *C. thoracicum* individuals in this study. For instance, the studied male developed two pairs of setal tufts on A1 and A7 in the sixth instar, whereas the two females displayed variation in this character (one female developed setal tufts in the final instar whereas the other female developed only protuberances in the final instar). A report for *C. auge* (León-Finalé and Barro 2014) presented data from the rearing of 36 male and female individuals, and no such difference was observed between the sexes. In that study, both sexes had six instars and developed setal tufts on A1 and A7 in the last instar (A. Barro pers. comm.), suggesting the absence of this feature in one of the females studied herein is unlikely to represent sexual dimorphism and may rather be due to intraspecific variation. Further data from the Arctiinae species *Histioea cepheus* (Cramer, 1779) also show that setal tufts occur in both sexes (Gernaat et al. 2018). We urge further work on this and other related species of Arctiinae to better understand the prevalence of such intraspecific variation in this and other characters.

Lasciasis ligulata is the first host plant reported for *C. thoracicum*, and the first Poaceae reported for a *Cosmosoma* species, since the other species with documented larval host plants feed on Asteraceae as reported for *C. auge* and *C. myrodora* (Dyar 1896a; Conner et al. 2000; León-Finale and Barro 2014). Several species within Asteraceae are known to produce pyrrolizidine alkaloids (PAs) (Dey et al. 2020; EFSA CONTAM Panel et al. 2017), secondary defensive compounds that are produced to protect against herbivores. Many species of Arctiinae acquire PAs either during larval feeding on PA-producing host plants or through adult pharmacophagy, and incorporate these compounds into their tissues to obtain chemical protection against predators (Boppré 1996; Zaspel et al. 2014; Martins et al. 2015). Within the subtribe Euchromiina, to which *Cosmosoma* belongs, adult acquisition of PAs has also been reported (Martins and Trigo 2016; Zaspel et al. 2014), and *C. myrodora* is the only *Cosmosoma* species in

which this behavior was confirmed experimentally (Conner et al. 2000). In the case of *C. thoracicum*, its larval host plant, *L. ligulata*, belongs to Poaceae, a family not generally recognized as a source of PAs, suggesting that they obtain PAs as adults. In fact, records exist of both a male and female *C. thoracicum* visiting the pyrrolizidine alkaloid-producing *Heliotropium* (Boraginaceae) plants in Tambopata, SE Peru (Grados unpublished data). Since some Arctiinae are polyphagous, even to extremes such as species of the genus *Hypercompe* Hübner that can feed up to 91 different species of plants (Gernaat et al. 2018; Wang et al. 2017), it is possible that the genus *Cosmosoma* might be polyphagous as well. However, polyphagy may result in variation in chemical defense among individuals depending on the host plant and plant tissue consumed. In the arctiine moth *Utetheisa ornatrix*, larvae feeding on host plants and tissues with different concentrations and structures of pyrrolizidine alkaloids (PAs) acquired different amounts of these compounds, which affected the effectiveness of chemical defense in the resulting adults (Martins et al. 2015). Similarly, substantial intra- and interspecific variation in the sequestration of plant-derived defensive compounds has been documented in other aposematic Lepidoptera, with some individuals of species considered chemically defended containing little or no detectable toxin (Dimarco and Fordyce 2017). Such variation may allow less-defended or undefended individuals to benefit from the warning signal displayed by more strongly defended conspecifics, a phenomenon known as automimicry (Barnett et al. 2014). Therefore, even if *C. thoracicum* proves to be polyphagous, not all individuals would necessarily acquire the same amount or type of chemical defenses, and chemical defense may vary according to host-plant use. Further research is therefore needed to determine the host plants used by the larval and adult stages of *C. thoracicum*, whether this species is polyphagous, which life stage(s) acquire chemical defenses, and whether the extent of chemical defense varies among individuals according to host-plant use.

The new synonym presented here for the specimen described by Strand (1915), *Poecilosoma mapirense*, which is, in fact, a female *C. thoracicum*, suggests the possibility of the existence of other synonymies in *Cosmosoma* species. This is further suggested by other studies that have also modified the genus *Cosmosoma*, for instance in establishing other synonymies (Pinheiro and Duarte 2013), assigning new species (Laguerre 2010) or re-assigning species to other genera (Grados 2021). Therefore, a major taxonomic revision using morphological and genetic approaches is justified for the genus.

The geographic range for *C. thoracicum* reported here overlaps at least to some degree with the host plant species *L. ligulata* also reported herein (La-Torre et al. 2004), possibly suggesting that *C. thoracicum* uses this plant species as a host throughout a large portion of its range. However, empirical evidence for this is lacking and our data do not allow us to determine whether this species is polyphagous as has been reported in other *Cosmosoma* species (*e.g.*, *C. auge*, *C. myrodora*). Further work should be done on this and other Arctiinae species to explore the ecological factors shaping their distribution.

The description of the immature stages and host plant of *C. thoracicum* herein is an important contribution to our current knowledge of *Cosmosoma* life history, which is otherwise severely lacking and may support and clarify the taxonomy of this diverse and complex group. Furthermore, in combination with future work, this information could help to revise the classification of species in this genus and increase the knowledge of Neotropical moths more generally, which are extremely species-rich but poorly studied (Pitkin 2002; Pinheiro and Duarte 2013).

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Author contributions GG, YSQ, JG, YV, and ZE designed the study. Data collection, analysis, and preparation of materials was performed by YSQ, JG, DC, JCM, YV, ZE, and GG. The first draft of the manuscript was written by GG, YSQ, and JG, and all authors reviewed, contributed to, and approved the final version with significant contributions by YV and ZE.

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Data Availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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