

Two new species of *Sinella* from Guangdong Province, China (Collembola: Entomobryidae)

Guo-Liang Xu¹, Wei-Yu Chen²

1 School of Geographical Sciences, Guangzhou University, Guangzhou 510006, P. R. China **2** Nanjing Plant Protection Station, No 169 Hanzhongmen Road, Nanjing 210036, P. R. China

Corresponding author: Guo-Liang Xu (xugl@gzhu.edu.cn)

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Abstract

Two new blind species of *Sinella* are described from Guangdong Province, China. *Sinella colubra* **sp. n.** possesses minute smooth postlabial chaetae, long mucronal spine, and 4+4(5) lateral mac on Abd. IV, and can be distinguished from two closely related species by the postlabial chaetae and the dorsal macrochaetotaxy. *Sinella zhangii* **sp. n.** is also described and can be diagnosed by having minute labial chaeta r and postlabial chaetae X and X₄, 5+5 mac on Abd. I, 4+4 central mac on Abd. II, and 4+4 central and 5+5 lateral mac on Abd. IV.

Keywords

Blind species, chaetotaxy, springtail, *Sinella colubra* sp. n., *Sinella zhangii* sp. n., South China

Introduction

The genus *Sinella* Brook, 1882 is distributed worldwide and is very abundant in China. Deharveng (1990), Chen and Christiansen (1993) and Zhang et al. (2009, 2011) made significant contributions to the modern taxonomy of the genus. Members of the genus have 4-segmented antennae, reduced eye number (0–6 on each side), pigment reduced or absent, polymacrochaetotic chaetotaxy, bidentate mucro, and no dental spines and scales. So far, 39 species, including 14 blind ones, have been recorded from China. Among them, only two eyed species have been recorded from Guangdong Province: *Sinella curviseta* Brook, 1882 and *Sinella longisensilla* Zhang, 2013. In this study, two new blind species are described from Guangdong.

Materials and methods

Specimens were cleared in Nesbitt's fluid (Krantz 1978), mounted under a coverslip in Hoyer's solution, and observed using a Nikon E80i microscope. The labial chaetae terminology follows Gisin's system (1967). The dorsal and ventral chaetotaxy of head are described after Chen and Christiansen (1993), completed for the anterior part of head after Jordana and Baquero (2005) and Soto-Adames (2008). Dorsal body chaetae are designated following Szeptycki (1979) and Zhang et al. (2011). The number of macrochaetae is given by half-tergite in the descriptions (left side of tergites drawn in figures). Tergal S-chaetotaxic formula follows Zhang and Deharveng (2015). All descriptions are based on fully developed adults if not otherwise mentioned. Symbols representing chaetal elements used in the figures are as follows: large circle, macrochaeta; small circle, mesochaeta; cross, bothriotrichum; circle with a slash, pseudopore; dotted circle, chaetae present or absent. All materials are deposited in the collections of the Department of Entomology, College of Plant Protection, Nanjing Agricultural University (NJAU), P. R. China.

Abbreviations:

Th.	thoracic segment;
Abd.	abdominal segment;
Ant.	antennal segment;
mac	macrochaeta/ae;
mic	microchaeta/ae;
mes	mesochaeta/ae
ms	S-microchaeta/ae;
sens	ordinary tergal S-chaeta/ae.

Taxonomy

Sinella colubra sp. n.

<http://zoobank.org/543604B9-A3BA-4FA9-ADC0-A506FCC99B04>

Figs 1–16, Table 1

Type material. Holotype: ♂ on slide, China, Guangdong Province, Huizhou City, Longmen County, Nankunshan Natural Reserve, 23°38'4.01"N, 113°51'15.25"E, altitude 497 m, 24 August 2010, Z-X Pan and Y-T Ma leg. (# S4143). Paratypes: ♂ and 3 ♀♀ on slides and 3 in alcohol, same data as holotype.

Other material. ♀ on slide, China, Guangdong Province, Nanling National Natural Reserve, 24°55'42.6"N, 113°0'58.3"E, altitude 1026 m, 22 July 2010, F Zhang and Z-H Li leg. (# C9640).

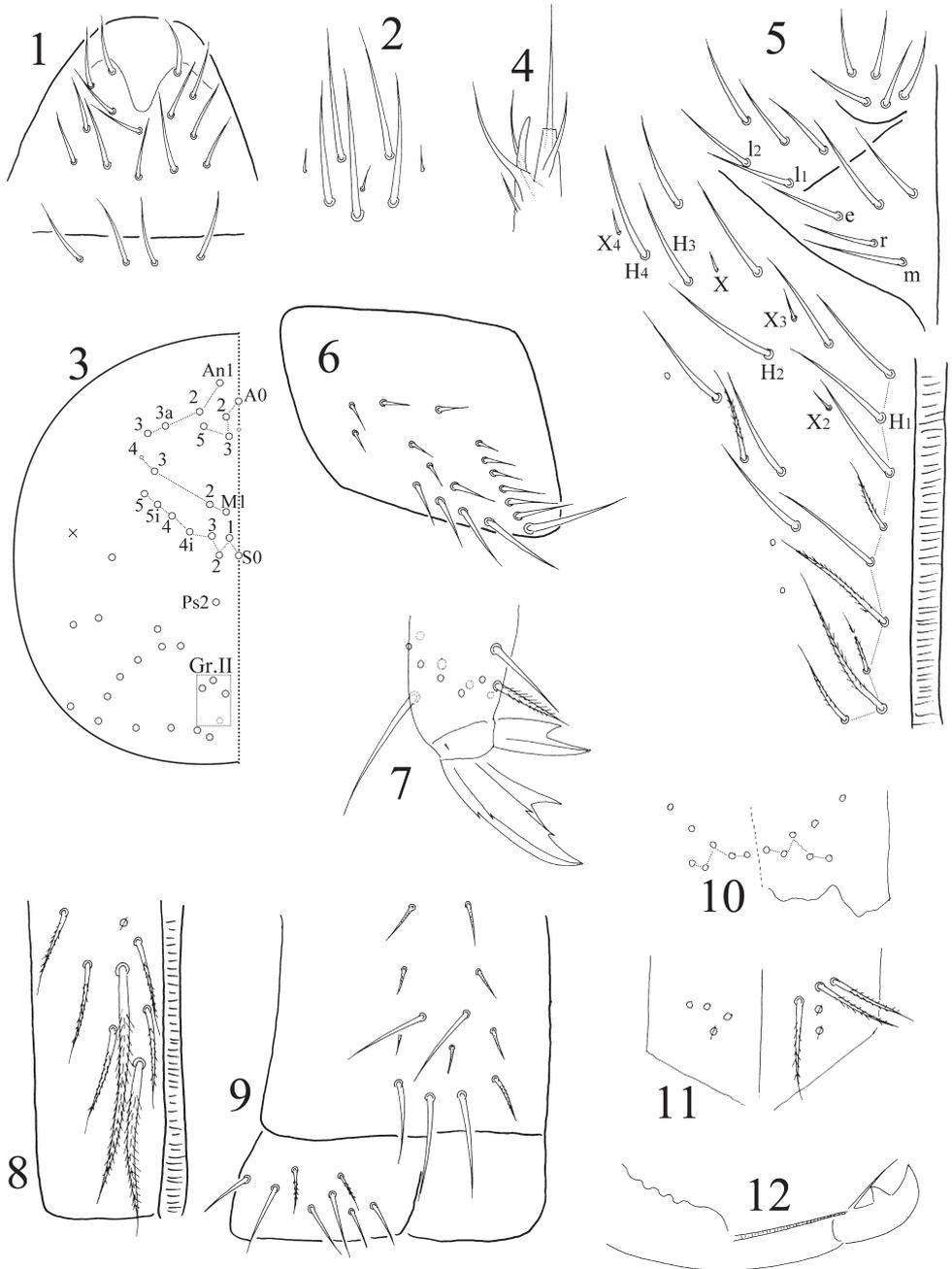
Diagnosis. No eyes. Long smooth straight chaetae present on antennae. Clypeal chaetae eight and median three much smaller. Labial chaetae as $mrel_1l_2$. Postlabial chaetae X and X_{2-4} minute. "Smooth" inner differentiated tibiotarsal chaetae present. Manubrium without smooth chaetae. Mucronal spine long, with tip nearly reaching apical tooth. Abd. I with 6+6 mac. Abd. II with 3+3 central mac. Abd. IV with 7+7 central and 4+4 lateral mac.

Description. Body length up to 1.50 mm. Body pale in alcohol.

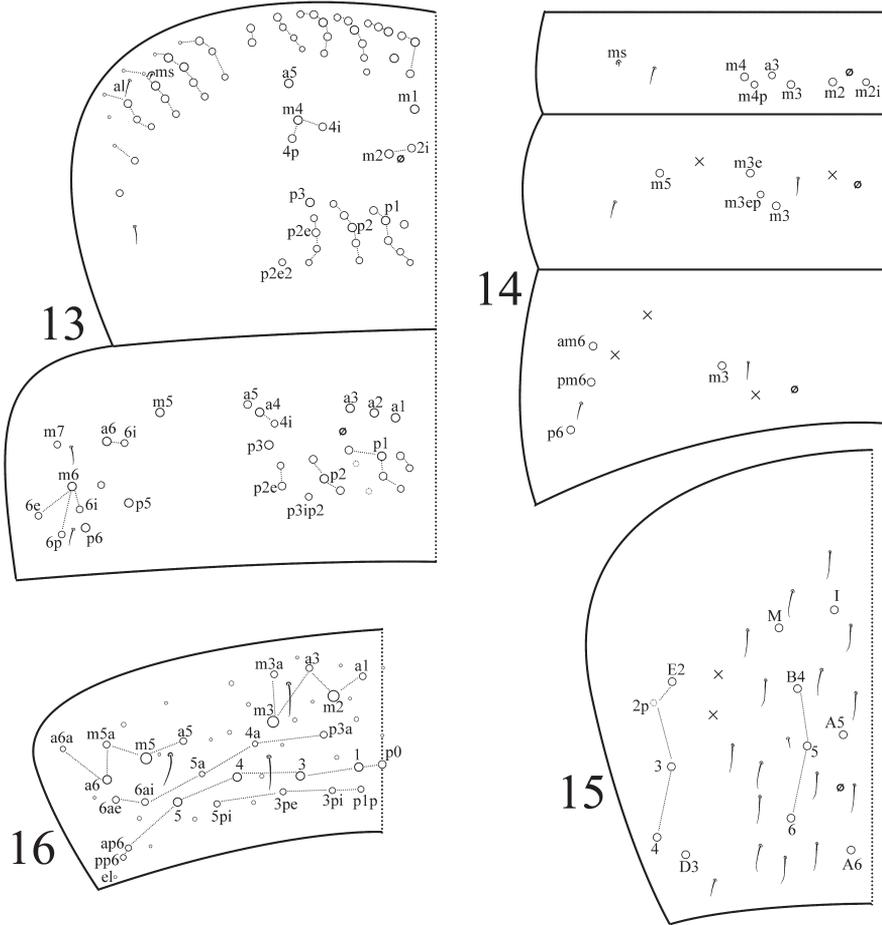
Antenna 1.63–1.93 times as long as cephalic diagonal. Antennal segments ratio as I : II : III : IV = 1 : 1.77–2.00 : 1.64–1.74 : 2.57–2.91. Smooth spiny mic at base of antennae: three dorsal, three ventral on Ant. I; one internal, one external and two ventral on Ant. II. Ant. II distally with one (rarely two) rod-like sens. Ant. III organ with two slightly expanded internal sens. Ant. IV with a knobbed subapical organ. Ant. II. with 2–4 ventral long smooth straight chaetae.

Eyes absent in all specimens. Prelabral and labral chaetae 4/ 5, 5, 4, all smooth; labral intrusion U-shaped (Fig. 1). Clypeal chaetae eight in number, including three small median chaetae (Fig. 2). Dorsal cephalic chaetotaxy with four antennal (An), three median (M) and eight sutural (S) mac; Gr. II with 3(4) mac (Fig. 3). Mandibles with 4/5 (left/right) teeth. Subapical chaeta of maxillary outer lobe slightly thicker than apical one; three smooth sublobal hairs on maxillary outer lobe. Lateral process of labial palp slightly thicker than normal chaetae, with tip extending beyond apex of labial papilla (Fig. 4). Labial chaetae as $mrel_1l_2$, all smooth, $r/m=0.67-0.79$; chaetae X and X_{2-4} minute; chaeta X_3 rarely absent; H_{1-4} smooth. Cephalic groove with 9(8) chaetae, four of them smooth and others ciliate (Fig. 5).

Trochanteral organ with 17–19 smooth spiny chaetae; 11–12 in arms and 5–7 internal (Fig. 6). Partial inner differentiated tibiotarsal chaetae "smooth" with ciliae closely appressed to axis (Chen and Christiansen 1993). Tibiotarsi distally with ten chaetae in a whorl. Unguis with three inner, one outer, and two lateral teeth; two paired teeth unequal, outer one large. Unguiculus with a large outer tooth. Tenent



Figures 1–12. *Sinella colubra* sp. n. **1** labrum **2** clypeal chaetae **3** dorsal cephalic chaetotaxy **4** lateral process and labial papilla **5** chaetae on the ventral side of head **6** trochanteral organ **7** hind claw **8** anterior face of ventral tube **9** ventral face and lateral flap of ventral tube **10** distal part of anterior face of manubrium **11** manubrial plaque **12** mucro.



Figures 13–16. Tergal chaetotaxy of *Sinella colubra* sp. n. **13** thorax **14** Abd. I–III **15** Abd. IV **16** Abd. V.

hairs of all legs pointed but clavate in one male specimen (Fig. 7). Abd. IV 3.72–4.60 times as long as Abd. III along dorsal midline. Ventral tube anteriorly with 6–7 ciliate chaetae on each side, two of them much larger than others (Fig. 8); posteriorly with about 13 chaetae, most of them small and weakly ciliate; each lateral flap with two ciliate and six smooth chaetae (Fig. 9). Male genital plate not clearly seen. Manubrium dorsally without smooth chaetae; ventrally with 5+5 distal ciliate chaetae (Fig. 10). Manubrial plaque with 2+2(1) pseudopores and 3+3 ciliate chaetae (Fig. 11). Distal smooth part of dens 1.08–1.57 as long as mucro. Mucro bidentate with apical tooth larger; basal spine long, with tip nearly reaching apical tooth (Fig. 12).

Th. II with three medio-medial mac (m1, m2, m2i), three medio-lateral mac (m4, m4i, m4p), 14–18 posterior mac, one ms and two sens; ms interior to sens al. Th. III with 29–32 mac and two lateral sens; a6i, p5, p6, m6, m6i, m6p, m6e and m6ai2 pre-

Table 1. Comparison among *S. colubra* sp. n., *S. insolens* and *S. sineocula*. Rare character states are noted and placed in parentheses.

Characters	<i>S. colubra</i> sp. n.	<i>S. insolens</i>	<i>S. sineocula</i>
Mac in Gr. II on dorsal head	3(4)	usually 4–5(6–8)	usually 5–6(4)
Labial chaeta M1s	absent	present	absent
Postlabial chaetae X and X ₂₋₄	smooth, minute	cliate, large	ciliate, large
Mac m5i on Th. III	absent	present	absent
Mac on Abd. I	6+6	7(6)+7(6)	7(6)+7(6)
Central mac on Abd. II	3+3	4+4	3+3
Lateral mac on Abd. IV	4(5)+4(5)	6+6	6+6

sent as mac; mac m5i absent (Fig. 13). Abd. I with six mac (a3, m2–4, m2i, m4p), one ms and one sens; sens interior to ms. Abd. II with three central mac (m3, m3e, m3ep), one lateral mac (m5) and two sens. Abd. III with one central mac (m3), three lateral mac (am6, pm6, p6) and two sens; ms absent (Fig. 14). Abd. IV with seven central mac (I, M, A5–6, B4–6), four (rarely five) lateral mac (D3, E2–4), and at least 17 sens (Fig. 15). Abd.V with three sens (Fig. 16).

Etymology. Named after the snake *Bungarus multicinctus* Blyth found in the sampling site.

Ecology. In soil of bamboo forest, near termitarium.

Remarks. *Sinella colubra* sp. n. is most similar to *Sinella insolens* Chen & Christiansen, 1993 and *Sinella sineocula* Chen & Christiansen, 1993 in morphology of unguis and unguiculus, long mucronal spine, absence of smooth chaetae on manubrium, medial and posterior mac on Th. II, 1+1 central and 3+3 lateral mac on Abd. III, and 7+7 central mac on Abd. IV. It differs from them in 3+3(4) cephalic mac on Gr. II, absence of labial chaeta M1s, minute postlabial chaetae X and X₂₋₄, absence of mac m5i on Th. III, 6+6 (a2 as mes) mac on Abd. I, absence of mac m3ei on Abd. II, and 4+4(5) lateral mac on Abd. IV.

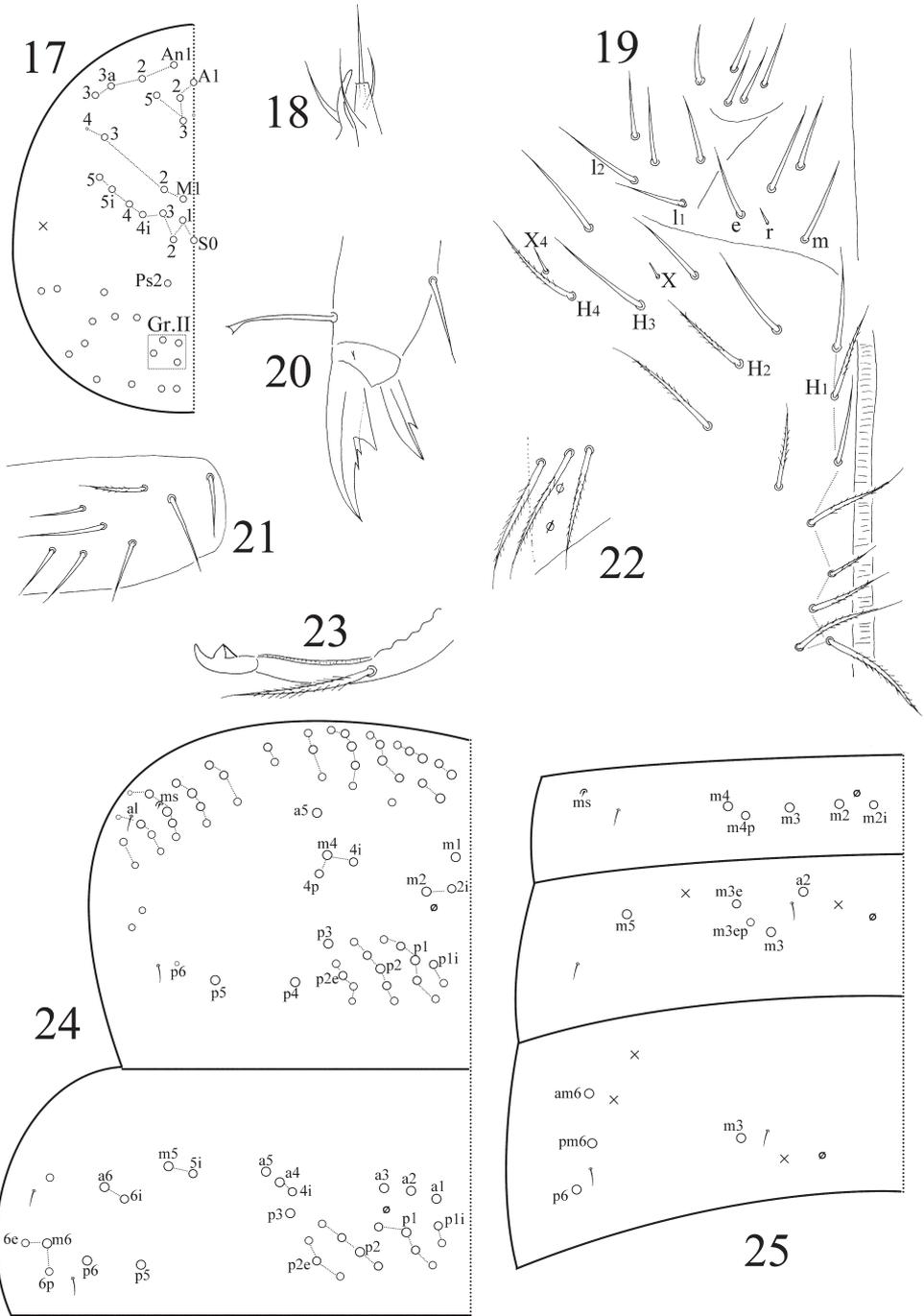
Sinella zhangii sp. n.

<http://zoobank.org/E8161EA4-8F9E-4C9C-8A90-C9CFEB9E8A01>

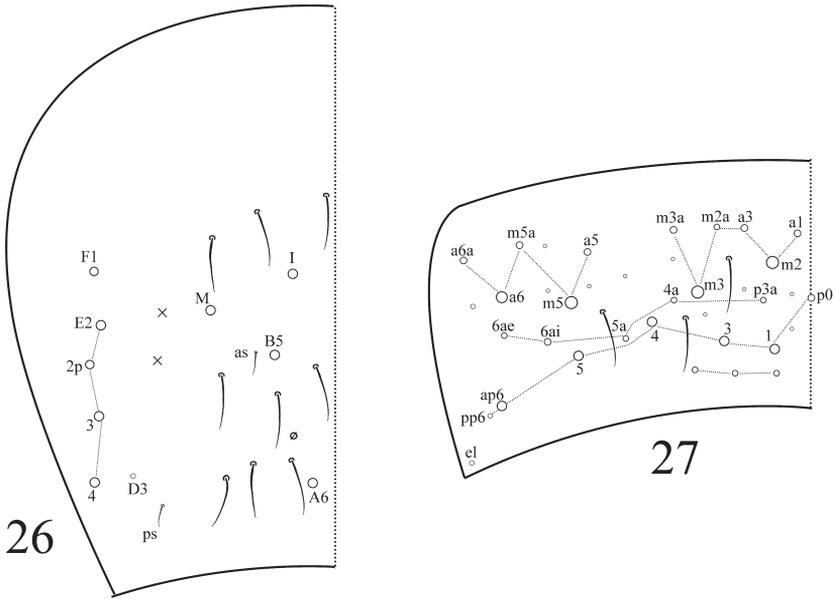
Figs 17–27

Type material. Holotype: ♂ on slide, China, Guangdong Province, He Mountain, in soil of secondary eucalypt forest, 22 October 2012, Guoliang Xu leg. (# Xu-2012). Paratypes: 1 ♀ on slide and 1 juvenile in alcohol, same data as holotype.

Diagnosis. No eyes. Long smooth straight chaetae absent on antennae. Labial chaeta r and postlabial chaetae X and X₄ minute. “Smooth” inner differentiated tibiotarsal chaetae present. Tenent hairs clavate. Manubrium without smooth chaetae. Mucronal spine short, with tip reaching subapical tooth. Chaeta p5 as mac on Th. II. Abd. I with 5+5 mac. Abd. II with 4+4 central mac. Abd. IV with 4+4 central and 5+5 lateral mac.



Figures 17–25. *Sinella zhangi* sp. n. **17** dorsal cephalic chaetotaxy **18** lateral process and labial papilla **E** **19** chaetae on the ventral side of head **20** hind claw **21** lateral flap of ventral tube **22** manubrial plaque **23** micro **24** thoracic chaetotaxy **25** chaetotaxy of Abd. I–III.



Figures 26–27. Tergal chaetotaxy of *Sinella zhangi* sp. n. **26** Abd. IV **27** Abd. V.

Description. Body length up to 1.32 mm. Body pale in alcohol.

Antenna 2.04 times as long as cephalic diagonal. Antennal segments ratio as I : II : III : IV = 1 : 1.71 : 1.86 : 2.71. Smooth spiny mic at base of antennae three dorsal, three ventral on Ant. I; one internal, one external and one ventral on Ant. II. Ant. II distally with one rod-like S-chaeta. Two internal sens of Ant. III organ rod-like. Long smooth straight chaetae absent on antennae.

Eyes absent in all specimens. Prelabral and labral chaetae 4/ 5, 5, 4, all smooth; three chaetae of first row longer than lateral chaetae. Clypeal chaetae not clearly seen. Dorsal cephalic chaetotaxy with four antennal, three median (M) and eight sutural (S) mac; Gr. II with four mac (Fig. 17). Mandibles with 4/5 (left/right) teeth. Subapical chaeta of maxillary outer lobe subequal to apical chaeta; three smooth sublobal hairs on maxillary outer lobe. Lateral process of labial palp thicker than normal chaetae, with tip extending beyond apex of labial papilla (Fig. 18). Labial chaetae as $mrel_{1,2}$, all smooth, $r/m=0.20$; chaetae X and X_4 smooth, minute; chaetae X_{2-3} absent; H_1 , H_2 and H_4 ciliate. Cephalic groove with eight chaetae, two smooth and others ciliate (Fig. 19).

Trochanteral organ with nine smooth spiny chaetae; five in arms and four internal. Some inner differentiated tibiotarsal chaetae “smooth” with ciliations closely appressed to axis. Tibiotarsi distally with ten chaetae in a whorl. Unguis with three inner teeth; two paired teeth unequal, outer one larger. Unguiculus with a large outer tooth. Tenent hairs clavate (Fig. 20). Abd. IV 3.42 times as long as Abd. III along dorsal midline. Ventral tube anteriorly with seven ciliate chaetae; two of them much larger than oth-

ers; posteriorly not clearly seen; each lateral flap with seven smooth and one ciliate chaetae (Fig. 21). Manubrium without smooth chaetae. Manubrial plaque with 2+2 pseudopores and 3+3 ciliate chaetae (Fig. 22). Distal smooth part of dens 1.72 times as long as mucro. Mucro bidentate with apical tooth longer than subapical tooth; basal spine short, reaching tip of subapical tooth (Fig. 23).

Th. II with three medio-medial mac (m1, m2, m2i), three medio-lateral mac (m4, m4i, m4p), 19 posterior mac, one ms and two sens; ms interior to sens al. Th. III with 30 mac and two lateral sens (Fig. 24). Abd. I with five mac (m2–4, m2i, m4p), one ms and one sens; sens interior to ms. Abd. II with four central mac (a2, m3, m3e, m3ep), one lateral mac (m5) and two sens. Abd. III with one central mac (m3), three lateral mac (am6, pm6, p6) and two sens; ms absent (Fig. 25). Abd. IV with four central mac (I, M, B5, A6), five lateral mac (E2–4, E2p, F1), and at least 11 sens; as and ps shorter than others (Fig. 26). Abd. V with three sens; chaetae m2, m3, m5, a6, p1, p3–5 and ap6 present as mac (Fig. 27).

Etymology. Named after the Chinese collembologist Dr. Feng ZHANG, who has made great contributions to the taxonomy of *Sinella*.

Ecology. In decomposing leaves along the roads.

Remarks. *Sinella zhangii* sp. n. is most similar to *Sinella quadriseta* Zhang, Bedos & Deharveng, 2014 in absence of eyes, tip of lateral process of labial palp beyond apex of labial papilla, morphology of unguis and unguiculus, and mucronal spine, but differs from it in smooth, minute labial and postlabial chaetae r, X and X₄, clavate tenent hairs, “smooth” inner differentiated tibiotarsal chaetae, 4+4 mac in Gr. II on dorsal head, absence of mac m2, m2i, m4i and m4p on Th. II, 5+5 mac on Abd. I (m4p present), and 4+4 central mac on Abd. II (m3ep present). It is also similar to Chinese species *Sinella affluens* Chen & Christiansen, 1993 in 4+4 mac on dorsal head, “smooth” inner differentiated tibiotarsal chaetae, clavate tenent hairs, number of teeth on unguis and unguiculus, minute postlabial chaetae X and X₄, 2+2 pseudopores and 3+3 ciliate chaetae on manubrial plaque, medial mac on Th. II, 1+1 central mac on Abd. III, and 4+4 central mac on Abd. IV, but differs from the latter in absence of eyes, short mucronal spine, minute labial chaeta r, p5 present as mac on Th. II, m5i present as mac on Th. III, 5+5 mac on Abd. I (a3) as mes, 4+4 central mac on Abd. II (a2 as mac), 5+5 lateral mac on Abd. IV (F1 as mac).

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Faunistic patterns of leaf beetles (Coleoptera, Chrysomelidae) within elevational and temporal gradients in Sierra de San Carlos, Mexico

Uriel Jeshua Sánchez-Reyes¹, Santiago Niño-Maldonado²,
Ludivina Barrientos-Lozano¹, Shawn M. Clark³, Robert W. Jones⁴

1 División de Estudios de Posgrado e Investigación. Instituto Tecnológico de Cd. Victoria. Boulevard Emilio Portes Gil No.1301, C.P. 87010. Ciudad Victoria, Tamaulipas, México **2** Facultad de Ingeniería y Ciencias. Universidad Autónoma de Tamaulipas. Centro Universitario Victoria. CP. 87149. Victoria, Tamaulipas, México **3** Brigham Young University, Monte L. Bean Life Science Museum, Provo, Utah 84602, U.S.A. **4** Facultad de Ciencias Naturales. Universidad Autónoma de Querétaro. Avenida de las Ciencias, s/n, 76230 Juriquilla, Querétaro, México

Corresponding author: Santiago Niño-Maldonado (coliopteranino@hotmail.com)

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Abstract

The study of biodiversity of Chrysomelidae in Mexico and its variation within ecological gradients has increased recently, although important areas in the country remain to be explored. We conducted a faunistic inventory and analyzed the elevational and temporal variation of leaf beetle communities in the Sierra de San Carlos, in the state of Tamaulipas, in northeastern Mexico. This is an area with high to extreme priority for conservation, and due to its insular geographical position and to the vegetational communities present, it must be considered as a sky island. We selected seven sample sites distributed in different elevations within three localities, and comprising different vegetational communities. At each site, we randomly delimited 12 sample plots of 400 m² where sampling was conducted by entomological sweep netting and collecting directly by hand. Sampling was conducted monthly at each plot, for a total of 1,008 samples between February 2013 and January 2014. By the end of the study, we had obtained a total of 3,081 specimens belonging to six subfamilies, 65 genera, and 113 species, with *Trichaltica scabricula* (Crotch, 1873) being recorded for first time in Mexico. Species richness was less than the values observed at other studies conducted in the same region, which is attributed to differences in the number of plant

species and to the insular location of Sierra de San Carlos; however, the higher diversity values suggest a higher quality of natural resources and vegetational communities. No consistent pattern of leaf beetle communities was correlated with elevation, although higher values of species richness and diversity were obtained at the highest elevation site. The seasonal gradient showed that the rainy season is most favorable for leaf beetle communities. We found that species composition was different between sites and months, and also that there exists a significant association between the abundance obtained at each site and particular months. These results highlight the importance of different microhabitats for species distribution, and suggest that each species of Chrysomelidae has a differential response to environmental factors that vary within the elevational gradient and according to seasons. Also, we confirm and emphasize the important status of Sierra de San Carlos as a key natural area for biological conservation.

Keywords

Biodiversity, chrysomelid beetles, ecological gradient, elevation, seasonality, sky island

Introduction

Chrysomelidae (excluding Bruchinae or seed beetles), whose members are also known as leaf beetles, is one of the most diverse taxa within Coleoptera, with more than 35,000 to 40,000 described species worldwide (Jolivet et al. 2009). As a predominantly phytophagous group, some species are important crop pests, while others are used efficiently to control weeds. This characteristic also makes them an important component of ecosystems, as they can compete with other herbivores (Gómez and González-Megías 2002). Also, leaf beetles have been used as indicators of regional biodiversity and environmental quality, and for monitoring changes in natural areas (Farrell and Erwin 1988, Flowers and Hanson 2003, Kalaichelvan and Verma 2005, Linzmeier et al. 2006, Baselga and Novoa 2007, Aslan and Ayvaz 2009). Because of their importance, numerous and detailed taxonomical works on Chrysomelidae had been conducted in North America north of Mexico, Central America, and South America (Riley et al. 2003). Recently, faunistic studies have been increasing for the Mexican leaf beetle fauna.

Mexico is located within an important geographic area, and the inhabiting fauna is the result of the interface of the Neotropical and Nearctic realms. So, the study of chrysomelid distribution in this region is useful to analyze the biogeographical and ecological patterns of its species in the American continent. In Mexico, the most explored and studied areas are the Baja California peninsula (Andrews and Gilbert 2005), the central and southern portions of the country, principally at the Biosphere Reserve of Sierra de Huautla (Ordóñez-Reséndiz and López-Pérez 2009, Ordóñez-Reséndiz et al. 2011, Ordóñez-Reséndiz et al. 2015), the state of Oaxaca (Furth 2013), and the state of Morelos (Burgos-Solorio and Anaya-Rosales 2004, Niño-Maldonado et al. 2016), where important faunistic and ecological data have been obtained. Other significant contributions have focused on the states of Jalisco (Niño-Maldonado et al. 2014b, Sandoval-Becerra et al. 2015), Hidalgo (Martínez-Sánchez et al. 2009, 2010), and Veracruz (Deloya and Ordóñez-Reséndiz 2008), and on the Sierra Tarahumara

in Chihuahua (Furth 2009), as well as on country-wide studies of the tribe Alticini (Furth and Savini 1996, 1998, Furth 2006). To date, 2,174 species of Chrysomelidae are reported to be present in Mexico (Ordóñez-Reséndiz et al. 2014), but the increasing numbers of studies have provided new distribution data, as well as species recorded for the first time in the country (Medvedev et al. 2012, Moseyko et al. 2013, García-Robledo et al. 2014, López-Pérez et al. 2015, Sánchez-Reyes et al. 2015b). However, much of the faunistic information about the distribution and presence of the species in Mexico, including most recent compilations (i.e., Ordóñez-Reséndiz 2014, Niño-Maldonado et al. 2016), are based principally on documents and studies published at least over 30 years ago (Jacoby 1880, 1881, 1882, 1883, 1884, 1885, 1886, 1887, 1888a, 1888b, 1889, 1890, 1891, 1892, Baly 1885, 1886, Champion 1893, 1894, Blackwelder 1946, Wilcox 1975, Moldenke 1970), and from collection localities cited in original descriptions of species. Moreover, many of the species from these sources lack specific localities and were only labeled as “Mexico.” This clearly demonstrates the need for new faunistic studies which provide accurate data on the present distributions of chrysomelid species in Mexico.

Recently, a series of faunistic and ecological studies on leaf beetle fauna has been conducted in the northeastern portion of Mexico, specifically in the state of Tamaulipas. To date, 250 species have been recorded from this state, which now ranks fourth in chrysomelid diversity from Mexico (Niño-Maldonado et al. 2014a, Ordóñez-Reséndiz et al. 2014). Faunistic data from the state have been obtained from El Cielo Biosphere Reserve (Niño-Maldonado et al. 2005) and Peregrina Canyon, where detailed ecological and distributional patterns were also described (Sánchez-Reyes et al. 2014). Both areas are located within the Sierra Madre Oriental, and they are included in a protection category. Another very important area for biological conservation in Mexico and the northeastern portion of the country is the Sierra de San Carlos. This mountain range has been categorized as a terrestrial area with high to extreme priority for conservation, because of its insular geographical location within the northern gulf coastal plain and because of the relatively well-preserved nature of its natural resources (Arriaga et al. 2000, CONABIO 2007). Despite its biological interest, the only known studies from this area have focused on vegetation (Martínez 1998, Briones-Villarreal 1991), and only a few groups of insects (Meléndez-Jaramillo et al. 2014, 2015). Also, preliminary faunistic and ecological research on Chrysomelidae has been conducted there, showing interesting patterns and new species distributions (Sánchez-Reyes et al. 2015a).

Although data from faunistic inventories constitute a very important descriptor of diversity and allow analysis of species distribution from a region, it is also important that the variation of ecological patterns are associated with natural gradients, as they reflect the ecological and evolutionary adaptations of species to various environmental conditions (Ricklefs 2006, 2007). Elevation is one of the most studied gradients in species richness and diversity, because it dictates changes in environmental variables and abiotic factors such temperature, humidity, wind velocity, land area, and total radiation (Körner 2007, Sundqvist et al. 2013), which in turn determine distribution of species (Hodkinson 2005). The resulting patterns from these environmental influences

are different according to the studied taxa, spatial scale, or geographic region, although evidence has shown that the most common pattern is a peak in diversity at mid-elevations (Lomolino 2001, Rahbek 2005, McCain and Grytnes 2010, Sanders and Rahbek 2012, Guo et al. 2013), including a peak in diversity of Chrysomelidae (Furth 2009, Sánchez-Reyes et al. 2014). Also, temporal and seasonal gradients, which determine various patterns of species diversity, are related to changes in elevation (Körner 2007). Indeed, factors that change according to elevation, such as temperature, humidity, and vegetation, are highly variable during seasonal and temporal succession in the same mountain (Barry 2008). All these characteristics show that mountains with their elevational gradients, such as Sierra de San Carlos, can be used as key natural scenarios for analysis of patterns of diversity and also for a future assessment of changes in distribution of leaf beetles and other taxa, related to climate change (McCain and Grytnes 2010, Sundqvist et al. 2013). Based on these criteria, the objectives of our study were to: 1) conduct a taxonomic inventory of chrysomelid species from the Sierra de San Carlos, Tamaulipas, Mexico; 2) analyze the elevational and seasonal patterns of species richness, abundance, and diversity of this taxon in the study area; and 3) identify the effects of the interaction between sites and months on leaf beetle communities.

Methods

Study area

The study was conducted in the Sierra de San Carlos (Figure 1), which includes the municipalities of Burgos, Cruillas, Jiménez, San Carlos, San Nicolás, and Villagran located in the central-west portion of the state of Tamaulipas, and also the municipality of Linares in the extreme eastern part of the state of Nuevo León, Mexico (Arriaga et al. 2000). The Sierra de San Carlos comprises an area of 2320 km², being a polygon with the northwestern limit at 24°52.000'N, 99°12.067'W, and the southeastern limit at 24°23.050'N, 98°32.667'W. It constitutes an isolated mountain range within the Tamaulipas biogeographic province, bounded at the south by the Mexican gulf province (Morrone et al. 2002). Almost all vegetation types within the Sierra have a high conservation status, and they occur in principally temperate ecosystems (oak and pine forests) in the mountain areas, but there are also various types of tropical scrub vegetation in the lower areas, as well as other vegetational communities.

One of the most important characteristics of Sierra de San Carlos is its designation as a Priority Conservation Area in Mexico due to its biological, ecological and physiogeographical features: it is the northern limit of the Cloud Forest vegetation in Mexico, and it has some endemic plant species; also, it is considered as a biogeographical island (“sky island”) due to its isolation from other nearby mountain ranges, such as the Sierra Madre Oriental and Sierra de Tamaulipas (Arriaga et al. 2000). Accordingly, some areas with median, high and extreme conservation priority are located within Sierra de San Carlos (CONABIO 2007).

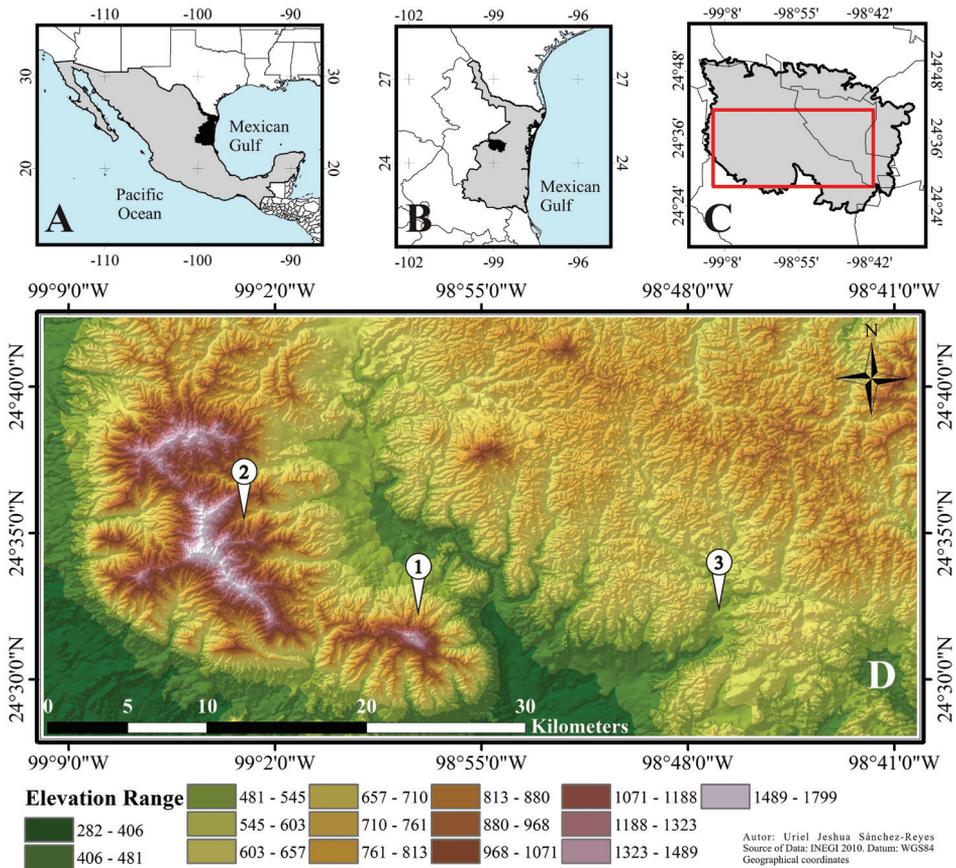


Figure 1. Study area. **A** Location of Tamaulipas in Mexico **B** Location of Sierra de San Carlos within Tamaulipas **C** Study area (red square) within Sierra de San Carlos **D** Details of study area: 1 = Cerro El Diente, 2 = Ejido Carricitos y Tinajas, 3 = San Nicolás.

Site location

We selected seven sampling sites distributed in three localities within Sierra de San Carlos (Figure 1D), including various elevations and vegetation types, as well as various conservation priorities. The first locality was Cerro El Diente which included four sampling sites: Site 1) containing submountain scrub vegetation, at a mean elevation of 550 masl; Site 2) consisting of Tamaulipan thorny scrub vegetation, at a mean elevation of 760 masl; Site 3) had oak forest vegetation, at a mean elevation of 960 masl; and Site 4) with Cloud Forest vegetation, at a mean elevation of 1080 masl. The second locality was Ejido Carricitos y Tinajas which had two sampling sites. These were: Site 5) with secondary elements of riparian vegetation, at a mean elevation of 730 masl; and Site 6) containing oak and pine forest vegetation, at a mean elevation of 820 masl. The

third locality was San Nicolás with a single sampling site: Site 7) with submountain and Tamaulipan thorny scrub vegetation, at a mean elevation of 500 masl. Both the Cerro El Diente and Ejido Carricitos y Tinajas are located within areas with extreme conservation priority; the locality of San Nicolás belongs to a median conservation category (CONABIO 2007).

Twelve sampling plots of 400 m² each (20 × 20 m) were established within each of the seven sampling sites. Plot dimensions were determined with the species-area curve method, using the nested quadrat type (Scheiner 2003). The number of plots sampled was established by Clench analysis, with 70% as a minimum limit of completeness (for a detailed analysis, see Jiménez-Valverde and Hortal 2003). The plots were previously and randomly located within each of these sites, using GIS software. This was accomplished by: 1) creating a polygon shape for the selected area of the sampling site, and 2) delimiting a square graticule inside this polygon using the Repeating Shapes tool, with the sides of the squares 20 meters in length; both procedures were made using ArcView GIS (1992–1999). 3) The graticule was exported to IDRISI Selva (1987–2012) and converted to a .kml format archive; 4) the new archive was displayed in Google Earth Pro software, permitting the visualization of the graticule of real dimension plots displayed over actual satellite imagery; and finally, 5) this graticule was treated as a coordinate system (rows and columns), and the location of each one of the 12 plots was selected by the random numbers tool in Microsoft Office Excel. These methods were employed for the seven sites, and the only difference was the dimensions of the polygon shape of the sample area which were adjusted to the vegetational communities. Plots were georeferenced and later located in the field. When a plot was located in areas not accessible or impossible to sample (i.e. steep hills, areas of bare soil), it was moved to the closest location where vegetational cover was available. Detailed geographical data (latitude and longitude coordinates, elevation) for each plot within each site are presented in Tables 1–3; detailed spatial arrangement of sampling plots within each site is presented in Figures 2–5.

Collection and processing of specimens

Systematic sampling was conducted between 10:00 and 17:00 h, using a standard entomological sweep net of 40 cm diameter. Individual samples consisted of 120–200 sweeps of the shrub and herbaceous vegetation in each plot. Contents of the net were emptied into a plastic bag, adding 60% ethanol and an indelible label with corresponding data. Each plot (12) within the seven sites was sampled monthly, from February 2013 to January 2014, comprising 1,008 total samples at the end of the study; sweeping was conducted by the same person during the whole study to reduce sampling error. Each sample and the specimens obtained were processed according to the method described by Sánchez-Reyes et al. (2014). Also, leaf beetles encountered independent of the standardized sweeps were added to the species checklist. Specimens are deposited in the collection of the Facultad de Ingeniería y Ciencias at the Universidad Autónoma de Tamaulipas, Ciudad Victoria, Tamaulipas, Mexico.

Table 1. Sampling data in the Cerro El Diente locality, Sierra de San Carlos, Mexico (coordinates at center of plot; elevation in meters).

Cerro El Diente							
Site 1 – Submountain scrub				Site 2 – Tamaulipan thorny scrub			
Sampling plot	Latitude	Longitude	Elevation	Sampling plot	Latitude	Longitude	Elevation
P1	24°33.020'N	98°57.004'W	550	P1	24°32.468'N	98°57.454'W	772
P2	24°33.048'N	98°57.013'W	548	P2	24°32.471'N	98°57.402'W	790
P3	24°33.062'N	98°56.960'W	544	P3	24°32.471'N	98°57.374'W	784
P4	24°33.068'N	98°57.047'W	547	P4	24°32.492'N	98°57.353'W	766
P5	24°33.104'N	98°57.073'W	535	P5	24°32.501'N	98°57.383'W	773
P6	24°32.996'N	98°57.096'W	555	P6	24°32.490'N	98°57.416'W	778
P7	24°32.936'N	98°57.082'W	561	P7	24°32.496'N	98°57.460'W	760
P8	24°32.920'N	98°57.173'W	570	P8	24°32.522'N	98°57.469'W	750
P9	24°33.031'N	98°57.333'W	571	P9	24°32.537'N	98°57.473'W	743
P10	24°33.105'N	98°57.316'W	557	P10	24°32.531'N	98°57.452'W	750
P11	24°32.995'N	98°57.237'W	560	P11	24°32.522'N	98°57.423'W	755
P12	24°33.046'N	98°57.137'W	540	P12	24°32.543'N	98°57.441'W	745
Site 3 – Oak forest				Site 4 – Cloud forest			
Sampling plot	Latitude	Longitude	Elevation	Sampling plot	Latitude	Longitude	Elevation
P1	24°32.038'N	98°57.496'W	938	P1	24°31.780'N	98°57.557'W	1077
P2	24°32.018'N	98°57.466'W	935	P2	24°31.795'N	98°57.565'W	1065
P3	24°32.021'N	98°57.500'W	950	P3	24°31.780'N	98°57.593'W	1070
P4	24°32.026'N	98°57.539'W	948	P4	24°31.774'N	98°57.622'W	1055
P5	24°31.996'N	98°57.489'W	964	P5	24°31.753'N	98°57.631'W	1085
P6	24°31.984'N	98°57.456'W	948	P6	24°31.760'N	98°57.672'W	1077
P7	24°31.973'N	98°57.480'W	971	P7	24°31.744'N	98°57.695'W	1093
P8	24°32.002'N	98°57.543'W	967	P8	24°31.730'N	98°57.738'W	1112
P9	24°31.995'N	98°57.516'W	974	P9	24°31.738'N	98°57.783'W	1109
P10	24°31.968'N	98°57.527'W	993	P10	24°31.751'N	98°57.816'W	1102
P11	24°31.981'N	98°57.550'W	982	P11	24°31.776'N	98°57.831'W	1086
P12	24°31.970'N	98°57.577'W	979	P12	24°31.793'N	98°57.868'W	1076

Taxonomic determination

Identification of specimens was made using available literature on Chrysomelidae (Wilcox 1965, White 1968, Wilcox 1972, Scherer 1983, White 1993, Flowers 1996, Riley et al. 2002, Staines 2002). Additionally, material was compared with identified specimens deposited in the collection of Chrysomelidae of the Facultad de Ingeniería y Ciencias, Universidad Autónoma de Tamaulipas. However, those specimens that could not be identified to the species level were compared with other unidentified specimens and carefully grouped into morphospecies, and so the designation of “species” in this study includes both morphospecies and determined species. Taxonomical arrangement follows the categories employed by Riley et al. (2003), except that the subfamily Bruchinae is not included in this study.

Table 2. Sampling data in the Ejido Carricitos y Tinajas locality, Sierra de San Carlos, Mexico (coordinates at center of plot; elevation in meters).

Ejido Carricitos y Tinajas							
Site 5 – Riparian and secondary vegetation				Site 6 – Oak and pine forests			
Sampling plot	Latitude	Longitude	Elevation	Sampling plot	Latitude	Longitude	Elevation
P1	24°35.807'N	99°2.450'W	700	P1	24°35.397'N	99°3.037'W	839
P2	24°35.789'N	99°2.484'W	701	P2	24°35.420'N	99°3.023'W	830
P3	24°35.764'N	99°2.508'W	704	P3	24°35.440'N	99°3.041'W	816
P4	24°35.727'N	99°2.534'W	712	P4	24°35.463'N	99°3.017'W	814
P5	24°35.684'N	99°2.600'W	716	P5	24°35.491'N	99°3.028'W	795
P6	24°35.719'N	99°2.654'W	720	P6	24°35.567'N	99°3.067'W	813
P7	24°35.673'N	99°2.766'W	740	P7	24°35.563'N	99°3.101'W	827
P8	24°35.632'N	99°2.851'W	757	P8	24°35.575'N	99°3.124'W	846
P9	24°35.605'N	99°2.894'W	764	P9	24°35.579'N	99°3.146'W	860
P10	24°35.571'N	99°2.870'W	763	P10	24°35.577'N	99°3.175'W	866
P11	24°35.545'N	99°2.806'W	773	P11	24°35.548'N	99°3.013'W	788
P12	24°35.533'N	99°2.909'W	776	P12	24°35.584'N	99°2.970'W	780

Table 3. Sampling data in the San Nicolás locality, Sierra de San Carlos, Mexico (coordinates at center of plot; elevation in meters).

Site 7 – Tamaulipan thorny scrub and submountain scrub vegetation			
Sampling plot	Latitude	Longitude	Elevation
P1	24°32.356'N	98°46.936'W	502
P2	24°32.319'N	98°47.006'W	501
P3	24°32.290'N	98°47.073'W	500
P4	24°32.224'N	98°47.117'W	499
P5	24°32.180'N	98°47.153'W	499
P6	24°32.371'N	98°46.883'W	503
P7	24°32.391'N	98°46.840'W	508
P8	24°32.427'N	98°46.797'W	510
P9	24°32.450'N	98°46.759'W	508
P10	24°32.485'N	98°46.702'W	508
P11	24°32.334'N	98°46.922'W	502
P12	24°32.295'N	98°46.906'W	503

Organization of seasonal data

We obtained environmental data from two meteorological stations located in the municipalities of San Carlos and San Nicolás in the study area. Historical data of total monthly rainfall and monthly average temperature (only the average from 1951-2010 was available) were plotted to visually analyze the fluctuation of these parameters. On

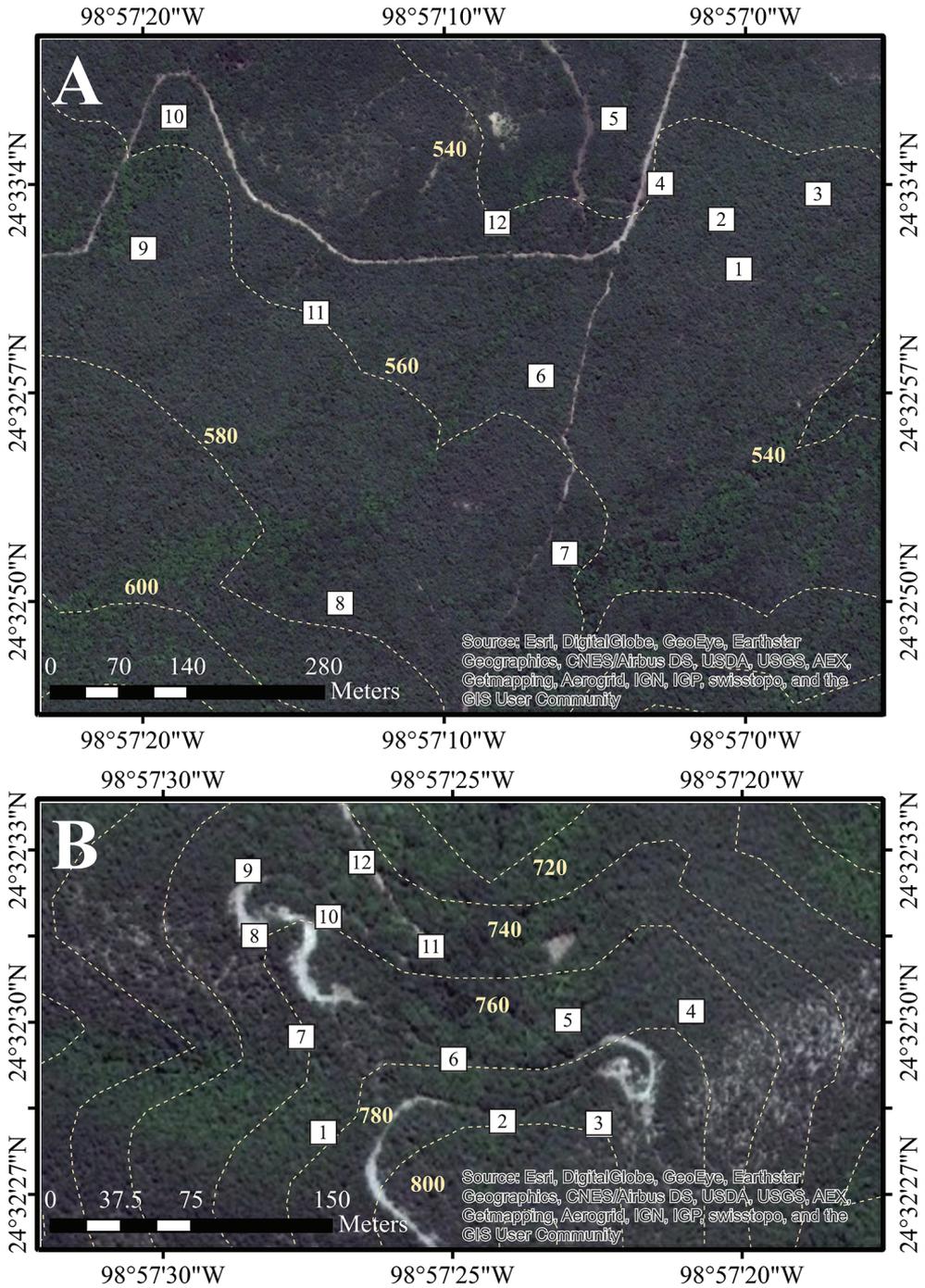


Figure 2. Detailed position of sampling plots in Sierra de San Carlos. Cerro El Diente locality: **A** Site 1 **B** Site 2. Dotted lines shows elevation curves.

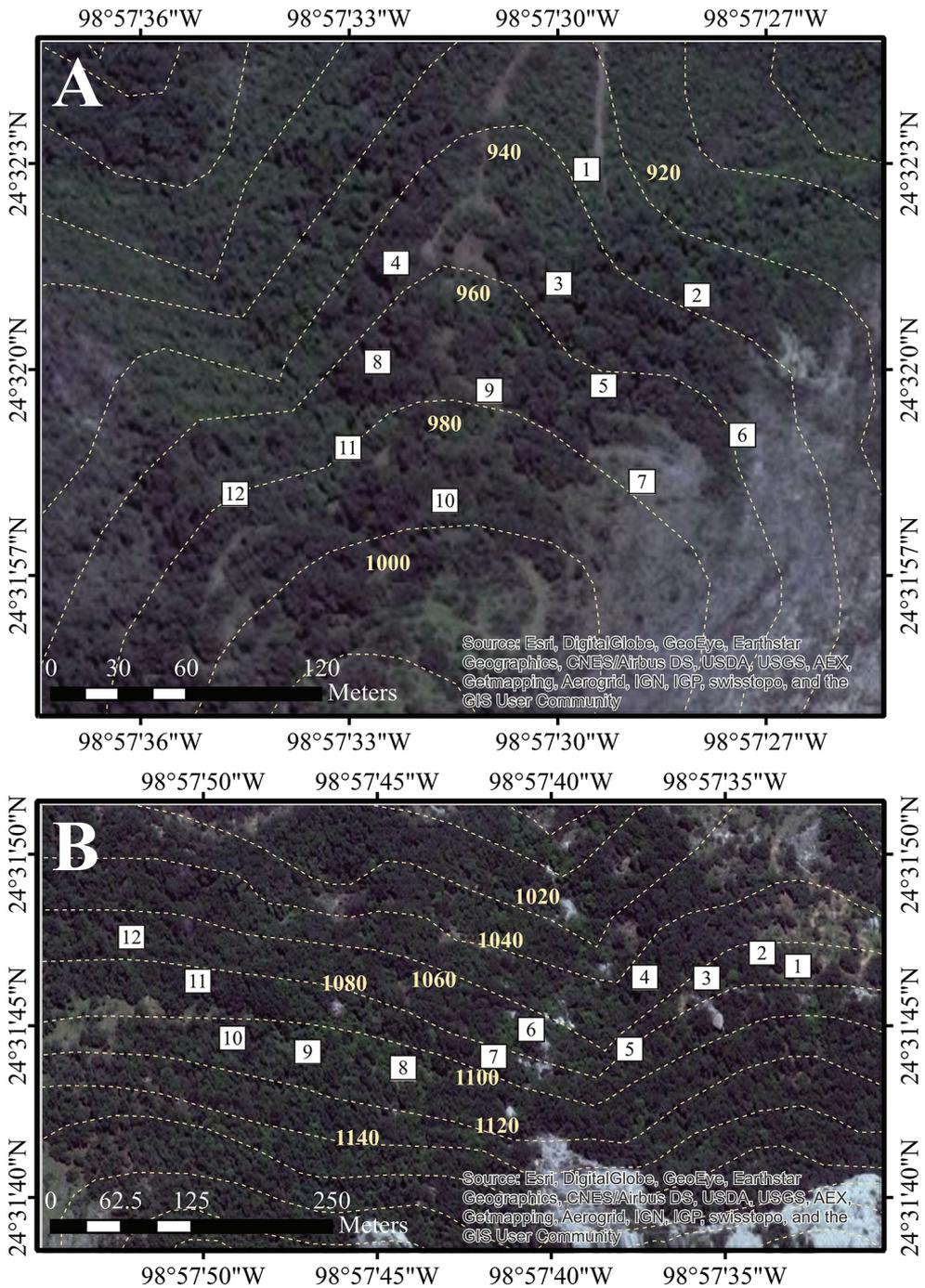


Figure 3. Detailed position of sampling plots in Sierra de San Carlos. Cerro El Diente locality: **A** Site 3 **B** Site 4. Dotted lines shows elevation curves.

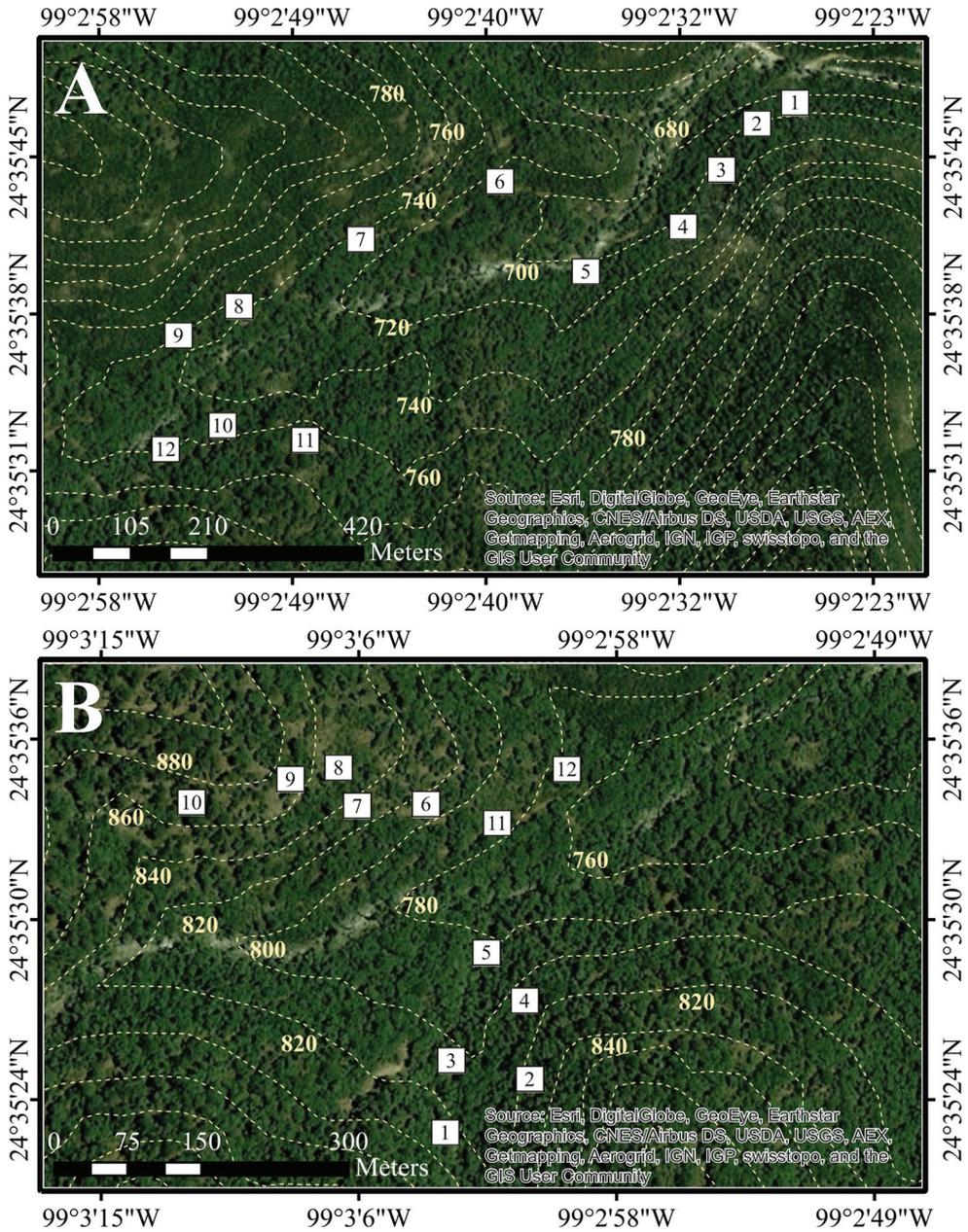


Figure 4. Detailed position of sampling plots in Sierra de San Carlos. Ejido Carricitos y Tinajas locality: **A** Site 5 **B** Site 6. Dotted lines shows elevation curves.

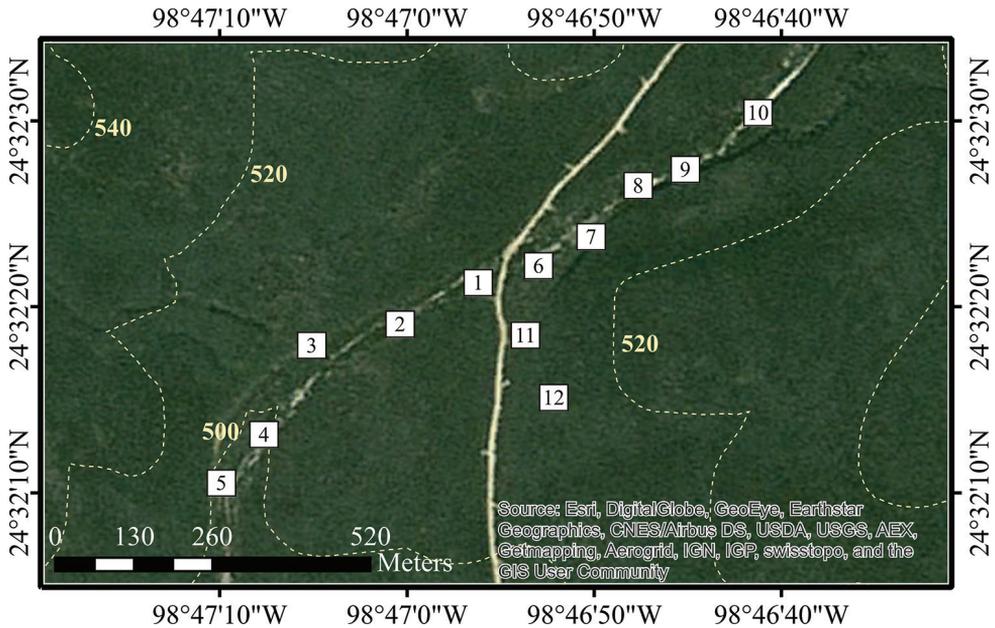


Figure 5. Detailed position of sampling plots in Sierra de San Carlos. San Nicolás locality, Site 7. Dotted lines shows elevation curves.

this basis, four seasons were defined: Early dry season (EDS: November, December, January), Late dry season (LDS: February, March, April), Early rainy season (ERS: May, June, July), and Late rainy season (LRS: August, September, October). Data of precipitation and temperature were correlated with species richness and abundance, using a Spearman correlation analysis in STATISTICA 8.0 (StatSoft Inc. 2007).

Data analysis

All the following analyses were made only with the data obtained through systematic sampling (i.e., by sweeping in 12 plots at each site). Species collected otherwise were excluded from the analysis, but are included in the checklist of species.

As a measure of species richness, we used the total number of species present throughout the Sierra de San Carlos, and at each site and season. Significant differences in the number of species were assessed through permutation tests in PAST 3.07 (Hammer et al. 2001). Estimated species richness at each level was measured by means of the nonparametric estimators ACE, Chao 1, and Jackknife 1 (Magurran 2004, Hortal et al. 2006, Gotelli and Colwell 2011), and was calculated with the software EstimateS 8.2 (Colwell 2013), using 100 randomizations without replacement and the abundance data of each species found per sampling unit (plot). Also, we used the Clench model to determine the sampling efficiency through the estimated species richness and

the slope of the species accumulation curve, which measures the inventory quality; calculations were made according to the method described by Jiménez-Valverde and Hortal (2003), and were performed in STATISTICA 8.0 (StatSoft Inc. 2007).

Species from Sierra de San Carlos were divided into five categories, according to their total abundance: 1) very common (more than 70 individuals); 2) common (11 to 70 specimens); 3) rare (3 to 10 specimens); 4) doubletons (two specimens); and 5) singletons (one specimen only). These categories were used because they have been implemented in similar studies with Chrysomelidae, also in the state of Tamaulipas (Sánchez-Reyes et al. 2014). Also, abundance was measured at each site and season, and differences between these values were analyzed with Kruskal-Wallis and Mann-Whitney nonparametric tests, as data did not meet the assumptions of normality. We used the Simpson dominance index (D) and the Shannon entropy index (H') to measure both principal components of alpha diversity (Magurran 2004). Values obtained were transformed to a true diversity value according to Jost (2006, 2007), and were calculated for the whole study area and for each site and season. Differences in species composition between each pairwise comparison of sites and months were assessed through PERMANOVA analysis, using the Bray-Curtis index as distance measure, with 9999 random permutations. Beta diversity was measured as the faunistic similarity between sites and months, using the Bray-Curtis index of similarity; also, a Cluster analysis was performed to define groups of sites and months according to species composition, using the Bray-Curtis index as a distance measure and the Ward method as an amalgamation algorithm. All calculations were made in PAST 3.07 (Hammer et al. 2001) and STATISTICA 8.0 (StatSoft Inc. 2007).

Finally, the association of abundance and species richness obtained at each elevational site during each month was measured with a Correspondence analysis. This is a multivariate technique based on contingency tables and count data, where the significant statistical dependence between rows (sites) and columns (months) is tested by a chi-square test (Beh 2004). The analysis was conducted in STATISTICA 8.0.

Results

Leaf beetles in Sierra de San Carlos

In total, 3,081 specimens, belonging to 109 species, 63 genera and six subfamilies, were obtained. An additional four species were obtained by independent collecting in various sites from study area, resulting in a total species richness of 113 species and 65 genera within the study period (2013-2014) in the Sierra de San Carlos (Appendix 1, Figures 6–7). According to ACE, Chao 1, and Jackknife indexes, the estimated species richness was between 115.88 and 128.98 species; also, the estimation using the Clench Model was 120 species. These values indicate that the proportion of observed species richness in relation to the richness estimates was 84.5 to 94% (Table 4). Slope value of the Clench Model suggests that faunistic inventory in Sierra de San Carlos was

Table 4. Observed and estimated species richness of Chrysomelidae by site and season at Sierra de San Carlos, Mexico. Elevation in meters. EDS = Early dry season, LDS = Late dry season, ERS = Early rainy season, LRS = Late rainy season.

	S_{obs}	Nonparametric indexes			Clench model		Completeness (%)
		Chao 1	Jack 1	ACE	S_{est}	Slope	
Elevation*							
500 (S7)	33 d	36.5±3.5	42.93±3.35	38.7±0.65	42.07	0.05	76.8–90.4
550 (S1)	38 abcd	41.57±3.1	48.92±3.75	47.58±0	53.82	0.07	77.6–91.4
730 (S5)	36 defg	52.9±12.72	49.9±4.06	50.57±0.71	48.31	0.066	68.05–72.1
760 (S2)	40 ae	40.89±1.26	46.95±2.57	43.43±0.46	50.51	0.05	85.19–97.82
820 (S6)	27 cg	39.25±13.15	33.95±2.93	33.62±0.71	31.47	0.03	68.78–79.52
960 (S3)	47 bf	50.38±3.06	56.93±3.35	52.83±0.53	60.83	0.074	82.55–93.29
1080 (S4)	50 b	58.64±6.82	62.91±5.44	58.76±0.49	60.89	0.065	79.47–85.26
Season*							
EDS	40 a	44±3.74	48.96±2.94	45.88±0.5	47.5	0.026	81.69–90.9
LDS	49 b	55.4±5.92	57.96±3.26	53.55±0.27	57.49	0.029	84.54–88.44
ERS	78 c	91.88±8.32	102.9±5.69	94.66±1.17	102.17	0.075	75.8–84.89
LRS	76 c	82.62±4.57	93.93±4.54	87.65±0.77	92.97	0.058	80.91–91.98
Total	109	115.88±4.5	128.98±5.06	122.47±0	120.46	0.012	84.5–94

S_{obs} = observed species richness; S_{est} = estimated species richness. *Species richness values of sites and seasons with different letters between rows are significantly different from each other ($p < 0.05$), according to permutation tests.

complete and reliable (slope = 0.012). The Dominance value for the Simpson index (D) was 0.066, with a diversity value (1/D) of 15.064. For the Shannon index (H'), the value was 3.41, with a diversity value ($e^{H'}$) of 30.29.

The most abundant subfamily in the study area was Galerucinae (including Alticini), with 53.6% (1,652 specimens) of the total abundance of Chrysomelidae in the Sierra de San Carlos, followed by Cryptocephalinae with 26.9% (828 specimens). Less abundance was found in Eumolpinae (12.6%, 388 specimens), Cassidinae (4.9%, 152 specimens), Chrysomelinae (1.1%, 33 specimens) and Criocerinae (0.9%, 28 specimens). Species counts per subfamily were greatest for Galerucinae, with 54 species (49.5%) representing half of the total species richness recorded in Sierra de San Carlos. Lower values were recorded for Cryptocephalinae with 27 species (24.8%), Eumolpinae with nine species (8.3%), Cassidinae and Criocerinae both with eight species (7.3%), and Chrysomelinae with only three species (2.8%).

Eight species were categorized as “very abundant species,” each with over 70 specimens that accounted for 60.3% (1,859 total specimens) of the total abundance obtained from Sierra de San Carlos. Of these eight species, *Syphrea* sp. 2 (475 specimens) and *Diachus* sp. 1 (418) were the most abundant, followed by *Xanthonia* sp. 1 (276), *Centralaphthona diversa* (Baly, 1877) (244), *Chrysogramma* sp. 1 (193), *Pachybrachis* sp. 1 (103), *Sumitrosis inaequalis* (Weber, 1801) (78), and *Margaridisa atriventris*

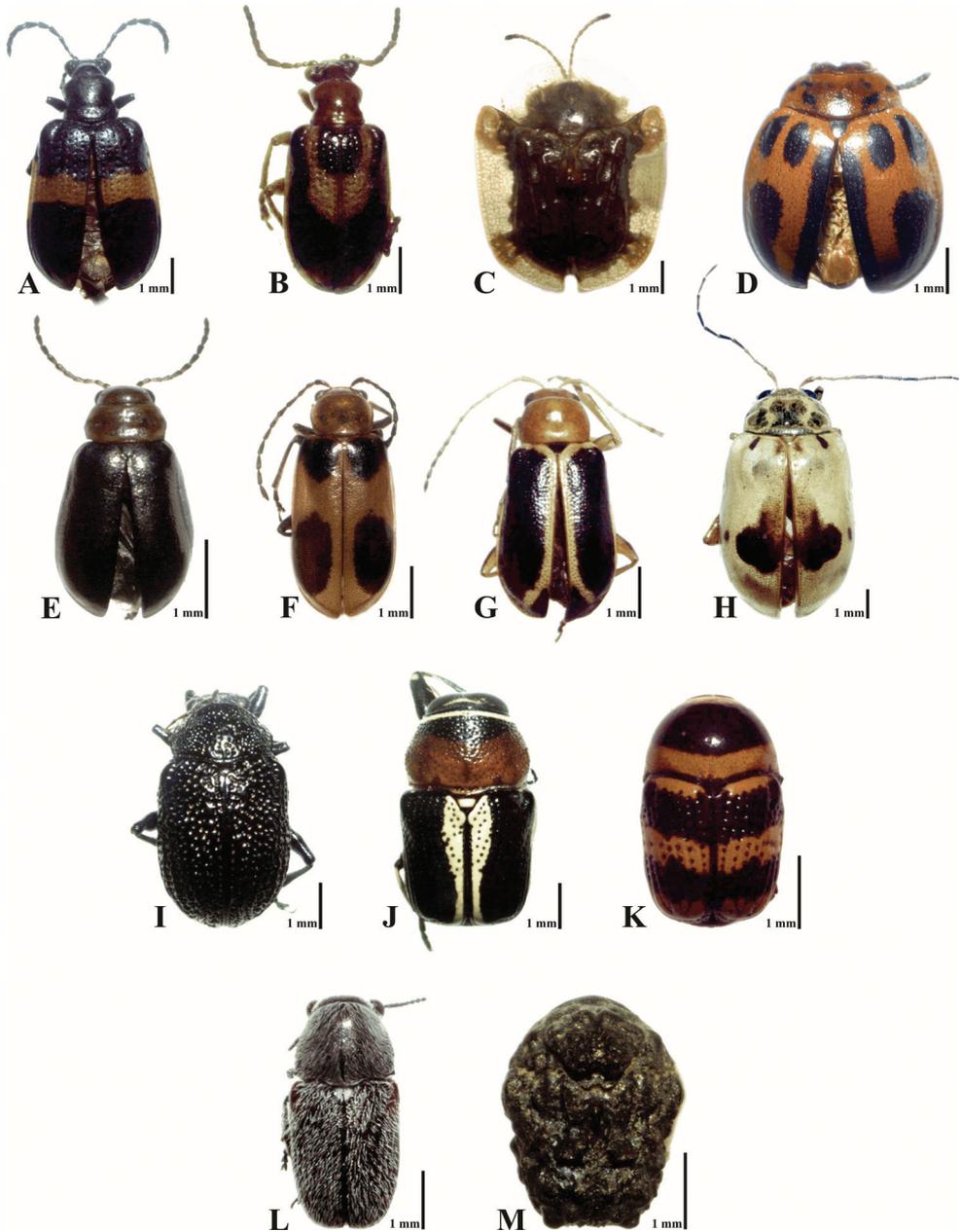


Figure 6. Examples of leaf beetle biodiversity from Sierra de San Carlos, Mexico. **A** *Lema balteata* LeConte, 1884 **B** *Lema opulenta* Harold, 1874 **C** *Helocassis clavata* (Fabricius, 1798) **D** *Plagioderma semivittata* Stål, 1860 **E** *Miraces aeneipennis* Jacoby, 1888 **F** *Malacorhinus acaciae* (Schaeffer, 1906) **G** *Cyclotrypema furcata* (Olivier, 1808) **H** *Acrocylum dorsalis* Jacoby, 1885 **I** *Colaspis melancholica* Jacoby, 1881 **J** *Griburium montezuma* (Suffrian, 1852) **K** *Cryptocephalus trizonatus* Suffrian, 1858 **L** *Coscinoptera tamaulipasi* Medvedev, 2012 **M** *Diplacaspis prosternalis* (Schaeffer, 1906).

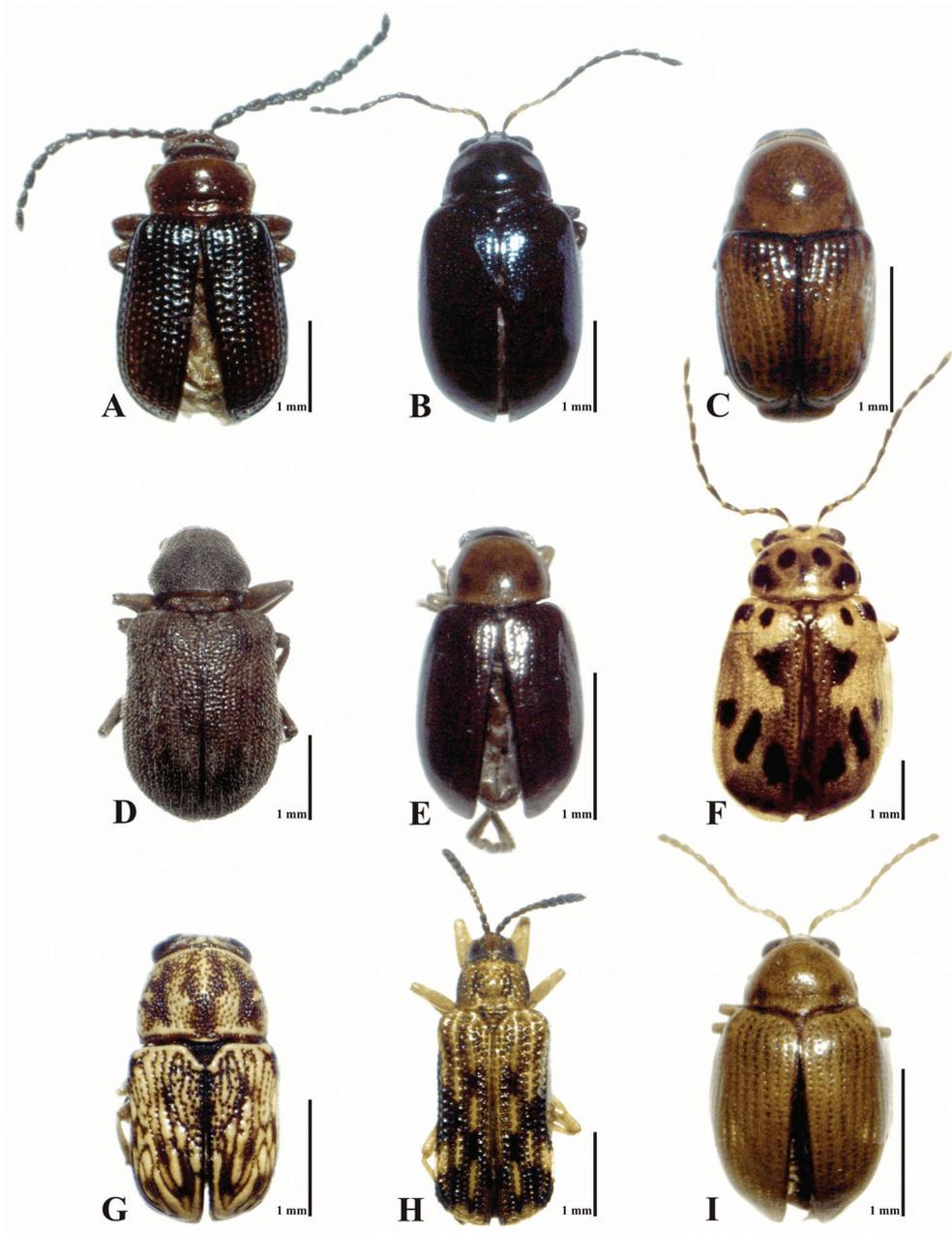


Figure 7. Examples of leaf beetle biodiversity from Sierra de San Carlos, Mexico. **A** *Trichaltica scabricula* (Crotch, 1873), new country record. In decreasing order from **B** to **I**, the most abundant species in the current study. **B** *Syphrea* sp. 2 **C** *Diachus* sp. 1 **D** *Xanthonia* sp. 1 **E** *Centralaphthona diversa* (Baly, 1877) **F** *Chrysogramma* sp. 1 **G** *Pachybrachis* sp. 1 **H** *Sumitrosis inaequalis* (Weber, 1801) **I** *Margaridisa atriventris* (Melsheimer, 1847).

(Melsheimer, 1847) (72) (Figure 7B-7I). The proportion of 31.6% (974 specimens) of the total abundance was accounted for by 34 species categorized as “common,” while 29 species were considered as “rare” (6.13% of the total abundance). Only 21 species were doubletons, and 17 were singletons. *Trichaltica scabricula* (Crotch, 1873) is recorded for the first time in Mexico (Figure 7A).

Species richness and inventory completeness of Chrysomelidae by elevation site and season in Sierra de San Carlos

No clear patterns of species richness were found with elevation. The greatest number of species (50) was recorded at the site of highest elevation (1080 masl), but this value was not significantly different from values observed at 960 (47 species) and 550 masl (38 species). The smallest number of species (27) was registered at a high elevation site (820 masl); however, it was not significantly different from sites at 730 (36 species) and 550 masl (Table 2). Completeness exceeded 70% in all sites, with a maximum value of 97% at Site 2 (760 masl), although lower values were obtained at both sites from the Carricitos y Tinajas locality (730 and 820 masl). The slope of the Clench model was less than 0.1 for each of the sites (Table 4).

Regarding seasonal analysis, the species richness increased progressively and significantly from early dry season (40 species) to early rainy season (78 species). The value decreased to 76 species during late rainy season, although this change was not significant. Seasonal values of estimated species richness through nonparametric indexes and the Clench model followed the same pattern as that of sites, because all values were above 70% of completeness, with slopes under 0.1 for all the seasons (Table 4).

Elevational patterns of leaf beetle abundance and diversity in Sierra de San Carlos

We found significant variations in abundance and diversity of Chrysomelidae between sites of differing elevation (Kruskal Wallis Test, $H=100.7$, $p<0.0001$). However, these parameters did not show a specific trend with the increase or decrease in elevation. For example, the highest abundance (665 individuals) was present at the lowest site (500 masl), whereas the lowest value (173 individuals) was obtained at the second lowest elevation (550 masl). Also, differences in abundance obtained between the site of lowest elevation (665 individuals) and site at 960 masl (561 individuals) were not significant, while the number of specimens (440) at the highest site was not statistically different from values observed at lower sites (960, 820 and 760 masl). The lowest abundances were present at 550 (173 specimens) and 730 masl (231 specimens), and these values were significantly different from other elevational sites (Tables 5, 6).

As observed with abundance, no clear patterns of diversity were found with elevation, although all sites were significantly different from each other. The highest

Table 5. Mann-Whitney pairwise comparisons of chrysomelid abundance between elevational sites in Sierra de San Carlos, Mexico. Upper diagonal = Mann-Whitney U values. Lower diagonal = p values; marked values (*) are significant.

	S1–550 m	S2–760 m	S3–960 m	S4–1080 m	S5–730 m	S6–820 m	S7–500 m
Site 1	–	6723	5344	6289	8234	6197	4675
Site 2	<0.0001*	–	8853	9920	8336	9735	8126
Site 3	<0.0001*	0.03007*	–	9232	6782	9509	9634
Site 4	<0.0001*	0.52	0.1042	–	7778	10100	8530
Site 5	0.001504*	0.003257*	<0.0001*	0.000181*	–	7707	6002
Site 6	<0.0001*	0.3634	0.2197	0.748	0.000121*	–	8758
Site 7	<0.0001*	0.001351*	0.2958	0.008679*	<0.0001*	0.02159*	–

Table 6. Elevational variation of abundance and diversity of Chrysomelidae in Sierra de San Carlos, Mexico.

Parameter	Study site [‡]						
	S7	S1	S5	S2	S6	S3	S4
Elevation (masl)	500	550	730	760	820	960	1080
Abundance [†]	665 a	173 b	231 c	432 d	579 df	561 aef	440 de
Diversity*							
D = Simpson index (dominance)	0.406 a	0.078 b	0.101 c	0.137 d	0.183 e	0.156 f	0.0508 g
1/D = Simpson Diversity index	2.46 a	12.66 b	9.89 c	7.29 d	5.45 e	6.38 f	19.66 g
H' = Shannon index	1.716 a	3.067 b	2.819 c	2.638 d	2.185 e	2.576 d	3.328 g
$e^{H'}$ = Shannon Diversity	5.56 a	21.47 b	16.76 c	13.98 d	8.89 e	13.14 d	27.88 g

[‡]S1 to S7 = Sites 1 to 7, arranged from low to high elevation. Details about the numbering of the sites are in the Materials and Methods section. [†] Abundance values with different letters between columns are significantly different from each other (Kruskal-Wallis, $H=100.7$, $p=0.000$), according to p values in Table 5. *Diversity values with different letters between columns are significantly different from each other ($p<0.05$), according to permutation tests.

dominance ($D=0.406$) and lowest entropy ($H'=1.716$) were obtained in the site of lowest elevation (500 m), indicating that the lowest diversity was found at this site ($1/D=2.46$; $e^{H'}=5.56$). However, the second highest value of diversity in the study area ($1/D=12.66$; and $e^{H'}=21.47$) was obtained at the second lowest elevation site (550 meters). Diversity decreased progressively from the third (730 meters) to the fifth elevational site (820 m), and then increased from 960 masl to the highest elevation site (1080 masl), where the lowest dominance ($D=0.0508$) and highest values of entropy ($H'=3.328$) and diversity ($1/D=19.66$; $e^{H'}=27.88$) were obtained (Table 6).

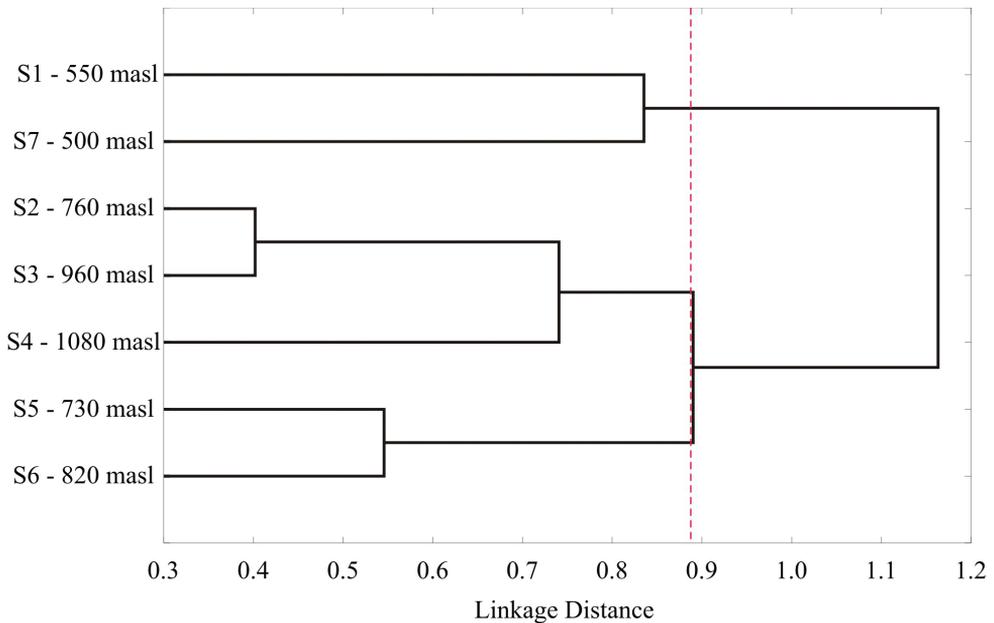
According to the PERMANOVA analysis, the leaf beetle composition between sites was statistically different ($SS_{total}=33.16$; $SS_{within-group}=23.22$; $F=5.492$, $p=0.0001$), and almost all pairwise comparisons were significantly different, except for Site 2 (760 masl) and Site 3 (960 masl) ($F=1.595$, $p=0.1151$) (Table 7). The Bray-Curtis index also showed that Site 2 and Site 3 were the most similar in the study area, with 59%

Table 7. PERMANOVA pairwise comparisons of chrysomelid composition between elevational sites in Sierra de San Carlos, Mexico. Upper diagonal = F values. Lower diagonal = p values.

	S7–500 m	S1–550 m	S5–730 m	S2–760 m	S6–820 m	S3–960 m	S4–1080 m
Site 7	–	7.446	11.65	10.89	12.17	9.959	9.959
Site 1	0.0001	–	4.59	3.452	5.391	4.057	4.692
Site 5	0.0001	0.0001	–	5.13	2.497	4.229	4.658
Site 2	0.0001	0.0001	0.0001	–	4.171	1.595	3.449
Site 6	0.0001	0.0001	0.0182	0.0001	–	3.231	3.636
Site 3	0.0001	0.0001	0.0001	0.1151	0.0002	–	2.644
Site 4	0.0001	0.0001	0.0001	0.0001	0.0001	0.0007	–

Table 8. Bray–Curtis similarity between elevational sites in Sierra de San Carlos, Mexico. Upper diagonal = Index values. Lower diagonal = values expressed as percentage of similarity.

	S1–550 m	S2–760 m	S3–960 m	S4–1080 m	S5–730 m	S6–820 m	S7–500 m
Site 1	–	0.25455	0.14441	0.16639	0.24752	0.16755	0.16468
Site 2	25.455	–	0.59819	0.31651	0.19005	0.36993	0.074749
Site 3	14.441	59.819	–	0.37163	0.18434	0.45965	0.03752
Site 4	16.639	31.651	37.163	–	0.27422	0.33562	0.050679
Site 5	24.752	19.005	18.434	27.422	–	0.45432	0.051339
Site 6	16.755	36.993	45.965	33.562	45.432	–	0.067524
Site 7	16.468	7.4749	3.752	5.0679	5.1339	6.7524	–

**Figure 8.** Cluster analysis of chrysomelid composition by elevational site in Sierra de San Carlos, Mexico. Delimitation of groups is indicated by red dotted line.

faunistic similarity. Values below 50% were obtained for all other comparisons, with the lowest percentages associated with Site 7 when compared to all others (Table 8). Cluster analysis suggested that three groups were generated on the basis of the difference in leaf beetle composition between elevation sites: Site 5 and Site 6 (Group 1); Site 2, Site 3 and Site 4 (Group 2); Site 1 and Site 7 (Group 3) (Figure 8).

Seasonal patterns of leaf beetle abundance and diversity in Sierra de San Carlos

Abundance and diversity values showed significant variation between seasons ($H=92.29$, $p<0.0001$). The lowest number of specimens (433) was recorded at early dry season, and abundance increased significantly at the end of the season (888 specimens). Abundance decreased at early rainy season (690 specimens), although this reduction was not significant; then, the value increased significantly at the late rainy season, which recorded the highest abundance (1,070 specimens) in this study (Tables 9, 10). Similarly, the highest dominance ($D=0.146$) and the lowest values of entropy ($H'=2.736$) and diversity ($1/D=6.84$; $H'=15.42$) were obtained in the early dry season. These values changed significantly at late dry season ($1/D=9.90$; $H'=17.01$) and also during the early rainy season, when the highest diversity was obtained ($1/D=18.68$; $H'=33.38$) (Table 10). Monthly temperature and precipitation data (Figure 9) showed a significant positive correlation ($p<0.05$) with the number of species recorded by month in Sierra de San Carlos, whereas abundance was not correlated with environmental parameters (Table 11).

Seasonal species composition and faunistic similarity were analyzed using monthly values. Significant differences in species composition between months were found ($SS_{\text{total}}=33.16$; $SS_{\text{within-group}}=27.33$; $F=1.395$, $p=0.0009$). Pairwise comparisons showed that differences were obtained principally between early (January, February, March, April and May) and later months (July, September, October, November and December) (Table 12). The highest similarity occurred between September-October (89.4%), January-February (72.1%), November-December (69.8%), April-May (69%), and February-March (63.6%), whereas other comparisons were less than or close to 50% (Table 13). Three clusters were formed according to monthly leaf beetle composition: January to June (Group 1), July to October (Group 2), and November-December (Group 3) (Figure 10).

Effect of elevation-month interaction on leaf beetle communities in Sierra de San Carlos

The Correspondence analysis showed no significant associations in the number of species obtained by site for each month (Total Inertia=0.08796, $\text{Chi}^2=74.147$, $df=66$, $p=0.23014$). However, the association of abundance between sites and months was significant (Total Inertia=0.32237, $\text{Chi}^2=993.24$, $df=66$, $p=0.0000$). The most clear

Table 9. Mann-Whitney pairwise comparisons for chrysomelid abundance between seasons in Sierra de San Carlos, Mexico. Upper diagonal = Mann-Whitney U values. Lower diagonal = p values; marked values (*) are significant.

	Early dry season	Late dry season	Early rainy season	Late rainy season
Early dry season	–	22600	23100	16400
Late dry season	<0.0001*	–	30900	25400
Early rainy season	<0.0001*	0.597	–	24300
Late rainy season	<0.0001*	0.000083*	0.0000038*	–

Table 10. Seasonal variation of abundance and diversity of Chrysomelidae in Sierra de San Carlos, Mexico.

Parameter	Dry Season		Rainy Season	
	Early (EDS)	Late (LDS)	Early (ERS)	Late (LRS)
Abundance[‡]	433 a	888 b	690 b	1070 c
Diversity*				
D = Simpson index (dominance)	0.146 a	0.101 b	0.053 c	0.104 b
1/D = Simpson Diversity index	6.84 a	9.90 b	18.68 c	9.59 b
H' = Shannon index	2.736 a	2.834 b	3.508 c	3.091 d
$e^{H'}$ = Shannon Diversity	15.42 a	17.01 b	33.38 c	21.99 d

[‡] Abundance values with different letters between columns are significantly different from each other (Kruskal-Wallis, $H=92.29$, $p=0.000$), according to p values in Table 9. *Diversity values with different letters between columns are significantly different from each other ($p<0.05$), according to permutation tests.

Table 11. Spearman correlation analysis for abundance and species richness of Chrysomelidae with temperature and precipitation in Sierra de San Carlos, Mexico. Marked values (*) are significant.

	Temperature [°C]		Precipitation [mm]	
	San Carlos	San Nicolás	San Carlos	San Nicolás
Abundance	0.532	0.559	0.531	0.349
Species Richness	0.809*	0.822*	0.826*	0.710*

associations were observed between abundance obtained at lower elevations (500 and 550 masl) and the period comprised by September to December, while the number of specimens in Site 3 (960 masl) were highly related to August. January and February were principally associated with Site 5 (730 masl) and Site 2 (760 masl). The March-May period was associated with Site 6 (820 masl), and the abundance found at the highest elevation site (1080 masl) was predominantly related with June (Figure 11).

Table 12. PERMANOVA pairwise comparisons of chrysolimid composition between months in Sierra de San Carlos, Mexico. Upper diagonal = F values. Lower diagonal = *p* values; values in bold are significant.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	–	0.964	0.344	0.063	0.105	0.312	0.029	0.076	0.017	0.022	0.010	0.031
Feb	0.191	–	0.799	0.055	0.093	0.299	0.040	0.162	0.036	0.029	0.014	0.039
Mar	1.076	0.629	–	0.666	0.350	0.115	0.031	0.179	0.023	0.014	0.010	0.033
Apr	1.668	1.583	0.812	–	0.939	0.206	0.038	0.075	0.009	0.004	0.012	0.047
May	1.442	1.407	1.076	0.493	–	0.587	0.287	0.163	0.008	0.006	0.014	0.035
Jun	1.147	1.168	1.416	1.23	0.902	–	0.467	0.685	0.083	0.082	0.005	0.013
Jul	1.749	1.607	1.639	1.563	1.12	0.995	–	0.879	0.546	0.479	0.071	0.078
Aug	1.566	1.33	1.34	1.495	1.264	0.844	0.638	–	0.739	0.627	0.012	0.032
Sep	1.89	1.713	1.819	1.973	1.786	1.459	0.933	0.709	–	0.962	0.107	0.088
Oct	1.89	1.8	1.988	2.08	1.831	1.486	0.986	0.821	0.041	–	0.078	0.101
Nov	1.916	1.809	1.722	1.718	1.778	1.929	1.491	1.864	1.544	1.624	–	0.972
Dec	1.678	1.607	1.562	1.448	1.552	1.725	1.461	1.672	1.502	1.528	0.106	–

Table 13. Bray-Curtis similarity between months in Sierra de San Carlos, Mexico. Upper diagonal = Index values. Lower diagonal = values expressed as percentage of similarity.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	-	0.721	0.487	0.36	0.398	0.433	0.298	0.356	0.295	0.309	0.230	0.273
Feb	72.1	-	0.636	0.347	0.35	0.367	0.313	0.390	0.309	0.318	0.203	0.215
Mar	48.7	63.6	-	0.563	0.482	0.340	0.319	0.401	0.353	0.365	0.161	0.176
Apr	36.0	34.7	56.3	-	0.690	0.403	0.325	0.294	0.264	0.291	0.140	0.176
May	39.8	35	48.2	69.0	-	0.509	0.314	0.267	0.248	0.262	0.150	0.144
Jun	43.3	36.7	34.0	40.3	50.9	-	0.367	0.382	0.331	0.349	0.161	0.186
Jul	29.8	31.3	31.9	32.5	31.4	36.7	-	0.584	0.567	0.580	0.368	0.353
Aug	35.6	39.0	40.1	29.4	26.7	38.2	58.4	-	0.573	0.547	0.259	0.277
Sep	29.8	30.9	35.3	26.4	24.8	33.1	56.7	57.3	-	0.894	0.446	0.368
Oct	30.9	31.8	36.5	29.1	26.2	34.9	58.0	54.7	89.4	-	0.422	0.428
Nov	23.0	20.3	16.1	14.0	15.0	16.1	36.8	25.9	44.6	42.2	-	0.698
Dec	27.3	21.5	17.6	17.6	14.4	18.6	35.3	27.7	36.8	42.8	69.8	-

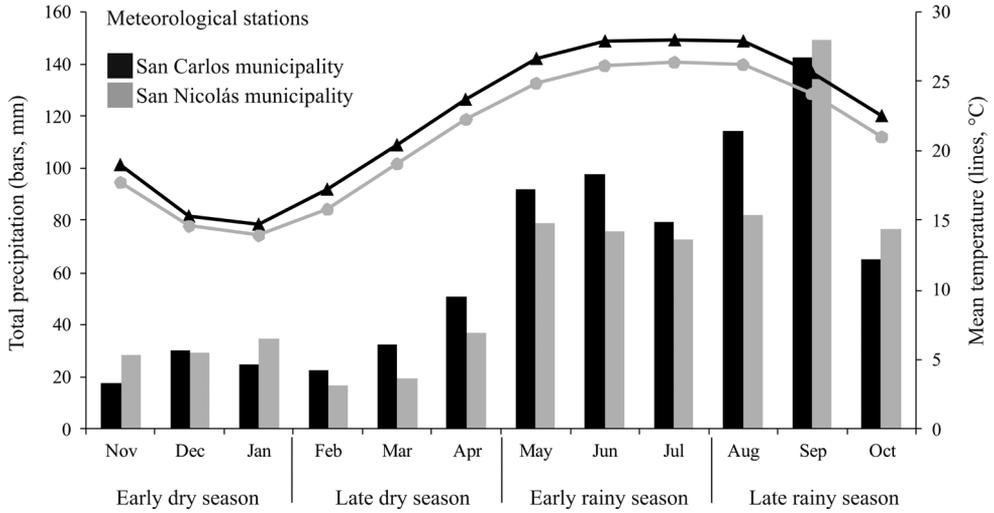


Figure 9. Historical monthly data of precipitation and temperature within Sierra de San Carlos, Mexico.

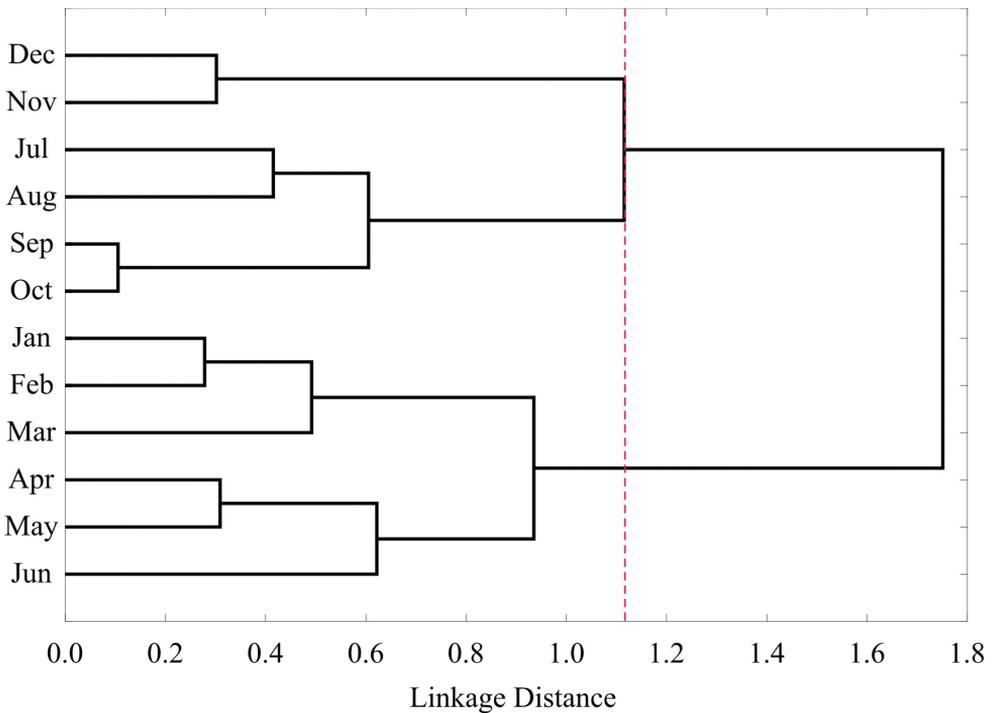


Figure 10. Cluster analysis of chrysomelid composition by month in Sierra de San Carlos, Mexico. Delimitation of groups is indicated by red dotted line.

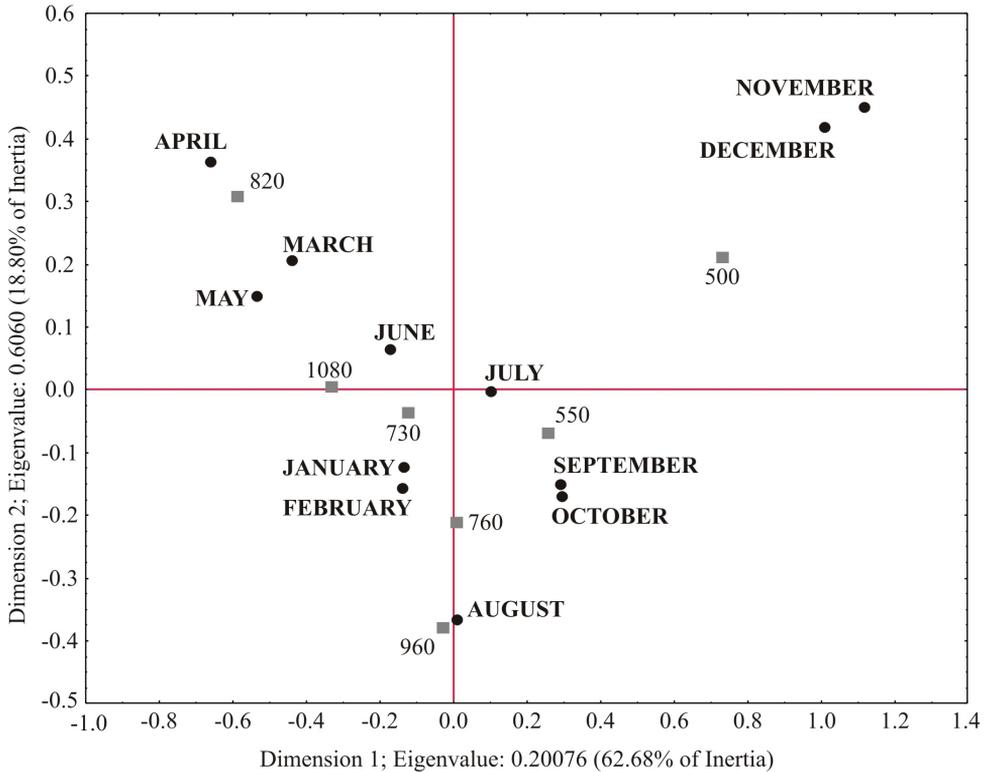


Figure 11. Correspondence analysis of chrysomelid abundance obtained per month at each elevational site in Sierra de San Carlos, Mexico.

Discussion

Faunistic inventory and biodiversity of Chrysomelidae in Sierra de San Carlos

The 113 species of Chrysomelidae recorded in this study document that the Sierra de San Carlos represents a proportion close to 50% of the total leaf beetle species richness presently reported from Tamaulipas (Niño-Maldonado et al. 2014a) and 5% of the total reported Mexican leaf beetle fauna (Ordóñez-Reséndiz et al. 2014). Also, *Trichaltica scabricula* represents a new species record for the chrysomelid fauna of Mexico, since this species was previously known only from numerous states in the United States, including Texas (Riley et al. 2003). Additionally, the high proportion of individuals identified as unnamed morphospecies in this and other studies suggests that the actual species richness of Chrysomelidae from Tamaulipas is still greater. The number of species recorded here from Sierra de San Carlos is lower when compared to other similar studies conducted with similar methods in the region. The most related study was done in Peregrina Canyon, approximately 100 km to the southwest, near Ciudad Victoria also in the state of Tamaulipas, from which 240 total samples, 2,228 specimens and 157 species were obtained (Sánchez-Reyes et al. 2014). In Sierra de San Carlos, 1,008

samples and 3,200 specimens were obtained, but only 109 species were recorded. Still, even with the low number of species obtained, Galerucinae was the most dominant subfamily, which is consistent with the observed patterns in various other studies (Bouzan et al. 2015), including those conducted in other areas of Tamaulipas and in other states in Mexico (Niño-Maldonado et al. 2005, Ordóñez-Reséndiz and López-Pérez 2009, Sánchez-Reyes et al. 2014).

Although the sampled area for both studies was almost the same (33,600 m² in Sierra de San Carlos *vs.* 37,500 m² in Peregrina Canyon), the total and site-season inventory completeness in Peregrina Canyon was close to 70% (Sánchez-Reyes et al. 2014), suggesting a higher proportion of species to be added to that inventory (Jiménez-Valverde and Hortal 2003), while values for this study were close to or above 90%. Moreover, seven different vegetational communities were sampled in this study, while only three sites were studied in Peregrina Canyon. These data indicate that the number of chrysomelid species present in Sierra de San Carlos was considerably less than the sites within the Sierra Madre Oriental. Because leaf beetles are dependent of their associated vegetational communities, we expected to find a higher species richness at our study area. Our data suggest that the insular nature of the geographical location of Sierra de San Carlos (Arriaga et al. 2000) results in lower species richness of Chrysomelidae when compared with habitats connected to the Sierra Madre Oriental, as is the Peregrina Canyon. Also, the lesser richness of plants in Sierra de San Carlos (441 compared to 676 species, Martínez 1998, Briones-Villarreal 1991) is probably directly correlated with the smaller number of leaf beetles, when compared with Peregrina Canyon in Altas Cumbres Natural Protected Area, where at least 1,164 species of vascular plants have been documented (García-Morales et al. 2014). Contrary to species richness, the higher diversity values obtained in Sierra de San Carlos possibly reflect a lower degree of anthropogenic disturbance and a higher quality of natural resources and vegetational communities (Arriaga et al. 2000). These factors may favor a more balanced ecological process, leading to higher evenness in abundance of species and thus the higher diversity values (Magurran 2004).

Elevational and seasonal effects on diversity patterns of Chrysomelidae

Elevation is one of the most important factors driving ecological communities, because the abiotic factors and biotic variables together modify species richness and composition of assemblages. Recent evidence suggests that the most common elevational pattern is the increase of diversity and species richness at intermediate elevations (Rahbek 2005, McCain and Grytnes 2010, Sanders and Rahbek 2012, Guo et al. 2013), which has been documented for various groups of Coleoptera (Escobar et al. 2005, Fernández et al. 2010), including Chrysomelidae (Furth 2009, Sánchez-Reyes et al. 2014). Other studies have shown a decrease of species richness with increasing elevation for various groups of insects (Wolda 1987, McCoy 1990, Sánchez-Ramos et al. 1993, Araújo and Fernandes 2003, Maveety et al. 2011, Jones et al. 2012). Indeed, it has been observed that species richness, abundance and diversity of Lepidoptera decreases with increas-

ing elevation in Cerro El Diente (Meléndez-Jaramillo et al. 2015), which is one of the sampling localities in our study. However, the leaf beetle communities here analyzed did not show any consistent correlation with the elevation, such as those observed in other studies of Chrysomelidae along elevational gradients (Furth 2009, Sánchez-Reyes et al. 2014, Bouzan et al. 2015). It has been determined that small elevational ranges, even with more intensive sampling (as was done in Sierra de San Carlos), could exhibit non-unimodal patterns, due to a limited geographical range over which such patterns could be expressed (Guo et al. 2013). For example, the locality of Cerro El Diente includes an elevation range from 400 to 1200 masl, but in our study only four sites were sampled at this area. It is possible that a more stepped sampling design might result in consistent patterns of species richness, abundance and diversity, as observed in other studies conducted exclusively at this locality (Meléndez-Jaramillo et al. 2015, Sánchez-Reyes et al. 2015a). However, we suggest that the insular nature of Sierra de San Carlos, its geomorphic properties, and the lack of connectivity between elevational sampling sites in different localities, could be the main drivers of results here obtained, because these factors have been recognized as key determinants of biodiversity patterns within elevational gradients (Bertuzzo et al. 2016).

Although a consistent elevational pattern was not found, the high proportion of inventory completeness through all methods employed indicates that the faunistic composition obtained at each site is representative; so, the values of abundance and diversity were reliable (Jiménez-Valverde and Hortal 2003). On this basis, we affirm that 1) highest values of diversity from Sierra de San Carlos were present at the highest and lowest elevations at the Cerro El Diente locality (Site 4, Cloud forest at 1080 masl; and Site 1, Submountain scrub at 550 masl), and also 2) the highest species richness was recorded in the highest elevation site from the same locality (Site 4, 1080 masl). This could be due to the vegetational composition and the characteristics at that area, since the contrasting more humid areas in the Cloud forest in the highest elevation site must be favoring the higher values obtained of diversity and species richness. Besides, we found higher values of species richness and diversity at sites within Cerro El Diente, compared with other sites from the Ejido Carricitos y Tinajas and San Nicolás localities. Land area is a determining factor in shaping communities within elevation gradients (Körner 2007). However, this factor might not affect species richness and diversity in our study, as fewer species were collected from more extensive sampling areas, such as Site 7 and both sites from the Ejido Carricitos y Tinajas locality; contrarily, intermediate vegetational communities from Cerro El Diente, even with sampling plots distributed randomly within corresponding elevational intervals, covered a smaller area (Figures 2, 3) but presented higher values of species richness and diversity. Considering that chrysomelid communities are directly influenced by plant-associated variables (Bach 1981, Řehounek 2002, Aslan and Ayvaz 2009, Sen and Gök 2009), we attribute these results to the higher quality of the vegetational communities at the Cerro El Diente locality (Arriaga et al. 2000, CONABIO 2007). These findings highlight the significance of this locality within Sierra de San Carlos, and constitute support for its designation as an area with extreme priority for conservation. Also, the presence of

Cloud forest in Sierra de San Carlos and the associated communities of leaf beetles are remarkable, since this ecosystem has a relict distribution in Mexico and is considered as an important center for high levels of biodiversity and endemism (Gual-Díaz and Rendón-Correa 2014); thus, our results contribute to the categorization of Sierra de San Carlos as a sky island and emphasize its protection urgency.

When analyzing species composition and beta diversity between sites, we observed that Sites 2 and 3 were the only sites with the same composition and a high faunistic similarity, while almost all other comparisons were different, which is contrary to other findings that show a high similarity of Lepidoptera between elevation and seasons at Cerro El Diente (Meléndez-Jaramillo et al. 2015). It has been determined that habitat heterogeneity and diverse characteristics of conservation areas can promote high beta diversity or low similarity between sites, regardless of the distance (Linzmeier and Ribeiro-Costa 2009). This was observed with the lowest site of Cerro El Diente and the other three sites within the same locality, as they formed different faunistic groups, although they are geographically close to each other. Moreover, we found that the lowest elevational sites from Sierra de San Carlos (Site 1 and Site 7) formed a faunistic group even when these were from distant localities. Undoubtedly, this is due to similar vegetational communities, which lead to similar leaf beetle faunas. Conversely, both sites were very different in terms of abundance of species, thus reflecting the specific responses of each species to abiotic and biotic characteristics at each site. This evidence suggests that differences in microhabitats result in very different assemblages of species, owing to an almost entirely different plant composition and also to the climatic or abiotic variation (Ødegaard 2006).

Regarding seasonal analysis, patterns observed at Sierra de San Carlos were different from those recorded in the most related study in Peregrina Canyon, Tamaulipas (Sánchez-Reyes et al. 2014), as our highest values of abundance, species richness and diversity were recorded in the rainy season. These findings are supported by other studies, because the dominance and increased abundance of adult leaf beetles in rainy or wet seasons is the most common result in studies of seasonal variation of this taxon and other insects (Ødegaard 2006, Furth 2009, Bouzan et al. 2015), which is highly related to the increase in plant density during this period. Besides, considering that higher seasonal peaks of abundance are associated with more marked seasons (Wolda et al. 1998), we suggest that the more seasonally dry environmental conditions at Sierra de San Carlos could be a primary factor in the species of Chrysomelidae being absent from samples or less active in the dry season, due to reduction in quality and availability of host plants, and to abiotic conditions (Medeiros and Vasconcellos-Neto 1994, Awmack and Leather 2002, Ishihara and Ohgushi 2006). Furthermore, evidence has shown that phytophagous insects locate temporary refugia when environmental conditions are less suitable (Janzen 1973), thus not being sampled in sweep catches and resulting in low values of abundance, species richness and diversity during dry seasons in non-refugia sites.

According to cluster analysis, three groups were formed, based on faunistic similarity between months: November and December, January to June, and July to October. This inconsistency between the four climate seasons (dry/rainy) and the clustering of

months by species compositions is possibly due to differential species responses to seasonal variations, as their temporal niche requirements are very distinct (Linzmeier and Ribeiro-Costa 2013). Similarly, seasonal variations, monthly composition and similarity patterns in leaf beetles reflect different ecological and biological strategies of each species, since reproduction and adult feeding phases may be different at certain times of the year. In Chrysomelidae, this has been attributed to abiotic variation during seasons, such the photoperiod, temperature, relative humidity, and to the quality and availability of host plants (Linzmeier and Ribeiro-Costa 2008, 2013). Also, seasonal and monthly patterns could reflect an existing sequence between Chrysomelidae and other phytophagous species to avoid competition and allow optimum resource exploitation (Pérez-Barroeta and Gurrea-Sanz 1994).

In addition to the influence of the geographical location of Sierra de San Carlos, the responses of the chrysomelid community in this study, being elevational, seasonal or both, are suggested to be driven by host plants and vegetational associated variables (Bach 1981, Erelli et al. 1998, Řehouněk 2002, Aslan and Ayyaz 2009, Sen and Gök 2009). So, although not investigated here, the study of relationships between Chrysomelidae and their associated vegetational communities is very important to understand the distribution patterns of this taxon. However, it has been noted that the interplay between the biotic and abiotic environment shapes consumer diversity along elevational gradients (Sundqvist et al. 2013). Therefore, changes in abundance, species richness and diversity within each locality, site and season/month could be driven by other factors related to elevation change, such as climate variables or abiotic environment (temperature, humidity, Körner 2007), which could be influencing the activity patterns of Chrysomelidae and the capacity of each species to obtain resources (Flinte et al. 2011, Bouzan et al. 2015). This influence of climate has been demonstrated in this study, since precipitation and temperature were significantly correlated with species richness; other studies on Chrysomelidae have reported similar effects (Linzmeier and Ribeiro-Costa 2008, Sánchez-Reyes et al. 2014).

Besides, the results obtained through Correspondence analysis confirm the same tendency of an interaction between abiotic and biotic factors on distribution of Chrysomelidae, because they show that abundance of the leaf beetle community at each site is associated with specific months. This was observed, for example, with the significant association of the lowest sites and abundance obtained at the rainy months, or that observed between Site 3 (960 masl) and August. Consequently, these associations suggest unique and specific temporal-site conditions for the communities of Chrysomelidae, which surely are the result of monthly changes in both environmental (abiotic) conditions and plant variables along the elevational gradient. Since elevational and temporal responses of biological communities arise from the effects (direct or indirect) of these gradients on each species (Hodkinson 2005, Sundqvist et al. 2013, Guo et al. 2013), future research on Chrysomelidae in Mexico needs to be targeted at the specific species patterns and their relationships with environmental variation, as well as at specific interactions between leaf beetle species and other ecosystem components.

Conclusions

The species richness of Chrysomelidae in Sierra de San Carlos was not as high as expected for an area with extreme priority for conservation, which could be the result of the geographical position of the study area. However, the high quality of the vegetational communities is presumably associated to the high diversity values. This is true for the highest site of our elevational gradient, where the highest values of species richness and diversity were obtained, and which must surely be associated with the environmental conditions of the cloud forest vegetation at that site, thus emphasizing the conservation urgency of this relict area and supporting the presence of a sky island within Sierra de San Carlos; hence, its high importance for biological conservation and for investigations of leaf beetle distribution.

The first record of a species for Mexico in Sierra de San Carlos is remarkable. Moreover, many of the specimens here determined as morphospecies could be later recognized as new distribution records, or new species. So, it is possible that leaf beetle species at Sierra de San Carlos constitute a very distinctive faunistic assemblage from other chrysomelid faunas in Mexico, which, added to the absence of a clear elevational pattern, suggests a strong effect of the insular geographical position and other geomorphic characteristics of Sierra de San Carlos on the Chrysomelidae distribution. Rainy season was associated with higher values of the ecological parameters of Chrysomelidae, being consistent with general patterns of temporal distribution of leaf beetles.

Regarding leaf beetle composition, we found evidence that different microhabitats, regardless of the distance, as well as different months, support distinct faunistic assemblages. Most importantly, communities within these particular sites are differentially influenced by changing conditions during seasonal/month variation, as suggested by the Correspondence analysis, and by the direct correlation of temperature and precipitation with species richness. These differences and variations in faunistic composition within the elevational and temporal gradients surely mirror differences in floristic composition and abiotic variables, since both are related to leaf beetle distribution. However, these changes must be addressed at a specific level, because the niche requirements of each species are very distinct. Since this is one of few studies conducted in Mexico concerning chrysomelid biodiversity and the variation along natural gradients, it is important that future research accounts for the specific influence of environmental modification (biotic and abiotic) on chrysomelid species at Sierra de San Carlos and other ecological gradients within Mexico. Also, forthcoming studies must address biogeographical relationships of chrysomelid species existent within this and others areas in the country.

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Appendix I

Table IA. Taxonomic checklist and abundance of Chrysomelidae by site and month in Sierra de San Carlos, Mexico. Site column: numbers in square brackets refer to the plot number where the species was collected within that site; see Material and methods (Tables 1, 2, 3 and Figures 2–5) for detailed data (coordinates, elevation, type of vegetation, spatial location) of each site-plot. Month column: numbers in parenthesis refer to the total abundance obtained for that month. Marked (*) species were obtained only by collecting, independent of the standardized sweeps. NR=New record for Mexico.

Taxon	Site [plot]	Month (abundance)
CRIOCERINAE Latreille, 1807		
Tribe Lemini Heinze, 1962		
<i>Lema balteata</i> LeConte, 1884	Site 4 [4]	Aug (1)
<i>Lema opulenta</i> Harold, 1874	Site 5 [6]	Aug (1)
<i>Lema</i> sp. 1	Site 3 [2]	Nov (1), Dec (1)
<i>Neolema</i> sp. 1	Site 1 [9]	Aug (1)
	Site 2 [4]	Sep (1), Oct (1)
	Site 3 [2]	Jul (1), Aug (1)
	Site 4 [4, 7, 8, 9, 10]	Jun (1), Jul (1), Aug (5), Sep (1), Oct (1)
<i>Neolema</i> sp. 2	Site 5 [1]	May (1)
<i>Oulema</i> sp. 1	Site 3 [3, 11]	Jul (1), Sep (1), Oct (1)
	Site 5 [3]	Aug (1)
<i>Oulema</i> sp. 2	Site 3 [1, 12]	Aug (1), Sep (1), Oct (1)
<i>Oulema</i> sp. 3	Site 4 [1, 7]	Jul (1), Aug (1)
CASSIDINAE Gyllenhal, 1813		
Tribe Chalepini Weise, 1910		

Taxon	Site [plot]	Month (abundance)
<i>Brachycoryna pumila</i> Guérin-Ménéville, 1844	Site 1 [1, 2, 4, 7, 9, 11]	May (2), Jun (1), Jul (1), Sep (3), Oct (2)
	Site 2 [1, 2, 3, 6, 7, 9, 11]	Jan (2), Feb (2), Apr (2), Jun (1), Jul (3), Aug (1), Sep (2), Oct (2)
	Site 4 [3, 4, 9]	May (1), Jul (1), Sep (1), Oct (1), Nov (1), Dec (1)
	Site 6 [7, 8, 11, 12]	Jan (1), Feb (2), May (1), Jun (2), Jul (1), Aug (4)
	Site 7 [1, 5]	Jul (1), Aug (1)
<i>Chalepus verticalis</i> (Chapuis, 1877)	Site 7 [6]	Sep (1), Oct (1)
<i>Sumitrosis inaequalis</i> (Weber, 1801)	Site 1 [6, 7, 8]	Jan (1), Feb (1), Jul (1), Sep (1), Oct (1), Nov (2)
	Site 2 [5, 8, 9, 10, 11, 12]	Jan (1), Feb (3), Mar (2), May (1), Jun (2), Jul (3), Aug (1), Sep (2), Oct (1), Nov (6), Dec (2)
	Site 3 [3, 6, 8]	Jun (1), Jul (1), Sep (1), Oct (1)
	Site 4 [5, 6, 7, 8, 9, 10, 11, 12]	Jan (1), Feb (1), May (6), Jun (2), Jul (8), Aug (4), Sep (7), Oct (5)
	Site 5 [2, 8, 11]	Jul (1), Aug (1), Sep (1), Oct (1)
	Site 6 [1, 3, 9]	May (1), Jul (4)
Tribe Mesomphaliini Hope, 1840		
<i>Ogdoecosta juvenca</i> (Boheman, 1854)	Site 4 [8, 9]	Jun (3), Jul (2), Aug (1)
Tribe Ischyrosonychini Chapuis, 1875		
<i>Physonota alutacea</i> Boheman, 1854	Site 1 [4]	Sep (1), Oct (1)
	Site 7 [1, 2, 12]	Jun (1), Sep (7), Oct (7), Nov (3), Dec (2)
Tribe Cassidini Gyllenhal, 1813		
<i>Coptocycla (Psalidonota) texana</i> (Schaeffer, 1933)*	Site 1	May
<i>Helocassis clavata</i> (Fabricius, 1798)	Site 2 [5]	May (1), Jul (1)
	Site 3 [4]	May (1)
	Site 5 [3]	Jun (1)
<i>Helocassis crucipennis</i> (Boheman, 1855)	Site 5 [7]	Aug (1)
	Site 6 [1]	Jul (1)
<i>Metrionella bilimeki</i> Spaeth, 1932	Site 4 [8, 9, 10, 11]	May (1), Jul (3), Aug (3), Sep (4), Oct (3)
CHRYSOMELINAE Latreille, 1802		
Tribe Chrysomelini Latreille, 1802		
Subtribe Doryphorina Motschulsky, 1860		
<i>Labidomera suturella</i> Chevrolat, 1844	Site 3 [3]	Nov (1), Dec (1)
	Site 4 [11]	Jul (1)
Subtribe Chrysomelina Latreille, 1802		
<i>Plagiodera semivittata</i> Stål, 1860	Site 2 [5, 10, 12]	Jan (1), Feb (1), Jun (2), Sep (2), Oct (2), Nov (1), Dec (1)
	Site 3 [3, 5, 7, 8]	Jan (1), Feb (1), May (2), Jun (6)
	Site 4 [2, 3]	Apr (1), Sep (1), Oct (1)
<i>Plagiodera thymaloides</i> Stål, 1860	Site 2 [8, 10, 11]	Jun (2), Jul (1), Aug (2)
	Site 3 [3, 8]	Jun (2)

Taxon	Site [plot]	Month (abundance)
GALERUCINAE Latreille, 1802		
Tribe Galerucini Latreille, 1802		
Group Coelomerites Chapuis, 1875		
<i>Corata subcyanescens</i> (Schaeffer, 1906)	Site 1 [1]	Jun (1)
<i>Miraces aeneipennis</i> Jacoby, 1888	Site 1 [4, 10, 11]	Aug (1), Sep (2), Oct (2), Nov (2), Dec (2)
	Site 2 [3, 4, 7]	Sep (6), Oct (4)
	Site 3 [4, 9, 10, 12]	Jun (1), Jul (1), Sep (5), Oct (5)
	Site 7 [12]	Jul (1), Nov (1), Dec (1)
Group Schematizites Chapuis, 1875		
<i>Monoxia</i> sp. 1	Site 1 [4]	Sep (1), Oct (1)
<i>Ophraella</i> sp. 1	Site 1 [9]	Jan (1), Feb (1)
Tribe Metacyclini Chapuis, 1875		
<i>Malacorhinus acaciae</i> (Schaeffer, 1906)	Site 7 [1, 6, 10]	Jun (3), Sep (3), Oct (3)
<i>Malacorhinus</i> sp. 1	Site 4 [4]	Nov (1), Dec (1)
Tribe Luperini Chapuis, 1875		
Subtribe Diabroticina Chapuis, 1875		
Group Diabroticites Chapuis, 1875		
<i>Acalymma invenustum</i> Munroe & Smith, 1980	Site 1 [5]	Sep (1), Oct (1)
	Site 3 [5]	Sep (1), Oct (1)
	Site 4 [4]	Aug (2)
<i>Gynandrobrotica lepida</i> (Say, 1835)	Site 5 [1, 2, 6, 7, 8, 10, 11, 12]	Apr (1), Aug (3), Sep (11), Oct (9), Nov (6), Dec (5)
	Site 6 [1, 3, 4, 6, 10, 11, 12]	Jul (1), Aug (2), Sep (12), Oct (9), Nov (3), Dec (2)
Group Cerotomites Chapuis, 1875		
<i>Cyclotrypema furcata</i> (Olivier, 1808)	Site 4 [6, 10, 12]	Jun (2), Aug (2)
	Site 5 [6]	Aug (1)
Tribe Alticini Newman, 1835		
<i>Acallepitrix</i> sp. 1	Site 1 [12]	Sep (1), Oct (1)
	Site 2 [3, 8]	Jan (2), Feb (2), Nov (1)
	Site 3 [9]	Mar (1)
	Site 4 [7, 8]	Mar (1), Aug (1)
	Site 5 [1, 2, 3, 6, 12]	Jan (1), Feb (1), Mar (1), Aug (3), Sep (5), Oct (3), Nov (2), Dec (2)
	Site 6 [1, 2, 4, 5, 6, 8, 9]	Jan (3), Feb (8), Mar (11), Apr (1), Jul (2), Aug (2)
<i>Acallepitrix</i> sp. 2	Site 5 [3, 7]	Aug (2)
	Site 6 [1, 2]	Mar (3), Apr (1), May (1), Jul (1)
<i>Acallepitrix</i> sp. 3	Site 4 [4]	Jun (1)
<i>Acallepitrix</i> sp. 4	Site 1 [2]	Sep (1), Oct (1)
	Site 3 [2, 3, 11]	Jul (2), Aug (1), Sep (2), Oct (2)
	Site 4 [2, 4, 6, 7, 8, 9, 11, 12]	Jun (1), Jul (3), Aug (4), Sep (4), Oct (2)
	Site 5 [3]	Sep (1), Oct (1)
	Site 6 [8]	Jun (2), Sep (1), Oct (1)

Taxon	Site [plot]	Month (abundance)
<i>Acrocyum dorsalis</i> Jacoby, 1885	Site 2 [3, 10]	Mar (1), Sep (1), Oct (1)
	Site 3 [2]	Jan (1), Feb (1)
<i>Alagoasa decemguttata</i> (Fabricius, 1801)	Site 4 [6, 8]	Apr (1), Sep (1), Oct (1)
<i>Altica</i> sp. 1	Site 4 [10]	Jul (1)
<i>Altica</i> sp. 2	Site 3 [1, 10]	Jul (1), Aug (1)
<i>Altica</i> sp. 3	Site 5 [11]	Apr (1)
<i>Blepharida rhois</i> (Forster, 1771)	Site 7 [1, 4, 11, 12]	Aug (1), Sep (2), Oct (2), Nov (3), Dec (2)
<i>Centralaphthona diversa</i> (Baly, 1877)	Site 1 [2, 3, 6, 12]	Jan (2), Feb (3), Jun (2), Aug (1), Sep (1), Oct (1)
	Site 2 [2, 4, 10, 12]	Jan (2), Feb (2), Mar (1), Jun (7), Aug (6), Sep (5), Oct (4), Nov (2), Dec (2)
	Site 3 [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12]	Jan (16), Feb (29), Mar (4), May (4), Jul (4), Aug (15), Sep (3), Oct (2)
	Site 4 [1, 2, 3, 4, 6, 8, 9, 10, 11, 12]	Jan (4), Feb (8), Mar (19), Apr (4), May (2), Jun (4), Jul (3), Aug (5), Sep (2), Oct (2)
	Site 5 [1, 2, 3, 4, 6, 11]	Jan (2), Feb (2), Apr (1), May (1), Jun (3), Jul (2), Aug (3), Sep (1), Oct (1)
	Site 6 [1, 4, 5, 6, 7, 8, 9, 10, 11, 12]	Jan (8), Feb (17), Mar (3), Apr (1), May (2), Jun (10), Jul (1), Aug (9), Sep (2), Oct (2)
	Site 7 [1, 3]	Apr (1), Aug (1)
<i>Centralaphthona</i> sp. 2	Site 2 [3, 4, 11]	Jan (1), Feb (1), Jul (1), Aug (1)
	Site 3 [9]	May (1)
	Site 6 [9]	May (1)
<i>Centralaphthona</i> sp. 3	Site 3 [3, 7]	Jan (1), Feb (1), Aug (1)
	Site 4 [9, 10]	Jan (1), Feb (1), Mar (1)
	Site 5 [9, 11, 12]	Jun (1), Aug (2)
	Site 6 [3, 4]	May (1), Jul (1)
<i>Centralaphthona</i> sp. 4	Site 6 [11]	Jul (1)
<i>Chaetocnema</i> sp. 1	Site 1 [2, 3, 7]	Jun (1), Jul (18), Aug (1), Sep (10), Oct (8)
	Site 5 [2, 3, 4]	Aug (3), Sep (3), Oct (3)
	Site 6 [6, 10, 11]	Aug (1), Sep (4), Oct (3)
<i>Chaetocnema</i> sp. 2	Site 1 [11]	Nov (1), Dec (1)
	Site 2 [10]	Nov (1), Dec (1)
	Site 3 [3, 8]	Apr (1), Nov (1), Dec (1)
	Site 4 [5, 10, 11, 12]	Jan (2), Feb (3), Mar (1), Aug (7)
	Site 5 [2, 11]	Jan (1), Feb (1), Mar (1)
	Site 6 [6, 9]	Jan (1), Feb (1), Apr (2)
<i>Chaetocnema</i> sp. 3	Site 1 [6]	Sep (1), Oct (1)
	Site 2 [3]	Jan (1), Feb (1)
	Site 3 [9]	May (1)
	Site 4 [1, 12]	May (3)
	Site 5 [2, 4, 5, 6]	Jan (1), Feb (1), Apr (1), May (5), Sep (1), Oct (1)
	Site 6 [6, 11]	Jan (2), Feb (2), Jun (1)
	Site 7 [1, 3, 6]	Nov (3), Dec (3)
<i>Chaetocnema</i> sp. 4	Site 6 [11]	May (1)

Taxon	Site [plot]	Month (abundance)
<i>Chrysogramma</i> sp. 1	Site 1 [6]	Apr (1)
	Site 2 [1, 2, 3, 4, 6, 7, 9, 10, 11, 12]	Jan (12), Feb (41), Mar (45), Apr (6), May (2), Jul (1)
	Site 3 [1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12]	Jan (14), Feb (34), Mar (26), Apr (8), May (3)
<i>Dibolia</i> sp. 1	Site 4 [4]	Aug (1)
<i>Disonycha glabrata</i> (Fabricius, 1781)	Site 5 [1, 6]	Aug (2)
<i>Disonycha stenosticha</i> Schaeffer, 1931	Site 1 [6]	Nov (2)
	Site 2 [3, 4, 6, 8, 11, 12]	Jul (2), Sep (2), Oct (2), Nov (5), Dec (1)
	Site 3 [1, 7, 9]	Jul (1), Nov (3), Dec (2)
	Site 6 [8]	Aug (1)
<i>Disonycha teapensis</i> Blake, 1933	Site 3 [1]	Sep (1), Oct (1)
<i>Dysphenges</i> sp. 1	Site 1 [4, 10]	Jul (2)
	Site 3 [1, 5, 8, 9]	Jul (4), Sep (1), Oct (1)
	Site 7 [2, 9]	Jul (1), Sep (1)
<i>Epitrix</i> sp. 1	Site 3 [8]	Jan (1), Feb (1)
	Site 4 [3, 5, 6, 8, 9, 10]	Jan (1), Feb (1), Mar (2), May (3), Jun (2), Aug (1)
	Site 5 [1, 2, 3, 4, 6, 7, 8, 12]	Jan (2), Feb (2), Mar (1), May (1), Jun (2), Jul (1), Aug (2), Sep (1), Oct (1)
	Site 6 [6, 9, 11, 12]	Jan (2), Feb (2), May (1), Aug (1), Sep (3), Oct (1)
<i>Epitrix</i> sp. 2	Site 1 [6]	Nov (1)
	Site 2 [2, 10]	Jan (1), Feb (1), Mar (1), Nov (1), Dec (1)
	Site 3 [1, 5, 8, 10, 11, 12]	Jan (3), Feb (3), Mar (4), Jul (1), Aug (1)
	Site 4 [5, 7, 11, 12]	Jan (1), Feb (1), Mar (2), Apr (1)
	Site 5 [6, 8]	Jan (1), Feb (1), Jun (1)
<i>Epitrix</i> sp. 3	Site 2 [9]	Mar (1)
	Site 4 [1, 9, 12]	Jan (1), Feb (1), Mar (2)
	Site 7 [6]	Sep (1), Oct (1)
<i>Epitrix</i> sp. 4	Site 5 [3]	Jun (2), Aug (2)
<i>Hypolampsis</i> sp. 1	Site 4 [6]	Jun (1)
<i>Kuschelina laeta</i> (Perbosc, 1839)	Site 7 [6]	Aug (1)
<i>Longitarsus</i> sp. 1	Site 1 [6]	Mar (1)
	Site 2 [2]	Jul (2)
	Site 4 [1, 3]	Mar (1), Apr (1)
	Site 7 [1, 6]	Jan (1), Feb (1), Sep (1), Oct (1)
<i>Longitarsus</i> sp. 2	Site 1 [8]	May (1)
	Site 2 [2, 5]	Jun (1), Aug (1)
	Site 3 [3, 4, 5, 8, 10]	Jul (1), Aug (1), Nov (3), Dec (2)
	Site 4 [1, 3, 4, 5, 7, 8, 9, 10]	Jan (3), Feb (4), Mar (5), Apr (1), May (1), Jun (1), Jul (5), Aug (2), Sep (3), Oct (1)
	Site 5 [1, 3, 5, 8]	May (1), Aug (3)
	Site 6 [5, 10]	Jul (2), Aug (1)
	Site 7 [1]	Jul (1)

Taxon	Site [plot]	Month (abundance)
<i>Lupraea</i> sp. 1	Site 3 [5]	Sep (1), Oct (1)
	Site 4 [1, 4, 5, 7, 8, 10, 11]	Apr (3), Jul (3), Aug (7), Sep (2), Oct (1)
<i>Lupraea</i> sp. 2	Site 3 [4]	Sep (1), Oct (1)
	Site 4 [1, 4]	Sep (4), Oct (2)
<i>Lysathia</i> sp. 1	Site 5 [6]	Mar (1)
<i>Margaridisa atriventris</i> (Melsheimer, 1847)	Site 2 [2, 5, 12]	Aug (3)
	Site 3 [1, 4, 5, 6, 8, 10, 11, 12]	Jan (1), Feb (1), May (1), Jun (1), Jul (7), Aug (14), Sep (2), Oct (2)
	Site 4 [8, 9]	Mar (1), Jul (2)
	Site 5 [1, 3, 10, 11]	Mar (1), Jun (1), Jul (2), Aug (2), Sep (1), Oct (1)
	Site 6 [1, 2, 4, 5, 7, 12]	Jan (1), Feb (1), May (1), Jun (2), Jul (18), Aug (5)
	Site 7 [6]	Aug (1)
<i>Monomacra</i> sp. 1	Site 4 [7]	May (2)
<i>Parchicola</i> sp. 1	Site 2 [2, 5, 7]	Jul (3), Aug (1), Sep (1), Oct (1)
	Site 3 [1, 10, 12]	Jul (4)
<i>Phydania nigriiventris</i> Jacoby, 1891	Site 3 [3]	Aug (1)
	Site 7 [11]	Aug (1)
<i>Phyllotreta</i> sp. 1	Site 1 [5, 9]	Mar (2)
	Site 2 [7]	Jan (1), Feb (1)
	Site 3 [2, 11, 12]	Mar (3), May (1)
	Site 4 [7, 9]	Mar (4), May (1)
	Site 5 [1]	Apr (1)
	Site 6 [6, 9, 10]	Mar (15)
<i>Plectrotetra</i> sp. 1	Site 3 [3]	Mar (1)
	Site 4 [1, 2, 3, 4, 5, 10, 12]	Apr (7), May (6), Jun (7)
<i>Sphaeronychus fulvus</i> (Baly, 1879)	Site 4 [4, 5, 9, 10, 11]	Jan (1), Feb (2), Mar (8), Jul (1), Sep (2), Oct (2)
<i>Syphrea</i> sp. 1	Site 2 [1]	Aug (2)
	Site 5 [2]	Jul (1)
	Site 7 [1, 5, 6, 7, 8, 11]	Mar (1), Apr (1), Jun (1), Jul (6), Aug (7), Sep (1), Oct (1), Nov (1), Dec (1)
<i>Syphrea</i> sp. 2	Site 1 [8]	Aug (1)
	Site 2 [2, 3, 5, 6, 8, 9, 10, 11, 12]	Jan (2), Feb (2), May (1), Jun (2), Jul (3), Aug (42), Sep (30), Oct (24)
	Site 3 [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12]	May (6), Jun (3), Jul (14), Aug (87), Sep (43), Oct (31)
	Site 4 [1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12]	Jan (3), Feb (5), Mar (4), Apr (3), May (1), Jun (1), Jul (12), Aug (6), Sep (2), Oct (2)
	Site 5 [5, 6, 8, 11]	Mar (1), May (3), Aug (2)
	Site 6 [1, 2, 3, 4, 5, 8, 12]	Jan (10), Feb (19), Mar (47), Apr (34), May (6), Jun (4), Jul (6), Aug (3), Sep (3), Oct (3), Nov (2), Dec (2)
<i>Systema</i> sp. 1	Site 7 [7]	Jul (1)
<i>Trichaltica scabricula</i> (Crotch, 1873). NR	Site 7 [6, 11, 12]	May (4)

Taxon	Site [plot]	Month (abundance)
EUMOLPINAЕ Hope, 1840		
Tribe Eumolpini Hope, 1840		
Group Iphimeites Chapuis, 1874		
<i>Brachypnoea</i> sp. 1	Site 2 [3,4]	Mar (2)
	Site 3 [4, 6, 8, 9, 10]	Mar (3), Apr (8), Sep (4), Oct (3)
	Site 4 [1, 2, 7, 11, 12]	Apr (1), May (5), Jun (3), Aug (1)
	Site 6 [3, 6, 10]	Mar (1), Apr (1), Jun (1)
<i>Brachypnoea</i> sp. 2	Site 1 [1]	Jun (1)
<i>Colaspis melancholica</i> Jacoby, 1881	Site 2 [9]	Jun (1), Jul (1)
	Site 4 [4]	Jun (1)
<i>Deuteronoda suturalis</i> (Lefèvre, 1878)*	Site 5	Jun
Tribe Adoxini Baly, 1863		
Group Leprotites Chapuis, 1874		
<i>Xanthonia</i> sp. 1	Site 2 [3]	Feb (1)
	Site 3 [5, 6, 7, 8, 9, 12]	Apr (2), May (1), Jun (3), Jul (2)
	Site 4 [1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12]	Apr (5), May (7), Jun (6), Jul (5), Aug (2)
	Site 5 [2, 4, 5, 6, 8, 9, 10, 11, 12]	Mar (12), Apr (13), May (22), Jun (4), Jul (1), Aug (2)
	Site 6 [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12]	Jan (6), Feb (12), Mar (56), Apr (59), May (37), Jun (10), Aug (8)
<i>Xanthonia</i> sp. 2	Site 4 [4, 5, 6, 8, 9, 10, 11, 12]	Apr (12), May (7), Jun (6), Jul (1)
<i>Xanthonia</i> sp. 3	Site 3 [7, 10]	Sep (3), Oct (3)
	Site 4 [12]	Sep (1), Oct (1)
<i>Xanthonia</i> sp. 4	Site 2 [11]	Apr (1)
	Site 3 [4, 6, 7, 10]	Mar (4), Apr (2)
<i>Xanthonia</i> sp. 5	Site 3 [5, 12]	Jul (1), Aug (2), Sep (2), Oct (2)
	Site 4 [5, 8, 9, 11]	May (1), Jun (1), Jul (6)
CRYPTOCEPHALINAE Gyllenhal, 1813		
Tribe Cryptocephalini Gyllenhal, 1813		
Subtribe Pachybrachina Chapuis, 1874		
<i>Griburius montezuma</i> (Suffrian, 1852)	Site 7 [4]	Jun (2)
<i>Griburius</i> sp. 1	Site 7 [1]	Jun (2)
<i>Pachybrachis</i> sp. 1	Site 1 [1, 3, 4, 5, 9, 10, 11]	Mar (1), Apr (1), Jul (1), Aug (2), Sep (4), Oct (4), Nov (1), Dec (1)
	Site 2 [3, 4, 5, 6, 8, 11]	Apr (1), Aug (3), Sep (3), Oct (3)
	Site 4 [12]	Jul (1)
	Site 5 [2, 4, 5]	May (2), Sep (3), Oct (3)
	Site 6 [6, 7, 8, 9, 10, 12]	Mar (7), Apr (3), May (3), Jun (4), Jul (1), Aug (4), Sep (3), Oct (3)
	Site 7 [1, 2, 3, 4, 5, 6, 7, 9, 11, 12]	Jan (4), Feb (5), Mar (5), Apr (1), May (1), Jun (2), Jul (3), Aug (5), Sep (5), Oct (4), Nov (3), Dec (3)

Taxon	Site [plot]	Month (abundance)
<i>Pachybrachis</i> sp. 2	Site 2 [3, 5, 7, 9]	Mar (1), Apr (5), May (5), Aug (1)
<i>Pachybrachis</i> sp. 3	Site 5 [4]	Jul (1)
	Site 6 [12]	Jun (1)
<i>Pachybrachis</i> sp. 4	Site 1 [3, 4, 7, 10, 11, 12]	Jan (2), Feb (2), Mar (4), May (1), Aug (1)
	Site 3 [3]	May (1)
	Site 4 [2, 12]	Jun (1), Sep (1), Oct (1)
	Site 7 [4, 7, 8, 9, 11, 12]	Jan (4), Feb (14), Mar (3)
<i>Pachybrachis</i> sp. 5	Site 1 [11]	Mar (1), Aug (1)
	Site 2 [3, 4, 7, 11]	Mar (1), Jun (1), Aug (2)
	Site 3 [3, 4, 7, 8, 10]	Mar (1), Apr (3), May (1), Jun (2), Jul (7), Aug (1)
	Site 4 [1, 2, 7, 9, 12]	Apr (1), May (4), Jun (1), Jul (1)
	Site 5 [4]	Apr (1)
	Site 6 [10]	Jul (1)
	Site 7 [12]	Aug (4)
<i>Pachybrachis</i> sp. 6	Site 2 [7]	Sep (1), Oct (1)
<i>Pachybrachis</i> sp. 7	Site 1 [4]	Jun (1), Aug (1), Sep (2), Oct (2)
	Site 2 [3]	Sep (1), Oct (1)
	Site 7 [2, 3, 4, 5, 7, 8, 9, 10]	Jan (2), Feb (2), Mar (1), Jun (7), Jul (5), Aug (3), Sep (6), Oct (6)
<i>Pachybrachis</i> sp. 8	Site 1 [4, 8]	Jan (1), Feb (1), Sep (1), Oct (1)
	Site 2 [1]	Mar (1)
	Site 3 [7]	Jul (1)
	Site 7 [1, 3, 4, 6, 8, 9, 11, 12]	Jan (1), Feb (2), Mar (3), Jun (1), Jul (1), Aug (1), Sep (2), Oct (2), Nov (7), Dec (5)
<i>Pachybrachis</i> sp. 9	Site 2 [3, 4, 5, 9]	Mar (2), Apr (2), May (1), Jul (1), Aug (1)
	Site 7 [3]	Apr (1)
<i>Pachybrachis</i> sp. 10	Site 5 [1]	Jan (2), Feb (2), Aug (1)
<i>Pachybrachis</i> sp. 11	Site 5 [2]	Jan (1), Feb (1)
<i>Pachybrachis</i> sp. 12	Site 1 [4]	Sep (1), Oct (1)
Subtribe <i>Cryptocephalina</i> Gyllenhal, 1813		
<i>Cryptocephalus downiei</i> Riley & Gilbert, 2000	Site 7	Apr (Sánchez-Reyes et al. 2015b)
<i>Cryptocephalus duryi</i> Schaeffer, 1906*	Site 5	Apr
<i>Cryptocephalus guttulatus</i> Olivier, 1808	Site 3 [11]	Jul (1)
	Site 4 [1, 8, 9, 10, 11, 12]	Jun (1), Jul (5), Aug (2)
	Site 5 [3]	Jun (1)
<i>Cryptocephalus trizonatus</i> Sufrian, 1858	Site 1 [1, 6, 9, 11]	Mar (1), Jun (1), Sep (1), Oct (1), Nov (2)
	Site 2 [3, 10, 12]	Aug (1), Sep (1), Oct (1), Nov (1)
	Site 7 [1, 4, 9, 10, 11]	Apr (1), Aug (1), Nov (5), Dec (2)

Taxon	Site [plot]	Month (abundance)
<i>Cryptocephalus umbonatus</i> Schaeffer, 1906	Site 1 [4, 11, 12]	Jul (1), Sep (2), Oct (1)
	Site 2 [3, 5, 6, 8, 9, 10, 11]	Jun (9), Jul (1), Aug (4), Sep (1), Oct (1)
	Site 3 [3, 7, 8, 11, 12]	Jun (2), Jul (2), Sep (1), Oct (1)
	Site 4 [4]	Aug (1)
	Site 5 [1, 2, 12]	Aug (1), Sep (2), Oct (2)
	Site 7 [1]	Aug (1)
<i>Diachus auratus</i> (Fabricius, 1801)	Site 1 [5, 6, 9, 10]	Mar (4)
	Site 2 [6]	Jan (1), Feb (1)
	Site 3 [2, 10]	Mar (1), Apr (2)
	Site 4 [2, 9, 10, 12]	Jan (1), Feb (2), Mar (5), May (1), Jun (2), Sep (1), Oct (1)
	Site 5 [3]	Mar (2)
	Site 6 [1]	Jan (1), Feb (1)
	Site 7 [7]	Jan (2), Feb (3)
<i>Diachus</i> sp. 1	Site 7 [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12]	Jan (10), Feb (15), Mar (19), Apr (8), May (4), Jun (6), Jul (55), Aug (40), Sep (69), Oct (50), Nov (98), Dec (44)
Tribe Clytrini Lacordaire, 1848		
Subtribe Clytrina Lacordaire, 1848		
<i>Anomoea ruffrons mutabilis</i> (Lacordaire, 1848)	Site 3 [3]	Jul (2)
	Site 4 [1]	May (1)
	Site 7 [3, 8]	Jun (7)
<i>Smaragdina agilis</i> (Lacordaire, 1848)	Site 4 [4]	Jun (1)
Subtribe Megalostomina Chapuis, 1874		
<i>Coscinoptera aeneipennis</i> (LeConte, 1858)	Site 2 [3, 7]	Jun (2)
<i>Coleorozena scapularis scapularis</i> (Lacordaire, 1848)	Site 1 [4]	Apr (1)
	Site 2 [3]	Apr (1)
<i>Coscinoptera tamaulipasi</i> Medvedev, 2012	Site [5, 9, 10, 11, 12]	Mar (4), Apr (1), May (2), Jul (1), Aug (1)
	Site 7 [2, 12]	Mar (2), May (1)
<i>Megalostomis dimidiata</i> Lacordaire, 1848	Site 1 [10]	Mar (1)
Subtribe Babiina Chapuis, 1874		
<i>Babia tetraspilota texana</i> Schaeffer, 1933	Site 1 [12]	Sep (1), Oct (1)
Tribe Fulcidacini Jakobson, 1924		
<i>Diplacaspis prosternalis</i> (Schaeffer, 1906)	Site 1 [2, 4, 9, 10]	Mar (2), Jul (2)
	Site 7 [2, 6, 8]	Mar (1), Jul (1), Aug (1)

Revisions of the genera *Lurama* Schaus, 1928 and *Ulmara* Schaus, 1928 (Lepidoptera, Mimallonoidea, Mimallonidae) with the descriptions of three new *Ulmara* species and a new genus

Ryan A. St. Laurent¹

¹ McGuire Center for Lepidoptera and Biodiversity, Florida Museum of Natural History, University of Florida, 3215 Hull Road, Gainesville, FL 32611-2710 USA

Corresponding author: Ryan A. St. Laurent (rstlaurent@flmnh.ufl.edu)

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Abstract

The Andean genera *Lurama* Schaus, 1928 and *Ulmara* Schaus, 1928 are revised. *Lurama* poses difficulty for revision due to lost male genitalia of the types of both described species. *Ulmara conjuncta* **sp. n.**, *U. azurula* **sp. n.**, and *U. dombroskiei* **sp. n.** are described as new in the genus *Ulmara*. A lectotype is designated for *Lurama quindiuna* Schaus, 1928 and *Ulmara rotunda* (Dognin, 1916). A new monotypic genus, *Cunicumara* **gen. n.**, which is externally similar to *Ulmara*, is described to include the new species *Cunicumara anae* **sp. n.** from low elevations of Bolivia and Paraguay. Male genital morphology does not support a close association of *Cunicumara* with *Lurama* or *Ulmara*. The latter two genera, however, are closely related based on similarities of male genitalia and biogeography.

Keywords

Andean, Bolivia, Colombia, *Cunicumara anae*, Ecuador, Peru, *Ulmara azurula*, *Ulmara dombroskiei*, *Ulmara conjuncta*

Introduction

Several recent works have been published focusing on the taxonomy of the previously understudied Mimallonidae, wherein 47 new species and four new genera have been described since 2012 (Herbin 2012, 2015, Herbin and Mielke 2014, Herbin and Monzón 2015, St Laurent and Dombroskie 2015, St Laurent and Dombroskie 2016, St Laurent and Mielke 2016, St Laurent and McCabe 2016). Each recent work since Herbin (2012) described new taxa of Mimallonidae from relatively low elevations (< 800 m) in Central America, South America, and the Caribbean, with relatively few taxa having been described from higher elevations. St Laurent and Dombroskie (2016) described two species apparently endemic to the Andean Cordillera Oriental from higher elevations, with the highest locale being about 1900 m. Until now, no work has been published focusing on Mimallonidae taxa endemic to higher elevations.

The present article revises two small and closely related genera, *Lurama* Schaus, 1928 and *Ulmara* Schaus, 1928, which are both endemic to high elevations (up to 3500 m) of the Andes, and describes an externally similar new, monotypic, genus from Bolivia and Paraguay. The genus *Lurama* currently consists of two species: *L. penia* (Dognin, 1919) and *L. quindiuna* Schaus, 1928. The monotypic genus *Ulmara* contains *U. rotunda* (Dognin, 1916). Both genera are diagnosed based on external characters and male genitalia, and all currently known species are redescribed. The female of *L. quindiuna* is described and figured for the first time, and three new species are described in *Ulmara*.

Methods

Dissections were performed as in Lafontaine (2004). St Laurent dissection preparation numbers follow the format of “St Laurent diss.,” followed by the preparation’s date, followed by a unique number for that date’s dissection. Morphological, including genitalia, terminology follows Kristensen (2003). The term “diaphragm” is used to describe the entirety of the membrane circumscribed by the XI segment ring (vinculum). Genitalia and abdomens are preserved in glycerol filled microcentrifuge tubes to preserve the three dimensional structure, or in the case of some dissections from MWM, are slide mounted.

Specimens from the following collections were examined:

AMNH	American Museum of Natural History, New York, New York, USA
CMNH	Carnegie Museum of Natural History, Pittsburgh, Pennsylvania, USA
CDH	Personal collection of Daniel Herbin, Garidech, France
CUIC	Cornell University Insect Collection, Ithaca, New York, USA
MNHU	Museum für Naturkunde der Humboldt-Universität zu Berlin, Germany
MWM	Museum Witt, Munich, Germany
NHMUK	Natural History Museum, London, U.K.
USNM	National Museum of Natural History [formerly United States National Museum], Washington, D.C., USA

Figures were manipulated with Adobe Photoshop CS4 (Adobe 2008). Male genitalia are figured in natural color with CS4 “auto color” used to improve white backgrounds. Adult specimens and genitalia were photographed with a Macroscopic Solutions Macropod Pro and Canon EOS 6D DSLR camera body. Adult specimens were photographed with a Canon EF 100 Macro USM AF/MF Lens. Each specimen was photographed thirty times and the images were stacked using Zerene Stacking Software. However, the images of the Ecuadorian (Loja) female of *Lurama quindiuana*, (MWM), the female of *Ulmara rotunda*, (MNHU), and the Paraguayan paratype of *Cunicumara anae* sp. n., (CDH), were provided by their respective places of deposition, and thus did not undergo image stacking. A Macro Photo MP-E 65mm f/2.8 1–5× Manual Focus Lens for EOS was used to take thirty (3×) photographs of each genitalia preparation in ethanol under glass, and stacked using Zerene Stacking Software. Maps were created with SimpleMappr (Shorthouse 2010) and edited with CS4. All geographical coordinates are approximate, and are based on the localities provided on specimen labels. GPS data were acquired with Google Earth.

Results and discussion

Lurama Schaus, 1928: 667

Luramana Strand, 1932: 147, unnecessary replacement name (Fletcher and Nye 1982).

Type species. *Perophora penia* Dognin, 1919; Schaus 1928: 668, by original designation.

Diagnosis. *Lurama* is immediately recognizable in both sexes among Mimallonidae by the yellow, yellow-gray, light-brown, or tan coloration of all wings, combined with prominent brown ante- and postmedial lines that strongly contrast against the lighter ground color. Wing veins are usually obvious and contrast against the ground color due to prominent brown scales lining them. Male genitalia are simple, but recognizable by the broad, short valves and the setae-covered lobes projecting from the transtilla. In *Lurama* the phallus is very narrow, pointed, and curved, being somewhat fishhook shaped. *Lurama* male genitalia are most similar to those of *Ulmara*, but can be distinguished by the following characters seen in *Lurama*: a much narrower phallus, less triangular valves, the absence of the gnathos, setae-covered structures on the ventrum of VIII, and teeth on the valves. The female genitalia are small, but stout and robust structures, with extremely reduced apophyses anteriores and corpus bursae. The highly reduced corpus bursae is the smallest in overall size in the family (compared to those examined so far). The female genitalia are similar in general structure to those of the female of *Ulmara*, but the genitalia of *Lurama* lack the broader, setae-covered lateral posterior lobe of VIII, and have a larger, though still very small by mimallonid standards, ductus bursae and corpus bursae, reflecting the much broader phallus of *Ulmara* relative to the extremely thin phallus of *Lurama*.

Description. Male. *Head:* Tan brown to straw colored, eyes very large, occupying more than two thirds area of head, bordered posteriorly by dark scales; antenna coloration as for head, bipectinate to tip; labial palpus very reduced, three segmented, tufted ventrally, especially basal-most segment, palpus not extending beyond frons, heavily clothed in long scales, scales darker dorsally. *Thorax:* Coloration as for head, though it may be somewhat lighter, lustrous gold overall, darker-brown scales present on prothoracic collar. *Legs:* Coloration as for thorax, vestiture fine, appearing as spun gold. Tibial spurs somewhat elongated, tubular, clothed in scales except for tip. *Forewing dorsum:* Forewing length: 14.5–18 mm, wingspan: 27–35 mm, n=24. Variable overall; short, subtriangular to triangular, margin nearly straight from apex until after passing M_3 , where wing smoothly curves toward anal margin. Ground color variable from brown to tan to nearly yellow, overall lightly to heavily speckled by dark-brown or brown-gray petiolate scales, especially postmedially. Antemedial line brown, narrow to relatively wide, occasionally somewhat diffuse, slightly bowed outward. Postmedial line nearly straight or slightly curved inward from anal margin to Rs_3 , Rs_4 , or between Rs_3 and Rs_4 , where line abruptly angled toward costa, forming nearly right angle, coloration and width as for antemedial line. Antemedial, medial, and postmedial areas concolorous, distance between lines variable. Costa and outer wing margin darker brown as in ante- and postmedial lines. Discal spot a dark-brown streak spanning width of discal cell, mesally slightly angled inward toward cell. Wing veins lined by dark-brown scales, colored as ante- and postmedial lines. Fringe poorly preserved (*L. penia*) or light brown with intermittent darker-brown scales. *Forewing ventrum:* Similar to dorsum but usually lighter; antemedial line nearly absent to absent and postmedial line may be lighter. *Hindwing dorsum:* Coloration as for forewing dorsum, antemedial line absent, postmedial line straight or curved outward. *Hindwing ventrum:* Following same pattern as forewing ventrum but postmedial line always curved outward. Base of wing usually covered by dark-brown scales from thorax. Frenulum present as single bristle, size somewhat variable. *Venation:* CuA_1 arising nearly midway between lower angle of cell and CuA_2 ; M_2 and M_3 arise from essentially same point of lower angle of cell, otherwise typical of Mimallonidae. *Abdomen:* Concolorous with thorax, distal tip with tuft of black scales. *Genitalia:* (Figs 11, 12) n=12. [based on *L. quindiuna* only] Simple; vinculum somewhat box-like, ventrally with reduced saccus, posterior edge of VIII attached to saccus, weakly bilobed. Uncus simple, triangular, excised laterally, highly truncated apically, laterally uncus beak-like. Gnathos absent. Valves short, irregularly shaped, somewhat triangular, truncated apically forming lobe, lobe occasionally narrow, valves often slightly curled mesally. Transtilla with inward angled lobes dorsal to phallus, from which extremely long, non-deciduous setae arise. Setae pointed outward directly over phallus. Saccular edge of valves with setae, occasionally nearly as long as those of lobes. Diaphragm forms balloon-like sac expanded inward into abdomen, sac covered in fine, inward facing setae surrounding phallus. Juxta partially fused to phallus, encircling it, lightly sclerotized, especially dorsal to phallus, weak sclerotization gives way to membrane con-

tiguous with diaphragm setae-sac. Phallus short, very thin, tubular, bent, fishhook-like, terminal opening oblique, from which very small vesica emerges; base of phallus somewhat variable in length. **Female.** [based on *L. quindiuna* only] *Head:* As for male but antennae much smaller overall, pectination particularly shorter. *Thorax:* As for male though brown scales along prothoracic collar may be darker. *Legs:* As for male. *Forewing dorsum:* Forewing length: 17–18 mm, wingspan: 32–34 mm, n=2. As for male but slightly broader, longer, discal mark skewed toward M_3 . *Forewing ventrum:* Similar to dorsum but may be more suffused with brown, antemedial line absent. *Hindwing dorsum:* Coloration as for forewing dorsum, antemedial line absent, postmedial line straight or curved outward. *Hindwing ventrum:* Following same pattern as forewing ventrum but postmedial line always curved outward. Frenulum as multiple bristles, length shorter than in male. *Abdomen:* Concolorous with or slightly darker than thorax, distal tip with tuft of black scales. *Genitalia:* (Fig. 13) n=2. Stout, robust; tergite of VIII forms smooth, posteriorly directed arch, VIII heavily sclerotized laterally, forming posteriorly directed lobes covered in minute, fine setae. Apophyses anteriores highly reduced, nearly absent, apophyses posteriores elongate, spanning length of genitalia structure. Lamella antevaginalis wide, robust, concave, covered in short setae, ventral margin of lamella smoothly curved or slightly angled upward mesally. Ductus bursae short, very narrow. Corpus bursae highly atrophied, baglike, wing scales present within corpus bursae in both dissections. Base of papillae anales with nested accordion-like sclerotizations. Papillae anales somewhat rectangular laterally, dorsal corner may be somewhat extended as lobe; papillae anales covered with fine setae.

Remarks. *Lurama* is a small, easily recognizable genus endemic to relatively high elevations of the Andes of Colombia and Ecuador. See individual species remarks for unresolvable issues pertaining to the type specimens of the two named species. A holistic revision is not possible for *Lurama* due to the issues pertaining to the type material of the named species; however, the genus is included in the present work due to the biogeographic similarity to *Ulmara* and the obvious homology in structures of the male and female genitalia. I recognize that more than one taxa likely exists under the name *L. quindiuna* in the present treatment, however due to aforementioned issues which will be explained in detail in each respective species remarks sections, no new taxa are described in *Lurama*.

Key to species of *Lurama**

- 1 Forewing rounded apically, ante- and postmedial lines broad, somewhat diffuse (Fig. 1) *L. penia*
- 2 Forewing triangular, somewhat pointed apically, ante- and postmedial lines usually sharply defined (Figs 2–10) *L. quindiuna*

*Note: the female of *L. penia* is unknown.

***Lurama penia* (Dognin, 1919)**

Fig. 1; Map 1

Perophora penia Dognin, 1919: 6, 7*Lurama penia*; Schaus 1928*Lurama penia*; Gaede 1931*Lurama penia*; Becker 1996

Type material. Holotype, ♂. **COLOMBIA: Cundinamarca/Distrito Capital:** Bogota [Bogotá], Colombia, 28–3200 m, Coll. Fassl / Dognin, Collection/ *Perophora penia*, type ♂ Dgn./ ♂ genitalia slide. 6 June '28, C.H. #5. [genitalia prep. not located]/ [label with wing vein sketch]/ [Holo]Type No.: 29698 U.S.N.M./ USNM-Mimal: 1108/ (USNM, examined). Type locality: Colombia: Cundinamarca/Distrito Capital: Bogotá.

Diagnosis. *Lurama penia* can be distinguished from *L. quindiuna* by the smaller size, shorter, more rounded wings, and somewhat more diffuse, broader postmedial and antemedial lines on the wings. The lines are also closer together and farther from the wing margin than in *L. quindiuna*. Additionally, the forewing postmedial line has its apical angle intersecting Rs4 very near the fork of Rs3+Rs4, rather than being much more distant from this fork in the other species.

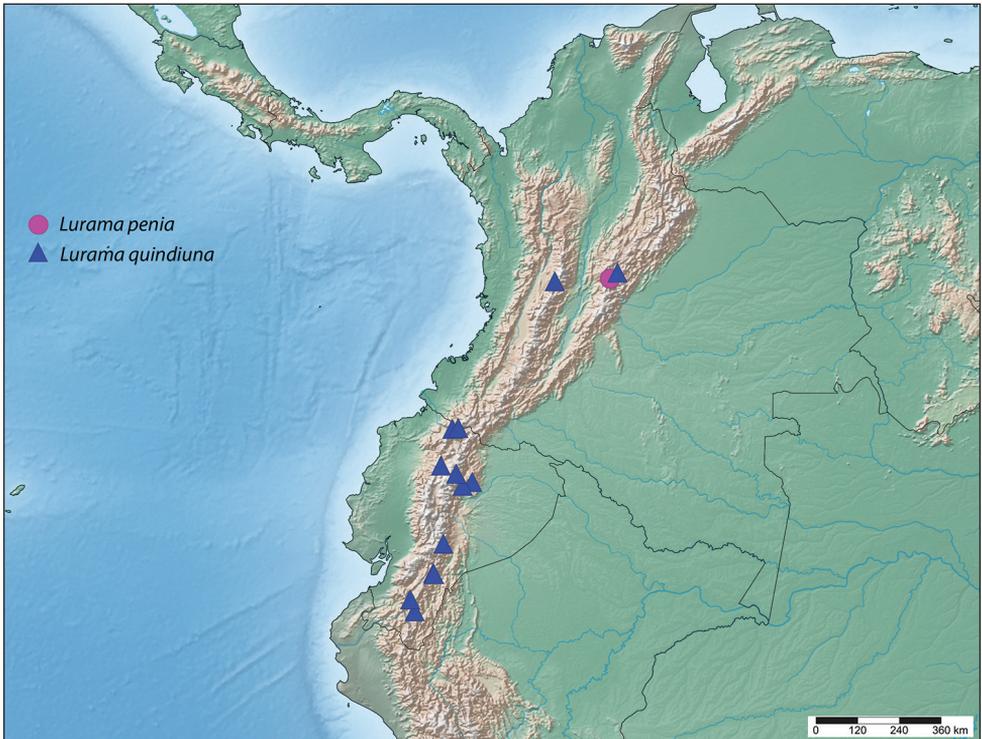
Description. Male. *Head:* As for genus but tan brown. *Thorax:* Coloration as for head, darker-brown scales present on prothorax. *Legs:* Coloration as for thorax, poorly preserved. *Forewing dorsum:* Forewing length: 14.5 mm, wingspan: ~27 mm, n = 1. Short, vaguely triangular, margin nearly straight from apex until after passing M₃ where wing smoothly curves toward anal margin. Ground color yellowish tan, overall lightly speckled by dark petiolate scales, especially postmedially. Antemedial line brown, relatively wide, somewhat diffuse, slightly curving outward. Postmedial line nearly straight from anal margin to Rs4 where it abruptly angles toward costa perpendicularly, coloration and width as for antemedial line. Antemedial, medial, and postmedial areas concolorous. Costa and outer wing margin darker brown. Discal spot a dark streak spanning width of discal cell, mesally slightly angled inward toward cell. *Forewing ventrum:* Similar to dorsum but with more concentrated speckling postmedially; antemedial line nearly absent, postmedial line fainter. *Hindwing dorsum:* Coloration as for forewing dorsum, antemedial line absent, postmedial line not reaching anterior wing margin. *Hindwing ventrum:* Following same pattern as forewing ventrum but postmedial line curved outward rather than straight as on dorsum. *Abdomen:* Partially missing, but anterior segments concolorous with thorax. *Genitalia:* Not examined. **Female.** Unknown.

Distribution (Map 1). *Lurama penia* is known only from the holotype, collected between 2800 and 3200 m near Bogotá, Colombia.

Remarks. This species is apparently very rarely collected, as it is known only from the male holotype. Unfortunately, the genitalia preparation of the holotype, probably made by Carl Heinrich (R. Hutchings pers. comm.), is lost and could not be located by the individuals tasked with trying to find it at the USNM. Schaus (1928) compared



Figure 1. *Lurama penia* holotype ♂, **a** dorsal **b** ventral. Colombia, Cundinamarca/Distrito Capital, Bogotá, 2800–3200 m (USNM). Scale bar = 1 cm.



Map 1. Known distribution of *Lurama*.

the genitalia of *Lurama* to that of *Ulmara*, and considered them similar. I note that among Schaus's examined *Lurama* material at the USNM and MNHU, the only dissected male *Lurama* specimen is the holotype of *L. penia*; therefore it is reasonable to assume that the missing genitalia of *L. penia* are similar to those of *Ulmara* because apparently Schaus did not look at any other *Lurama* dissections. This is expected given the similarity between *Ulmara* male genitalia and those of *L. quindiuna*, for which the male genitalia are available for examination.

As for *L. quindiuna* below, the issue of missing type genitalia for these two species results in some difficulties determining the identity of non-type specimens. Fortunately, external diagnostic characteristics are ample enough to maintain both currently described species as valid, but prevents me from describing new species in the genus at this time. It is vital that more material be located for this and the following species at each of their respective type localities so that more conclusive diagnostic characters can be given, particularly in regards to the genitalia.

Lurama quindiuna* Schaus, 1928, *sensu lato

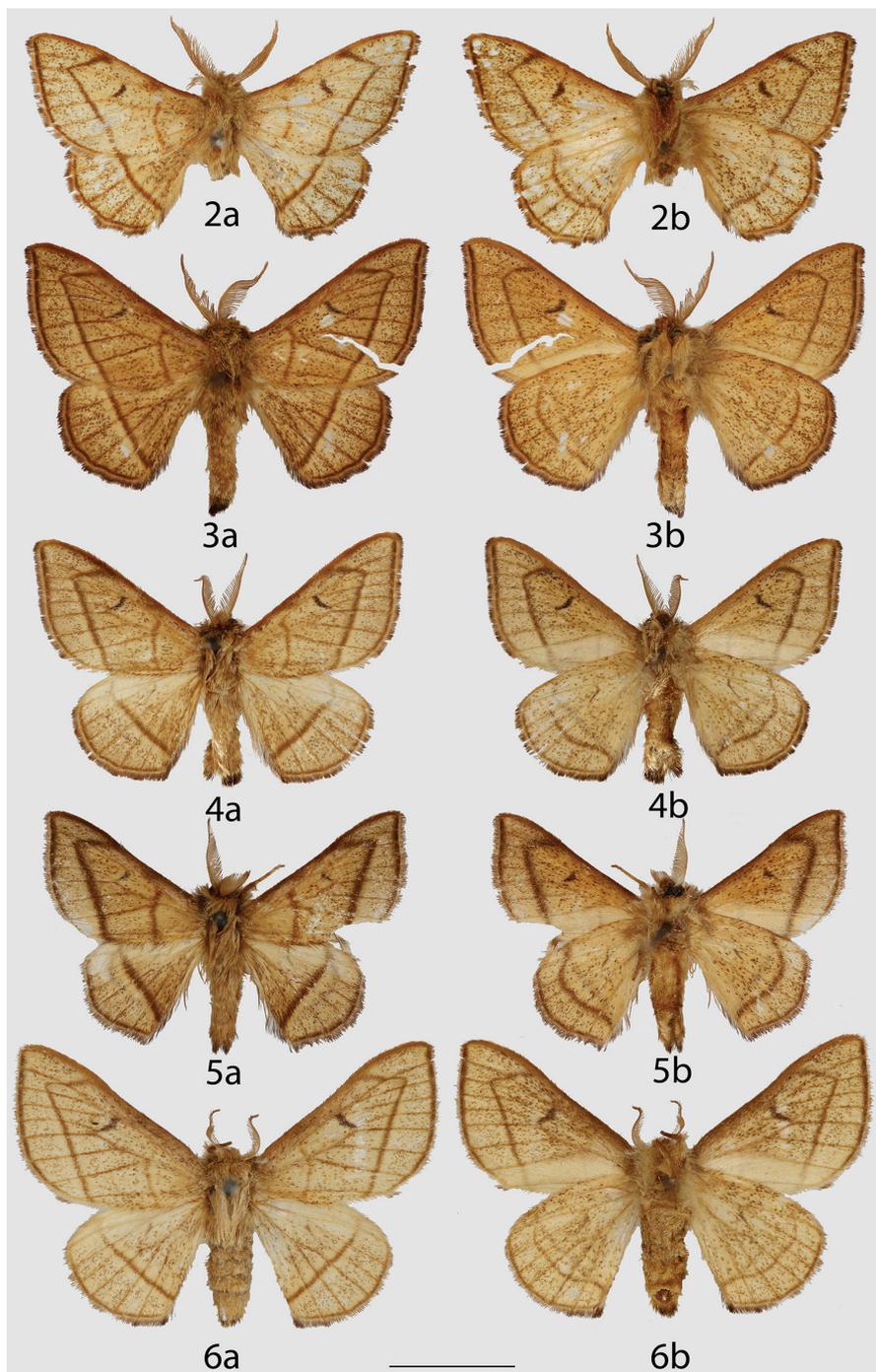
Figs 2–13; Map 1

Lurama quindiuna Schaus, 1928: 669; Fig. ♂ 88h

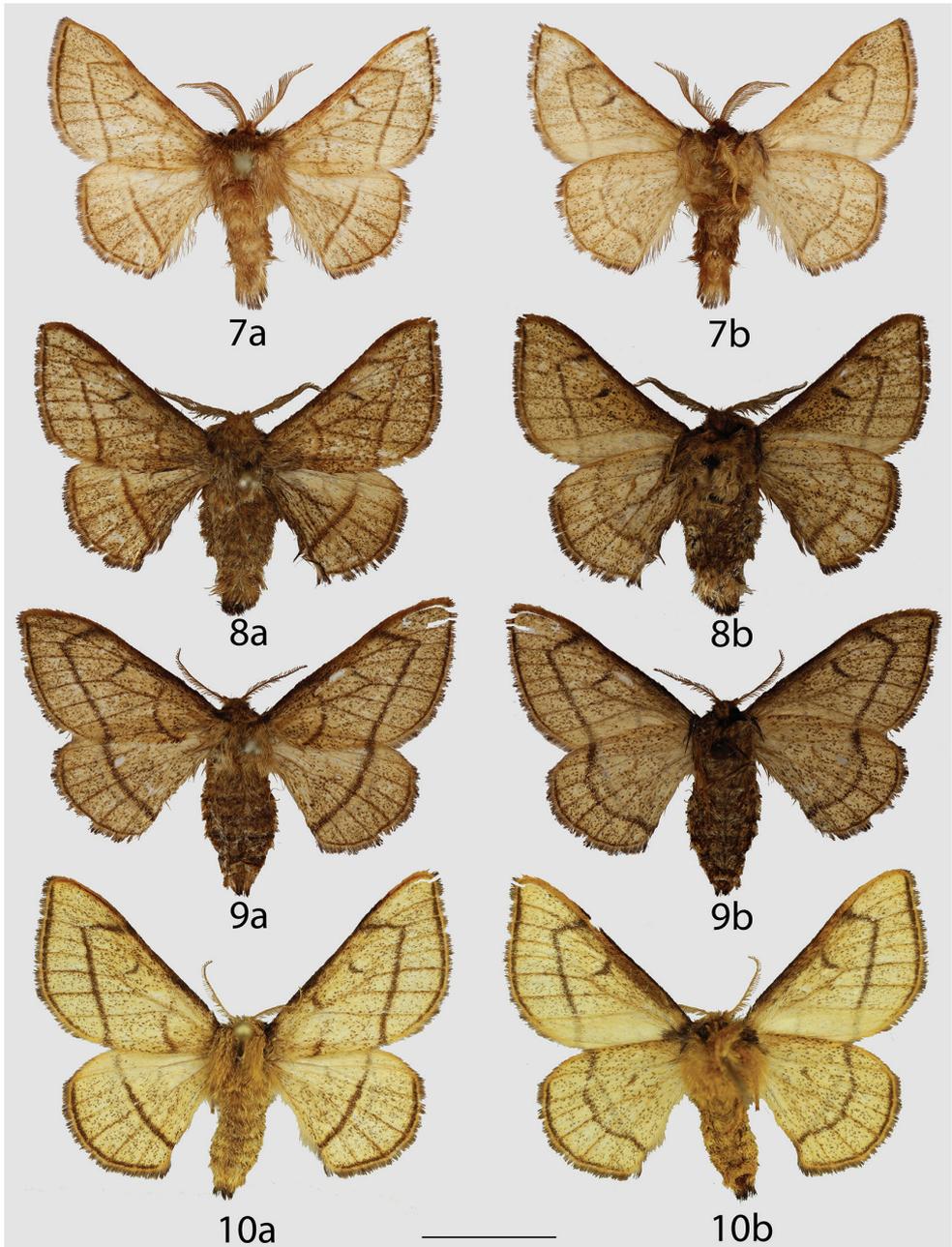
Lurama quindiuna; Gaede 1931

Type material. Lectotype (here designated), ♂. COLOMBIA: Quindío: Typus/ Paso del Quindiu, Colomb. Cent. Cord. [Paso del Quindío, Cordillera Central], 3500 m, Coll. Fassl/ *Lurama quindiuna*, type Schaus/ St Laurent diss.: 2-14-16:1 [abdomen and genitalia excluded from holotype, see remarks]/ **LECTOTYPE** ♂ *Lurama quindiuna* designated by St Laurent, 2016 [handwritten red label]/ (MNHU). Type locality: Colombia: Paso del Quindío.

Additional specimens examined. (60 ♂, 3 ♀) **COLOMBIA: Cundinamarca:** 7 ♂, Bogotá, Puebla Guasca: F. Johnson donor, USNM-Mimal: 2640–2643, 2645, 2646, St Laurent diss.: 2-14-16:3, 2-14-16:4, 2-14-16:5, 2-19-16:1 one specimen labeled as “*Lurama quindiuna* nr toptype?” by Schaus (6 ♂, USNM); (1 ♂, CUIC). 9 ♂, 1 ♀, No locality labels, but almost certainly belonging to F. Johnson’s series from Bogotá, Puebla Guasca, USNM-Mimal: 2866, 2879–2886, 2888, St Laurent diss.: 3-4-16:1, 3-4-16:2, 3-4-16:3, the following label is hereby added to these 10 specimens: “Originally unlabeled, but almost certainly: COLOMBIA: Cudinamarca: Puebla Guasca nr. Bogotá ex. F. Johnson [locale det.: R. St Laurent]” (USNM). **ECUADOR: Carchi:** 3 ♂, 35 km W. Tufiño, west slope, cloud forest, 3120 m: 20.XI.1987, R. Davidson, C. Young, St Laurent diss.: 3-11-16:3 (CMNH). 5 ♂, El Angel Ecol. Reserve, road Tulcan – El Chical, 0°48'46"N, 78°00'40"W, 3300 m: 14.XI.2012, leg. Victor Sinyaev, Expedition Ron Brechlin (MWM). 5 ♂, El Angel Ecol. Reserve, 0°45'31"N, 78°01'40"W, 3320 m: 7–8.XI.2012, leg. Victor Sinyaev, Expedition Ron Brechlin (MWM). 1 ♂, El Moran, 0°45'50"N, 78°02'38"W, 2940 m: 1–3.V.2012, leg. R. Brechlin & V. Siniaev (MWM). **Pichincha:** 1 ♂, Oyacachi, montane tropical forest, 3300 m: Jan Hillman, St Laurent diss.: 3-14-16:2 (CMNH). **Napo:** 2 ♂, 1 ♀, South Slopes, Cerro Sumaco, wet cloud/moss forest, 2950 m: 18.XI.1995, Jan Hillman, St Laurent diss.: 3-14-16:4, 3-14-16:5 (CMNH). 2 ♂, Cordillera Huacamayos [Cordillera Guacamayos], Estero Chico, virgin humid forest, 2650 m: 5.VIII.1996, J. Hillman, St Laurent diss.: 3-11-16:2, 3-14-16:3 (CMNH). 1 ♂, 10 km E. Papallacta, Hacienda Bosque on Quito-Baeza road, disturbed montane forest, 2600 m: 11.XI.1995, Jan Hillman (CMNH). 3



Figures 2–6. Colombian *Lurama quindiuna* s. l. adults, **a** dorsal **b** ventral. **2** Lectotype ♂, Quindío, Paso del Quindío, 3500 m (MNHU) **3** ♂, Cundinamarca, Bogotá, Pueblo Guasca (USNM) **4, 5** ♂, Specimens unlabeled, but almost certainly the same data as Figure 3 (USNM) **6** ♀, Unlabeled, but almost certainly the same data as Figures 3–5 (USNM). Scale bar = 1 cm.

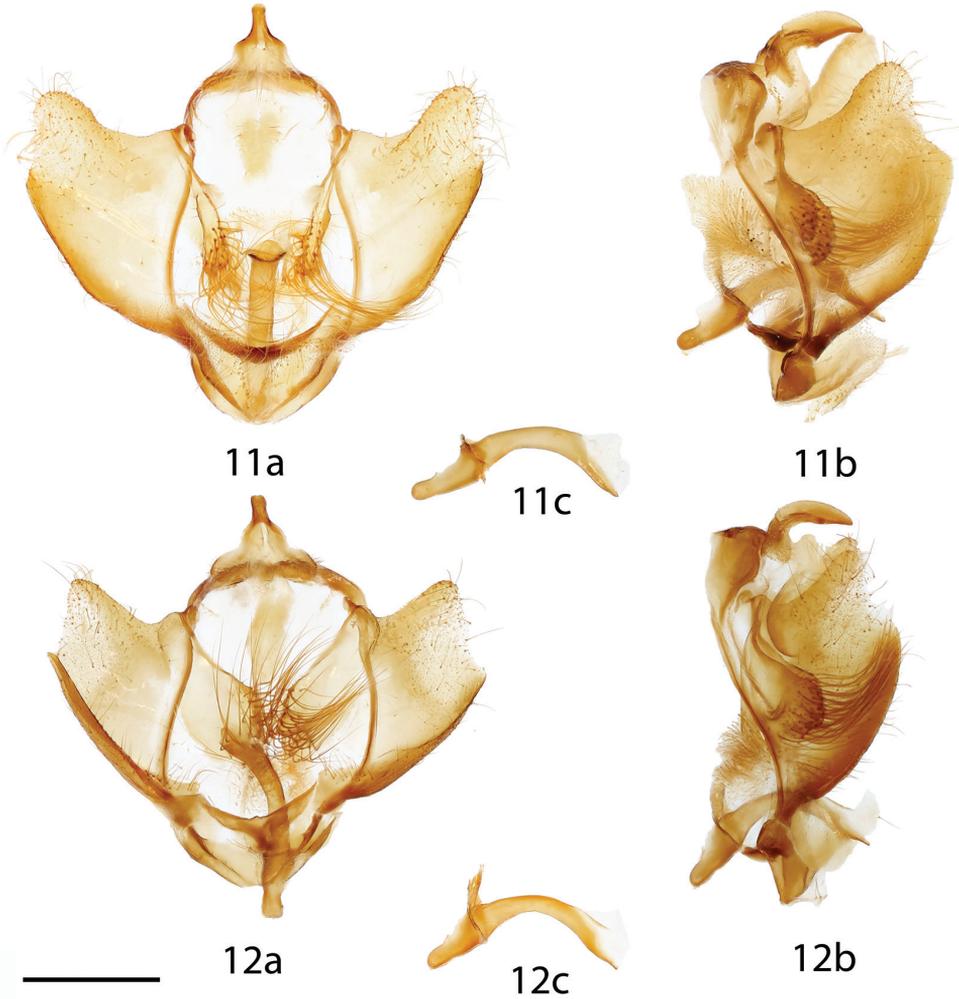


Figures 7–10. Ecuadorian *Lurama quindiuna s. l.* adults, **a** dorsal **b** ventral. **7** ♂, Carchi, 35 km W. of Tufiño, west slope, 3120 m (CMNH) **8** ♂, Napo, South Slopes, Cerro Sumaco, 2950 m (CMNH) **9** ♀, Napo, South Slopes, Cerro Sumaco, 2950 m (CMNH) **10** ♀, Loja, Road between Loja-Zamora, 2700 m [photo courtesy of Harald Sulak] (MWM). Scale bar = 1 cm.

♂, Papallacta, Rio San Pedro, 0°22'56"S, 78°7'27"W, 3010 m: 18.I.2012, 22.III.2012, leg. R. Brechlin & V. Siniaev (MWM). 2 ♂, Rio Papallacta, Cuyuja, 0°25'17"S, 78°1'19"W, 2525 m: 6.XI.2011, leg. V. Siniaev & O. Romanoc (MWM). **Azuay:** 1 ♂, Road between Gualaceo-Méndez, Limon, 2°59'4"S, 78°39'50"W, 3410 m: 8.III.2013, leg. Ackermann, Käch, & Dr. R. Brechlin (MWM). **Loja:** 1 ♀, Road Loja-Zamora, 3°58'45"S, 79°08'28"W, 2700 m: 22.II.2012, leg. R. Brechlin & V. Siniaev (MWM). 2 ♂, 6 km S Saraguro, 3°40'01"S, 79°15'17"W, 3065 m: 20.II.2012, leg. R. Brechlin & V. Siniaev (MWM). 1 ♂, 15 km E Loja to Zamora, 3°58'45"S, 79°08'28"W, 2700 m: 1.III.2011, leg. H. Kaech & R. Brechlin (MWM). **Morona-Santiago:** 2 ♂, Road Gualaceo, Plan de Milagro, 3°00'13"S, 78°38'46"W, 3176 m: 19.XI.2011, leg. V. Siniaev & O. Romanov (MWM); 17.II.2012, leg. R. Brechlin & V. Siniaev (MWM). 3 ♂, 30 km Road Plan de Milagro to Gualaceo, 3°00'21"S, 78°38'28"W, 2970 m: 1–2. II.2012, leg. R. Brechlin & V. Siniaev (MWM). 1 ♂, 62 km road Rio Bamba-Macas, 2°12'40"S, 78°23'51"W, 2700 m: 27.III.2012, leg. R. Brechlin & V. Siniaev, Genital präparat Nr. 28.995 Museum Witt München (MWM). 7 ♂, 34 km Road Plan de Milagro to Gualaceo, 3°00'13"S, 78°38'46"W, 3176 m: 30.I.2012, leg. R. Brechlin & V. Siniaev (MWM). 2 ♂, 34 km Road Plan de Milagro to Gualaceo, 3°01'24"S, 78°35'6"W, 2157 m, 28.I.2012, leg. R. Brechlin & V. Siniaev (MWM).

Diagnosis. *Lurama quindiuana* can be distinguished from the previous species by the larger size, more triangular wings, and by the (usually) thinner, more well-defined ante- and postmedial lines. The lines are situated closer to the wing margin than in *L. penia*, and form a sharp angle apically. Additionally, the forewing postmedial line has its apical angle either intersecting Rs4 or between Rs3 and Rs4 and is distant from the fork of Rs3+Rs4.

Description. Male. *Head:* As for genus. *Thorax:* As for genus. *Legs:* As for genus. *Forewing dorsum:* Forewing length: 14.5–17.5 mm, avg.: 16.1 mm, wingspan: 27–35 mm, n=23. Somewhat variable; usually triangular, margin nearly straight from apex until after passing M₃ where wing smoothly curves toward anal margin. Ground color variable from brown to tan to nearly yellow, overall lightly to heavily speckled by dark-brown or brown-gray petiolate scales, especially postmedially. Antemedial line brown, usually narrow, rarely wide, slightly bowed outward. Postmedial line nearly straight or slightly curved inward from anal margin to Rs3, Rs4, or between Rs3 and Rs4, where line abruptly angled toward costa, forming nearly right angle, coloration and width as for antemedial line. Antemedial, medial, and postmedial areas concolorous, distance between lines variable. Costa and outer wing margin darker brown as in ante- and postmedial lines. Discal spot a dark-brown streak spanning width of discal cell, mesally slightly angled inward toward cell. Wing veins lined by dark-brown scales, colored as for ante- and postmedial lines. Fringe light brown with intermittent darker-brown scales. *Forewing ventrum:* Similar to dorsum but usually lighter; antemedial line nearly absent to absent and postmedial line may be lighter. *Hindwing dorsum:* Coloration as for forewing dorsum, antemedial line absent, postmedial line straight or curved outward. *Hindwing ventrum:* Following same pattern as forewing ventrum but postmedial line always curved outward. Base of wing usually covered by dark-brown scales from



Figures 11–12. *Lurama quindiuna* ♂ genitalia, **a** ventral **b** lateral **c** phallus. **11** Colombia, Cundinamarca, Bogotá, Pueblo Guasca, St Laurent diss.: 2-14-16:5 (USNM) **12** Ecuador, Napo, Cordillera Guacamayos, Estero Chico, 2650 m, St Laurent diss.: 3-14-16:3 [note, phallus with remnant of juxta still attached] (CMNH). Scale bar = 1 mm.

thorax. Frenulum present as single bristle, size somewhat variable. *Abdomen*: Concolorous with thorax, distal tip with tuft of black scales. *Genitalia*: See generic description. **Female**. See generic description.

Distribution (Map 1). *Lurama quindiuna* is an Andean species known from Colombia and Ecuador at moderate elevations ranging from 2157–3500 m. According to data on Ecuadorian specimens, this species can be encountered in humid montane cloud and moss forests.

Remarks. Confusion surrounds the whereabouts of the genitalia of the lectotype of *L. quindiuna*. When initially examining the lectotype, I noticed that the abdomen

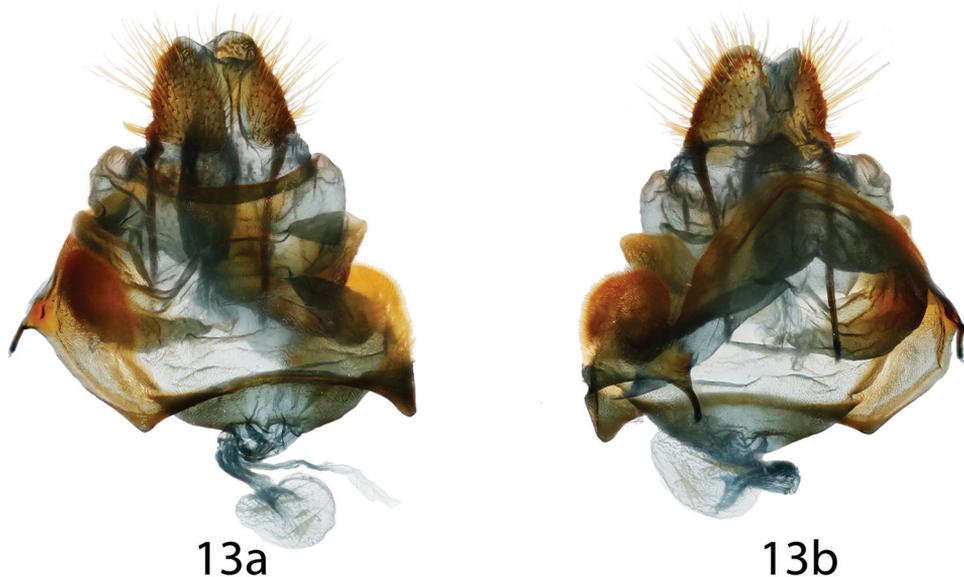


Figure 13. *Lurama quindiuna* ♀ genitalia, **a** ventral **b** dorsal. Specimen unlabeled, but almost certainly: Colombia, Cundinamarca, Bogotá, Pueblo Guasca, St Laurent diss.: 4-14-16:1 (USNM). Scale bar = 1 mm.

was visibly small and noticeably lighter in color relative to the rest of the specimen. The abdomen was odd enough that it appeared out of place on the specimen, and a dissection further supported this notion. The dissection revealed complicated genitalia unlike any other in Mimallonidae, especially compared with other dissections of *L. quindiuna* from nearby locations. The elongated saccus and thin, golf club like phallus is reminiscent of some Bombycidae (pers. obs.), whereas the valve structure is similar to some Notodontidae. Alexander Schintlmeister (pers. comm.) has suggested Lasio-campidae rather than Notodontidae and Daniel Herbin (pers. comm.) mentioned the possibility of it belonging to Phiditiidae although Joël Minet (pers. comm.) does not consider this likely due to the presence of a saccus. So far, the exact determination of the genitalia is inconclusive. Apparently the abdomen of the *L. quindiuna* lectotype was misplaced and incorrectly replaced with a foreign abdomen at some point after its original description. Wolfram Mey (pers. comm.) confirmed that this, unfortunately, is a known issue with material in the MNHU. Furthermore, it is worth noting that Schaus (1928) figures the lectotype of *L. quindiuna*, illustrating a regularly proportioned and colored abdomen. Unfortunately, Schaus (1928) makes no mention of the abdomen nor genitalia in his original description. I chose not to figure these “mystery” genitalia for fear of causing inadvertent association with *Lurama*.

By Article 73.1.5, the abdomen (and my subsequent genitalia preparation: St Laurent diss.: 2-14-16:1) is hereby excluded from the lectotype of *Lurama quindiuna*, and although it will be preserved for historical purposes, it cannot be considered a component of this lectotype (ICZN 1999).

The lectotype of *L. quindiuna* differs in maculation from the series from Bogotá, particularly in regards to the arrangement of the forewing postmedial line. In the lectotype, the postmedial line is farther from the wing margin, angled toward the costa more proximal to the fork of Rs3 + Rs4, and has an apical angle that intersects Rs4 rather than being situated between Rs3 and Rs4. Furthermore, the postmedial and antemedial lines are closer together in the lectotype. While these characters were nearly consistently different between the lectotype and all specimens from Bogotá, Pueblo Guasca, substantial variations in these same characters were found within the Pueblo Guasca series (compare Figs 2–6). The variation within this series prevents me from considering these two populations as distinct, especially without access to genitalia of topotypical material. The material from Ecuador is also quite variable in the same characters, and thus there seems to be a high degree of phenotypic plasticity in the species, but I found no external characters applicable to any single geographic region. Male genitalia are rather consistent among all populations, with only minor variation in the valves, namely in their width, thickness, and curvature, as well as in the shape of the apical lobe. These minor variations are seen within both Colombian and Ecuadorian populations, but some Ecuadorian specimens tend to have thinner (in terms of thickness, not width), more concave valves. Antennal size also differs somewhat within populations, but more markedly between Colombian and Ecuadorian specimens such that Ecuadorian specimens tend to have shorter pectinations.

Female genitalia, however, do differ between Colombian and Ecuadorian *L. quindiuna* specimens. The width of the VIII tergite, shape of papillae anales and lamella antevaginalis, as well as the size of the corpus bursae all differed between these locations. However, given the lack of differentiating characters in the usually much more reliable male genitalia (pers. obs.) as well as the low sample size of female specimens, it does not seem reasonable to consider the Colombian and Ecuadorian populations separate species based on this information alone. Molecular evidence may later be useful in comparing these two populations, although recently collected Colombian material is currently lacking.

It is critical to locate more material of *L. quindiuna* from the type locality at Paso del Quindío, Colombia, so that the necessary genitalia comparisons between topotypical and other populations can be made. Also, it would be important to determine if populations from Paso del Quindío display similar levels of variation as in the other examined populations to further justify conclusions presented in the present work.

Lurama quindiuna was omitted from Becker (1996).

***Ulmara* Schaus, 1928: 666**

Type species. *Cicinnus rotunda* Dognin, 1916; Schaus 1928: 666, by original designation.

Diagnosis. The unique genus *Ulmara* shows no apparent external resemblance to any known Mimallonidae. The stout, broad wings, dark, nearly black coloration, serrated postmedial lines, combined with impressively long pectinations of the antennae

in males, are all characters that should immediately allow the recognition of *Ulmara*. Although the long pectinations of the antennae are seen in the other two genera treated in the present work, neither genus is so darkly colored. *Cunicumara* gen. n., described below, is similar in having both broad antennae and stout wings, but is easily distinguished by the straight, rather than serrate postmedial line present in *Ulmara*. The male genitalia of *Ulmara* are actually rather similar to those of *Lurama* (see diagnosis of *Lurama*) but wholly unlike those of *Cunicumara* gen. n. The genitalia of *Ulmara* are recognized by the short, broad phallus with a scoop-like ventral projection, apically-toothed valves, and the unique, paired, setae-covered sclerotizations on the ventrum of VIII, which are variously connected to an extension of the saccus.

Description. Male. *Head:* Very dark brown to nearly black, eyes very large, occupying more than two-thirds area of head; antennal coloration pale tan to dark brown, if lighter in color, contrasting against dark head, scape with contrasting pale off-white tuft of scales, antenna bipectinate to tip, pectinations very long, the longest nearly one-fourth length of antenna overall; labial palpus relatively long, extending beyond head, three segmented, tufted ventrally, heavily clothed in long scales. *Thorax:* Coloration as for head but often with pale-gray to brown scales beneath darker-black to steel-blue scales, vestiture very long, shaggy, scales thin, scales of prothorax lighter brown. *Legs:* Coloration as for thorax, but lighter ventrally, vestiture fine, elongated. Femur and tibia clothed in particularly long scales. Tibial spurs somewhat elongated, tubular, clothed in light khaki-colored scales except for naked tip. *Forewing dorsum:* Forewing length: 17.5–21 mm, wingspan: 34–43 mm, n=16. Short subtriangular, margin convex, apex barely accentuated. Ground color usually very dark grayish black, often with nearly steel-blue sheen, older and worn specimens expose lighter pale-brown scales beneath thicker, darker-scales; wider petiolate scales absent. Antemedial line brown, zigzagged, usually obscured by darker surrounding scales so line nearly absent. Brown postmedial line serrated at each wing vein, postmedial line may be very distinct, especially when lighter scales present along inner side, and near tornus, or postmedial line may be overshadowed by darker surrounding scales; line angled toward costa at Rs4. Between Rs4 and costa, line slightly undulated, but otherwise less serrate, may be notched near costa. Location of postmedial line variable, from one-fourth wing length distant from wing margin to nearly two-thirds distant. Antemedial, medial, and postmedial areas concolorous, although postmedial area may be lighter gray blue than medial area, particularly along postmedial line. Discal spot a small white mark, either somewhat circular in shape or oblong. Fringe consisting of elongated scales, coloration as for medial area except some lighter off-white scales present in semi-regular pattern along margin. *Forewing ventrum:* Similar to dorsum but much lighter, grayer, maculation reduced; antemedial line absent, postmedial line less distinct to nearly absent, brown outline lacking if present on dorsum. *Hindwing dorsum:* Coloration as for forewing dorsum, antemedial line absent, discal mark absent, outer margin of wing may be serrate or mostly smooth. *Hindwing ventrum:* Following same pattern as forewing ventrum. Base of wing sometimes covered by dark-brown scales emanating outward from thorax. Frenulum present as single

bristle. *Venation*: Similar to *Lurama* but CuA_1 arises nearer to lower angle of cell; M_2 and M_3 do not originate from same point at lower angle of cell, and are more separated. *Abdomen*: Concolorous with thorax, but usually slightly lighter brown, distal tip with paired tuft of elongate scales. *Genitalia*: Simple; vinculum somewhat box-like or ovoid, ventrally with reduced saccus, projection of saccus attached to VIII, forming paired, setae-covered sclerotizations. Uncus simple, highly truncated apically with triangular base or broad basally, with reduced apical extension, laterally uncus beak-like. Gnathos variable, from nearly absent, to mesally gapped, to a single fused plate. Valves short, generally triangular, somewhat truncated apically, with single tooth projecting from saccular edge near apex of valve, tooth variable in length. Transtilla with weakly sclerotized, inward-facing setae-covered extensions, setae variable in thickness from very fine to thick. Setae pointed outward directly over phallus. Diaphragm forms small, balloon-like sac expanded inward into abdomen, sac covered in fine, inward-facing setae surrounding phallus. Juxta partially fused to phallus, encircling it, lightly sclerotized, especially dorsal to phallus. Phallus short, stout, anterior half tubular or bent, apex more heavily sclerotized, forming scoop-like extension below vesica; vesica small, sac-like, weakly scobinate, poorly differentiated diverticula may be present; base of phallus much narrower than apical half, but variable in thickness, angled backward from apex of phallus. **Female.** *Head*: As for male, but antennae much smaller overall, pectinations particularly shorter, labial palpus slightly reduced. *Thorax*: As for male. *Legs*: As for male, but vestiture seemingly sparser. *Forewing dorsum*: Forewing length: 21.5 mm, wingspan: 41 mm, $n=2$. As for male but more elongated, slightly narrower, discal mark reduced. *Forewing ventrum*: Similar to dorsum but much lighter, grayer, maculation reduced; antemedial line absent, postmedial line less distinct. *Hindwing dorsum*: Coloration as for forewing dorsum, antemedial line absent. *Hindwing ventrum*: Following same pattern as forewing ventrum. Frenulum as multiple bristles, length shorter than in male. *Abdomen*: Concolorous with thorax, similar to male but not truncated to a point. *Genitalia*: (Fig. 28) $n=1$. [based on *U. conjuncta* sp. n. only] Stout; tergite of VIII forms smooth, thick posteriorly directed arch, laterally VIII heavily sclerotized, forming pair of posteriorly directed lobes on each side, anterior lobe covered in minute, fine setae, posterior lobe with about 10 sparse, long setae. Apophyses anteriores slightly more than half length of apophyses posteriores, apophyses posteriores very long, as long as length of genitalia structure. Lamella antevaginalis wide, concave, only posterior edge well sclerotized, covered in minute setae, ventral margin of lamella smoothly curved. Ductus bursae short, almost as wide as corpus bursae. Corpus bursae reduced, baglike. Papillae anales somewhat convex laterally, papillae anales covered with fine setae, setae at base of papillae anales more compactly distributed, forming lateral tuft.

Remarks. The genus *Ulmara* contains some of the darkest colored and highest elevation inhabiting Mimmalloniidae, and is immediately recognizable by characters given in the diagnosis. Most species in the genus are quite similar to one another, but can be primarily differentiated by male genitalia. Distribution and overall size should also be adequate for simple diagnosis.

Key to species of *Ulmara**

- 1 Forewing length 19 mm or greater, usually not strongly iridescent blue (Figs 14–19), Colombia to Ecuador **2**
- Forewing length usually less than 19 mm, strongly iridescent (Figs 20–22), Peru southward..... **3**
- 2 Ground coloration dark brown to blackish brown, postmedial line obvious due to brown inner lining (Figs 14–16), gnathos with mesal gap, phallus broad, not bent (Figs 23, 24). Colombia..... ***U. rotunda***
- Ground coloration almost black, postmedial line indistinct, no brown inner lining along postmedial line (Figs 17–19), gnathos fused mesally, phallus bent downward (Fig. 25). Ecuador ***U. conjuncta* sp. n.**
- 3 Postmedial line one-quarter from wing margin (Fig. 20), gnathos highly reduced, setae on flaps extending from transtilla very thick, splayed saccular projections wider than vinculum, phallus narrow when viewed dorsally (Fig. 26)..... ***U. azurula* sp. n.**
- Postmedial line one-quarter to one-third from wing margin (Fig. 21, 22), gnathos reduced but almost converges mesally, setae on flaps extending from transtilla very thin, splayed saccular projections barely wider than vinculum, phallus broad, compressed, when viewed dorsally (Fig. 27)..... ***U. dombroskiei* sp. n.**

*Note: the females of *U. azurula* sp. n. and *U. dombroskiei* sp. n. are unknown.

***Ulmara rotunda* (Dognin, 1916)**

Figs 14–16, 23, 24; Map 2

Cicinnus rotunda Dognin, 1916: 20–21

Ulmara rotunda; Schaus 1928: Figs ♂ and ♀ 88 g

Ulmara rotunda; Gaede 1931

Ulmara rotunda; Becker 1996

Type material. 2 ♂ **syntypes**, [deposition of one syntype unclear, but probably among series from type locality at MNHU or specimen “2602” in possession of R. Hutchings, available syntype from USNM designated as lectotype below]. Type locality: Colombia: Monte Tolima [Nevado del Tolima?].

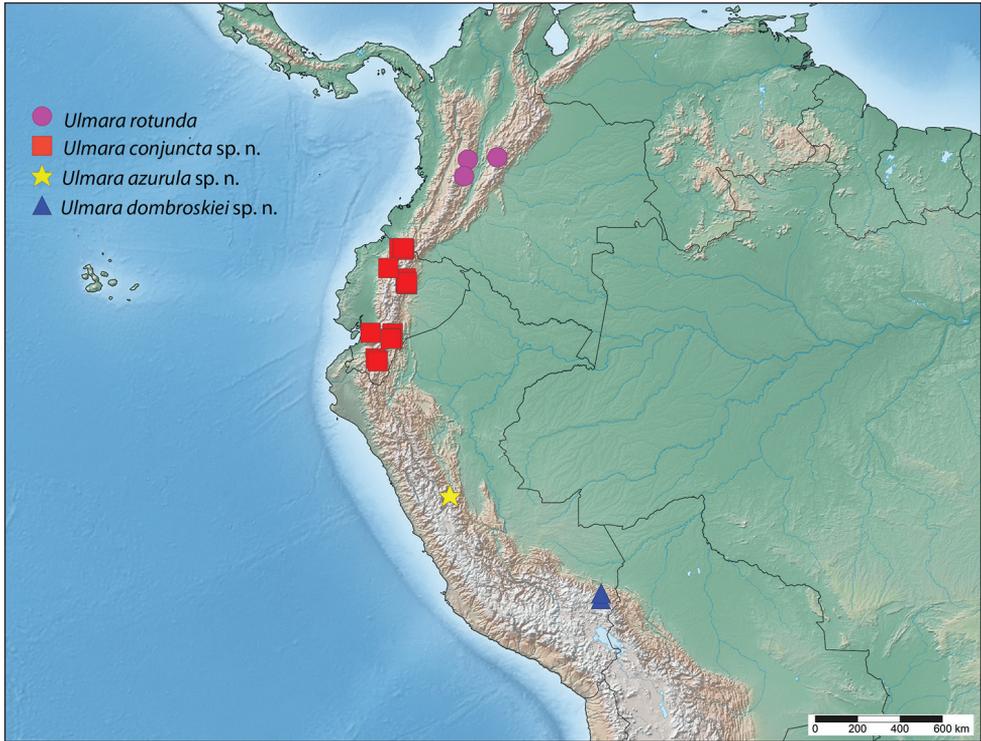
Lectotype (here designated), ♂. **COLOMBIA: Tolima:** Monte Tolima, 3200 m, Colomb. Cent. Cord. [Nevado del Tolima?, Cordillera Central]/ Type No.: 29689 U.S.N.M./ USNM-Mimal: 1109/ St Laurent diss.: 2-14-16:2/ **LECTOTYPE** ♂ *Cicinnus rotunda* designated by St Laurent, 2016 [handwritten red label]/ (USNM).

Additional specimens examined. (6 ♂, 1 ♀) **COLOMBIA: Tolima:** 3 ♂, Monte Tolima [Nevado del Tolima], 3200 m: Coll. Fassl, St Laurent diss.: 4-5-16:3



Figures 14–16. *Ulmara rotunda* adults, **a** dorsal **b** ventral. **14** Lectotype ♂, Colombia, Tolima, Nevado del Tolima, 3200 m (USNM) **15** ♂, Colombia, Tolima, Nevado del Tolima, 3200 m (MNHU) **16** ♀, Colombia, Cundinamarca/ Distrito Capital, Bogotá [photo courtesy of Wolfram Mey] (MNHU). Scale bar = 1 cm.

(MNHU). 1 ♂, Mt. Tolima [Nevado del Tolima], 2800 m: II.1910, A. H. Fassl, NHMUK010355070 (NHMUK). 1 ♂, San Antonio, 5800 ft: G.M. Palmer, St Laurent diss.: 4-15-16:1, NHMUK010355069 (NHMUK). **Cundinamarca/Distrito Capital:** 1 ♂, Bogotá: Rothschild Bequest BM 1939–1, St Laurent diss.: 4-15-16:2, NHMUK010355068 (NHMUK). 1 ♀, Bogotá [additional locality information illegible]: 13.IV.1871, Nolcken, Coll. Staudinger, “*Ulmara rotunda* ♀ type, Schaus” with label “Typus” [Not a true type, Schaus invalidly designated this as an allotype



Map 2. Known distribution of *Ulmara*.

retroactively well after original description. Abdomen missing, no genitalia preparation.] (MNHU).

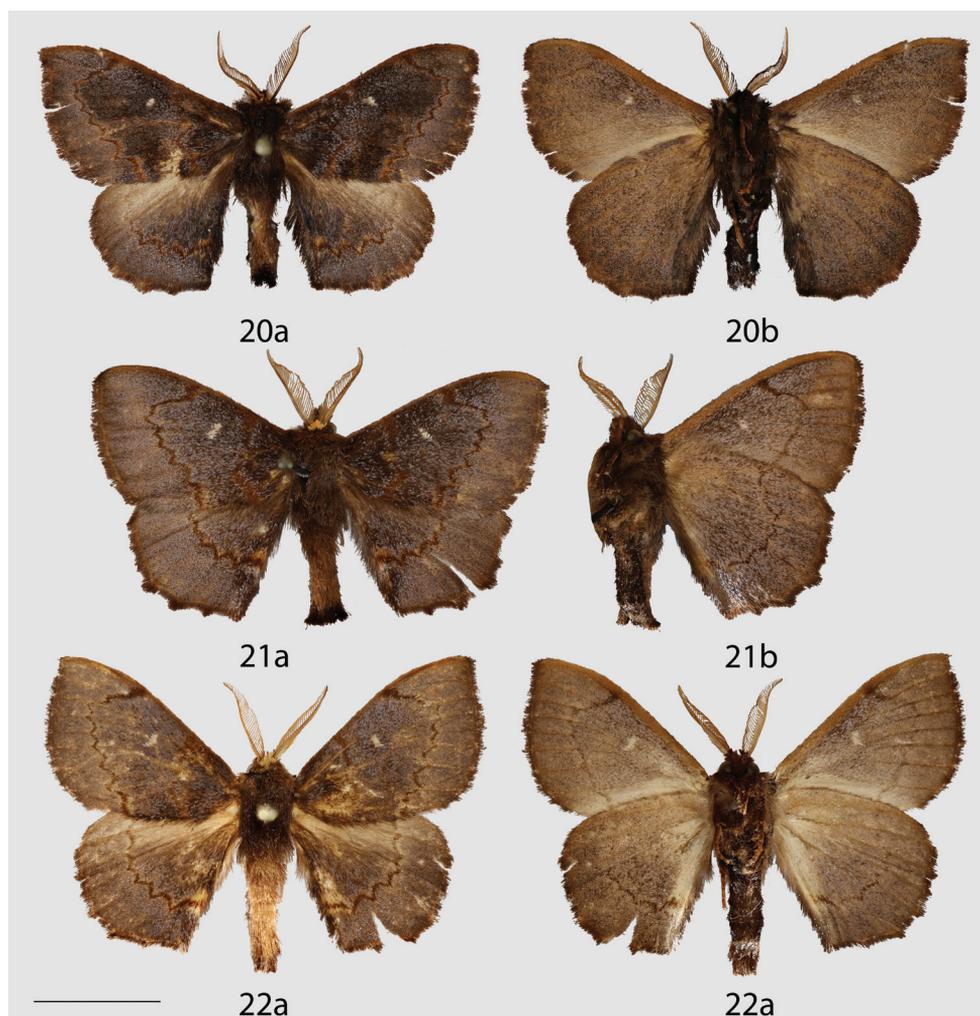
Diagnosis. *Ulmara rotunda* is the largest and most northernmost representative of the genus, being the only species so far reported from Colombia. Apart from distribution and large size, *U. rotunda* can be recognized by the nearly complete gnathos, which while not fused mesally, is only separated by a small gap with heavily sclerotized terminal ends on either side of the gap. The valves are among the largest in the genus, and are triangular, the phallus is also recognizable by its oblong shape where the distal half is much wider (when viewed laterally) than the basal half.

Description. Male. Head: As for genus but labial palpus particularly long, extending well beyond frons. **Thorax:** As for genus. **Legs:** As for genus. **Forewing dorsum:** Forewing length: 19.05–21 mm, avg.: 20.4 mm, wingspan: 39–43 mm, n=6. As for genus but ground color dark brown rather than black, postmedial line located about one third wing length away from wing margin, usually very obvious due to lighter brown edging along inner side without blue sheen, postmedial line only weakly notched between Rs4 and costa. **Forewing ventrum:** As for genus, light-brown edging of postmedial line absent. **Hindwing dorsum:** Coloration as for forewing dorsum, antemedial line absent, discal mark absent, outer margin of wing serrate. **Hindwing ventrum:** As for genus. **Abdomen:** As for genus, but more robust, dorsally with lighter brown scales and



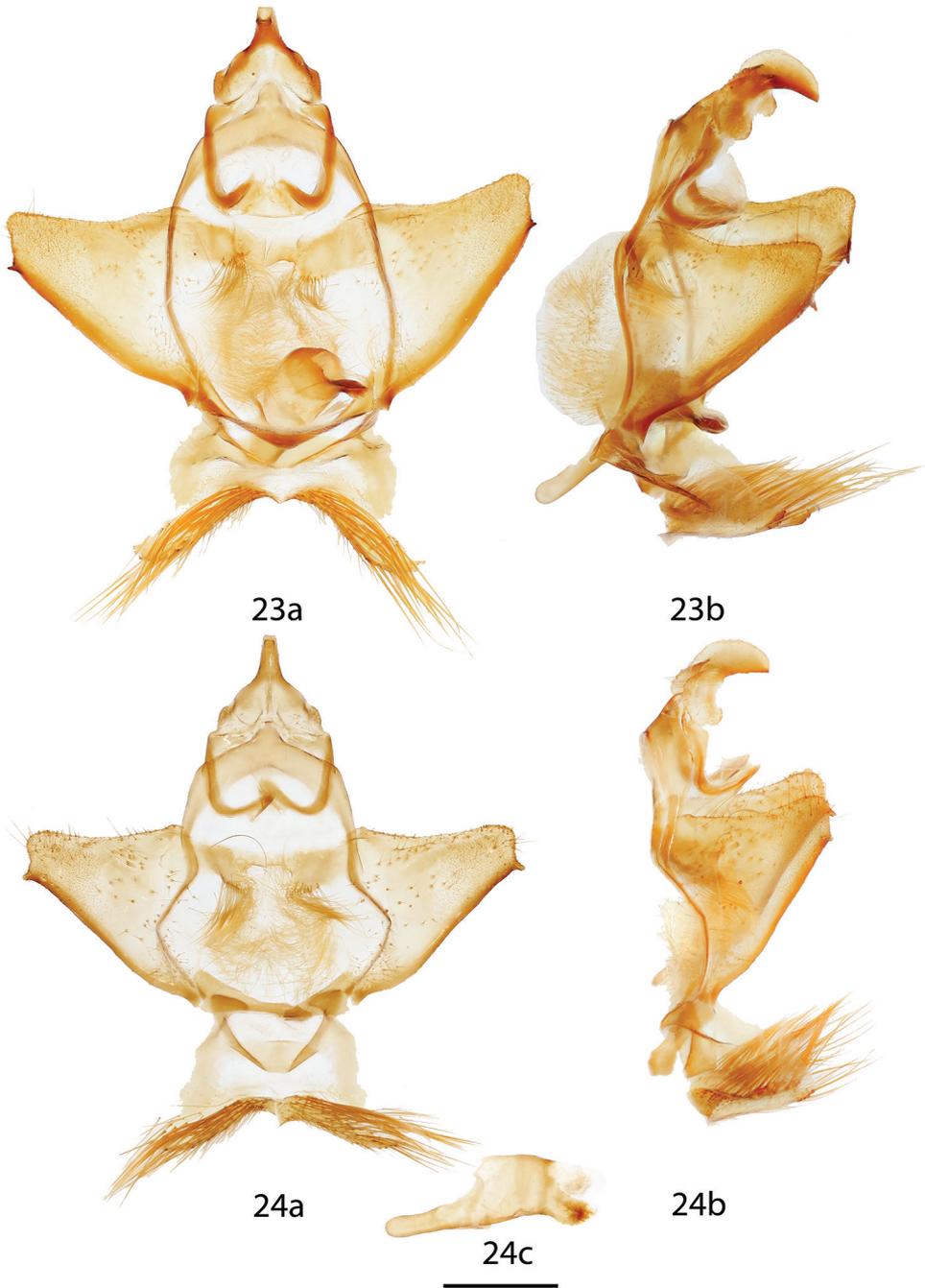
Figures 17–19. *Ulmara conjuncta* adults, **a** dorsal **b** ventral. **17** Holotype ♂, Ecuador, Loja, N. Loja, road to Cuenca, 2220 m (CMNH) **18** Paratype ♂, Ecuador, Napo, Cordillera Guacamayos, Estero Chico, 2650 m (CMNH) **19** Paratype ♀, Ecuador, Loja, Road between Loja-Zamora, 2700 m (MWM). Scale bar = 1 cm.

well-defined dark terminus due to elongated tuft of dark-brown scales. *Genitalia*: (Figs 23, 24) $n = 4$. Vinculum ovoid, ventrally with reduced saccus, bilobed projections of saccus weakly attached to VIII, paired, setae-covered sclerotizations of VIII splayed mesally, extensions wider than ventral margin of vinculum. Uncus simple, highly truncated apically with triangular base. Gnathos nearly complete but gap present mesally, strongly sclerotized, especially terminally at gap. Valves moderately sized, triangular, somewhat truncated apically, with single tooth projecting from saccular edge near apex of valve, tooth variable in length. Transtilla with weakly sclerotized, inward facing se-



Figures 20–22. Peruvian *Ulmara* species adults, **a** dorsal **b** ventral. **20** *U. azurula* holotype ♂, Peru, Huánuco, Carpish, 2700 m (AMNH) **21** *U. dombroskiei* holotype ♂, Peru, Puno, Carabaya, Agualani, 9000 ft (NHMUK) **22** *U. dombroskiei* paratype ♂, Peru, Puno, Carabaya, Santo Domingo (NHMUK). Scale bar = 1 cm.

tae-covered extensions. Setae pointed outward directly over phallus. Diaphragm forms large, balloon-like sac expanded inward into abdomen, sac covered in fine, inward facing setae surrounding phallus. Juxta partially fused to phallus, encircling it, lightly sclerotized, especially dorsal to phallus. Phallus short, stout, anterior half cylindrical, ventral apex heavily sclerotized, forming scoop-like extension below vesica; vesica small, sac-like, weakly scobinate; base of phallus much narrower than apical half, in same plane as apical half, not bent. **Female.** [description based on single, faded specimen] *Head:* As for male but antennae smaller overall, pectinations particularly shorter, labial palpus slightly reduced. *Thorax:* As for male. *Legs:* As for male, but vestiture seemingly



Figures 23, 24. *Ulmara rotunda* ♂ genitalia, **a** ventral **b** lateral **c** phallus. **23** Lectotype, Colombia, Tolima, Nevado del Tolima, 3200 m, St Laurent diss.: 2-14-16:2 [phallus not excised] (USNM) **24** Colombia, Tolima, Nevado del Tolima, 3200 m, St Laurent diss.: 4-5-16:3 (MNHU). Scale bar = 1 mm.

sparser. *Forewing dorsum*: Forewing length: 21.5 mm, wingspan: ~41 mm, n = 1. As for male but more elongated, slightly narrower, discal mark reduced. *Forewing ventrum*: Somewhat similar to dorsum but much lighter, grayer, maculation reduced; antemedial line absent, postmedial line less distinct. *Hindwing dorsum*: Coloration as for forewing dorsum, antemedial line absent. *Hindwing ventrum*: Following same pattern as forewing ventrum. *Abdomen and genitalia*: Absent from unique specimen.

Distribution (Map 2). *Ulmara rotunda* so far appears to be isolated within central Colombia with no records from neighboring countries. This species can be encountered at elevations ranging from 1767–3500 m.

Remarks. Until the present work, only *U. rotunda* was known from the genus, and was previously reported from both Nevado del Tolima and Bogotá (Schaus 1928), thus the only new location reported herein is San Antonio, Tolima, Colombia (NHMUK).

***Ulmara conjuncta* St Laurent, sp. n.**

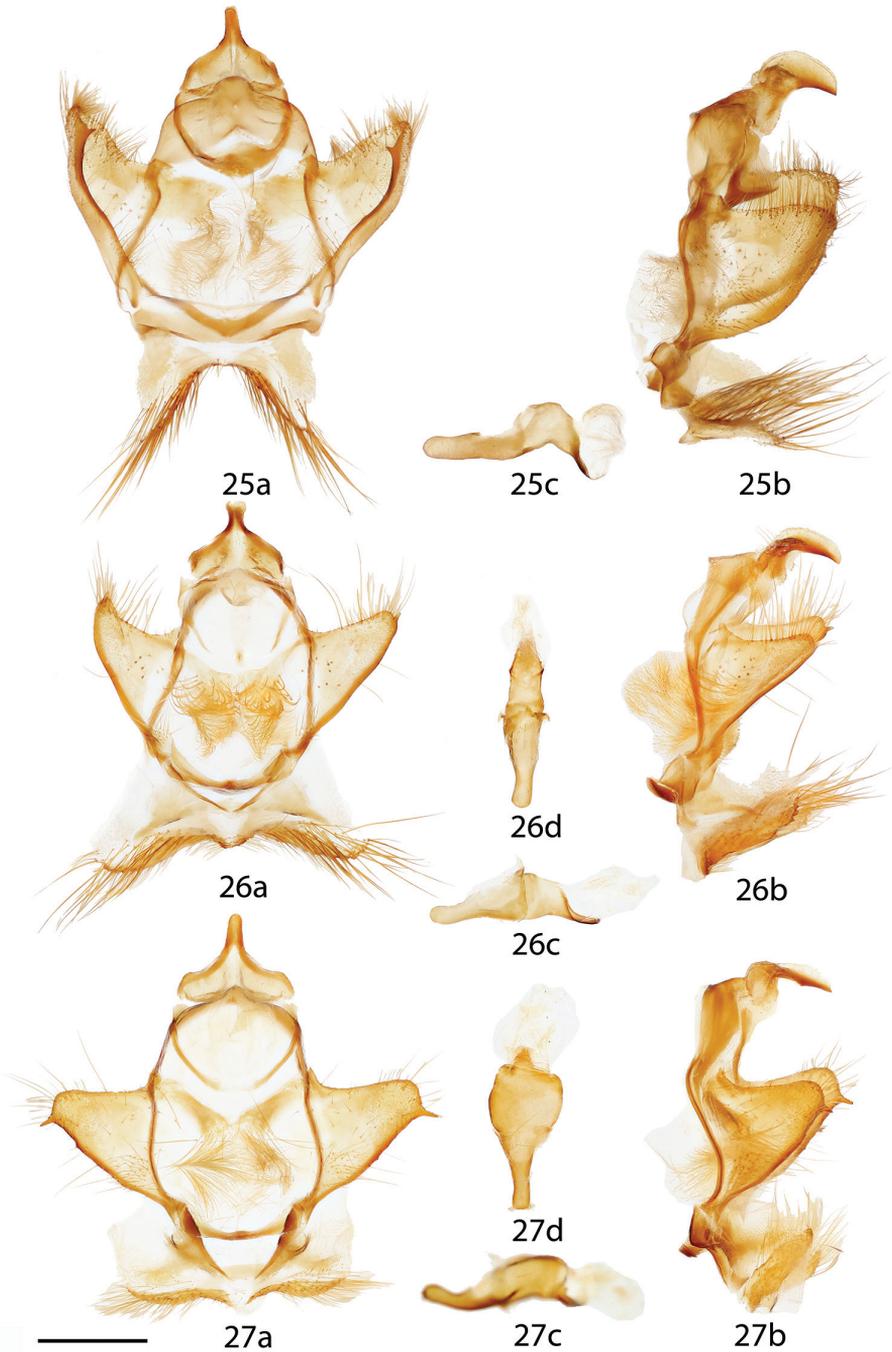
<http://zoobank.org/EC14FACE-6B67-4708-8E43-F99B4D12469C>

Figs 17–19, 25, 28; Map 2

Ulmara rotunda; Lemaire and Minet 1998: Fig ♂ 18.2 B [*U. conjuncta* sp. n. figured]

Type material. Holotype, ♂. ECUADOR: Loja: ECUADOR: Loja. N Loja, road to Cuenca, 2220 m, 25 March 1993, Jan Hillman. Disturbed forest and pastures/ St Laurent diss.: 4-5-16:4/ HOLOTYPE ♂ *Ulmara conjuncta* St Laurent, 2016 [handwritten red label] (CMNH).

Paratypes, 23 ♂, 1 ♀. ECUADOR: Carchi: 2 ♂, El Angel Ecol. Reserve, road Tulcan-El Chical, 0°48'46"N, 78°00'40"W, 3300 m: 14.XI.2012, leg. Victor Sinyaev, Expedition Ron Brechlin (MWM). 2 ♂, 70 km Road El Chical-Tulcan, 0°50'29"N, 78°03'25"W, 2440 m: 22.XI.2012, leg. Sinyaev & Romanov, expedition Ron Brechlin (MWM). 5 ♂, El Angel Ecol. Reserve, 0°46'14"N, 78°03'27"W, 2785 m: 9–11. XI.2012, leg. Victor Sinyaev, expedition Ron Brechlin (MWM). 1 ♂, Road El Chical to Carolinae, 0°50'20"N, 78°13'39"W, 2360 m: 20.XI.2012, leg. Sinyaev & Romanov, Expedition Ron Brechlin (MWM). **Azuay:** 2 ♂, Cochabamba, Pan de Agucar, 2°46'18"S, 79°26'52"W, 2840 m: 11.XII.2012, leg. Sinyaev & Romanov, expedition Ron Brechlin (MWM). **Pichincha:** 2 ♂, Camping Bella Vista, 0°00'41"S, 78°41'17"W, 2230 m: leg. V. Siniav & Romanov (MWM). **Napo:** 1 ♂, Cordillera Huacamayos [Cordillera Guacamayos], Estero Chico, virgin humid forest, 2650 m: 5.VIII.1996, J. Hillman, St Laurent diss.: 4-8-16:1 (CMNH). 1 ♂, Cordillera Huacamayos [Cordillera Guacamayos], San Isidro, Rio Aliso, 00-37-36S, 77-57-12W, deforested hacienda, 2250 m: 3.VIII.1996, Jan Hillman (CMNH). 1 ♂, Cordillera Huacamayos [Cordillera Guacamayos], San Fernando de Sierra Azul, disturbed montane forest, 2350 m: 4.VIII.1996, Jan Hillman (CMNH). 1 ♂, Rte Pifo to Baeza, km 52, 2600 m: 2–3.II.1975, H. Descimon, C. Herbulot, C. Lemaire, P. Thiaucourt, N.



Figures 25–27. *Ulmara* ♂ genitalia, **a** ventral **b** lateral **c** phallus. **25** *U. conjuncta* holotype ♂, Ecuador, Loja, N. Loja, road to Cuenca, 2220 m, St Laurent diss.: 4-5-16:4 [note: valves not fully spread in Fig. 25a] (CMNH) **26** *U. azurula* holotype ♂, Peru, Huánuco, Carpish, 2700 m, St Laurent diss.: 4-8-16:2 (AMNH) **27** *U. dombroskiei* holotype ♂, Peru, Puno, Carabaya, Agualani, 9000 ft., St Laurent diss.: 4-8-16:3 (NHMUK). Scale bar = 1 mm.

Venedictoff, Brit. Mus. 1975–140, *Ulmara rotunda* Dognin det. J.E. Chainey, 2003, NHMUK010355071 (NHMUK). 1 ♂, 6 km SE of Cosanga, 0°37'14"S, 77°54'08"W, 2240 m: 22.I.2012, leg. R. Brechlin & Siniaev (MWM). **Morona-Santiago**: 1 ♂, Rte Gualaceo to Méndez, km 41, 2400 m: 10–11.I.1975, H. Descimon, C. Herbulot, C. Lemaire, P. Thiaucourt, N. Venedictoff, St Laurent diss.: 4-15-16:3, Brit. Mus. 1975–140, *Ulmara rotunda* Dognin det. J.E. Chainey, 2003, NHMUK010355072 (NHMUK). 1 ♂, 9 km W Plan de Milagro to Gualaceo, 3°00'04"S, 78°30'49"W, 2375 m: 6–7.III.2013, leg. Ackermann, Käch & Dr. R. Brechlin (MWM). 2 ♂, Road Gualaceo-Plan de Milagro, 3°01'24"S, 78°35'06"W, 2157 m: 21.XI.2011, leg. V. Siniaev & O. Romanov (MWM). **Loja**: 1 ♀, Road between Loja-Zamora, 3°58'45"S, 79°08'28"W, 2700 m: 22.II.2012, leg. R. Brechlin & V. Siniaev, St Laurent diss.: 4-19-16:1 (MWM). – All paratypes with the following yellow label: PARATYPE ♂/♀ *Ulmara conjuncta* St Laurent, 2016.

Diagnosis. This new species is most similar to *U. rotunda* in external appearance, but can be distinguished from it by the more southerly distribution, darker, nearly black ground color, smaller size overall, lack of a brown inner edging along the postmedial line of the fore and hindwings, and the near absence of the postmedial line on the ventrum of the wings. The male genitalia also offer good characters for differentiation: in *U. conjuncta* the gnathos is fused mesally, giving rise to a thin plate-like extension, smaller, more rounded valves, and the sharply downwardly bent phallus, which is much thinner overall and more elongated at the ventral apex. Other characters, such as the setae-covered sclerotizations on the ventrum of VIII, also differ, but are less readily useful in recognizing *U. conjuncta*.

Description. Male. *Head*: As for genus. *Thorax*: As for genus. *Legs*: As for genus. *Forewing dorsum*: Forewing length: 19–19.5 mm, avg.: 19.3 mm, wingspan: 36–37 mm, n=5. As for genus, except ground color nearly black, postmedial line located about one-third wing length away from wing margin, line usually obscured due to dark surrounding ground color and absence of lighter brown edging along inner side, overall with faint metallic-blue sheen, especially antemedially; postmedial line strongly notched between Rs4 and costa. *Forewing ventrum*: As for genus. *Hindwing dorsum*: Coloration as for forewing dorsum, antemedial line absent, discal mark absent, outer margin of wing weakly serrate. *Hindwing ventrum*: As for genus. *Abdomen*: As for genus, but slightly darker and less robust. *Genitalia*: (Fig. 25) n= 3. Vinculum somewhat box-like, ventrally with reduced saccus; saccus weakly attached to VIII, forming paired, setae-covered, downwardly-angled sclerotizations, not splayed beyond width of vinculum. Uncus simple, highly truncated apically with wide triangular base. Gnathos fused, extended mesally as thin plate that may be notched mesally. Valves small, subtriangular, edges somewhat curled, with single tooth projecting from saccular edge near apex of valve, tooth variable in length. Transtilla with weakly-sclerotized, inward-facing setae-covered extensions; setae very fine. Setae pointed outward directly over phallus. Diaphragm forms small balloon-like sac expanded inward into abdomen; sac covered in fine, inward-facing setae surrounding phallus. Phallus short, anterior half moderately to sharply bent downward, ventral apex heavily sclerotized into elongated

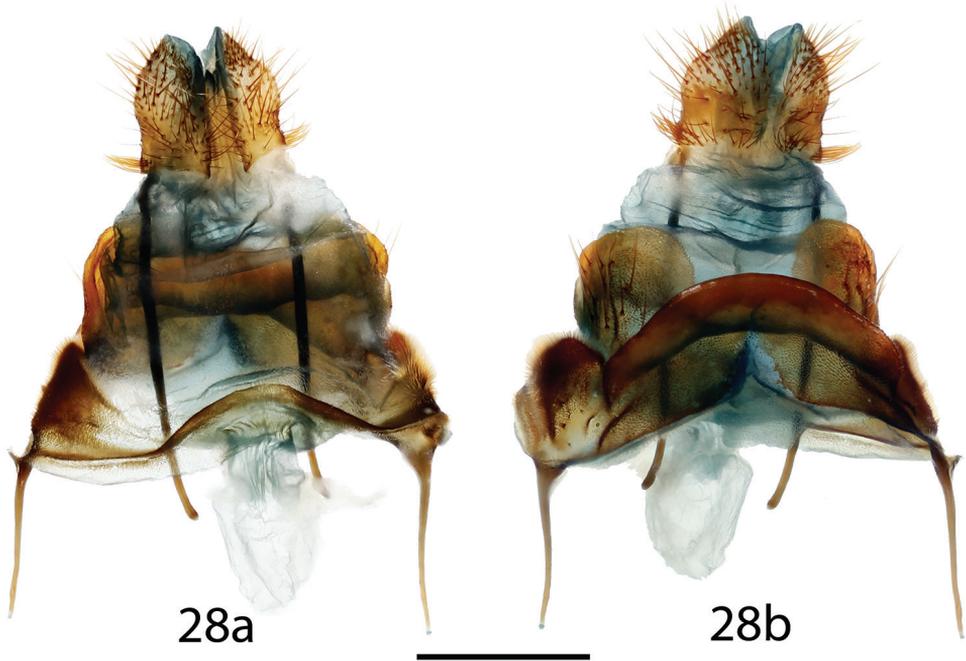


Figure 28. *Ulmara conjuncta* paratype ♀ genitalia, **a** ventral **b** dorsal. Ecuador, Loja, Road between Loja-Zamora, 2700 m, St Laurent diss.: 4-19-16:1 (MWM). Scale bar = 1 mm.

point; vesica small, sac-like, weakly scobinate with some evidence of diverticula; base of phallus narrower than apical half, in same plane as apical half, not bent. **Female.** *Head:* As for male but antennae much smaller overall, pectinations particularly shorter, labial palpus slightly reduced. *Thorax:* As for male. *Legs:* As for male, but vestiture thinner. *Forewing dorsum:* Forewing length: 21.5 mm, avg.: 21.5 mm, wingspan: 41 mm, n= 1. As for male, but more elongated, slightly narrower, discal mark reduced. *Forewing ventrum:* Somewhat similar to dorsum but much lighter, grayer, maculation reduced; antemedial line absent, postmedial line less distinct. *Hindwing dorsum:* Coloration as for forewing dorsum, antemedial line absent. *Hindwing ventrum:* Following same pattern as forewing ventrum. Frenulum as multiple bristles. *Abdomen:* See generic description. *Genitalia:* See generic description.

Distribution (Map 2). This species is known from northern and southern Ecuador, with records lacking from the center of the country. *Ulmara conjuncta* is another Andean species, and is found at elevations ranging from 2157–3300 m.

Etymology. This species is named for the complete, connected (*conjuncta* Latin), gnathos, a character unique to this species in the genus.

Remarks. *Ulmara conjuncta*, although similar to *U. rotunda*, is easily distinguished by both distribution and all characters given in the diagnosis. According to the data on the labels of a number of specimens collected by Jan Hillman, this species can be collected in “virgin humid forests” as well as “disturbed” forests, pastures, and “deforested haciendas.”

This is the only species in the genus with a well-defined gnathos, which, when present, is an important character for distinguishing similar species within genera in Mimallonidae (pers. obs).

***Ulmara azurula* St Laurent, sp. n.**

<http://zoobank.org/3B1C65B5-CDC0-4628-9C32-0C8289587A45>

Figs 20, 26; Map 2

Type material. Holotype, ♂. PERU: Huánuco: Carpish, Huanuco [Huánuco], Peru 2700 m, Oct. 25, 1946/ Felix Woytkowski Collector/ St Laurent diss.: 4-8-16:2/ HOLOTYPE ♂ *Ulmara azurula* St Laurent, 2016 [handwritten red label] (AMNH).

Paratypes, 4 ♂. PERU: Huánuco: Carpish, 2700 m: 8.X.1946 (2 ♂), 14.X.1946 (1 ♂), 26.X.1946 (1 ♂), Felix Woytkowski Collector, St Laurent diss.: 4-5-16:5 (AMNH). – All paratypes with the following yellow label: PARATYPE ♂ *Ulmara azurula* St Laurent, 2016.

Diagnosis. *Ulmara azurula* is the smallest species in the genus (on average), and so far the only species known from central Peru. The small size and distribution should allow this species to be distinguished from the previous two. The following characters differentiate *U. azurula* from the most similar species, *U. dombroskiei* sp. n. to be described below, but also differentiate it from both *U. rotunda* and *U. conjuncta*. Although *U. azurula* is externally similar in size and coloration to *U. dombroskiei* sp. n., namely by the metallic bluish sheen, in *U. azurula*, the postmedial line of the fore and hindwings is located closer to the wing margin than in *U. dombroskiei* sp. n. Furthermore, the width of the splayed, setae-covered sclerotizations of VIII are much wider than the vinculum, whereas in *U. dombroskiei* sp. n. these sclerotizations are highly reduced overall, and have shorter setae. Additionally, the gnathos of *U. azurula* is the most reduced of the entire genus, and exists as only weakly-sclerotized lateral bars, whereas in *U. dombroskiei* sp. n. the gnathos nearly converges mesally. The setae-covered flaps projecting inward from the transtilla in *U. azurula* bear thicker setae than in any other *Ulmara*. Finally, the phallus shape is perhaps the best genital character for distinguishing these two Peruvian species: in *U. azurula* the phallus is uniformly cylindrical from a dorsal perspective, whereas in *U. dombroskiei* sp. n. the phallus is very wide distally.

Description. Male. *Head:* As for genus. *Thorax:* As for genus. *Legs:* As for genus. *Forewing dorsum:* Forewing length: 17.5–19 mm, avg.: 18.1 mm, wingspan: 35–36 mm (approximate), n= 5. As for genus but ground color nearly black, overall metallic-blue sheen present due to angled, reflective scales. Postmedial line about one-fourth wing length away from wing margin, postmedial line obvious due to pale blue-gray suffusion surrounding line, postmedial line nearly straight between Rs4 and costa. *Forewing ventrum:* As for genus. *Hindwing dorsum:* Coloration as for forewing dorsum, antemedial line absent, discal mark absent, outer margin of wing weakly serrate. *Hindwing ventrum:* As for genus. *Abdomen:* As for genus. *Genitalia:* (Fig. 26) n=2. Vinculum

lum somewhat box-like, ventrally with reduced saccus, bilobed saccus attached to VIII, forming paired, setae-covered sclerotizations; splayed sclerotizations wider than ventral margin of vinculum. Uncus simple, highly truncated apically with wide base. Gnathos highly reduced, with only weakly sclerotized lateral arms. Valves small, subtriangular, with single tooth projecting from saccular edge near apex of valve, tooth variable in length. Transtilla with weakly-sclerotized, inward-facing setae-covered extensions; setae very thick. Setae pointed outward directly over phallus. Diaphragm forms small balloon-like sac expanded inward into abdomen, sac covered in fine, inward-facing setae surrounding phallus. Juxta partially fused to phallus, encircling it, lightly sclerotized, especially dorsal to phallus. Phallus short, anterior half cylindrical, straight, ventral apex heavily sclerotized as elongated, sharp point, vesica small, sac-like, weakly scobinate; base of phallus narrower than apical half, basal part shorter than, and in same plane, as cylindrical terminal part. **Female.** Unknown.

Distribution (Map 2). This new species is known only from the type locality in Huánuco, central Peru, at an elevation of 2700 m.

Etymology. This species is named for its small size (diminutive *-ula* Latin) and blue (*azurea* Latin) iridescence.

Remarks. Although the known range of this species is located between the distributions of *U. conjuncta* in Ecuador and *U. dombroskiei* sp. n. in southern Peru, *U. azurula* is not intermediate in external or genital morphology between these species, but is instead more similar to *U. dombroskiei* sp. n. than either previously described species. Considering the consistently smaller size, almost entirely absent gnathos, narrower phallus, and more elongated saccular extensions relative to *U. dombroskiei* sp. n., as well as previously mentioned wing characters, this species is apparently distinct from the southern Peruvian populations named *U. dombroskiei* sp. n. below. The iridescent blue sheen, characteristic of the genus *Ulmara*, is most distinct in the Peruvian species, but is not clearly reproduced in photographs.

***Ulmara dombroskiei* St Laurent, sp. n.**

<http://zoobank.org/4FFDF534-9C02-41C2-906C-654A98E1F7BF>

Figs 21, 22, 27; Map 2

Type material. Holotype, ♂. PERU: Puno: Agualani, Carabaya [Puno], 9000 ft., Dec. 05. wet season, (G.R. Ockenden)./ *Ulmara rotunda* Dognin, Pearson det./ Rothschild Bequest BM 1939–1/ NHMUK010355067/ St Laurent diss.: 4-8-16:3/ HOL-OBJECT ♂ *Ulmara dombroskiei* St Laurent, 2016 [handwritten red label]/ (NHMUK).

Paratypes, 4 ♂. PERU: Puno: 2 ♂, Santo Domingo, Carabaya [Puno], 6000 ft: III.1902, IV.1902, Ockenden, wet season and end of wet season, Rothschild Bequest BM 1939–1, St Laurent diss.: 4-15-16:4, NHMUK010355073, 010354877 (NHMUK). 1 ♂, Santo Domingo, S. E. Peru, 6000 ft: G. Ockenden, “not in B. M.,” Joicey Coll. Brit. Mus. 1925–157, NHMUK010354878 (NHMUK). 1 ♂, Santo Domingo, Carabaya [Puno], 6500 ft: XII.1902, G. Ockenden, wet season, 623,

Rothschild Bequest BM 1939–1, NHMUK010355066, St Laurent diss.: 4-26-16:1 (NHMUK). – All paratypes with the following yellow label: PARATYPE ♂ *Ulmara dombroskiei* St Laurent, 2016.

Diagnosis. This species is most similar to *U. azurula*, see the diagnosis of that species for characters necessary for differentiation. However, it is worth repeating the characters entirely unique to this species in the entire genus: postmedial line somewhat variable in distance from wing margin but may be as far as one-third wing length away from the margin, the gnathos is reduced but nearly converges mesally (or does so very weakly), and is overall not heavily sclerotized, distinguishing it *U. rotunda*, the uncus is highly truncated, the saccular extensions are highly reduced, and the phallus is very wide distally.

Description. Male. *Head:* As for genus. *Thorax:* As for genus. *Legs:* As for genus. *Forewing dorsum:* Forewing length: 17.5–19.5 mm, avg.: 18.7 mm, wingspan: 34–37 mm, n= 3. As for genus but ground color nearly blue-gray, overall blue metallic sheen present due to angled, reflective scales. Postmedial line located about one-fourth to one third wing length distant from wing margin, postmedial line obvious due to pale blue-gray suffusion surrounding line, postmedial line sharply notched between Rs4 and costa. *Forewing ventrum:* As for genus. *Hindwing dorsum:* Coloration as for forewing dorsum, antemedial line absent, discal mark absent, outer margin of wing weakly to moderately serrate. *Hindwing ventrum:* As for genus. *Abdomen:* As for genus. *Genitalia:* (Fig. 27) n=3. Vinculum somewhat box-like, ventrally with reduced saccus, bilobed projections of saccus attached to VIII, forming small, paired, setae-covered sclerotizations, splayed sclerotizations barely extending beyond width of vinculum. Uncus simple, highly truncated apically with very wide base. Gnathos incomplete, reduced, but nearly converging mesally, weakly sclerotized. Valves small, subtriangular, with single tooth projecting from saccular edge near apex of valve, tooth variable in length. Transtilla with weakly-sclerotized, inward-facing setae-covered extensions, setae very fine. Setae pointed outward directly over phallus. Diaphragm forms small balloon-like sac expanded inward into abdomen, sac covered in fine, inward facing setae surrounding phallus. Phallus short, anterior half greatly widened, ventral apex more heavily sclerotized forming point, vesica small, sac-like, weakly scobinate; base of phallus much narrower than apical half, basal part much narrower than terminal part, angled slightly downward. **Female:** Unknown.

Distribution (Map 2). This species is known only from two nearby localities, separated by about 30 km, in Puno, southeastern Peru at elevations ranging from 1828–2743 m, and is the most southerly distributed species of *Ulmara*.

Etymology. This species is named for Jason Dombroskie (CUIC), a colleague, mentor, and friend to the author. Additionally, Jason is one of the few individuals who has been involved in the taxonomy of the poorly known Mimmalloniidae, and thus has been integral in deepening our understanding of this fascinating family of moths.

Remarks. As previously mentioned in the remarks for *U. azurula*, the two Peruvian species, although distinct, are related, given the reduction of the gnathos, the small valves, and the blue iridescence of the wing scales. As mentioned previously, this blue iridescence is not well represented in the figures.

Although five specimens and three dissections of *U. dombroskiei* were examined when writing the description, only one specimen (the holotype) is from Agualani at the higher elevation. This specimen displayed the most accentuated characters that define this species, namely the very broad phallus and the postmedial lines of the fore and hindwings, which are relatively distant from the wing margin. Therefore, this specimen is designated as the holotype. The differences between the holotype and paratypes, namely slightly less broadened phallus and postmedial line located nearer to the wing margin, may be due to elevation differences considering the proximity of the localities and the otherwise same general structures of the genitalia.

***Cunicumara* St Laurent, gen. n.**

<http://zoobank.org/B4788F32-4454-49E0-AFFD-A93E144B9849>

Type species. *Cunicumara anae* St Laurent, 2016, sp. n.

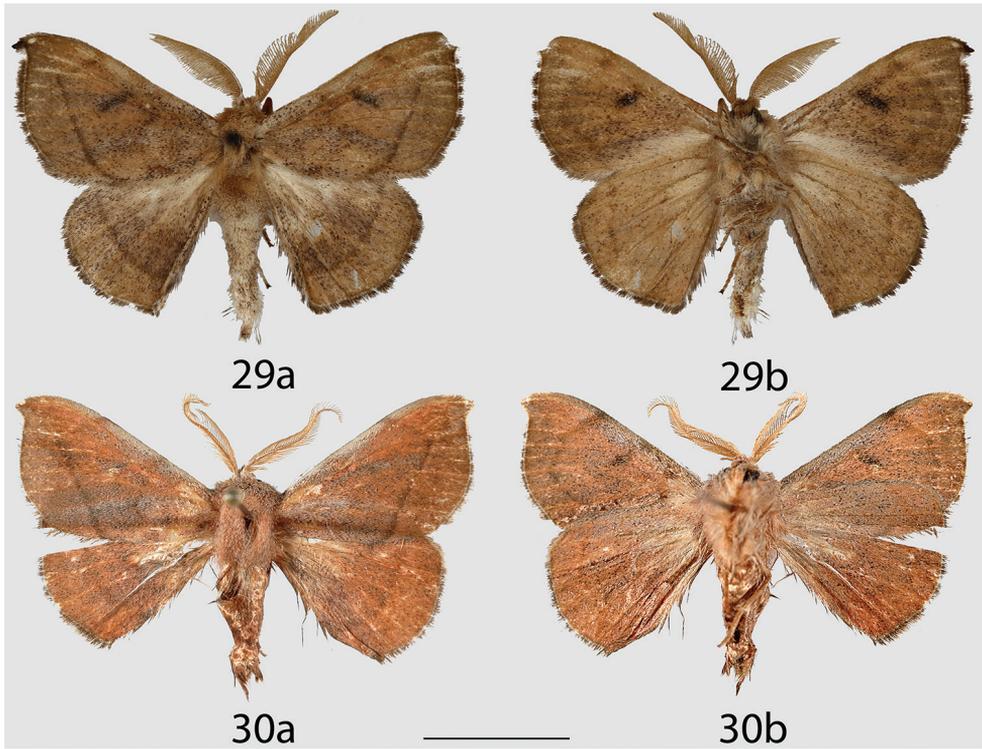
Etymology. The name for this new genus comes from *cuniculus* (Latin), meaning rabbit, referring to the somewhat layered appearance of brown coloration of *C. anae* sp. n., which is reminiscent of rabbit fur. Furthermore, the particularly long antennae relative to the size of the body and wings is quite remarkable, therefore the name is appropriate in calling to mind the long ears of a rabbit. The ending *-mara* notes a slightly superficial similarity to *Ulmara*.

Diagnosis. This new genus can be recognized by the salmon to orange-brown, fading to light, sandy tan ground color, interspersed with gray, pale-khaki, and dark-brown scales, which give moths of this genus a somewhat hoary appearance. The wings are very broad, with a weakly accentuated, barely falcate apex. The long bipectinate antennae are more than half the length of the short forewings, and have distinctly long pectinations. The combination of these characters should immediately allow *Cunicumara* to be distinguished from all other known Mimallonidae. The complex male genitalia are also unique, characterized by the presence of a basally-fused, bifurcated gnathos, basally-toothed sacculus, and the phallus with curled, horn-like juxtal processes, which are dorsal to the phallus; a third, singular horn-like process arises between the curled juxtal processes.

Description. Male. *Head:* Khaki brown, eyes very large, occupying more than two-thirds area of head, bordered posteriorly by dark scales; antenna coloration pale tan, very long, more than half length of forewing, antenna bipectinate to tip, pectinations very long, longest nearly one-fourth length of antennae overall; labial palpus very reduced, not extending beyond head, apparently three segmented, but segmentation obscured by thick tufts ventrally. *Thorax:* Coloration as for head but with gray-tipped scales giving thorax a hoary appearance overall. *Legs:* Coloration as for thorax, vestiture thick, long. Tibial spurs robust, covered in scales except for tip. *Forewing dorsum:* Forewing length: 14–15.5 mm, avg.: 14.8 mm, wingspan: 30–31 mm, n=3. Short, subtriangular, margin convex except for where concave very near apex; apex

slightly falcate. Ground color light with slight salmon hue, especially along anterior half of wing until costa; wing with layered appearance due to presence of light-gray, dark-brown, and brown scattered scales, particularly contrasting gray scales concentrated basally and along costa, giving wing hoary appearance. Antemedial line very faint, light brown, somewhat wavy. Gray-brown postmedial line straight from anal margin until Rs4 where line angled toward costa. Antemedial, medial, and postmedial areas mostly concolorous, although ante- and medial areas appear lighter due to gray scales; likewise salmon and light-brown coloration of ground color most evident near apical angle of postmedial line and postmedially. Discal mark nearly absent, or as thick, dark streak spanning cell. Fringe poorly preserved in examined specimens, but consisting of elongated scales, coloration as for medial area except some lighter off-white scales present in semi-regular pattern along margin. *Forewing ventrum*: Very similar to dorsum but appearing lighter, due to more diffuse presence of gray scaling, dark-brown scales may also be more prevalent in some individuals; antemedial line absent, postmedial line less distinct, outwardly curved, roughly following wing margin in shape, not straight as on dorsum. *Hindwing dorsum*: Coloration, patterning as for forewing dorsum, but antemedial line absent, discal mark absent, postmedial line slightly curved following outline of wing margin, postmedial line may be very faint. *Hindwing ventrum*: Following same pattern as forewing ventrum, but lighter due to pale-khaki scales basally. Frenulum present as single bristle. *Venation*: More typical of Mimallonidae than either *Lurama* or *Ulmara* with respect to M_1 – M_3 , with each vein being more evenly spaced along obliquely angled cell, CuA_1 arises from lower angle of cell; Rs3 + Rs4 short stalked. *Abdomen*: Lighter than thorax, with coppery luster in fresh specimen, fading to pale khaki in older material. Vestiture thick, long, distal tip of abdomen with elongated, dark-brown tipped scales. *Genitalia*: (Fig. 31) $n=2$. Complex. Vinculum somewhat ovoid, ventrally with reduced rounded saccus. Uncus simple, triangular, truncated apically to point. Gnathos very robust, broad basally arising from heavy sclerotization of tegumen, gnathos separated distally into paired, fingerlike processes. Valves elongated, narrow, weakly curved distally, saccus with prominent, heavily sclerotized tooth. Mesal costal ridge present along basal half of valve. Juxta partially fused to phallus, juxtal processes present dorsal to phallus, processes curled forming shape of bovid horns, between processes arises a third, somewhat flattened, singular process, unlike curled processes on either side; strong membrane connects juxtal processes to base of vinculum, ventral lip of juxta fused to vinculum base, lip cut to excise phallus. Base of phallus with somewhat elongated backward-facing lobes. Phallus short, broadened distally, width of phallus somewhat variable, vesica short, bag-like. **Female**. Unknown.

Remarks. *Cunicumara* is distinct among the family Mimallonidae, externally bearing some resemblance to *Ulmara* by the presence of the massive antennae and the short, broad wings, while at the same time displaying male genitalia that in some ways resemble the distinct genus *Menevia* Schaus, 1928, namely the presence of complex juxtal processes and the basally bifurcated lobes of the phallus.



Figures 29, 30. *Cunicumara anae* adults, **a** dorsal **b** ventral. **29** Holotype ♂, Bolivia, Santa Cruz, Asunción (CMNH) **30** Paratype ♂, Paraguay, Concepción, Garay Cue, 212 m [photo courtesy of Daniel Herbin] (CDH). Scale bar = 1 cm.

***Cunicumara anae* St Laurent, sp. n.**

<http://zoobank.org/A5E187EE-7AC8-4E23-AC35-7156DA0188F3>

Figs 29–31; Map 3

Type material. Holotype, ♂. BOLIVIA: Santa Cruz: Asumpcion [Asunción], Bolivia, June 15, 1909, Haseman/ Carn. Mus., Acc. 4043/ Asumpsion, Bolivia, June 15-1909/ St Laurent diss.: 3-14-16:6/ HOLOTYPE ♂, *Cunicumara anae* St Laurent 2016 [handwritten red label]/ (CMNH). Type locality: Bolivia: Santa Cruz: Asunción.

Paratypes, 2 ♂. BOLIVIA: Santa Cruz: 1 ♂, Asunción: 15.VI.1909, Haseman leg. (CMNH). **PARAGUAY: Concepción:** 1 ♂, Garay Cue, 22°41'S, 57°22'W, 212 m: 4–9.VI.2013, Coll. D. Herbin, BC-Her 4868 [BOLD barcode number], D. Herbin genitalia prep. H1105 (CDH). – Paratypes with the following yellow label: PARATYPE ♂ *Cunicumara anae* St Laurent, 2016.

Diagnosis. See generic diagnosis.

Description. See generic description.

Distribution (Map 1). This species is known only from Santa Cruz Department, Bolivia, and Concepción Department, Paraguay at low elevations.

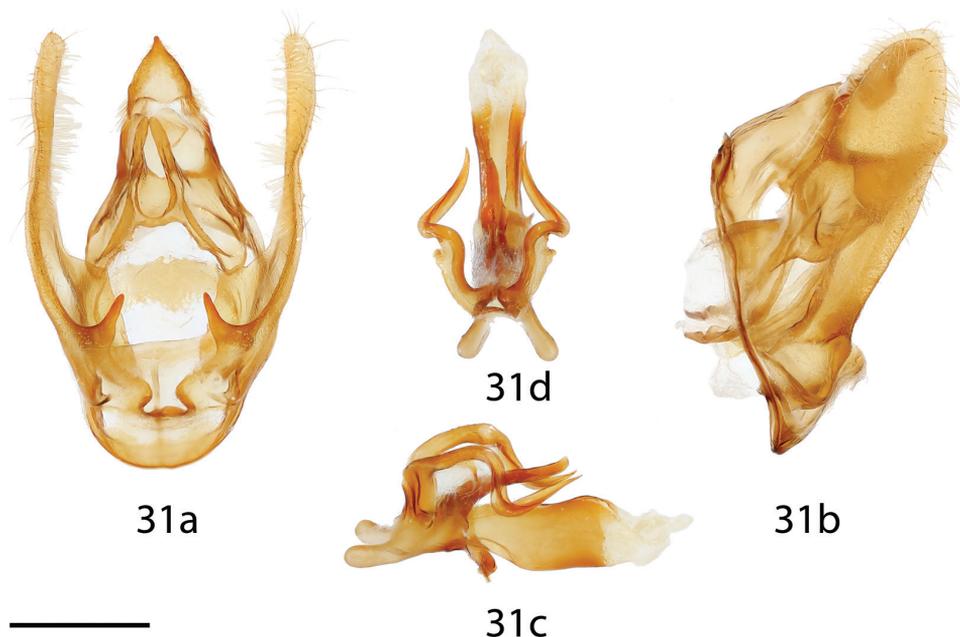


Figure 31. *Cunicumara anae* holotype ♂ genitalia, **a** ventral **b** lateral **c** phallus lateral **d** phallus dorsal. Bolivia, Santa Cruz, Asunción, St Laurent diss.: 3-14-16:6 [note: valves not fully spread in Fig. 31a] (CMNH). Scale bar = 1 mm.

Etymology. This species is named for Ana Paula dos Santos de Carvalho, a lepidopterist interested in the sexual dynamics of Papilionoidea. Ana is the best friend and source of the most joy in the author's life.

Remarks. This new species, and thus the genus *Cunicumara* in general, is very poorly represented in collections. However, very little Mimallonidae material is available from the type locality or similar regions in Brazil, Paraguay, and Bolivia, and thus the rarity of this species in collections is probably only due to under collecting. The two localities both border on the Brazilian Pantanal Biome (IBGE 2004), and thus it is possible that this species is endemic to the wet lowlands, or the borders thereof, of this part of South America.

The two figured specimens (Figs 29 and 30) differ in coloration and antenna size. However, it is critical to note that the Bolivian specimens were collected in 1909 while the Paraguayan specimen was collected much more recently, in 2013. Therefore, differences in color can be attributed to the wide range of dates of collection. The salmon color that is apparent on the fresh specimen is faint, but present, when examining the wings of the old specimens under magnification. Furthermore, the figured Bolivian specimen (the holotype) is missing the distalmost portion of the antennae. Genitalia of these specimens are nearly identical (St Laurent diss.: 3-14-16:6 and D. Herbin genitalia prep. H1105).

According to Daniel Herbin (pers. comm.) the COI barcode data for Paraguayan paratype (BC-Her 4868) is quite distinct from other genera.



Map 3. Known distribution of *Cunicumara anae*.

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Composition and natural history notes of the coastal snake assemblage from Northern Bahia, Brazil

Ricardo Marques^{1,2,6}, Konrad Mebert², Érica Fonseca^{3,6},
Dennis Rödder^{2,4}, Mirco Solé², Moacir Santos Tinôco^{5,6}

1 Universidade Federal da Paraíba, Departamento de Sistemática e Ecologia, Programa de Pós-Graduação em Ciências Biológicas (Zoologia). Cidade Universitária. Rua José Dionísio da Silva, s/n, 58059-900, João Pessoa, PB, Brazil **2** Universidade Estadual de Santa Cruz, Programa de Pós-Graduação em Zoologia. Rodovia Jorge Amado, km 16. CEP 45662-900. Ilhéus, BA, Brazil **3** Universidade Federal de Santa Maria, Programa de Pós-Graduação em Biodiversidade Animal. Avenida Roraima, n° 1000, Cidade Universitária. CEP 67105-900. Camobi, Santa Maria, RS, Brazil **4** Zoological Research Museum Alexander Koenig, Department of Herpetology, Adenauerallee 160, 53113 Bonn, Germany **5** University of Kent at Canterbury; DICE - Durrell Institute of Conservation and Ecology; School of Anthropology and Conservation. Marlowe Building, Kent, CT2 7NZ, UK **6** Universidade Católica do Salvador, PROPP-PPGPA - Centro de Ecologia e Conservação Ambiental – ECOA. Avenida Prof. Pinto de Aguiar, 2589. CEP 41740-090. Pituvaçu, Salvador, BA, Brazil

Corresponding author: Ricardo Marques (rcdmarquess@gmail.com)

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Abstract

Information about the snake diversity and their natural history from the Atlantic forest domain in Brazil refer mostly to inland forests than to coastal region. Within the state of Bahia, this knowledge is concentrated to the southeastern coastal stretch. Herein we report on the diversity of snakes from the restinga, ombrophilous forest and anthropogenic environment from the northern Atlantic coast of Bahia. We sampled nine sites for three years and visited four museum collections. Furthermore, we provide anecdotal natural history information, voucher analyses, literature complements, and a key to facilitate species identification. We report a total of 774 snakes belonging to 50 species and 23 new distribution records for northeastern coast of Bahia, supplemented by new data on feeding and reproduction. The number of detected species is similar to numbers obtained in comparable studies from other Brazilian ecoregions. This study reports and focuses for the first time on all known species of snakes from the northeastern coast of Bahia.

Keywords

Atlantic forest, coastal sand dunes, conservation, ombrophilous forest, restinga, snakes, conservation

Introduction

Studies on diversity inventories and natural history increase the knowledge of a regional fauna, its interaction with other organisms, and the environment in general (Greene 1994). As such, they provide relevant basis data to better understand the complexity of ecosystems. This is not different with snakes, which represent an integral part of such ecosystems, be them as prey, predator, host and other functions within the network of ecosystem relations. Therefore, snakes, as well as other constituents of a local ecosystems, are important and need to be understood and protected. Hence, novel data about our target group is elementary for further conservation studies on these taxa (Greene and Losos 1988, Shine and Bonnet 2009).

As a first step, pertinent and relevant taxa-related information can be acquired through species inventories and studies describing aspects of natural history that increase our knowledge on the different habitats and habits of regional snakes (Greene 1997). These studies include biodiversity components in terms of richness, abundance, distribution, diet composition, activity periods, reproduction, morphological variation, parasitism, predators and other intrinsic data of the group (Martins and Oliveira 1998). All these aspects enhance the knowledge of snakes (Cadle and Greene 1993), but these studies are not evenly distributed among the different Brazilian ecoregions. For example, there are several contributions on snake communities from the Amazon (e.g. Cunha and Nascimento 1978, Martins and Oliveira 1998, Santos-Costa et al. 2015), as well as the Cerrado (e.g. Recoder and Nogueira 2007, Sawaya et al. 2008), Caatinga (e.g. Vanzolini et al. 1980, Vitt and Vanglinder 1983, Guedes et al. 2014) and Pantanal (e.g. Strüssmann and Sazima 1993). Regarding the Atlantic forest, the snake fauna from the Southeast and South of Brazil is well represented (e.g. Marques et al. 2001, Marques and Sazima 2004, Hartmann et al. 2009a, b), but despite the increase of these studies in recent years, the natural history of these animals from most northeastern states of Brazil has remained poorly documented.

Studies involving snakes from northeastern Brazil are often species inventories from the Caatinga and transition areas with other ecoregions (Vanzolini et al. 1980, Vitt and Vanglinder 1983, Pereira Filho and Montingelli 2011, Loebmann and Haddad 2010, Ribeiro et al. 2012, Garda et al. 2013, Mesquita et al. 2013, Guedes et al. 2015). Unfortunately, the Atlantic forest in northeastern Brazil is represented by few studies only (Argôlo 2004, Santana et al. 2008, Morato et al. 2011, França et al. 2012), rendering a regional study, such as the one presented herein, the more important. A total of 131 snake species are currently known from the state of Bahia (Hamdan and Lira-da-Silva 2012, Curcio et al. 2012, Fernandes and Hamdan 2014), but there is a lack of detailed studies. Argôlo (2004) provides the most complete compilation of the snake assemblage of the Atlantic forest in southern Bahia, reporting species from

different forested, disturbed and open habitats. Dias and Rocha (2014) surveyed the herpetofauna from restinga in the northern and southern coast of the state, while Marques et al. (2011) recorded snakes from a single restinga location in the northern coast of Bahia. Herein we include: (1) a checklist of all snake species from the northern coast of Bahia; (2) natural history information (frequency, size, distribution, habitat, microhabitat, activity and environmental variables, diet, reproduction and defensive behavior); (3) conservation aspects, and (4) an identification key to the snakes from this region.

Material and methods

Study area

The present study was conducted on the northern coast of Bahia, which extends for 220 km from Salvador to the boundaries of the state of Sergipe (Figure 1). The climate in this region varies from humid to subhumid with a weak dry season in the southernmost portion and a two months dry season in the remaining area. Precipitation fluctuates from 1300 to 1900 mm per year (Figure 2) (IBGE 2002, SEI 2013). The vegetation in the coastal municipalities (next lower subdivision of the state) consists of pioneer vegetation with marine influence, called restinga. Four typical vegetation types compose the restinga of the region: beach vegetation, flooded plain, shrub vegetation and restinga dry forest (Menezes et al. 2009, 2012). Farther inland, the landscape changes to dense ombrophilous forests and semideciduous stationary forests, both with Cerrado enclaves (SEI 2013).

Sample design

a) Fieldwork

Snakes were sampled during 18 bimonthly fieldtrips from 2010 to 2013, covering three dry seasons and three rainy seasons, totaling in 162 field days. We sampled eight coastal sites of the restinga ecosystem: Busca Vida (-12.8619 S, -38.2708 W), Arembepe (-12.7236 S, -38.1416 W), Praia do Forte (-12.5748 S, -38.0147 W), Imbassaí (-12.4791 S, -37.9602 W), Massarandupió (-12.3172 S, -37.8404 W), Baixio (-12.1123 S, -37.7062 W), Barra do Itariri (-11.9478 S, -37.6113 W) and Costa Azul (-12 S, -37.496 W); and the Instituto da Mata, an ombrophilous forest fragment of 410 ha at 20 km from coast (-12.450073 S, -38.234579 W). Surveys were authorized under ICMBio No 23355-2.

Four sampling sources were used to acquire data on snakes: (1) Visual Encounter Survey (VES) limited by time, i.e. recording visually detected and manually captured snakes; (2) dead specimens found by locals; (3) carcasses and shed skins detected by us; and (4) incidentally encountered and recorded snakes outside the

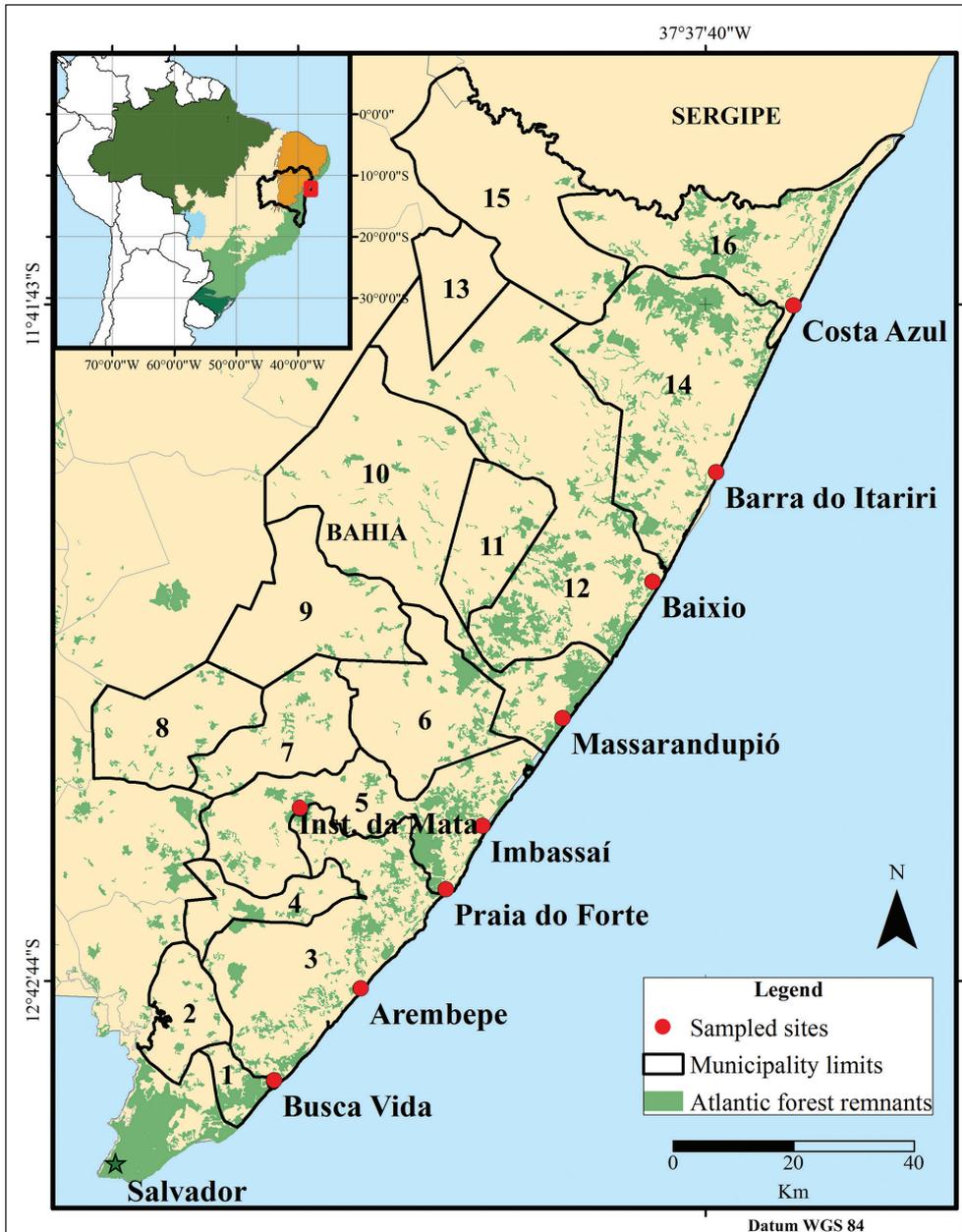


Figure 1. The northern coast of Bahia and municipalities of the study: 1 Lauro de Freitas 2 Simões Filho 3 Camaçari 4 Dias D'Ávila 5 Mata de São João 6 Itanagra 7 Pojuca 8 Catu 9 Araçás 10 Entre Rios 11 Cardeal da Silva 12 Esplanada 13 Acajutiba 14 Conde 15 Rio Real 16 Jandaíra.

VES. For the VES, we walked for two hours on four 500 m transects placed on four aforementioned vegetation types. The VES covered the period from 06:00 h and 18:00 h in six turns: 06:00–08:00; 08:00–10:00; 10:00–12:00; 12:00–14:00;

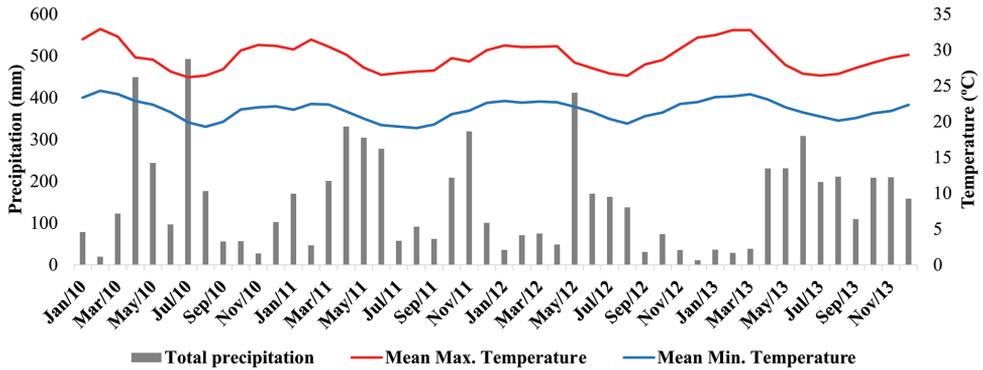


Figure 2. Variation of temperature, maximum (red) and minimum (blue), precipitation as bars. Data from January 2010 and December 2013 (Source: INMET).

14:00–16:00; 16:00–18:00. In the last year VES was performed during nighttime from 19:00 h to 21:00 h at Busca Vida, Baixio, Barra do Itariri and Instituto da Mata, totaling a sample effort of 3024 h (2592 h diurnal and 432 h nocturnal). During the VES and incidental encounters we recorded for each snake the time of activity, predominant vegetation type and microhabitat. Each captured snake was marked and then released at its site of capture. Marking involved fluorescent elastomer applied subcutaneously in the ventral scales. The i^{th} number of the ventral scale, with the first number being the ventral scale anterior the anal plate, corresponding to the i^{th} number of the captured snake (adapted from Hutchens et al. 2008). We used four different colors, one for each vegetation type to see if animals were moving among the vegetation types in case of recapture. Voucher specimens are deposited in the Coleção Herpetológica do Centro de Ecologia e Conservação Animal at the Universidade Católica do Salvador.

b) Animal characterization

All species were identified according to the literature (Peters and Orejas-Miranda 1970; Vanzolini et al. 1980, Cunha and Nascimento 1978, Dixon 1986, 1989, Dixon et al. 1993, Campbell and Lamar 2004, Fernandes 2006, Albuquerque 2008, Lima 2012, Ascenso 2013, Pires et al. 2014).

Snout-Vent Length (SVL) and sex was recorded from all captured animals and museum specimens when possible. We observed predation events, and during the last year of surveys, we forced animals to regurgitate their stomach content through manual palpation.

Morphological characteristics of the animals from the region comprising scale counts, body shape and coloration allowed us to elaborate an identification key to all species recorded in this study. We complemented the information of animals with records obtained from the literature, as well as field observations and data from voucher specimens. We did not include natural history notes of introduced (non-native) species.

c) Data collection in museums

Specimens of four scientific collections from the state of Bahia were analysed: Museu de Zoologia at Universidade Estadual de Santa Cruz (MZUESC, Ilhéus); Coleção herpetológica do Museu de Zoologia at Universidade Federal da Bahia (MZUFBA, Salvador); Coleção Herpetológica do Museu de Zoologia at Universidade Estadual de Feira de Santana (MZUEFS, Feira de Santana); and Coleção Herpetológica de Referência do Centro de Ecologia e Conservação Ambiental at Universidade Católica do Salvador (CHECOA, Salvador). Considering the extensive region and lack of surveys from northeastern Bahia, and in particular its inland portions, we included additional records using voucher specimens from 10 neighbouring municipalities: Lauro de Freitas (-12.869 S, -38.315 W), Simões Filho (-12.768 S, -38.407 W), Dias D'Ávila (-12.5888 S, -38.269 W), Pojuca (-12.410 S, -38.321 W), Catu (-12.323 S, -38.420 W), Itanagra (-12.302 S, -38.059 W), Araçás (-12.16 S, -38.123 W), Cardeal da Silva (-12.072 S, -38.98 W), Acajutiba (-11.670 S, -38.017 W) and Rio Real (-11.502 S, -37.955 W) (Figure 1). No snakes were obtained from the municipalities of Araçás, Acajutiba, Cardeal da Silva and Rio Real. When possible, stomach contents and reproductive status were verified. Vouchers are listed in Appendix 1.

Statistics

Species richness and frequency were computed based on the species sampled during fieldwork only, excluding specimens housed in collections. The frequency of the species from the northern coast of Bahia followed the model adapted by Mesquita et al. (2013) (extracted from Abreu and Nogueira 1989 and Luiselli 2006). The frequency of a certain snake species is computed by dividing the number of samples (18 bimonthly field trips) containing the target species by the total number of samples \times 100. The resulting percentage classified the species as accidental (0.1%-25%), accessory (25%-50%) or constant (50%-100%). We calculated the dominance with the number of specimens of the target species divided by the total number of snakes recorded during fieldwork \times 100, applying the categories: accidental (0%-2.5%), accessory (2.5%-5%) and dominant (5%-100%). The combination of frequency and dominance enables the classification of the species as: 1) very rare (accidental/accidental, dominance $<$ 1%), 2) rare (accidental/accidental), 3) intermediate (constant/accessory, constant/accidental, accessory/accidental, accessory/dominant, accessory/accessory), and 4) common (constant/dominant).

Results

A total of 194 snakes were recorded during fieldwork and 580 obtained from museum collections, totaling 774 snakes of a total of 49 native species. Of those, 32 species were recorded during fieldwork and 17 species were complemented through museum

records and literature references. Twenty-three new distributional records of species are added for the northern coastal stretch of Bahia (see Table 1 for details). In the municipality of Camaçari one specimen of an introduced species, *Pantherophis guttatus*, which is native to North America (see Fonseca et al. 2014) was detected. As it is non-native, any natural history descriptions were excluded, but included in the frequency statistics.

The most diverse family was Dipsadidae (25 spp.), representing 50% of the records. The second most diverse family was Colubridae (13 spp.), followed by Viperidae (5 spp.), Boidae (4 spp.), Elapidae (2 spp.) and Typhlopidae (1 sp.). Among the recorded species *Philodryas nattereri* (n = 38), *Chironius flavolineatus* (n = 22) and *Boa constrictor* (n = 19) were the most frequent species in restinga habitat, whereas *Helicops angulatus* (n = 11) dominated ombrophilous forest edges.

Epicrates assisi, *Drymarchon corais corais*, *Drymoluber dichrous*, *Mastigodryas bifosatus*, *Clelia plumbea*, *Phimophis guerini*, *Pseudoboa nigra*, *Erythrolamprus aesculapii venustissimus*, *E. miliaris merremii*, *E. poecilogyrus schotti*, *E. viridis viridis*, *Xenodon rhabdocephalus rhabdocephalus*, *Micrurus corallinus*, *Bothrops erythromelas*, *B. lutzi* and *Lachesis muta rhombeata* were detected only through museum vouchers, and appear to be rare (n ≤ 4), except for *E. p. schotti* (n = 21) and *P. nigra* (n = 7).

Diurnal activity was recorded for 158 snakes during all surveys with members of the families Typhlopidae, Colubridae (except *T. melanocephala*) and Elapidae restricted to diurnal activity. Our observations show snakes were mostly active during morning between 08:00 h and 11:59 h and less frequently observed during the afternoon (Figure 3). During the hottest period of the day (12:00 h – 14:00 h) we recorded 17 snakes; eight of those were *P. nattereri* foraging on the ground. This species might tolerate high temperatures, since we observed an adult (SVL ≥ 800 mm) moving on the sandy soil at 55 °C. We present occasional encounters and nighttime surveys from the last year (18:00 h–21:00 h; Figure 3), when we observed mostly *H. angulatus*, *L. annulata*, *Oxyrhopus* spp. and viperids. We also recorded 13 snakes on roads of which four were killed by cars.

Food items

Stomach contents of 11 species were analysed. Lizards represented 40% of food items, followed by amphibians (20%), mammals and snakes (15% each), fishes and invertebrates (5% each). The lizard *Ameivula ocellifera* was the most recurrent prey item in restinga with observed predatory events between 09:50 h and 13:06 h. Two isolated events of *Oxyrhopus trigeminus* feeding on *A. ocellifera* were recorded, when the snakes (SVL = 320 mm and 315 mm) preyed on three lizards (SVL = 53.8 mm and 51.9 mm; a partially digested specimen, respectively). Another lizard species ingested by *O. trigeminus* was *Tropidurus hygomi*. In addition, *A. ocellifera* was also a food item of *Philodryas nattereri* in two different events. In the first, the snake (SVL = 390 mm) regurgitated a partially digested *A. ocellifera*. In the second event, an adult *P. nattereri* subdued the lizard and disappeared immediately thereafter with it. We report the first predatory event of the

Table 1. Snake species from the northern coast of Bahia. Number of specimens from fieldwork (N), frequency (f%), dominance (D%) and number of specimens from museum specimens (NC). New records (*); Introduced species (**); Extracted from Dias and Rocha (2014) (***).

Species	N	f%	D%	NC
Infraorder Scolecophidia Cope, 1864	-	-	-	-
Typhlopidae Merrem, 1820	-	-	-	-
<i>Amerotyphlops brongersmianus</i> (Vanzolini, 1976)*	1	5.55	0.51	6
Infraorder Henophidia Nopcsa, 1923				
Boidae Gray, 1825				
Boinae Gray, 1825				
<i>Boa constrictor constrictor</i> Linnaeus, 1758	19	72.22	9.79	4
<i>Corallus hortulanus</i> (Linnaeus, 1758)	1	5.55	0.51	-
<i>Epicrates assisi</i> Machado, 1945*	-	-	-	1
<i>Eunectes murinus</i> (Linnaeus, 1758)	3	16.67	1.54	2
Caenophidia Hoffstetter, 1939				
Colubridae Oppel, 1811				
<i>Chironius bicarinatus</i> (Wied, 1820)***	-	-	-	-
<i>Chironius carinatus</i> (Linnaeus, 1758)*	2	11.1	1.03	-
<i>Chironius exoletus</i> (Linnaeus, 1758)	1	5.55	0.51	13
<i>Chironius flavolineatus</i> (Jan, 1863)	22	72.22	11.34	16
<i>Drymarchon corais corais</i> (Boie, 1827)*	-	-	0.51	2
<i>Drymoluber dichrous</i> (Peters, 1863)*	-	-	0.51	4
<i>Leptophis abaelulla liocercus</i> (Wied, 1824)*	1	5.55	0.51	3
<i>Mastigodryas bifossatus</i> (Raddi, 1820)*	-	-	-	4
<i>Oxybelis aeneus</i> (Wagler, 1824)	6	22.22	3.09	5
<i>Pantherophis guttatus</i> (Linnaeus, 1766)**	-	-	-	1
<i>Spilotes pullatus pullatus</i> (Linnaeus, 1758)	2	11.11	1.03	7
<i>Spilotes sulphureus sulphureus</i> (Wagler, 1824)	1	5.55	0.51	-
<i>Tantilla melanocephala</i> (Linnaeus, 1758)*	2	11.11	1.03	9
Dipsadidae Bonaparte, 1838				
Dipsadinae Bonaparte, 1838				
Dipsadini Bonaparte, 1838				
<i>Sibynomorphus neuwiedi</i> (Ihering, 1911)	2	11.11	1.03	13
Imantodini Myers, 2011				
<i>Imantodes cenchoa cenchoa</i> (Linnaeus, 1758)	1	5.55	0.51	1
<i>Leptodeira annulata annulata</i> (Linnaeus, 1758)*	5	22.22	2.57	21
Xenodontinae Bonaparte, 1845				
Echinantherini Zaher, Grazziotin, Cadle, Murphy, Moura-Leite & Bonatto, 2009				
<i>Taeniophallus occipitalis</i> (Jan, 1863)	5	27.78	2.57	4
Hydropsini Dowling, 1975				
<i>Helicops angulatus</i> (Linnaeus, 1758)*	11	27.78	5.67	10
<i>Helicops leopardinus</i> (Schlegel, 1837)*	1	5.55	0.51	14
Philodryadini Cope, 1886				
<i>Philodryas nattereri</i> Steindachner, 1870	38	83.33	19.58	11

Species	N	f%	D%	NC
<i>Philodryas olfersii herbeus</i> Wied, 1825	9	33.33	4.63	13
<i>Philodryas patagoniensis</i> (Girard, 1858)	14	50	7.21	18
Pseudoboini Bailey, 1967				
<i>Clelia plumbea</i> (Wied, 1820)*	-	-	-	3
<i>Oxyrhopus petolarius digitalis</i> Reuss, 1834*	2	11.11	1.03	3
<i>Oxyrhopus trigeminus</i> Duméril, Bibron & Duméril, 1854	9	33.33	4.63	46
<i>Phimophis guerini</i> (Duméril, Bibron & Duméril, 1854)	-	-	-	4
<i>Pseudoboa nigra</i> (Duméril, Bibron & Duméril, 1854)*	-	-	-	7
<i>Siphlophis compressus</i> (Daudin, 1803)	1	5.55	0.51	-
Thachymenini Bailey, 1967				
<i>Thamnodynastes pallidus</i> (Linnaeus, 1758)	1	5.55	0.51	-
Xenodontini Bonaparte, 1845				
<i>Erythrolamprus aesculapii venustissimus</i> Wied, 1821*	-	-	-	1
<i>Erythrolamprus almadensis</i> (Wagler, 1824)*	2	11.11	1.03	17
<i>Erythrolamprus miliaris merremii</i> (Wied, 1821)*	-	-	-	3
<i>Erythrolamprus poecilogyrus schotti</i> (Schlegel, 1837)*	-	-	-	21
<i>Erythrolamprus reginae semilineatus</i> (Wagler, 1824)	1	5.55	0.51	8
<i>Erythrolamprus taeniogaster</i> (Jan, 1863)	1	5.55	0.51	12
<i>Erythrolamprus viridis viridis</i> (Günther, 1862)*	-	-	-	1
<i>Xenodon merremii</i> (Wagler, 1824)*	1	5.55	0.51	23
<i>Xenodon rabdocephalus rabdocephalus</i> (Wied, 1824)*	-	-	-	2
Elapidae Boie, 1827				
Elapinae Boie, 1827				
<i>Micrurus corallinus</i> (Merrem, 1820)*	-	-	-	1
<i>Micrurus ibiboboca</i> (Merrem, 1820)	16	55.56	8.24	81
Viperidae Laurenti, 1768				
Crotalinae Oppel, 1811				
<i>Bothrops erythromelas</i> Amaral, 1923	-	-	-	2
<i>Bothrops leucurus</i> Wagler, 1824	10	44.44	5.15	146
<i>Bothrops lutzi</i> (Miranda-Ribeiro, 1915)	-	-	-	3
<i>Crotalus durissus cascavella</i> Wagler, 1824	3	16.67	1.54	13
<i>Lachesis muta rhombeata</i> Wied-Neuwied, 1824*	-	-	-	1
Total number of specimens	194	-	100%	580

alien species *Hemidactylus mabouia* (SVL = 41.5 mm) by *Chironius flavolineatus* (SVL = 610 mm). The viper *B. leucurus* collected in a nearby anthropogenic construction site at the Instituto da Mata contained *T. hispidus* remnants in its stomach.

Amphibians were the second most frequent food item. An unidentified tadpole (total length = 39.4 mm) was ingested by a juvenile *Chironius exoletus* (SVL = 190 mm). We recorded the ingestion of *Leptodactylus natalensis* by *Helicops angulatus* in two events, both partially digested. One of these events also revealed frog eggs, possibly of the same prey species. Herein we report the first predation record of *Amerotyphlops*

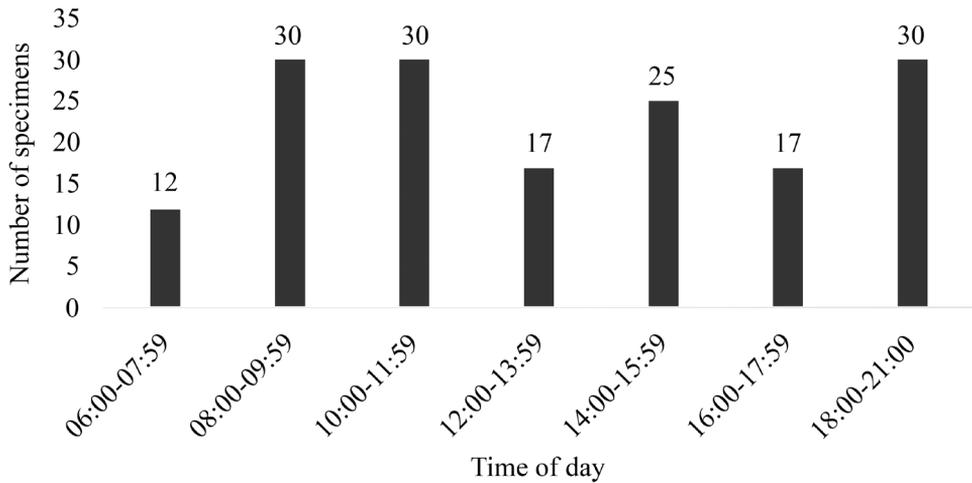


Figure 3. Activity of snakes recorded during the day.

Table 2. Stomach content of snake from the northern coast of Bahia, number of items found by species (N). New records for this species' diet (*).

Species	N	Food item
Colubridae		
<i>Chironius flavolineatus</i>	1	<i>Hemidactylus mabouia</i> (Squamata, Gekkonidae)*
<i>Chironius exoletus</i>	1	Tadpole
Dipsadidae		
<i>Sibynomorphus neuwiedi</i>	1	Gastropod (Mollusca, Veronicellidae)
<i>Helicops angulatus</i>	2	<i>Leptodactylus natalensis</i> (Anura, Leptodactylidae)*
	1	Anuran eggs
<i>Helicops leopardinus</i>	1	<i>Geophagus brasiliensis</i> (Pisces, Cichlidae)
<i>Oxyrhopus trigeminus</i>	1	<i>Tropidurus hygomi</i> (Squamata, Tropiduridae)*
	3	<i>Ameivula ocellifera</i> (Squamata, Teiidae)
	1	<i>Oxyrhopus trigeminus</i> (Serpentes, Dipsadidae)*
<i>Philodryas nattereri</i>	2	<i>Ameivula ocellifera</i> (Squamata, Teiidae)
<i>Philodryas patagoniensis</i>	1	<i>Philodryas olfersii</i> (Serpentes, Dipsadidae)
Elapidae		
<i>Micrurus ibiboboca</i>	1	<i>Amerotyphlops brongersmianus</i> (Serpentes, Typhlopidae)*
Viperidae		
<i>Bothrops leucurus</i>	1	<i>Tropidurus hispidus</i> (Squamata, Tropiduridae)
	2	<i>Rattus norvegicus</i> (Mammalia, Muridae)
<i>Crotalus durissus</i>	1	<i>Rattus</i> sp. (Mammalia, Muridae)

brongersmianus (SVL = 321.1 mm) by *Micrurus ibiboboca* (SVL = 558 mm) and the first cannibalism event of *O. trigeminus* in which a specimen (SVL = 390 mm) ingested a juvenile (SVL approximately 140 mm). We list all food items and new predatory records in Table 2.

Natural history notes of species

TYPHLOPIDAE Merrem, 1820

Amerotyphlops brongersmianus Vanzolini, 1976

Fig. 4A

A rare species, small sized (min SVL = 110 mm, max SVL = 315 mm). Recorded at Reserva Sapiranga, Imbassaí and Barra do Itariri. Inhabits ombrophilous forest and restinga dry forest, where a *Micrurus ibiboboca* predated a specimen on 06/03/2013. Marciano Junior et al. (2010) reported a bluish coloration in offsprings. This observation is confirmed from a young museum specimen (SVL \leq 185 mm) with remnants of juvenile bluish coloration transitioning into brownish coloration. Strüssmann and Sazima (1993) reported insects as part of its diet.

BOIDAE Gray, 1825

Boa constrictor constrictor Linnaeus, 1758

Fig. 4B

A common species, large sized (min SVL = 430 mm, max SVL = 1850 mm). Recorded at Busca Vida, Camaçari, Imbassaí, Baixio and Costa Azul. Observed from January to November, active from 06:26 h to 21:15 h. We detected adults on ground (n = 8), leaf litter (n = 4), juveniles (SVL \leq 640 mm) coiled on the base of bromeliad leaves (n = 2) and one specimens each on a fallen trunk, suspended branch, herbaceous vegetation, bushes and anthropogenic material. Inhabits open and forested habitats (Vitt and Vangilder 1983, Vitt et al. 2005), is terrestrial and semiarboreal, active during day and night (Strüssmann and Sazima 1993, this study). Feeds on small mammals, lizards and birds (Pizzatto et al. 2009, Bernarde and Abe 2010). In the municipality of Salvador, a juvenile (SVL \leq 400 mm) regurgitated an unidentified hummingbird after palpation (pers. obs.). During encounters, behavior of boas ranged from calm to agitated hissing.

Corallus hortulanus (Linnaeus, 1758)

Fig. 4C

A very rare species (see Marques et al. 2012c). It was recorded in an ombrofilous forest remnant on the leaf litter basking in the sun at 14:00 h in September (SVL = 1140 mm). *Corallus hortulanus* is arboreal, often found on vegetation of different habitats during the night (Cunha and Nascimento 1978, Guedes et al. 2014). Feeds on frogs, lizards, birds and small mammals including bats (Henderson et al. 1995, Kok et al. 2006, Pizzatto et al. 2009). We observed this species in an S-coil position, when encountered, followed by strikes and bites when molested.

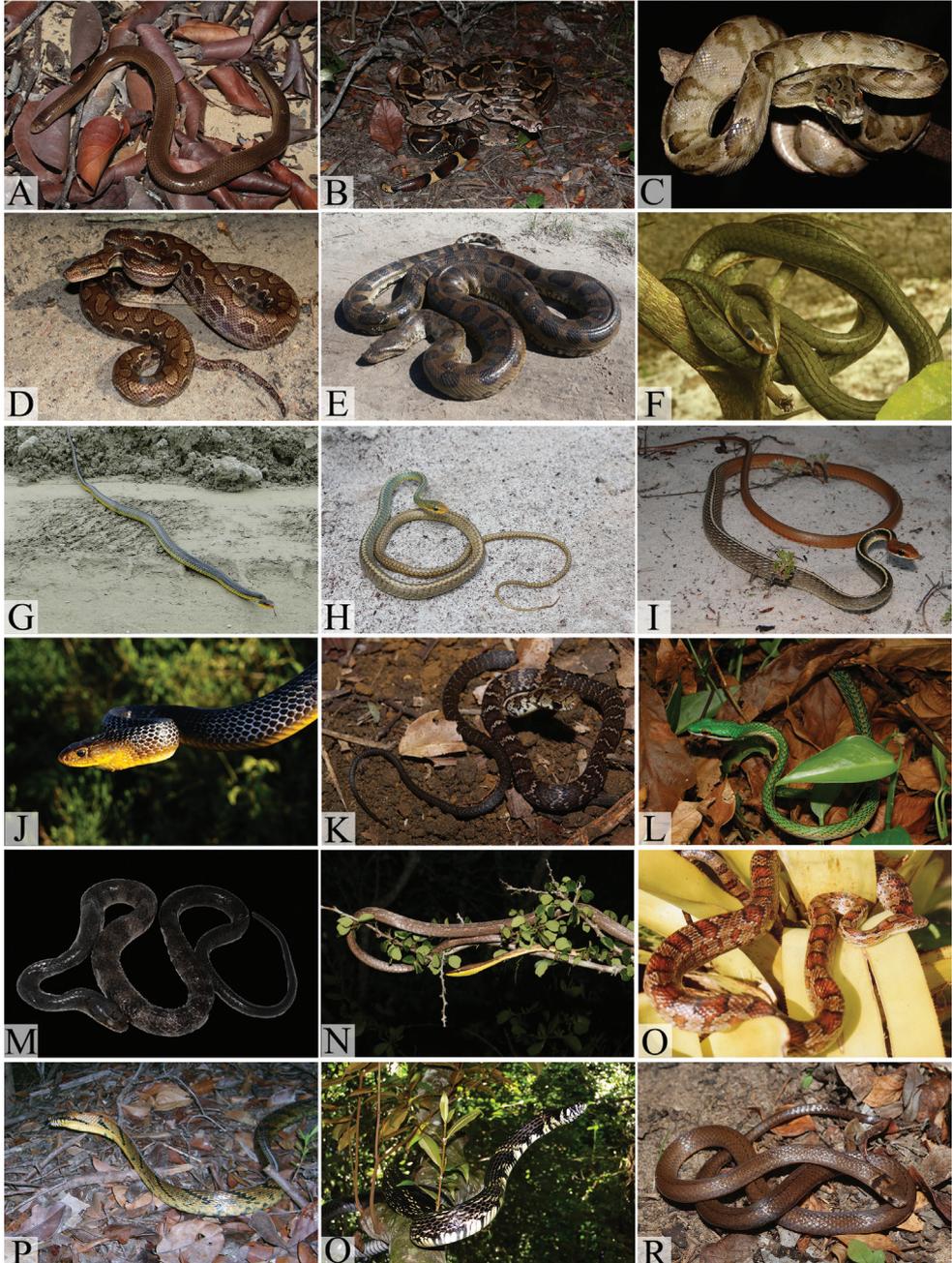


Figure 4. Typhlopidae, boids and colubrids from the northern coast of Bahia: **A** *Amerotyphlops brongersmianus* **B** *Boa constrictor constrictor* **C** *Corallus hortulanus* **D** *Epicrates assisi* **E** *Eunectes murinus* **F** *Chironius bicarinatus* **G** *Chironius carinatus* **H** *Chironius exoletus* **I** *Chironius flavolineatus* **J** *Drymarchon corais* **K** *Drymoluber dichrous* (juvenile) **L** *Leptophis abhaetulla liocercus* **M** *Mastigodryas bifossatus* **N** *Oxybelis aeneus* **O** *Pantherophis guttatus* **P** *Pseustes sulphureus sulphureus* **Q** *Spilotes pullatus pullatus* **R** *Tantilla melanocephala*. (Photo **F** by M. A. Passos; **D** by W. Pessoa; **J**, **K** by M. L. O. Travassos).

***Epicrates assisi* Machado, 1945**

Fig. 4D

A single specimen was recorded in the municipality of Mata de São João in ombrophilous forest habitat with a cerrado enclave. After erected to a species level by Passos and Fernandes (2008), the distribution of *E. assisi* is restricted to open habitat of northeastern Brazil but it also apparently colonized disturbed habitats that once were forested (Morato et al. 2011, Garda et al. 2013). It is a nocturnal and terrestrial species (Rodrigues and Prudente 2011) which feeds on small mammals (Pizzatto et al. 2009).

***Eunectes murinus* (Linnaeus, 1758)**

Fig. 4E

A rare species, large sized (min SVL = 1000 mm, max SVL = 3340 mm). Recorded at Praia do Forte, Imbassaí, Massarandupió and Baixio. Due to the aquatic life habit, this species was recorded only on flooded plains in the restinga (n = 3) on May and June, during periods of heavy precipitation. The earliest record was at 07:56 h when the animal was basking among reed vegetation (*Juncus* sp.) in a riverbed, whereas the other observations occurred around 13:00 h. Of those two, one specimen was crossing a road between two lakes and the other was basking in a flooded area among herbaceous vegetation. The species is strongly associated with wetlands, inhabiting rivers and ponds from the Atlantic forest and Amazon, but also moving on land to additionally feed and give birth (Cunha and Nascimento 1978, Argôlo 2004). Feeds on fishes, frogs, lizards, crocodylians, birds and mammals (Beebe 1946, Cunha and Nascimento 1978, Henderson et al. 1995, Martins and Oliveira 1998, Pizzatto et al. 2009).

COLUBRIDAE Opperl, 1811***Chironius bicarinatus* (Wied, 1820)**

Fig. 4F

Dias and Rocha (2014) recorded the species in restinga habitat at Costa Azul. Despite being most frequently encountered in forested habitats and riparian forests, it also occurs in open habitats (Marques and Sazima 2004, Vaz-Silva et al. 2007, Garda et al. 2013). The species is diurnal and forages on soil and in vegetation. It feeds on frogs (Dixon 1993, Marques et al. 2001).

***Chironius carinatus* (Linnaeus, 1758)**

Fig. 4G

A rare species. Recorded at the Instituto da Mata in March and July. Detected in an ombrophilous remnant forest adjacent to a pasture. We observed one large specimen (total length > 1000 mm) swimming in a stream at 16:22 h, while the other record is based on a shed skin. The species inhabits forests, riparian forests, igapós, cocoa plantations, pastures and open habitats. *Chironius carinatus* is diurnal, semiariboreal and terrestrial (Cunha and Nascimento 1978, Vanzolini et al. 1980, Argôlo 2004). It feeds on frogs, birds and lizards (Beebe 1946, Dixon 1993).

***Chironius exoletus* (Linnaeus, 1758)**

Fig. 4H

A very rare species of medium size (min SVL = 190 mm, max SVL = 620 mm). Recorded at Praia do Forte, Imbassá, Massarandupió and Costa Azul. We observed one specimen foraging on bromeliads in restinga dry forest at 08:33 h in September. Marques et al. (2011) recorded the species on a flooded plain. Voucher specimens originated from restinga (n = 9) and ombrophilous forest (n = 5). *Chironius exoletus* also inhabits forested habitats and pastures. The species is diurnal, terrestrial and semiariboreal, feeding on frogs (Marques and Sazima 2004, Bernarde and Abe 2006, 2010, Hartmann et al. 2009b). Some tried to bite when handled.

***Chironius flavolineatus* (Boettger, 1885)**

Fig. 4I

A common species of medium size (min SVL = 274 mm, max SVL = 1000 mm). Recorded at Busca Vida, Guarajuba, Praia do Forte, Imbassá, Massarandupió, Baixio and Barra do Itariri. Occurs in the whole region in restinga, ombrophilous forest and urban environments. The species inhabits predominantly open habitats, but also forests, urban and disturbed environments (Carvalho and Nogueira 1998, Vaz-Silva et al. 2007, França et al. 2012, Miranda et al. 2012). Observed from February to December, active from 06:43 h to 17:20 h. We observed specimens on soil (n = 9), in bushes (n = 5), on the leaf litter (n = 3), coiled on a branch during nighttime, in bromeliad, herbaceous vegetation, pond and on a fallen trunk (n = 1 each microhabitat). Feeds on frogs, mainly hylids (Pinto et al. 2008). In Cerrado, females contained oviductual eggs from October to March (Pinto et al. 2010). In September we detected a gravid female (SVL = 610 mm; 3 eggs; 28.5 – 31.2 mm). The species occasionally bites when handled. One specimen was observed to move from leaf litter to suspended branches to evade capture.

***Drymarchon corais corais* (Boie, 1827)**

Fig. 4J

Large sized snake (min SVL = 425 mm, max SVL = 1100 mm). Recorded in the municipalities of Dias D'Ávila and Catu, where vegetation consists mainly of ombrophilous forest. It inhabits the restinga, open areas and urban environments (McCranie 1980, Vaz-Silva et al. 2007, Miranda et al. 2012). The species is diurnal, terrestrial and arboreal and feeds on frogs, lizards, snakes, bird eggs and mammals (Beebe 1946, Cunha and Nascimento 1978, Bernarde and Abe 2010).

***Drymoluber dichrous* (Peters, 1863)**

Fig. 4K

Medium sized snake (min SVL = 220 mm, max SVL = 570 mm). Recorded in the municipality of Catu in ombrophilous forest. It inhabits mainly forested habitats, transition areas and disturbed habitats (Silva et al. 2011, Costa et al. 2013). Diurnal and terrestrial, occasionally resting on vegetation (Martins and Oliveira 1998). It feeds on frogs and lizards (Dixon and Soini 1986, Martins and Oliveira 1998).

***Leptophis abaetulla liocercus* (Wied, 1824)**

Fig. 4L

A very rare species of medium size (min SVL = 595 mm, max SVL = 850 mm). Recorded at Reserva Sapiroanga and Instituto da Mata. We observed a specimen on a suspended branch at 13:22 h in December. Specimens were recorded in restinga dry forests. Inhabits pastures, restinga and urban environment in other regions (Carvalho and Nogueira 1998, Bernarde and Abe 2006, Miranda et al. 2012). Feed mostly on hylid frogs and occasionally on lizards. The species is diurnal and arboreal, foraging in vegetation (Albuquerque et al. 2007, Mesquita et al. 2013). When handled the species intimidates with mouth gaping and bites.

***Mastigodryas bifossatus* (Raddi, 1820)**

Fig. 4M

Medium sized snake (min SVL = 300 mm, max SVL = 802 mm). Recorded in the municipalities of Lauro de Freitas, Mata de São João, Catu and Jandaíra, without information on habitat. Terrestrial and diurnal, inhabits forested and deforested environments (Strüssmann and Sazima 1993). Argôlo (2004) and Leite et al. (2007) observed most specimens in plantation and around human habitation. Feeds preferably on frogs, also lizards, snakes, birds and mammals (Strüssmann and Sazima 1993, Leite et al. 2007, Marques and Muriel 2007).

***Oxybelis aeneus* (Wagler, 1824)**

Fig. 4N

An intermediate frequent species of medium size (min SVL = 236 mm, max SVL = 754 mm). Recorded at Arembepe, Praia do Forte and Imbassaí from June to November. Found in activity between 09:05 h and 12:45 h. We observed individuals on suspended branches (n = 2) and bush (n = 1). In the region, it inhabits restinga and ombrophilous forest. In other ecoregions, it occupies also primary forests, disturbed and open habitats (Keiser 1982, Silva et al. 2011, Miranda et al. 2012, Garda et al. 2013). The species is arboreal and diurnal, feeding mostly on lizards and occasionally frogs (Martins and Oliveira 1998, Marques et al. 2001). We observed mouth gaping or immediate fleeing.

***Spilotes pullatus pullatus* (Linnaeus, 1758)**

Fig. 4P

A rare species of large size (in SVL = 139.1 mm, max SVL = 1600 mm). Recorded at Busca Vida, Praia do Forte and Imbassaí in July and August. We observed an individual foraging on the leaf litter at 15:46 h. It inhabits forests, open and disturbed habitats, is diurnal and semiarboreal (Vanzolini et al. 1980, Argôlo 2004, Bernarde and Abe 2006). It feeds on frogs, lizards, birds, eggs, marsupials and rodents (Cunha and Nascimento 1978, Marques and Sazima 2004). We observed immediate fleeing or inflating of the gular region.

***Spilotes sulphureus sulphureus* (Wagler, 1824)**

Fig. 4Q

A very rare species. Recorded at Praia do Forte in August. Marques et al. (2011) reported the species from Imbassaí, captured in a restinga dry forest (SVL = 1970 mm). Inhabits primary forest, ombrophilous forest, relict wet forest and cabruca, foraging more on vegetation than on the ground (Martins and Oliveira 1998, Argôlo 2004, Lisboa et al. 2009, Loebmann and Haddad 2010). The species is arboreal and diurnal, feeding on birds and rodents (Beebe 1946, Marques et al. 2001). We observed defensive behaviors of elevating the anterior of the body, striking and biting.

***Tantilla melanocephala* (Linnaeus, 1758)**

Fig. 4R

A rare species of small size (min SVL = 130 mm, max SVL = 277 mm). Recorded at Busca Vida, Praia do Forte and Imbassaí. Occurred in restinga (n = 9) and ombrophil-

ous forest (n = 2). The recorded specimens were active at 06:00 h and 19:00 h in May and June, both foraging on soil. The species is terrestrial, fossorial, diurnal and nocturnal (Vanzolini et al. 1980, Marques and Puerto 1998, Sawaya et al. 2008, this study). It feeds on insects and mostly chilopods. Santos-Costa et al. (2006) report ovoposition of three eggs in February, June and September. We observed the ovoposition of two eggs in May (SVL = 277 mm). The tail of this species apparently breaks easily, since we observed two specimens from different sites with broken tails near the cloaca, not exceeding eight subcaudal scales.

DIPSADIDAE Bonaparte, 1838

***Sibynomorphus neuwiedi* (Ihering, 1911)**

Fig. 5A

A rare species of small size (min SVL = 175 mm, max SVL = 455 mm). Recorded at Instituto da Mata in July and October and the municipalities of Pojuca and Catu. Dias and Rocha (2014) reported this species from the restinga of Costa Azul. We found this species only in ombrophilous forest. It is nocturnal, terrestrial and semiarboreal and feeds exclusively on slugs (Maia-Carneiro et al. 2012). Females from southeastern Brazil exhibited vitellogenesis from July to December and oviductual eggs from August to February (Pizzatto et al. 2008). We observed seven ovarian follicles (3.6 – 4.7 mm) in October and oviductual eggs (SVL = 480 mm; 6 eggs; 14.5 – 16.6 mm) in April. If threatened, it flattens its head.

***Imantodes cenchoa cenchoa* (Linnaeus, 1758)**

Fig. 5B

A very rare species of medium size (min SVL = 455 mm, max SVL = 670 mm). Recorded at Instituto da Mata in November (see Marques et al. 2013) and the municipality of Simões Filho. Occurs in the ombrophilous forest in the study region. The species is nocturnal and we recorded it at 20:23 h. The animal was foraging on a bromeliad. Despite its arboreal habit, *I. cenchoa* often forages on ground level in forests and disturbed habitats (Cunha and Nascimento 1978). It feeds on frogs and lizards (Marques et al. 2001). Cloacal discharge was observed.

***Leptodeira annulata annulata* (Linnaeus, 1758)**

Fig. 5C

An intermediately frequent species of medium size (min SVL = 195 mm, max SVL = 325 mm). Recorded at Praia do Forte, Reserva Sapiranga, Imbassaí, Massarandupió,



Figure 5. Dipsadids from the northern coast of Bahia: **A** *Sibynomorphus newwiedi* **B** *Imantodes cenchoa cenchoa* **C** *Leptodeira annulata annulata* **D** *Taeniophallus occipitalis* **E** *Helicops angulatus* **F** *Helicops leopardinus* **G** *Philodryas nattereri* **H** *Philodryas olfersii herbeus* **I** *Philodryas patagoniensis* **J** *Clelia plumbea* **K** *Oxyrhopus petolarius digitalis* **L** *Oxyrhopus trigeminus* **M** *Phimophis guerini* **N** *Pseudoboia nigra* **O** *Siphlophis compressus* **P** *Thamnodynastes pallidus* **Q** *Erythrolamprus aesculapii venustissimus* **R** *Erythrolamprus almaedensis*.

Baixio and Costa Azul from May to October. Occurs in wooded vegetation of restinga and ombrophilous forest. Also inhabits forests, open and dry habitats (Martins and Oliveira 1998, Garda et al. 2013). The species is nocturnal and we found it active from 18:05 h to 21:00 h. The snakes were observed on soil (n = 3), in anthropogenic environment (n = 1) and two meters high on vegetation (n = 1), always near ponds or lakes. It feeds on frogs, lizards and snakes (Cantor and Pizzatto 2008). Head flattening and cloacal discharge was observed.

***Taeniophallus occipitalis* (Jan, 1863)**

Fig. 5D

An intermediately frequent species of small size (min SVL = 215 mm, max SVL = 325 mm). Recorded at Praia do Forte, Instituto da Mata and Reserva Sapiranga from May to November. Occurs in restinga (n = 4), disturbed ombrophilous forest (n = 1) and pasture (n = 1). Also distributed in the Amazon and Caatinga (Argôlo 2004). The species is diurnal, active from 08:47 h to 10:20 h (n = 3) and one record at 16:48 h. Strictly terrestrial, we observed the species on the leaf litter (n = 4). It feeds on frogs, lizards and snakes (Cunha and Nascimento 1978, Argôlo 2004, Balestrin and Di-Bernardo 2005). A female contained oviductal eggs (SVL = 315 mm; 3 eggs; ≤ 12.5 mm) in May.

***Helicops angulatus* (Linnaeus, 1758)**

Fig. 5E

An intermediately frequent species of medium size (min SVL = 173 mm, max SVL = 810 mm). Recorded at Praia do Forte, Reserva Sapiranga, Instituto da Mata and Costa Azul in March and from September to November. Occurs in ombrophilous forest (n = 10) and restinga (n = 3). The species can be abundant in urbanized and open environments and less frequent in forest habitats (Martins and Oliveira 1998, França et al. 2012). We observed snakes in rain puddles, lake shores and rivers and in open areas. *Helicops angulatus* is mainly nocturnal, active from 18:38 h to 21:08 h (n = 10) with a single record at 10:42. It feeds on fishes and frogs (Dixon and Soini 1986, Martins and Oliveira 1998, Ford and Ford 2002). We observed defensive behaviors, such as biting, struggling and occasional cloacal discharge.

***Helicops leopardinus* (Schlegel, 1837)**

Fig. 5F

A very rare species of medium size (min SVL = 109 mm, max SVL = 638 mm). Recorded at Arembepe, Imbassaí and Baixio in February and October. We found only specimens in the restinga, but vouchers originate also from forested habitats (n = 13). We observed

snakes at edges of lakes and only during diurnal activity from 10:00 h to 16:12 h. However, *Helicops leopardinus* is known to be mainly nocturnal. It feeds on fishes and frogs (Strüssmann and Sazima 1993, Ávila et al. 2006). We observed biting when handled.

***Philodryas nattereri* Steindachner, 1870**

Fig. 5G

A common species of medium size (min SVL = 295 mm, max SVL = 840 mm). Recorded at Areembepe, Guarajuba, Praia do Forte, Imbassaí, Massarandupió, Baixio, Barra do Itariri and Costa Azul during the year. We found it only in restinga (n = 38) during fieldwork, supported also by voucher specimens. It inhabits mainly open and semiarid habitats, also recorded at brejos de altitude (isolated fragments of humid forests surrounded by arid Caatinga) and disturbed habitats (Vanzolini et al. 1980, Marques et al. 2011, Pereira-Filho and Montingelli 2011, Mesquita et al. 2013, this study). The species is diurnal and active from 08:30 h to 17:50 h. *Philodryas nattereri* is mainly terrestrial, as we observed it on the ground (n = 19), on the leaf litter (n = 14), among bush branches (n = 2), over herbaceous vegetation (n = 1) and on a branch that was four meters suspended (n = 1). It feeds on frogs, lizards, snakes, birds and mammals (Mesquita et al. 2011). We observed the elevating of its anterior body and immediate fleeing behavior, where it moved from the ground to a nearby suspended branch.

***Philodryas olfersii herbeus* Wied, 1825**

Fig. 5H

An intermediately frequent species of medium size (min SVL = 200 mm, max SVL = 770 mm). Recorded at Busca Vida, Areembepe, Instituto da Mata, Imbassaí, Massarandupió and Costa Azul in January and from July to December. We found it in restinga (n = 9) and disturbed areas of ombrophilous forest (n = 2). The species is diurnal and active from 07:56 h to 14:56 h. We observed snakes foraging on ground (n = 3), on leaf litter (n = 2) and in herbaceous vegetation (n = 1). The species is terrestrial and semi-arboreal (Marques et al. 2001). It feeds on frogs, birds and rodents (Leite et al. 2009). In the Caatinga domain, the species is mating from November to January (Mesquita et al. 2013). We analyzed a fertile male (SVL = 551 mm) in November. We observed cloacal discharge and biting as a defensive behaviour.

***Philodryas patagoniensis* (Girard, 1858)**

Fig. 5I

A common species of medium size (min SVL = 184 mm, max SVL = 848 mm). Recorded at Busca Vida, Areembepe, Praia do Forte, Imbassaí, Massarandupió, Barra do

Itariri and Costa Azul from February to December. Occurs in restinga (n = 14), urbanized environment (n = 5) and ombrophilous forest (n = 3). Usually found in open and disturbed habitats (Sawaya et al. 2008, Hartmann et al. 2009a). The species is diurnal, active from 06:54 h to 15:48 h. It is terrestrial and we observed it on the ground (n = 8), on leaf litter (n = 4) and among bushes (n = 1). It feeds on frogs, lizards, snakes, birds and small mammals (Hartmann and Marques 2005). Marques et al. (2012a) observed this species preying on *P. olfersii*.

***Clelia plumbea* (Wied, 1820)**

Fig. 5J

A medium sized snake (min SVL = 335 mm, max SVL = 820 mm). Recorded in the municipality of Catu. Voucher specimens were from urban habitation. Inhabits mainly forests, disturbed, and open habitats (Zaher 1996, Argôlo 2004). The species is terrestrial and diurnal, feeding on lizards, snakes and mammals (Bernarde and Abe 2006). The reproductive cycle is continuous and the clutch size varies from four to 29 eggs (Gaiarsa et al. 2013).

***Oxyrhopus petolarius digitalis* Reuss, 1834**

Fig. 5K

A rare species of small size (min SVL = 176 mm, max SVL = 445 mm). Recorded at Praia do Forte and Instituto da Mata in July and November. We observed animals on pasture (n = 2) near ombrophilous forest remnants. A voucher specimen was obtained from the restinga. The species is terrestrial, forages on the ground (n = 2) and is nocturnal, detected at 21:10 h. Inhabits forest and disturbed habitats (Argôlo 2004, França et al. 2012). It feeds on lizards, birds, eggs and mammals and has a clutch size of two to 12 eggs (Gaiarsa et al. 2013). We observed winding when handled.

***Oxyrhopus trigeminus* Duméril, Bibron & Duméril, 1854**

Fig. 5L

An intermediately frequent species of medium size (min SVL = 178 mm, max SVL = 656 mm). Recorded at Busca Vida, Arembepe, Guarajuba, Praia do Forte, Imbassaí, Massarandupió, Baixio, Barra do Itariri and Costa Azul from January to October. Occurs in restinga, ombrophilous forest and anthropic environments. The species is mainly nocturnal and we observed it from 18:05 h to 21:00 h, except for two specimens foraging at 09:50 h and 11:00 h. *Oxyrhopus trigeminus* is terrestrial. It was recorded on the ground (n = 5), in the leaf litter (n = 2), in bush and herbaceous vegetation (n = 1 each). It feeds on lizards, birds and small mammals. In southeastern Brazil, females are

fertile from January to November (Alencar et al. 2012). We observed two reproductive males (SVL = 380 and 440 mm) and a female with ovarian follicles (SVL = 450 mm; $n = 6$; ≥ 3 mm) in May. Defensive behaviour consists of occasional cloacal discharge.

***Phimophis guerini* (Duméril, Bibron & Duméril, 1854)**

Fig. 5M

A medium sized snake (min SVL = 323 mm, max SVL = 754 mm). Recorded at Guarajuba, Praia do Forte and Imbassaí (see Marques et al. 2012b). Occurs in restinga ($n = 3$) and anthropogenic habitat ($n = 1$). Dias and Rocha (2014) report the species from the restinga of Costa Azul. This species inhabits several types of open habitat including urban environments (Carvalho and Nogueira 1998, Sawaya et al. 2008, Valdujo et al. 2009). It feeds on lizards (Sawaya et al. 2008). Gaiarsa et al. (2013) reports clutch size of three to seven eggs.

***Pseudoboa nigra* (Duméril, Bibron & Duméril, 1854)**

Fig. 5N

A medium sized snake (min SVL = 214 mm, max SVL = 870 mm). Recorded at Busca Vida and Jauá, and in the municipalities of Mata de São João and Catu. Occurs in ombrophilous forests and restinga. *Pseudoboa nigra* also inhabits open and disturbed habitats and forests (Argôlo 2004, Gaiarsa et al. 2013). The species is terrestrial and nocturnal. It feeds on frogs, lizards and mammals (Vanzolini et al. 1980, Vitt and Vanglinder 1983, Orofino et al. 2010, França et al. 2012). Orofino et al. (2010) reported offspring with a SVL of 340 mm. We analyzed offspring with SVL of 214 mm and 274 mm.

***Siphlophis compressus* (Daudin, 1803)**

Fig. 5O

A very rare species of medium size (SVL = 738 mm). Recorded at Instituto da Mata (see Marques et al. 2013) in May. We found it in ombrophilous forest remnants foraging at ground level on the leaf litter at 21:00 h. The species inhabits forests in Amazonia and Atlantic coast (Guedes et al. 2011). Nocturnal and arboreal, occasionally found on the ground. It feeds mainly on lizards (Martins and Oliveira 1998, Marques et al. 2001, Argôlo 2004). Clutch size varies from 3–12 eggs (Gaiarsa et al. 2013).

***Thamnodynastes pallidus* (Linnaeus, 1758)**

Fig. 5P

A very rare species of small size (SVL = 363 mm). Recorded at the Instituto da Mata (see Marques et al. 2013). We observed it in ombrophilous forest remnants. We con-

firm that this snake is nocturnal, as we found one foraging on the ground at 20:30 h. The female did not contain ovarian follicles in May. Marques et al. (2014) report ovarian follicles in July and eggs in September. Cunha and Nascimento (1978) report *T. pallidus* inhabiting the humid ground on forests and feeding on frogs and insect larvae.

***Erythrolamprus aesculapii venustissimus* Wied, 1821**

Fig. 5Q

A medium sized snake (SVL = 655 mm). Recorded in the municipalities of Lauro de Freitas collected in 1994, without habitat information. Morato et al. (2011) record the species from the state of Sergipe at 175 km from our record. Inhabits forests, disturbed habitats and plantations (Sazima and Abe 1991, Argôlo 2004). This species is terrestrial and diurnal, but occasionally nocturnal, feeding mainly on snakes (Sazima and Abe 1991, Marques and Sazima 2004).

***Erythrolamprus almadensis* (Wagler, 1824)**

Fig. 5R

Rare species of medium size (Min SVL = 136 mm, Max SVL = 450 mm). Recorded at Arembépe, Instituto da Mata, Imbassaí and Baixio in March and October. Occurs in ombrophilous forest (n = 8), restinga (n = 4), pasture and disturbed habitats (n = 1 each). Also recorded from urban environment (França et al. 2012). We recorded diurnal activity at 08:21 h and 11:40 h. The species is terrestrial and feeds on frogs (Strüssmann and Sazima 1993, Bernarde and Abe 2010).

***Erythrolamprus miliaris merremi* (Wied, 1821)**

Fig. 6A

A medium sized snake (min SVL = 145, max SVL = 642 mm). Recorded from the municipalities of Simões Filho, Dias D'Ávila and Pojuca. Occurs in ombrophilous forest remnants and disturbed areas. The species is semiaquatic with diurnal and nocturnal activities, inhabiting forests and open habitats. It feeds on fishes, caecilians, frogs, amphisbaenians, lizards, and snakes (Marques and Sazima 1994, Bonfiglio and Lema 2006, Hartmann et al. 2009b).

***Erythrolamprus poecilogyrus schotti* (Schlegel, 1837)**

Fig. 6B, C

A medium sized snake (min SVL = 150 mm, max SVL = 623 mm). Recorded from the municipalities of Camaçari, Lauro de Freitas, Mata de São João, Catu and Pojuca. It



Figure 6. Dipsadids, elapids and viperids from north coast of Bahia: **A** *Erythrolamprus miliaris merremi* **B** *Erythrolamprus poecilogyrus schotti* (juvenile with a *E. p. poecilogyrus*-like pattern) **C** *Erythrolamprus poecilogyrus schotti* (adult) **D** *Erythrolamprus reginae semilineatus*, **E** *Erythrolamprus taeniogaster* **F** *Erythrolamprus viridis viridis* **G** *Xenodon merremii* **H** *Xenodon rhabdocephalus rhabdocephalus* **I** *Micrurus coralinus* **J** *Micrurus ibiboboca* **K** *Bothrops erythromelas* **L** *Bothrops leucurus* **M** *Bothrops lutzi* **N** *Crotalus durissus cascavella* **O** *Lachesis muta rhombeata* (Photos **F**, **G**, **K** by M.L.O. Travassos; **O** by W. Pessoa).

occurs in ombrophilous forest, but inhabits also cocoa plantations, pastures, swamps, and urbanized habitats (Pontes and Rocha 2008). One specimen was obtained from an industrial complex. In the state of Bahia, it occurs in the area north of Belmonte, being replaced by the nominate taxon *Erythrolamprus p. poecilogyrus* farther south (Fernandes

2006). The species is diurnal and nocturnal, and feeds on frogs and lizards (Marques et al. 2001, Argôlo 2004, Sawaya et al. 2008). Populations from the Atlantic forest from northeastern Brazil reproduce throughout the year with a clutch size of 3–17 eggs (Pizzato et al. 2008b).

***Erythrolamprus reginae semilineatus* (Linnaeus, 1758)**

Fig. 6D

A very rare species of small size (min SVL = 191 mm, max SVL = 494 mm). Recorded at the Instituto da Mata (see Marques et al. 2013) and the municipalities of Catu and Pojuca. We observed it in ombrophilous forest in February. Commonly found near ponds, forest edges, fields and disturbed habitats (Dixon and Soini 1986). The snake was foraging on the leaf litter at 10:26 h. The species is terrestrial, occasionally using the vegetation to rest (Martins and Oliveira 1998). It feeds on frogs, tadpoles and lizards (Cunha and Nascimento 1978, Bernarde and Abe 2010). We detected a gravid female (SVL = 403 mm; 1 egg, 26 mm) in June. We observed dorsoventral flattening.

***Erythrolamprus taeniogaster* Jan, 1863**

Fig. 6E

A very rare species of medium size (min SVL = 147 mm, max SVL = 583 mm). Recorded at Praia do Forte, Imbassaí, and the municipalities of Lauro de Freitas, Simões Filho, Camaçari and Catu. We observed it in restinga in June, with voucher specimens also from restinga (n = 5) and ombrophilous forest (n = 4). In northeastern and southeastern Brazil, the species has a coastal distribution (Fernandes et al. 2002). In southern Bahia, Argôlo (2004) reported the species from sites near flooded areas, dams and swamps. We observed the species on a dirt road near a flooded plain at 15:00 h in urban habitation. The species struggles when handled.

***Erythrolamprus viridis viridis* (Günther, 1862)**

Fig. 6F

A small sized snake (SVL = 382 mm). Recorded in the municipality of Mata de São João. Occurred in ombrophilous forest, but also in transition areas from Atlantic forests and agreste (hilly north south chain with hot and sub-humid climate) region (Dixon 1987). The species is terrestrial but forages also in vegetation (Vanzolini et al. 1980). It feeds mainly on frogs and lizards (Vitt 1983, Mesquita et al. 2013).

***Xenodon merremii* (Wagler, 1824)**

Fig. 6G

A very rare species of large size (min SVL = 186 mm, max SVL = 1003 mm). Recorded at Guarajuba, Praia do Forte, Instituto da Mata, Imbassaí and Sauípe. Occurs in open areas. Voucher specimens were from deforested ombrophilous forest (n = 9) and restinga (n = 6). Terrestrial and diurnal, feeds exclusively on amphibians (Vitt 1983, Vitt and Vanglinder 1983). Pizzatto et al. (2008b) report offspring of *X. merremii* between January and May in southeastern Brazil. We captured one offspring in July.

***Xenodon radocephalus radocephalus* (Wied, 1824)**

Fig. 6H

A medium sized snake (min SVL = 232 mm, max SVL = 654 mm). Recorded from the municipalities of Camaçari and Catu. Occurs in ombrophilous forest, cocoa plantation and pastures. The species is terrestrial and feeds on frogs and occasionally on tadpoles (Dixon and Soini 1986, Martins and Oliveira 1998, Argôlo 2004).

ELAPIDAE Boie, 1827***Micrurus corallinus* (Merrem, 1820)**

Fig. 6I

A small sized snake (SVL= 405 mm). Recorded from the municipality of Simões Filho in ombrophilous forest. Campbell and Lamar (2004) report this species from forested areas with coastal (maritime) influence. *Micrurus corallinus* is diurnal and cryptozoic, feeding on frogs, amphisbaenians and snakes (Lema et al. 1983, Marques and Sazima 1997, Marques and Sazima 2004).

***Micrurus ibiboboca* (Merrem, 1820)**

Fig. 6J

A common species of medium size (min SVL= 210 mm, max SVL = 1092 mm). Recorded at Busca Vida, Arembepe, Jacuípe, Guarajuba, Praia do Forte, Reserva Sapiroanga, Instituto da Mata, Imbassaí, Sauípe, Baixio and Barra do Itariri from January to November. We observed it in restinga (n = 9), ombrophilous forest (n = 2), deforested, open and disturbed habitats (n = 3). In restinga, it inhabits the dry part of the forest. We found it active on the leaf litter (n = 9) and soil (n = 5) from 08:11 h to 17:30 h. *Micrurus ibiboboca* is ophiophagous (Lema et al. 1983, Marques et al. 2001, Campbell and Lamar 2004). We captured a reproductive male in November (SVL =

520 mm). Defensive or protective behaviour included immediate fleeing, coiling and elevating the tail, dorsoventral flattening, head hiding under its body and struggling when handled.

VIPERIDAE Opper, 1811

Bothrops erythromelas Amaral, 1923

Fig. 6K

A medium sized snake (adult SVL ca. 570 mm). Recorded from the municipalities of Camaçari and Lauro de Freitas (MZUFBA 499 and 1366, respectively). The vegetation of both municipalities varies from restinga to ombrophilous forest with enclaves of cerrado, but no precise information was available on either of the two specimens' habitats. This is a terrestrial and nocturnal species that inhabits arid and semiarid regions, from sandy and rocky areas to deciduous forests, mainly associated with the Caatinga and Cerrado (Campbell and Lamar 2004).

Bothrops leucurus Wagler, 1824

Fig. 6L

An intermediately frequent species of large size (min SVL = 115 mm, max SVL = 1600 mm). Recorded at Arembepe, Guarajuba, Itacimirim, Praia do Forte, Instituto da Mata, Imbassaí, Sauípe, Massarandupió, Baixio and Mangue Seco. We found it in restinga (n = 9), nearby human habitation and pastures (n = 1) from February to October. *Bothrops leucurus* is more active during nighttime (Argôlo 2004), but we observed it mainly active from 06:10 h to 08:15 h. One adult moved at 15:30 h and two juveniles at 20:00 h and 20:08 h. We observed it mostly on the ground (n = 5), moving over bushes, coiled on short palm trees and on anthropogenic material (n = 1 each). Juveniles feed on frogs and adults mostly on rodents (Argôlo 2004, Fagundes et al. 2009). When threatened, they coil their body, vibrate the tail and occasionally strike.

Bothrops lutzii (Miranda-Ribeiro, 1915)

Fig. 6M

A small sized snake (SVL = 451 mm). This species is confirmed from north of Salvador by four specimens, three by Lira-da-Silva et al. (2003) near sea level in the municipalities of Camaçari and Dias D'Ávila and one voucher at the Institute Butantan, also from Camaçari (IBSP 959). Terrestrial species, inhabits savannas and higher plateaus in the Cerrado (Loebmann 2009, Campbell and Lamar 2004) and Caatinga < 250 m asl. (Loebmann and Haddad 2010).

***Crotalus durissus cascavella* Wagler, 1824**

Fig. 6N

A rare species of medium size (min SVL = 255 mm, max SVL = 1268 mm). Recorded at Busca Vida, Imbassaí and Massarandupió on March, August and September. Voucher specimens were from ombrophilous forest (n = 9), probably from deforested areas (Bastos et al. 2005) and restinga (n = 4). We observed a specimen crossing a road at 20:00 h while others were found on soil and leaf litter. This species is terrestrial and nocturnal, inhabiting open habitats and feeding on rodents (Vanzolini et al. 1980, Graça Salomão et al. 1995, Tozetti and Martins 2013). When handled the squirting of cloacal discharge can reach 1.5 m and if threatened, they coil their body and vibrate the tail and rattle.

***Lachesis muta rhombeata* Wied-Neuwied, 1824**

Fig. 6O

A single record exists from the region based on a skin of an animal captured on a farm in the municipality of Entre Rios in 1996. The species inhabits primary forests, riparian forest, lowlands and cocoa plantations in southern Bahia. Occasionally it is found in secondary forest and surroundings. The species is nocturnal and feeds on small rodents (Cunha and Nascimento 1978, Argôlo 2004).

Discussion

The number of snake species from the northern coast of Bahia represents 38% of all species known from the state of Bahia (Hamdan and Lira-da-Silva 2012, Curcio et al. 2012, Fernandes and Hamdan 2014) and contains six families. Disregarding the mistaken record of *Bothrops jararaca* by Marques et al. (2011), we recorded 49 native species in the study region. The absence of 17 species during our fieldwork, confirmed only from older museum specimens without new voucher deposits over at least ten years, suggests they have either become extinct in the region or our search method was insufficient (time spent) or non-appropriate, since our larger effort were on restinga. Three of these missing species (*D. corais corais*, *P. guerini* and *P. nigra*) are known from restinga habitat, whereas other species relate mostly to wooded areas, such as *D. dichrous*, *C. plumbea*, *E. aesculapii venustissimus*, *E. miliaris merremii*, *E. viridis viridis*, *X. rhabdocephalus rhabdocephalus*, *M. corallinus* and *L. muta rhombeata*. These assumptions can only be confirmed with additional sampling efforts in the few forest remnants of the region.

Three species require taxonomic comments. First, the pitviper *Bothrops lutzi* from our study region, which appears isolated and far distant from the next known populations of ca. 425 km distance in Petrolina, Pernambuco, which was erroneously report-

ed as 325 km in Lira-da-Silva (2000). We measured three specimens from Camaçari and Dias d'Ávila with ventral scale counts from 153–156, confirming Campbell and Lamar's (2004) findings that these are the lowest scale counts known for this species, which usually ranges from 161–179 ventral scales. These low values are more typical for *B. erythromelas* which exhibits 160 or lower ventral scales, which raises the question of potential mis-identification or hybridization between both viperid species. However, the *B. erythromelas* from the same region north of Salvador (Camaçari and Lauro de Freitas) yielded species typical 19-19-17 dorsal scales, whereas the sympatric *B. lutzi* exhibited species specific 21/23-21-19 dorsal scales. Moreover, the color pattern of latter specimens from Camaçari and Dias D'Ávila resembles rather typical *B. lutzi* than *B. erythromelas*, including diffuse and narrow trapezoid dorsal blotches (approaching a quadrangle), a diffuse and posteriorly not broadening postorbital stripe beginning behind the eye, and labials mostly darkened or mottled in the dorsum ground color with a few white spots. In contrast, *B. erythromelas* has comparatively wider angled dorsal blotches (resembling triangles, either pointed or rounded at the top), a larger postorbital stripe beginning below the eye and broadening posteriorly, and labials mostly white with occasional few larger spots. Machado et al. (2014) reported shared haplotypes between the two pitvipers, suggesting an introgressive hybridization, where the two species come into contact in western Bahia. The low ventral counts for the *B. lutzi* from the municipality of Salvador region may be another example of hybridization/introgression, but so far this is only suggested due to the low ventral scale count, which alternatively may represent a case of geographically isolated variation.

Furthermore, there are several enclaves of Cerrado type vegetation (Campo Cerrado, Campo-limpo-de-Cerrado) from Camaçari (Salvador region) 200 km north to Ribeiro do Pombal, Bahia (Ab'Saber 1977, IBGE 2004). These enclaves allow the unusual presence of "Cerrado-species" in this area, such as *Dendropsophus nanus*, *D. rubicundulus*, *Hypsiboas raniceps* and *Dermatonotus muelleri* (Xavier et al. 2015). These remnant patches of Cerrado vegetation propose a scenario of a previous grassland corridor for an expansion of *B. lutzi* from its western populations in the current Cerrado domain (approx. 450 km distant). Subsequent aridification and expansion of Caatinga domain interrupted the corridor (Ab'Saber 1977) with the populations north of Salvador becoming relictual during the late Pleistocene 0.63 – 0.11 mya (Ab'Saber 1977, Prado and Gibbs 1993, Pennington et al. 2000, Werneck 2011, Machado et al. 2014), while the intervening dried area was colonized by *B. erythromelas*. Drastic urban sprawl and intense agricultural practices may have also extirpated local grassland populations of *B. lutzi*. This may relate to notes that *B. lutzi* was once common in the low and humid region of southern Rio Paraguçu, Recôncavo da Bahia, close to Salvador (*B. lutzi* labelled as *B. n. neuwiedi* in Amaral 1925, see cit. in Silva and Rodrigues 2008). Possibly more relictual *B. lutzi* populations exist on higher elevated grassland within the Caatinga today. For example, the holotype of *Bothrops neuwiedi bahiensis* Amaral, 1925 (IBSP 3012) originates from Itiuba, Bahia, a town in the midst of mountains that might have yielded grassland suitable for *B. lutzi*, while it is surrounded by Caatinga, that likely provides habitat for *B. erythromelas*. Similarly, combined information

suggests sympatry of these vipers in central Piauí (Cambell and Lamar 2004, Benicio et al. 2015) or Guanambi (Silva and Rodrigues 2008, Machado et al. 2014). The specimen from Itiuba is perceived as *B. newwiedi* by Silva and Rodrigues (2008, and their figs 14A–B), but possibly represents a *B. lutzi* based on the authors' qualitative characters assigned to *B. lutzi*, such as diffuse, at least partially, interspace blotches, white supralabial spots vertically directed on 4th and posterior supralabials, white spotting more marked posterior the 3rd supralabial, and lack of dorsal postcephalic stripe. In contrast, this specimen has also well defined dorsal blotches, a *newwiedi* character acc. Silva and Rodrigues (2008). However, the first author of the latter publication co-authored new records of *B. lutzi* from Minas Gerais (Moura et al. 2013), that, together with records of an adult *B. lutzi* from São Desidério in Bahia or a juvenile of approximately 30 cm total length from Grande Sertão Veredas National Park, Minas Gerais (Figure 7), indicate that these *newwiedi*-characters are often within the variation of *B. lutzi*, rendering it more polymorphic than previously described. The suggestion of *B. lutzi* at Itiuba is also biogeographically plausible, as this specimen is nearest to other *B. lutzi*, north at Petrolina, Paraíba (Silva and Rodrigues 2008) southeast at Camaçari and Dias d'Avila (Lira-da-Silva et al. 2003) and west at Ibiraba, Bahia (Machado et al. 2014).

Comments on the second species relate to the confusingly polymorphic species *Erythrolamprus poecilogyrus* divided into multiple subspecies based mainly on color pattern variation that shows also drastic changes throughout ontogeny. Offspring and juvenile pattern resembling two taxa, *E. p. poecilogyrus* and *E. p. schotti*, have been recorded by us from the study area. According to Dixon and Markezich (1992) the only key characters to distinguish *E. p. poecilogyrus* from *E. p. schotti* that do not change with ontogeny are: (1) dorsal transverse bands from head to posterior including the mid-body section in *E. p. poecilogyrus* versus changing to a dorsal line or interruption of transverse bands in *E. p. schotti*; and (2) dark to black edged cephalic shields in *E. p. poecilogyrus* versus relatively featureless cephalic shields in *E. p. schotti*. In addition, young (SVL < 350 mm) *E. p. schotti* from northeastern Brazil are characterized by widely spaced mid-dorsal marking.

In our study area, offspring and juvenile specimens were found displaying characters of color pattern of both taxa noted above, whereas other juveniles exhibited widely spaced dorsal markings and some specimens showed intermediate expression of dark-edging of cephalic shields. This pattern concurs with the polymorphic scenario evaluated by Fernandes (2006), where the pattern of young *E. p. schotti* predominates in northeastern Brazil, but with some juveniles exhibiting characters of *E. p. poecilogyrus* (from 16% with conspicuous transverse dorsal bands to 74% with well-defined ventral markings). In contrast stands the color pattern variation of adults, whereby *E. p. schotti* and *E. p. poecilogyrus* separate well at or near the Jequitinhonha River, ca. 16° latitude at Belmonte, Bahia (Fernandes 2006). From there north, only *E. p. schotti* adult color pattern occurs including our study region north of Salvador. This demarcation between these two taxa is consistent with a decrease in the number of ventral scales and maxillary teeth from *E. p. poecilogyrus* (south) to *E. p. schotti* (north) found by Dixon and Markezich (1992). Hence, we conclude that the *E. p. poecilogyrus*-



Figure 7. Strongly marked polymorphism of *Bothrops lutzi* from São Desidério, Bahia (**A**) and Grande Sertão Veredas National Park, Minas Gerais (**B**) (Photos **A** by R. Gaiga; **B** by M. Sacramento).

like color pattern in some offspring and juveniles from north of Salvador has been and still is part of their regional morphological variation, and is not related to true *E. p. poecilogyrus*, which does not occur in our study area. A first hypothesis states, that the *E. p. poecilogyrus*-like juvenile color pattern represents simply an ancestral trait, still occurring in small proportions (i.e. has not been lost through selection or genetic drift) in populations in northeastern Brazilian populations of *E. p. schotti*.

A second hypothesis includes a historical component, whereby the occasional occurrence of *E. p. poecilogyrus* color pattern characters in the *E. p. schotti* range reflect a late Pleistocene/Holocene scenario of expansion and contraction of both taxa's range, or a shifting of their contact and overlap zones, triggered by greater paleoclimatic and vegetation shifts (e.g. Ab'Saber 1977, Xavier et al. 2015). Northeastern Brazil exhibits a mosaic of ecoregions and range limits with taxa and their co-adapted gene complexes associated to Atlantic Forest, Cerrado and Caatinga relicts (e.g., Freitas 2014). Similar to a scenario suggested for the pitvipers *Bothrops lutzi* and *B. erythromelas* above, a period with dry climate within the late Pleistocene 0.63 – 0.11 mya, in particular during the Last Glacial Maximum 12000–18000 years ago (e.g. Ab'Saber 1977; Pennington et al. 2000), may have caused the expansion of *E. p. schotti* to current coastal stretches of northeastern Brazil as far south as Belmonte, Bahia. The occurrence of mainly *E. p. schotti* morphology along the coast of northeastern Brazil indicates, that this species of Cerrado and Caatinga (at least for the northern half of Brazil) has adapted to environmental conditions of the Atlantic Forest. This is possibly facilitated by genetic exchange with *E. p. poecilogyrus* (an Atlantic Forest species) during postglacial warming from their Pleistocene refuges of Atlantic Forests along the coast (Carnaval and Moritz 2008) or a northward introgression of *E. p. poecilogyrus* from its core area south of Belmonte. The few color pattern characters by *E. p. poecilogyrus* in the *E. p. schotti* range would be such imprints of historical introgression.

As a consequence, the area around Salvador exhibits a large polymorphism in *E. p. poecilogyrus*, with specimens of each parental form, and those with prominent or only a few intermediate characters, or a combination of distinctive characters from each species, similar as was described in hybrid zones and the occurrence of relictual in-

trogged morphological characters in North American watersnakes (Mebert 2008, 2010). As Dixon and Markezich (1992) noted, character gradients between *E. p. schotti* and *E. p. poecilogyrus* in northeastern Brazil are less steep than in southeastern Brazil, which supports the aforementioned relatively recent, late Pleistocene and postglacial expansion/contraction events between these two taxa. However, the occurrence of *E. p. poecilogyrus* color pattern characters in more western dry areas of Minas Gerais, Bahia, and Piauí is rather in support of the first hypothesis in regards to color pattern (*E. p. poecilogyrus* is an ancestral trait persisting in *E. p. schotti* populations), which may not restrict gene flow between both taxa along the southern Bahia coast.

The third species in need of discussion relates to *Erythrolamprus aesculapii* ssp. Peters and Orejas-Miranda (1970) attribute five subspecies to *E. aesculapii*, with two possibilities for the state of Bahia (Curcio 2008): *Erythrolamprus a. monozoa* and *E. a. venustissimus*. *Erythrolamprus aesculapii monozoa* does not apply to our specimen according to inter-ring distances. Freitas (2014) recorded *E. a. aesculapii* also from Lauro de Freitas, but it is unlikely since it is allocated to the Amazon population of the species. *Erythrolamprus a. aesculapii* differs from *E. a. venustissimus* by a light head color with dark body bands and red rings of same size as black rings, whereas *E. a. venustissimus* presents a blackish head with light body bands and red rings twice the size of black rings (Peters and Orejas-Miranda 1970). Therefore, following coloration and geographic distribution, we considered *E. a. venustissimus* more likely to represent the regional *E. aesculapii*. The taxonomy of this species is confusing and its population's status should be reviewed soon (F. Curcio, pers. comm.).

When we compare the snake species richness of the northern coast of Bahia with other snake assemblages from studies with similar sampling effort and field days, the region exhibits a higher species richness (see Table 3). Guedes et al. (2014) gathered voucher specimens from the entire Caatinga domain, resulting in 112 species. The Serra do Mar region extends along the coast from the state of Rio de Janeiro to Santa Catarina, containing 74 snake species (Marques et al. 2001). Santos-Costa et al. (2015) reported 53 species from a large area within Amazon forest, while Argôlo (2004) obtained 61 species from the southern coastal region of Bahia, covering several types of habitats.

Stomach content in eleven species was found with lizards representing 40% of food items, amphibians 20%, mammals and snakes 15% each, fishes and invertebrates 5% each. Some of these natural history notes are complemented by references. For example, Mesquita et al. (2011) observed *Philodryas nattereri* to be more active during the warmest period of the day, as well as the ingestion of *Ameivula ocellifera*, which probably is a common prey since both species are abundant along the coastal region. In contrast, most other species recorded at mid-day were in vegetation or in water, likely due to cooler ambient temperatures. In regards to our night observations, the principal activity of *Helicops angulatus* at the margin of lakes and ponds related to the foraging and predation of *Leptodactylus natalensis*, confirming that this snake occasionally feeds on frogs (Martins and Oliveira 1998). Species belonging to the genus *Chironius* are diurnal predators specialized on frogs, confirmed by us through an unidentified tadpole (total length = 39.4 mm) that was ingested by a juvenile *C. exoletus*

Table 3. Richness of snake species: comparison between the northern coast of Bahia and other regions of Brazil.

References	Richness	Region
Guedes et al. (2014)	112	Caatinga domain
Marques et al. (2001)	74	Serra do Mar (SdM)-RJ-SP-PR-SC
Argôlo (2004)	61	Atlantic forest of South of state of Bahia -BA
Santos-Costa et al. (2015)	52	Floresta Nacional de Caxiuana-PA
This study	49	North coast of Bahia
França and Braz (2013)	47	Parque Nacional Chapada dos Veadeiros-GO
Loebmann and Haddad (2010)	44	Planalto do Parnaíba-CE
Sawaya et al. (2008)	36	Estação Ecológica de Itirapina-SP
Hartmann et al. (2009a)	27	Núcleo Santa Virgínia, SdM-SP
Marques and Sazima (2004)	25	Estação Ecológica Juréia Martins-SP
Miranda et al. (2012)	24	Parque Nacional dos Lençóis Maranhenses
Hartmann et al. (2009b)	24	Núcleo Picinguaba, SdM-SP
Strussmann and Sazima (1993)	22	Pantanal
Mesquita et al. (2013)	22	Caatinga-CE

(SVL = 190 mm) (Dixon et al. 1993, Pinto et al. 2008). However, the ingestion of a *Hemidactylus mabouia* by *C. flavolineatus* could also represent an opportunistic, likely nocturnal predation event. Alencar et al. (2012, 2013) state that lizards are the most frequent food item of *Oxyrhopus trigeminus*, but Bernarde and Abe (2010) classified it as a nocturnal generalist. However, our survey and predation records show the species may also forage during day, as we found two diurnal lizard species in its diet, *Ameivula ocellifera* and *Tropidurus hygomi*. Alternatively, these lizards were found sleeping and preyed on during nocturnal foraging. Ophiophagy is also common in the genus *Micrurus* (Campbell and Lamar 2004), yet there was no previous record of *M. ibiboboca* ingesting *Amerotyphlops brongersmianus*. We also report the first cannibalism event of *O. trigeminus* in which a specimen (SVL = 390 mm) ingested a juvenile (SVL approximately 140 mm). The ingestion of rodents by vipers is widely reported (Martins and Oliveira 1998, Argôlo 2004) and is confirmed herein with a rat (*Rattus* sp.) ingested by a juvenile *Crotalus durissus cascavela* (SVL = 275 mm) and two *Rattus norvegicus* ingested by adults of *Bothrops leucurus*. But we also detected the remnants of the lizard *Tropidurus hispidus* in the stomach of *B. leucurus* near the Instituto da Mata. *Sibynomorphus newwiedi* feeds exclusively on slugs (Maia-Carneiro et al. 2012), which was also confirmed in this study, similar to the ingestion of fish by *Helicops leopardinus* (Ávila et al. 2006), for which we recorded the fish *Geophagus brasiliensis* as prey.

Aspects of snake conservation on northern coastal Bahia

The herpetofauna of the north coast of Bahia is mainly threatened by habitat loss and degradation, including the ongoing expansion of residential areas and hotel-resorts

(Tinôco 2011). IUCN (2014) lists only *Siphlophis compressus*, *Thamnodynastes pallidus*, *Erythrolamprus viridis*, *Bothrops erythromelas*, *B. lutzi* and *Crotalus durissus* as species of Low Concern. The threat of habitat loss is listed for *S. compressus*, whereas the status of *E. viridis* only relates to Caatinga specimens, and is not including *E. viridis viridis* found in the Atlantic forest.

Another deleterious aspect to snake conservation is the negative human perception towards snakes. Religious beliefs and superstition transcend an ancient fear about these animals, combined with the lack of contemporary knowledge (Greene 1997, Shine and Bonnet 2000, Fernandes-Ferreira et al. 2011), which results in countless killing of snakes including non-venomous and mimetic species. The presence of snakes around human habitation often leads to the death of these animals due to the prejudiced perception and low education of residents (Moura et al. 2010). In this study, we observed animals with damaged heads and bodies, mainly viperids (*Bothrops erythromelas*, *B. leucurus*, *B. lutzi*), but also colubrids and dipsadids (*Chironius flavolineatus*, *Erythrolamprus almadensis*, *Lepotideira annulata*, *Oxyrhopus trigeminus*, *O. petolarius*, *Philodryas olfersii*, *Spilotes pullatus* and *Micrurus ibiboboca*). Furthermore, accidental and intentional road killing are additional factors that affect snake populations negatively (Weatherhead and Madsen 2009).

Twelve species were classified as common or intermediately frequent. Since snakes are difficult to sample (Sawaya et al. 2008, Gaston and Fuller 2007), this emphasizes that common and easily sampled species are relevant to better understand the biology of snakes and to better contribute to the conservation of a region as a whole. This study attempts to report for the first time all known snake species from the northern coast of Bahia. This region exhibits a snake species diversity as high as the southern part of the state of Bahia, which likely is the consequence of its distinct mosaic nature of habitat related species assemblages, including species from three distinct morphoclimatic domains, Cerrado, Caatinga, and Tropical Atlantic domains (Xavier et al. 2015). The 17 undetected species during the three years of fieldwork might have become extinct in the region, or simply require more field effort to be detected. Nonetheless, it reflects the lack of knowledge about the status of the northern coast of Bahia. We recommend continuation of monitoring programs, especially those of the forest fragments and inner portions of the region. This will provide an updated overview on the suggested extinct or threatened species, as well as all other species recorded here for the first time and new records.

Key to snake species from northern coastal Bahia

- 1 Rudimentary eyes; ventral and dorsal scales of equal size.....
.....**Typhlopidae** (*Amerotyphlops brongersmianus*)
- Developed eyes; ventral scales larger than dorsals **2**
- 2 Presence of loreal pit; solenoglyph dentition; keeled scales **Viperidae**
- Absence of loreal pit..... **3**
- 3 Robust body; small undifferentiated cephalic scales; more than 30 dorsal scales.....**Boidae**

- Distinctive cephalic scales 4
- 4 Proteroglyph dentition..... **Elapidae**
- Aglyph or opisthoglyph dentition **Colubridae** and **Dipsadidae**

Viperidae

- 1 Tail tip with distinguished structures 2
- Tail tip undistinguished; postocular stripe present 3
- 2 Tail with rattle; brown arrow shaped dorsal scales with white bordered and dark center diamond shape ***Crotalus durissus cascavela***
- Tail tip with spiked scales; orange coloration with dark diamond blotches along the body; postocular stripe present ***Lachesis muta rhombeata***
- 3 Dorsal scales with 19 or 21 rows; Pale brown coloration, reddish blotches half-moon shaped with circular spots on margin; fewer than 158 subcaudals.....
..... ***Bothrops erythromelas***
- Dorsal scales with 21 or more rows 4
- 4 Dorsal coloration varies from grayish to dark brown; Dark dorsal blotches bow shaped bordered by 1–2 white scales and separated by circular blotches; venter cream and pigmented; Immaculate supralabials. 172–212 ventrals.....
..... ***Bothrops leucurus***
- Ground color grayish with elongated dark blotches half-moon shaped; Occasional white spots on supralabials; 153–156 ventrals for three specimens from north of Salvador (elsewhere 161–179, Campbell and Lamar 2004)
..... ***Bothrops lutzi***

Boidae

- 1 Labial pits present; dark stripes on head 2
- Labial pits absent 3
- 2 Deep labial pits; variable coloration, usually brown, with dark round blotches along the body; long and prehensile tail; higher than 105 subcaudals
..... ***Corallus hortulanus***
- Shallow labial pits; amber coloration with lighter ocelli on dorsum; lateral white and brown stripes present at 1/3 of the body; lateral ocelli uniform of brownish coloration and white spots on top; 40–60 subcaudals
..... ***Epicrates assisi***
- 3 Large sized snake; olive green dorsal coloration with black ocelli along the body; venter yellowish and pigmented ***Eunectes murinus***
- Grayish coloration with brown blotches; lateral brown ocelli; tail with reddish brown blotches separated by a white stripe; postocular stripe present
..... ***Boa constrictor constrictor***

Elapidae

- 1 Monadal pattern with white or yellowish edges of black rings separated by red rings; black head cap from rostral to parietals; tail with black and white rings.....*Micrurus corallinus*
- Triad pattern separated by red rings; black rings of similar size intercalated with white rings; 8–12 triads on body; divided cloacal plate; 212–244 ventrals; 18–30 subcaudals.....*Micrurus ibiboboca*

Colubridae and Dipsadidae

- 1 Even dorsal scale rows.....2
- Odd dorsal scale rows6
- 2 Higher than 14 scale rows; apical pits presents; round pupil; black coloration and yellowish venter occasionally reaching dorso-lateral region.....*Spilotes pullatus pullatus*
- Fewer than 12 scale rows; keeled paravertebral scale rows; light vertebral stripe present3
- 3 Brown head; grayish-black coloration bordering the light stripe up to 1/3 of body; brown on the remaining body; 12/12/8 scale rows, rarely 12/12/10....*Chironius flavolineatus*
- Coloration not as above4
- 4 12/12/10 scale rows; olive dorsum; light stripe bordered by black line; yellowish venter from labials; divided subcaudals with dark stripe between them....*Chironius bicarinatus*
- 12/12/8 or 14/12/8 scale rows5
- 5 Olive dorsum at 1/3 of the body and brownish on the remaining portion; paravertebrals in lighter coloration; yellowish venter up to labials; dark stripe dividing dorsals and subcaudals; 132–144 ventrals.....*Chironius exoletus*
- Dark olive dorsum, lighter towards the venter; white chin; yellow venter; dorsal scales on tail with yellow center; 12/12/8 or 14/12/8 scale rows*Chironius carinatus*
- 6 17 or less scale rows at midbody7
- 19 or more scale rows at midbody.....20
- 7 15 scale rows on midbody.....8
- 17 scale rows on midbody.....14
- 8 15/15/11 scale rows; keeled dorsal scales; metallic green with brown vertebral stripe; dark stripe above supralabials up to the end of head; big eye with round pupil*Leptophis abaetulla liocercus*
- 15/15/15 scale rows9
- 9 Two black ring pattern separated by red rings; black rings separated by white or yellow rings; big and dark eyes; opisthoglyph dentition; 179–195 ventrals; 35–46 subcaudals*Erythrolamprus aesculapii venustissimus*

- Brown or green coloration, never red..... **10**
- 10 Brownish head and dorsum; elliptical pupil; dark brown bands on dorsum; 163–182 ventrals; 59–77 subcaudals; single anal plate *Sibynomorphus newwiedi*
- Ocelli or uniform pattern; divided anal plate **11**
- 11 Brown head; Ocelli behind the head up to midbody; dorsum greyish to reddish-brown; yellowish venter; 160–173 ventrals; 70–77 subcaudals.....
..... *Taeniophallus occipitalis*
- Not as above..... **12**
- 12 Body uniform brown; pigmented head and nuchal stripe; vertebral stripe; small eye; 138–156 ventrals; 50–63 subcaudals..... *Tantilla melanocephala*
- Uniform, ocelli or dark bands pattern..... **13**
- 13 Dark brown or dark green coloration; juveniles present brown or reddish bands separated by white or cream stripes; 157–180 ventrals; 86–110 subcaudals...
..... *Drymoluber dichrous*
- Brown head; dorsum light brown with dark ocelli; lateral blotches of the same color; venter lightly pigmented; ≥ 165 ventrals; ≥ 87 subcaudals
..... *Mastigodryas bifossatus*
14. Without scale row reduction; vertebral scales modified; slender body; head strongly distinct; big eyes and elliptical pupil; brownish coloration with dark diamond shape blotches..... *Imantodes cenchoa cenchoa*
- With scale row reduction **15**
- 15 17/17/13 scale rows **16**
- 17/17/15 scale rows **17**
- 16 Elongated head and slender body; big eyes with round pupil; brown coloration; chin and ventral gular portion yellowish or white; Dark oral mucosa...
..... *Oxybelis aeneus*
- Smooth scales; single anal plate; 2+2/2+3 temporals; postocular brown stripe; yellow gold coloration with black and yellow spots up to midbody.....
..... *Thamnodynastes pallidus*
- 17 Single anal plate; juveniles present yellowish coloration with darker transversal bands; adults present approximately dark anterior up to 2/3 of the body and yellow to the remaining portion; yellow venter..... *Drymarchon corais corais*
- Divided anal plate..... **18**
- 18 Green-brownish coloration; single apical pit present; dorsolateral stripes from midbody to the end of tail; supralabials, chin and venter yellowish; Venter with alternating dark bands *Erythrolamprus reginae semilineatus*
- Without apical pits **19**
- 19 Head light-brown; supralabials cream with black border; olive dorsum; black nuchal stripe followed by a cream stripe; venter yellow-cream with black blotches *Erythrolamprus miliaris merremi*
- Dorsum black with transversal cream stripes; supralabials lighter than dorsum; white chin; reddish venter with 25–35 black bands
..... *Erythrolamprus taeniogaster*
- 20 Without apical pits **21**

–	With apical pits	26
21	Single internasal scale.....	22
–	Pair of internasal scales	23
22	Dorsum light-brown or cream with dark blotches; scales strongly keeled; cream venter with black bands; 112–124 ventrals; 79–99 subcaudals.....	
 <i>Helicops angulatus</i>	
–	Olive coloration with dark ocelli; scales weakly keeled; red venter with black bands; white chin; 121–133 ventrals; 57–79 subcaudals ...	<i>Helicops leopardinus</i>
23	Brown coloration lighter on the head; white or cream supralabials, chin and venter; modified rostral scale; smooth scales.....	<i>Phimophis guerini</i>
–	Regular rostral scale	24
24	Green coloration; juveniles present dark green with black spots along the body; supralabials, chin and anterior portion of body yellowish; 19/19/17 scale rows; >176 ventrals.....	<i>Erythrolamprus viridis viridis</i>
–	Other color pattern.....	25
25	Top of the head brown with a cream or white V or Y shape mark; Dorsum present brownish bands divided by grayish stripes; dorsolateral cream stripes; orange-reddish venter with black bands; 19/19/17 scale rows	
 <i>Erythrolamprus almadensis</i>	
–	19/19/15 scale rows; Brownish coloration, occasionally with diagonal black ribs; cream venter weakly pigmented....	<i>Erythrolamprus poecilogyrus schotti</i>
26	Single apical pit	27
–	Two apical pits	30
27	Body uniform green, venter in lighter coloration; long tail; divided anal plate; 164–208 ventrals; 92–132 subcaudals.....	<i>Philodryas olfersii herbeus</i>
–	Brown pattern, never green.....	28
28	Brown head; coloration varies from uniform brown to grayish; White venter; divided anal plate; 166–189 ventrals; 76–113 subcaudals	
 <i>Philodryas patagoniensis</i>	
–	19/19/17 scale rows arranged in oblique rows.....	29
29	Head with small blotches and stripes from internasals to postocular portion; brown coloration with bow shape blotches connected bilaterally or usually alternated.....	<i>Xenodon merremii</i>
–	Single blotch on head bifurcated on the neck; Brown dorsum with dark bow shape blotches along the body; pigmented venter.....	
 <i>Xenodon rhabdocephalus rhabdocephalus</i>	
30	Modified vertebral row; orange head; juveniles present white stripe on parietals; black nuchal stripe and red-wine coloration with black bands; white venter; >230 ventrals; >105 subcaudals	<i>Siphlophis compressus</i>
–	Vertebral scales not modified	31
31	Keeled scales in 19 or 21 rows; brown head; Internasals, prefrontals and labials pigmented; black postocular stripe present; dark-brown dorsum, yellowish towards the venter with black diagonal stripes	
 <i>Spilotes sulphureus sulphureus</i>	

- Smooth scales 32
- 32 19 or 21 scale rows; brown head, darker on parietals; juveniles present white stripe on parietals; brown coloration with dark blotches *Leptodeira annulata annulata*
- Pattern black, brown or with red, black and white rings 33
- 33 21 scale rows; brown head with white stripes above the eyes up to parietals; white supralabials weakly pigmented; brown-grayish coloration with dorso-lateral dark stripes and white paraventral stripe; white venter with dark stripe on edge of ventrals *Philodryas nattereri*
- 19 scale rows, single anal plate 34
- 34 Uniform coloration with or without irregular spots 35
- Pattern of black, red and white rings, white venter 36
- 35 Black or dark-brown coloration; juveniles present a white stripe on head, dark nuchal stripe and red-wine coloration; 207–235 ventrals; 53–81 paired subcaudals *Clelia plumbea*
- Black coloration with or without white blotches; juveniles present a white stripe on head, dark nuchal stripe and red-wine coloration; 188–202 ventrals; 81–97 single subcaudals *Pseudoboia nigra*
- 36 Black head up to parietals; supralabials grayish; red nuchal stripe; triad of black and white rings separated by red rings; white chin *Oxyrhopus trigeminus*
- Black head with red nuchal stripe; juveniles present black and white coloration; adults present black and red coloration *Oxyrhopus petolaris digitalis*

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Appendix I

Museums examined voucher specimens from the municipalities of the study in alphabetical order.

Amerotyphlops brongersmianus: Camaçari: MZUFBA 1725. Conde: CHECOA 2896. Mata de São João: CHECOA 1093, 1304, 1592, 2953, MZUEFS 1421. ***Boa constrictor constrictor***: Camaçari: CHECOA 2777. Catu: CHECOA292. Mata de São João: CHECOA 2778, MZUFBA 1968. ***Bothrops erythromelas***: Camaçari: MZUFBA 499. Lauro de Freitas: MZUFBA 1366. ***Bothrops leucurus***: Camaçari: CHECOA 2875, MZUEFS 381, 882, 1075, MZUFBA 320, 494, 499, 501, 695, 696, 697, 698, 699, 744, 745, 749, 869, 874, 875, 878, 917, 922, 932, 937,939, 940, 996, 1220, 1223, 1225, 1226, 1228, 1239, 1241, 1242, 1249, 1257, 1281, 1901. Catu: MZUFBA 473, 476, 941, 1950, 2411, 2437. Conde: MZUFBA 1255. Dias D’Ávila: MZUEFS 1179, 1180, 1467, MZUFBA 1528, 2409. Entre Rios: MZUEFS 1745. Esplanada: CHECOA 194. Itanagra: MZUFBA 746, 876, 925, 928, 938, 1246. Jandaíra: MZUEFS 8634, MZUFBA 901. Lauro de Freitas: MZUFBA 739, 923, 930, 936, 1250, 1254, 1447, 1633, 1634, 1878, 2020, 2116, 2139, 2151, 2227. Mata de São João: CHECOA 1055, 1251, 1257, 1258, 1302, 1303, 1334, 1335, 1336, 1337, 1338, 1339, 1343, 1345, 1599, 1894, 2468, 2781, 2782, 2783, 2784, 3088, MZUEFS 488, 1021, 1107, 1425, 1426, 1427, 1429, 1507, MZUFBA 420, 495, 693, 752, 812, 931, 933, 1227, 1229, 1240, 1243, 1406, 1526, 1532, 1547, 1885, 1886. Pojuca: MZUFBA 701. Simões Filho: MZUFBA

314, 487, 491, 497, 700, 747, 748, 814, 868, 909, 916, 919, 924, 1001, 1248, 1546, 1876, 1880, 1997, 2112, 2115, 2223, 2438. ***Bothrops lutzi***: Camaçari: MZUFBA 985, 986, 1191. ***Chironius exoletus***: Catu: CHECOA 278, 290, 291, MZUFBA 466, 467. Entre Rios: 1591. Mata de São João: CHECOA 1314, 1325, 1327, 1340, MZUFBA 418, 2209. Simões Filho: MZUFBA 619. ***Chironius flavolineatus***: Camaçari: CHECOA 2918, 2998, MZUFBA 1199. Catu: MZUFBA 610. Conde: CHECOA 1589. Dias D'Ávila: MZUEFS 1469. Entre Rios: CHECOA 1583. Itanagra: MZUFBA 401. Lauro de Freitas: MZUFBA 1277. Mata de São João: CHECOA 1297, 1298, 1326, 1328, 1575, 1896, 1897. Simões Filho: MZUFBA 1603. ***Clelia plumbea***: Catu: CHECOA 265, 269, 294. ***Corallus hortulanus***: Lauro de Freitas: CHECOA 2801. ***Crotalus durissus cascavella***: Camaçari: MZUFBA 1003, 1549, 2363. Catu: CHECOA 196, MZUFBA 455. Entre Rios: CHECOA 2859. Esplanada: MZUFBA 907. Lauro de Freitas: MZUFBA 2143, 2148. Mata de São João: CHECOA 1111, 1112, 1344, 2788, 2789. ***Drymarchon corais corais***: Catu: CHECOA 284. Dias D'Ávila: MZUEFS 1466. ***Drymoluber dichrous***: Catu: CHECOA 176, MZUFBA 2156, 2158, 2162. ***Epicrates assisi***: Mata de São João: CHECOA 1613. ***Erythrolamprus aesculapii venustissimus***: Lauro de Freitas: MZUEFS 733. ***Erythrolamprus almadensis***: Camaçari: MZUFBA 833 1284. Catu: CHECOA 276. Dias D'Ávila: MZUEFS 1463, 1464. Lauro de Freitas: MZUEFS 741, 744, MZUFBA 1283. Mata de São João: CHECOA 1418, 1419, MZUEFS: 1423, 1422. Pojuca: CHECOA 239, 240, 241, 242, 243. ***Erythrolamprus miliaris merremi***: Dias D'Ávila: MZUEFS 1172. Pojuca: CHECOA 244. Simões Filho: CHECOA 2912. ***Erythrolamprus poecilogyrus schotti***: Camaçari: MZUFBA 300. Catu: CHECOA 251, 268, MZUFBA 478, 765, 538. Mata de São João: CHECOA 1577, MZUFBA 410, 423, 424, 425, 426. Lauro de Freitas: MZUEFS 739. Pojuca: CHECOA 222, 223, 224, 228, 229, 230, 245, 246. ***Erythrolamprus reginae semi-lineatus***: Catu: CHECOA 293, MZUFBA 487, 288. Mata de São João: CHECOA 2588. Pojuca: CHECOA 234, 235, 236, 237. ***Erythrolamprus taeniogaster***: Camaçari: MZUFBA 563. Catu: CHECOA 270, 271, 272, MZUFBA 474, 479. Lauro de Freitas: MZUFBA 1559, 2484. Mata de São João: CHECOA 1593, 2791, MZUFBA 1640. Simões Filho: MZUFBA 608. ***Erythrolamprus viridis viridis***: Mata de São João: MZUFBA 429. ***Eunectes murinus***: Camaçari: MZUEFS 1074. Mata de São João: MZUFBA 2395. ***Helicops angulatus***: Camaçari: CHECOA 2904, MZUFBA 333. Catu: CHECOA 255, 256, MZUFBA 461, 163, 2159. Mata de São João: CHECOA 1895, 2773. Simões Filho: MZUFBA 1935. ***Helicops leopardinus***: Camaçari: MZUFBA 1939. Catu: CHECOA 279, 280, MZUFBA 462. Lauro de Freitas: MZUEFS 1044, MZUFBA 1286, 2140, 2152. Mata de São João: CHECOA 1247, 1260. Pojuca: CHECOA: 225, 231, 232. ***Imantodes cenchoa cenchoa***: Mata de São João: CHECOA 2883. Simões filho: MZUFBA 2867. ***Leptophis abaetulla liocercus***: Catu: MZUFBA 2219. Mata de São João: CHECOA 2952. Simões Filho: MZUFBA 510. ***Leptodeira annulata annulata***: Camaçari: MZUEFS 1090, MZUFBA 633. Catu: MZUFBA 570. Entre Rios: CHECOA 1585, MZUEFS 1744, 1746. Jandaíra: CHECOA 2965. Lauro de Freitas: MZUEFS 693, MZUFBA 493. Mata de São João: CHECOA 1089, 1255, 1330, 1331, 1332, 1341, 1590, 1601, 2779, 2780, MZUEFS 1428. ***Mastigodryas bifossatus***: Catu: MZUFBA 841. Jandaíra: MZUESC 3238. Lauro de Freitas: MZUFBA 569. Mata

de São João: MZUFBA 422. **Micrurus ibiboboca**: Camaçari: CHECOA 743, 2909, MZUFBA 403, 773, 787, 1016, 1276, 1358, 1388, 1635, 2334, 2335. Catu: CHECOA 193, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 220, MZUFBA 469, 470, 471, 566, 567, 612, 613, 614, 615, 632. Dias D'Ávila: MZUEFS 1460, 1461, 1462, MZUFBA 371. Entre Rios: CHECOA 1470. Esplanada: CHECOA 2900. Lauro de Freitas: MZUEFS 748, MZUFBA 1441, 1870, 1947, 1948, 1974, 2297, 2404. Mata de São João: CHECOA 1051, 1054, 1077, 1114, 1148, 1293, 1294, 1295, 1410, 1597, 1602, 1604, 1606, 1607, 1608, 2115, 2792, 2966, 3091, 3113, MZUFBA 409, 436, 450, 980, 1462, 1972, 2237, 2454. Simões Filho: MZUEFS 516, 1050, MZUFBA 636, 772, 774, 813, 2373. **Micrurus corallinus**: Simões Filho: MZUFBA 997. **Oxybelis aeneus**: Catu: CHECOA 286, MZUFBA 472, 2157. Mata de São João: CHECOA 1048, 1254. **Oxyrhopus petolarius digitalis**: Camaçari: MZUFBA 1285, Catu: MZUFBA 764. Mata de São João: CHECOA 88, 2964, 3092. **Oxyrhopus trigeminus**: Camaçari: CHECOA 2910, 2911, MZUFBA 375, 384, 444, 629, 1321, 1298. Catu: MZUFBA 468, 475, 2155. Dias D'Ávila: MZUEFS 1465. Entre Rios: CHECOA 1584. Lauro de Freitas: MZUEFS 745, MZUFBA 343, 417, 786, 943, 1932, 1942. Mata de São João: CHECOA 1146, 1147, 1253, 1296, 1316, 1317, 1318, 1415, 1582, 1594, 1596, 1598, 1600, 2790, MZUEFS 437, 855, MZUFBA 413, 414, 415, 416. Simões Filho: MZUFBA 443. **Pantherophis guttatus**: Camaçari: CHECOA 142.

Phimophis guerini: Camaçari: MZUFBA 1960, 2471. Mata de São João: CHECOA 1411, 1420. **Philodryas nattereri**: Camaçari: MZUFBA: 1961. Catu: MZUFBA 465. Mata de São João: CHECOA 1305, 1320, 1321, 1322, 1587, MZUFBA 1431, 2238, 2371. **Philodryas olfersii herbeus**: Camaçari: CHECOA 2421, 2906. Catu: CHECOA 257, 266. Dias D'Ávila: MZUFBA 1426. Jandaíra: 2527. Lauro de Freitas: MZUFBA 643, 2341, 2491. Mata de São João: CHECOA 1052, 1062, 1299, 1300, 1301, 3089. **Philodryas patagoniensis**: MZUEFS 1407. Camaçari: CHECOA 1109, 1410, 2884, 2908, MZUFBA 356, 1275, 1282, 1297, 1364, 1491, 1492, 2282. Catu: CHECOA 258, MZUFBA 1281. Lauro de Freitas: MZUFBA 1278, 1294. Mata de São João: MZUEFS 599. **Pseudoboa nigra**: Camaçari: CHECOA 1053, MZUFBA 492, 1323, Catu: MZUFBA 484, 485. Mata de São João: MZUFBA 421, 2435. **Sibynomorphus newwiedi**: Catu: CHECOA 252, 253, 254, 259, 260, 261, 262, 263, 264, 287, 288. Mata de São João: CHECOA 2965, 3090 Pojuca: CHECOA 247. **Siphlophis compressus**: Mata de São João: CHECOA 2854. **Spilotes pullatus pullatus**: Camaçari: MZUFBA 2142. Mata de São João: CHECOA 1422, 2785, 2786, MZUEFS 1093, 1307. Simões Filho: MZUFBA 621. **Taeniophallus occipitalis**: Camaçari: MZUEFS 1308. Mata de São João: CHECOA 1049, 1262, 3093. **Tantilla melanocephala**: Camaçari: CHECOA 2065, MZUFBA 1726, 1727. Mata de São João: CHECOA 1256, 1313, 1315, 1342, 1603, 1893, 2798. **Thamnodynastes pallidus**: Mata de São João: CHECOA 2852. **Xenodon merremii**: Camaçari: CHECOA 2907, MZUFBA 396, 449, 452, 1311. Catu: CHECOA 283, MZUFBA 456, 458, 459, 460, 464, 477. Dias D'Ávila: MZUEFS 1468. Mata de São João: CHECOA 226, 1306, 2787, MZUFBA 405, 411, 850, 1007, 1437, 1527. Pojuca: MZUFBA 298. **Xenodon rabdocephalus rabdocephalus**: Camaçari: MZUFBA 442. Catu: MZUFBA 831, 2154.