

# A new species of *Dicranocentrus* (Collembola, Entomobryidae) from China with comments on the systematic position of the genus

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## Abstract

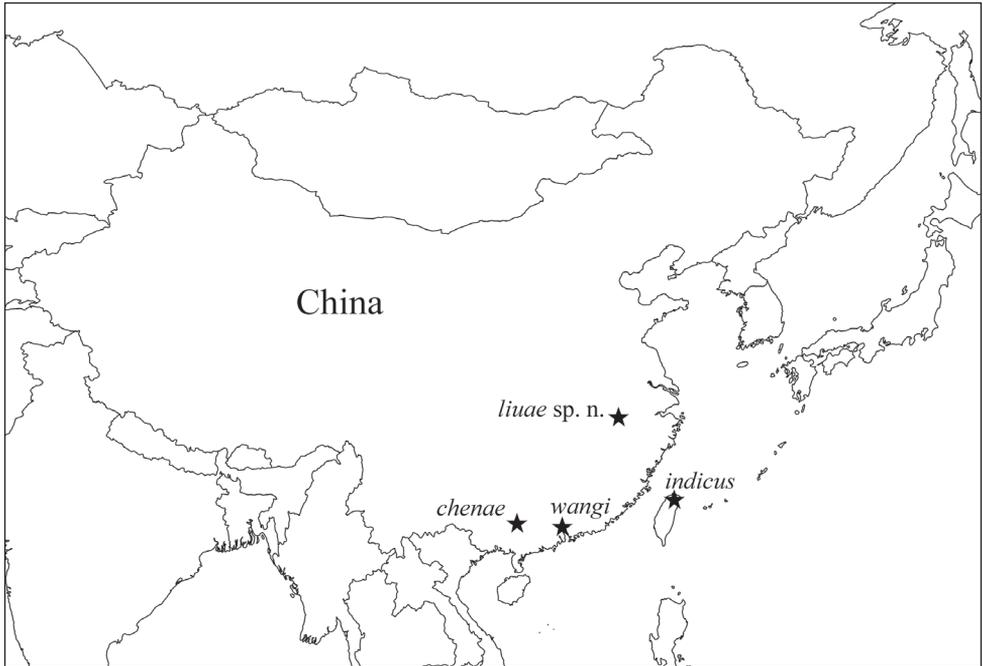
*Dicranocentrus liuae* sp. n. is described from the northern subtropical region of China. The new species is most similar to *D. wangi* Ma & Chen, 2007, but differs from it in the relatively shorter Ant. V, the 1+1 central macrochaetae on Abd. III, the number of chaetae on tenaculum, and the absence of dental spines. The systematic position of *Dicranocentrus* is also discussed. Present evidence, particularly S-chaetotaxy, indicates that the genus is closer to *Heteromurus* than to the unscaled species of *Orchesella* and *Orchesellides*.

## Keywords

*D. liuae* sp. n., chaetotaxy, Orchesellinae, *Heteromurus*

## Introduction

The genus *Dicranocentrus* was erected by Schött (1893) for *D. gracilis*. It is characterized by 6-segmented antennae, the ratio between abdominal segments IV/III less than 2.0, scales present on antennae, legs, body, manubrium and ventral side of dens, eyes



**Figure 1.** Geographical distribution of *Dicranocentrus* species from China.

8+8, postantennal organ absent, and mucro bidentate with a basal spine. Mari-Mutt (1979) published an excellent revision of the taxonomy, biology, and geographical distribution. Mari-Mutt (1980) divided the Orchesellinae into four tribes mainly based on the number of antennal segments, with Orchesellini (*Dicranocentrus* included), Heteromurini and Corynothrichini having 6, 5, and 4 segments, respectively. Soto-Adames (2008) did not change Mari-Mutt's taxonomical framework, but simply added two new small tribes. However, recent molecular phylogeny of the Entomobryidae (Zhang et al. 2014a) placed *Dicranocentrus* together with *Heteromurus* in a separate clade, apart from the unscaled taxa (*Orchesella*/*Orchesellides*).

So far, three *Dicranocentrus* species have been reported from China: *D. indicus* Bonet, 1930 from Taiwan, *D. chenae* Ma, Chen & Soto-Adames, 2006 from Guangxi, and *D. wangi* Ma & Chen, 2007 from Gangdong (Fig. 1). Here, we describe a new species from the northern subtropical region of China, compare it with other orchesellids, and discuss the systematic position of the genus.

## Materials and methods

Specimens were mounted in Marc André II solution after clearing in lactic acid and were studied using a Nikon E600 and SMZ-1000 microscope. Photographs were en-

hanced with Photoshop CS2/PC (Adobe Inc.). The number of macrochaetae is given by half-tergite in the descriptions. Dorsal cephalic chaetotaxy and interocular chaetae follow Mari-Mutt (1979, 1986). Types are deposited in the collections of the Department of Entomology, College of Plant Protection, Nanjing Agricultural University (NJAU), P. R. China.

Abbreviations. Th. I–III – thoracic segment I–III; Abd. I–VI – abdominal segment I–VI; Ant. I–IV – antennal segment I–IV; mac – macrochaeta/ae; mic – microchaeta/ae; ms – S-microchaeta/ae; sens – ordinary tergal S-chaeta/ae; post-labial quadrangle – PLQ.

## Taxonomy

### *Dicranocentrus liuae* sp. n.

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Figs 2–14, Table 1

**Type locality.** China, Anhui, Shitai, Guniujiang, 30.092°N, 117.482°E, altitude 208m.

**Material.** Holotype: ♀ on slide, China, Anhui, Shitai, Guniujiang, the entrance of Yan hamlet, 30.092°N, 117.482°E, altitude 208m, 15 August 2011, F Zhang, DY Yu and YH Ren leg. (#C9676). Paratypes: 3 ♀♀ and 1 ♂ on slides, 4 in alcohol, same data as holotype. Other material: 1 ♀ on slide, China, Anhui, Shitai, Gongxi, 27 August 1994, JX Chen leg. (#C8391); 1 ♀ on slide, China, Zhejiang, Jin Xian, Tiantongshan National Natural Reserve, 10 June 1995, JX Chen leg. (#C8458).

**Description.** Body length up to 1.8 mm.

Ground colour pale yellow. Eye patches dark. Blue pigment present on antennae and legs (Fig. 2). Scales brown, rounded, truncate, or pointed with numerous short striations; scales present on Ant. I–IV, body, legs, both side of ventral tube and manubrium, and ventral side of dens.w

Antenna 2.0–2.7 times as long as cephalic diagonal. Ant. V and VI annulated and their length ratio as 1.2–0.7 : 1. Four types of common chaetae observed: ciliate, thin (Fig. 3A) or thick (Fig. 3B) mic; smooth, straight, spiny mic on Ant. I and III (Fig. 3C); long, straight chaetae smooth or weakly ciliate (Fig. 3D). Most S-chaetae slightly curved, short (Fig. 3 E–I) or long (Fig. 3J). Distal Ant. II with 1 rod-like S-chaeta ventrally (Fig. 3K), 2 strongly curved, thickened S-chaetae externally (Fig. 3 L–M). Ant. VI apical bulb absent.

Eyes 8+8, G and H smaller. Prelabral and labral chaetae 4/5, 5, 4, all smooth; prelabral ones stronger than labral ones. Labral papillae 4, cone-like with apical spine often curved (Fig. 4). Mandibles with 4+5 apical teeth. Lateral process of labial palp papillae E as thick as normal chaetae, with tip not reaching apex of labial papilla. Sub-apical chaeta of maxillary outer lobe thicker than apical; 3 smooth sublobal hairs on maxillary outer lobe. Labium with 5 smooth proximal chaetae and 8–10 submentum chaetae; the most external one A<sub>5</sub> on mentum shorter than A<sub>1–5</sub>; at most 1 ciliate chaeta



**Figure 2.** *D. liuae* sp. n. Habitus.

on submentum (Fig. 5). PLQ chaetae smooth and 2+2 weakly ciliate chaetae posterior to PLQ. Dorsal cephalic chaetotaxy with 10–13 antennal (An), 3 median (M), sutural  $S_{0-7}$ , 1 postocular ( $P_0$ ) and 9 posterior (P) mac. Interocular chaetae 3 as p, s, t (Fig. 6).

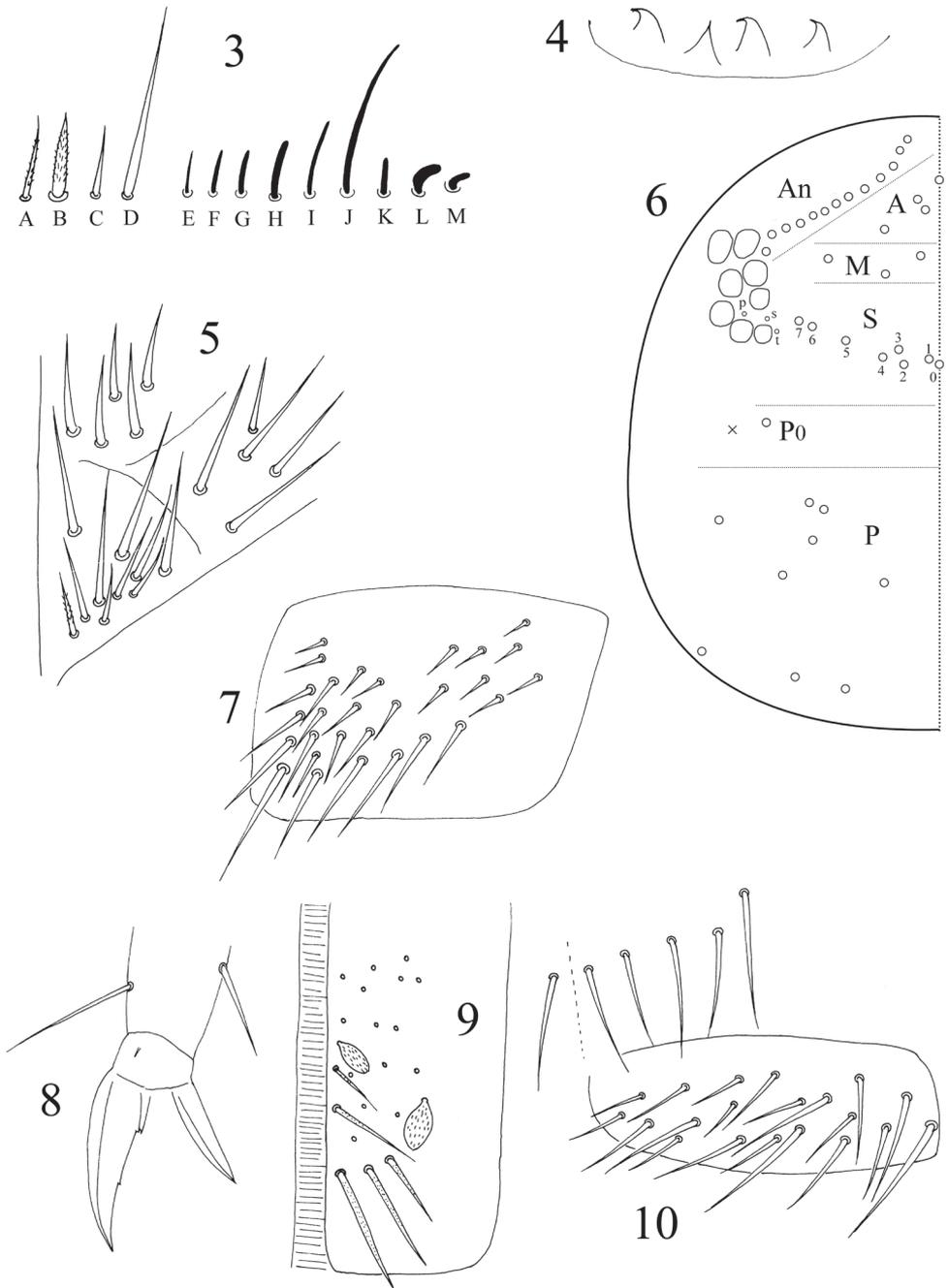
Trochanteral organ with about 30 smooth spiny chaetae (Fig. 7). Some inner differentiated tibiotarsal chaetae smooth under light microscope. Unguis with 3 inner teeth, all minute. Unguiculus lanceolate with outer edge smooth. Tenent hairs acuminate (Fig. 8).

Abd. IV 1.66–1.89 times as long as Abd. III along dorsal midline. Ventral tube anteriorly with many weakly ciliate chaetae and some scales (Fig. 9); posteriorly with many smooth chaetae; both sides with scales; each lateral flap with about 20 smooth chaetae (Fig. 10). Tenaculum with 4+4 teeth, corpus with 2–4 smooth chaetae. Manubrial plaque with 3 pseudopores and 5–9 ciliate chaetae on each side (Fig. 11). Manubrium dorsally with rows of smooth chaetae but their number not clear. Dens without inner spines. Dental of lobe with 1+1 large blunt ciliate and about 5+5 small smooth chaetae. Smooth distal part of dens 4.4–5.7 times as long as mucro; mucro bidentate with two subequal teeth (Fig. 12).

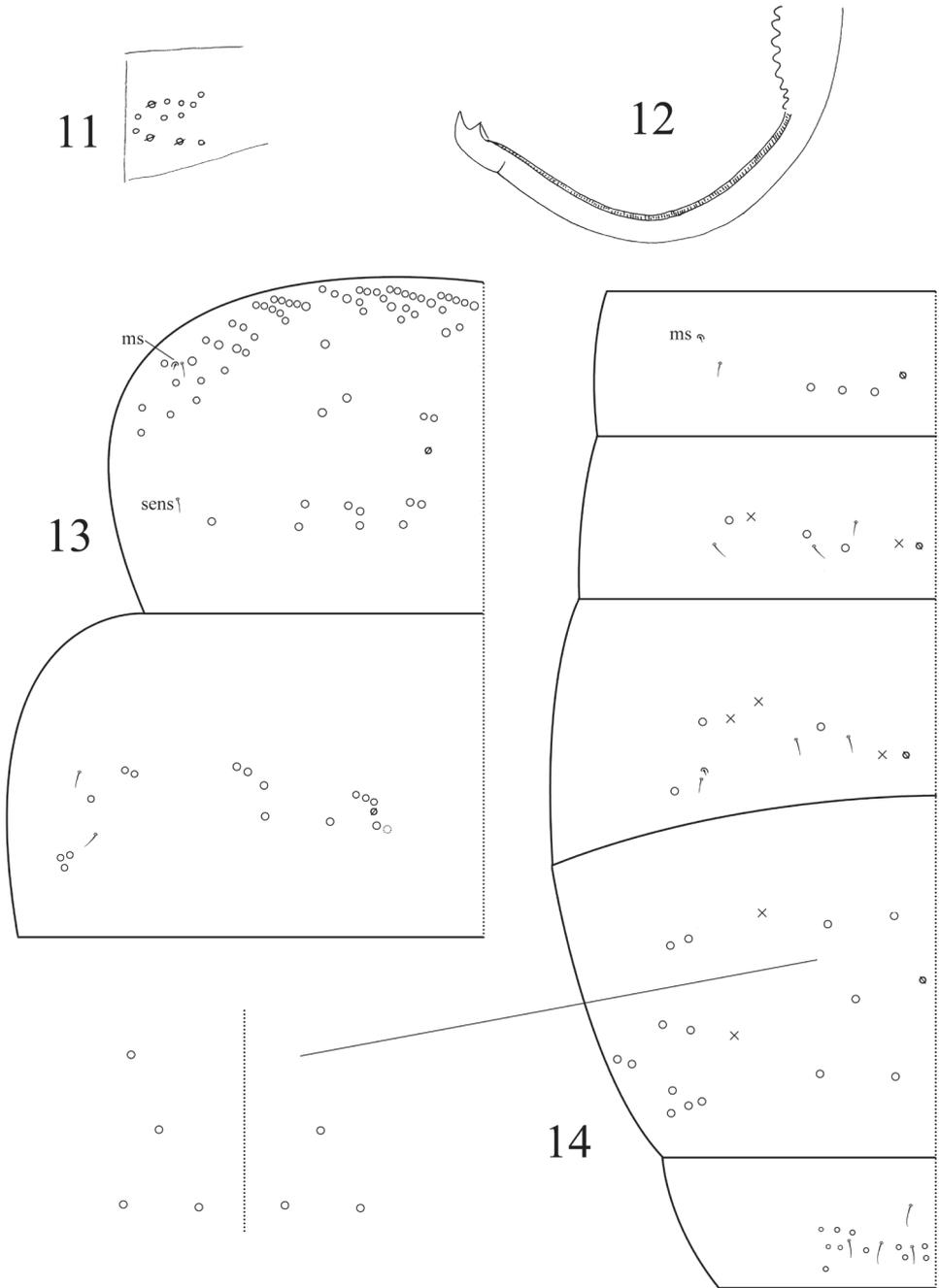
Th. II with 2 inner and 2 outer mac on medial area, 9 posterior mac, 1 ms and 2 sens; anterior ms external to sens. Th. III with 15–16 mac and 2 lateral sens (Fig. 13). Abd. I with 3 mac, 1 ms and 1 sens; ms external to sens. Abd. II with 2 inner, 1 lateral mac and 3 sens. Abd. III with 1 inner, 2 lateral mac, 1 ms and 3 sens. Abd. IV with 3–5 inner, 10 lateral mac, and many (number undetermined) elongate sens. Abd. V with 4 sens (Fig. 14).

**Etymology.** Named after the former member Ms L. Liu in our lab, who initiated the study of the genus in China.

**Ecology.** In litter or on leaves of forest floor.



**Figures 3–10.** *D. liuae* sp. n. **3** antennal chaetae **4** labral papillae **5** labial chaetae **6** dorsal cephalic chaetotaxy **7** trochanteral organ **8** hind claw **9** anterior face of ventral tube **10** distal posterior and lateral flap chaetae of ventral tube.



**Figures 11–14.** *D. liuae* sp. n. **11** manubrial plaque **12** micro **13** thoracic chaetotaxy **14** abdominal chaetotaxy, inset, variation in number of inner mac.

**Table 1.** Comparison between *D. liuae* sp. n. and *D. wangi*.

Characters	<i>D. liuae</i> sp. n.	<i>D. wangi</i>
Ratio of Ant. V/VI	0.7–1.2	1.2–2.3
Posterior cephalic mac	9	5
Lateral flap of ventral tube	about 20	28–50
Chaetae on tenaculum	2–4	4–10
Dental spines	absent	present
Inner mac on Abd. III	1	2

**Remarks.** This new species belongs to *sundanensis*-group according to Mari-Mutt(1979). It is the only member with 1+1 inner mac on Abd. III in *sundanensis*-group. It is most similar to *D. wangi* in labrum, cephalic chaetotaxy, trochanteral organ, tergal chaetotaxy of thorax and Abd. I–II, ventral tube, and claw structure. It differs from the latter in having a shorter Ant. V, 9 posterior cephalic mac, 1+1 inner mac on Abd. III, 2–4 chaetae on tenaculum, and the absence of dental spines (Table 1). S-chaetotaxy is also described in the genus for the first time: ms 1, 0|1, 0, 1, 0, 0 and sens 2, 2|1, 3, 3, ?, 4.

## Discussion

Mari-Mutt (1979) considered that the closest relatives of *Dicranocentrus* were *Orchesella* and *Dicranorchesella* because the three genera shared 6-segmented antennae. None questioned the systematic position of *Dicranocentrus* before the work of Zhang et al. (2014a), who also discussed the disputable use of secondary and unstable structures (such as number of antennal segments and number of chaetae on trochanteral organ) during development in modern taxonomy. Taking no account of antennae, *Dicranocentrus* shares most characters with *Heteromurus*: the presence of the same type of body scales, pigment reduced or scattered on the body, relatively fewer tergal macrochaetae, dental spines often present, and 3 ordinary S-chaetae on Abd. II/III (see also *H. nitidus*, Szeptycki 1979). An additional middle ordinary S-chaeta compared to those on species belonging to the Entomobryini/Willowsiini implies that both *Dicranocentrus* and *Heteromurus* are possibly closer to the Entomobryinae *sensu* Szeptycki, 1979, than previously thought. The pattern of four S-chaetae on Abd. V in *Dicranocentrus* is also similar to that of *Heteromurus* with the latter lacking the middle one. Compared to *Dicranocentrus/Heteromurus*, *Orchesella/Orchesellides* have much more abundant macrochaetae on each tergum and S-chaetae (usually >5) on Abd. II, III and V. The idea that the presence of body scales is a synapomorphy in *Dicranocentrus/Heteromurus* was strongly supported by molecular phylogeny, although body scales cannot be assumed to be a synapomorphy of the scaled genera (Willowsiini) of Entomobryinae by Zhang et al. (2014b). Body scales have been used successfully to define many groups, such as the Tomoceridae, Oncopoduridae, Seirinae, Lepidocyrtinae, and Cyphoderinae.

Mari-Mutt (1979) proposed that *Dicranocentrus* originated from *Orchesella* via an intermediate stage represented by *Dicranorchesella* (with short ciliated chaetae and scales present). Mari-Mutt (1979) stated that *Dicranorchesella*, which has abundant cephalic and tergal macrochaetae, is quite close to *Orchesella*. However, of the pointed and fusi-form scales of *Dicranorchesella* indicate that it represents a lineage independently derived from *Dicranocentrus*; its relationship with *Orchesella* possibly resembles that of *Willowsia/Entomobrya* as shown by Zhang et al. (2014a, b). A systematic review and phylogeny based on larger samples would ultimately resolve the systematic position of *Dicranocentrus*.

## Acknowledgments

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# The effect of latitudinal gradient on the species diversity of Chinese litter-dwelling thrips

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## Abstract

To understand the global distribution patterns of litter-dwelling thrips, a total 150 leaf litter samples were collected from 6 natural reserves located in three climatic regions, temperate, subtropical and tropical. The results showed the relative abundance of Thysanoptera was over 3.0% in 4 natural reserves from subtropical and tropical zone, and reached 5.9% in one tropical reserve, only less than Acarina and Collembola. In contrast it was only 0.3% in the warm temperate natural reserves, and no thrips were collected in a mid temperate reserve. The order on the average species numbers per plot of litter thrips was tropic > subtropics > temperate ( $n=25$ ,  $p<0.05$ ). Mean density of litter thrips per plots in the tropics and subtropics was significantly higher than that in the temperate region ( $n=25$ ,  $p<0.05$ ), but the average density was not significantly different between tropical and subtropical zones ( $n=25$ ,  $p>0.05$ ). The diversity of litter thrips in the tropics and subtropics was much higher than that in the temperate area based on comparisons of Shannon-Wiener diversity index ( $H'$ ), Pielou evenness index ( $J$ ), and Simpson dominance index ( $D$ ). All of these results indicated that litter-dwelling thrips lived mainly in tropical and subtropical regions; meanwhile, species number and relative abundance increased with decreasing latitude.

## Keywords

Soil invertebrate, leaf-litter thrips, species diversity, latitudinal gradient, global distribution pattern, China

## Introduction

Global distribution patterns of organisms have become a hot research topic in recent years due to increasing concerns about the global loss of species richness (Gaston 2000). The cogent statement of the increase in species diversity from polar to equatorial regions was confirmed by plants and vertebrate animals (Willig et al. 2003), but little is known about global pattern in species level of soil invertebrates, although these are recognized as one of the most species rich groups on earth (Wardle et al. 2004; Fierer et al. 2009). Maraun et al. (2007) investigated the latitudinal diversity gradient in a soil taxon, oribatid mites, and made a negative conclusion that diversity increases from the boreal to the warm temperate regions, but did not increase further in the tropics. Recently, Wu et al. (2011) used a molecular approach to analyze samples from 11 locations worldwide and suggested that there may be an inverse relationship between above-ground plant biodiversity and soil invertebrate animal biodiversity.

Litter-dwelling thrips is a group of thysanopteran insects that have adopted the habitat of forest litter or surface soil where they feed only on either fungal hyphae or fungal spores during the early stages of leaf decay (Mound 2005; Wang and Tong 2012). The diversity of these litter thrips is usually related to environmental factors, including temperature and humidity of the soil, the plant species that produce the litter (Tree and Walter 2012) and the species of fungi involved in decomposition (Ananthakrishnan 1996). This diversity is a potential indicator to assess changes in the forest environment (Mound 1977). A majority of litter-dwelling thrips species are wingless, usually have weak migratory ability, and can well provide materials for analyzing the fauna and zoogeography (Mound 1970). Another important role was played by some species which could be effective in the natural control particularly those efficient spore feeders of plant pathogenic fungi (Ananthakrishnan 1981).

Most publications of litter-dwelling thrips species were descriptions of new genera and species, sometimes with little information on their vegetation or microhabitat associations (Dang et al. 2013; Haga 1973; Mound 1970, 1976, 1977, 2002, 2013; Mound and Palmer 1983; Mound et al. 2013; Okajima 1981, 1994, 1998; Okajima and Urushihara 1992; Wang and Tong 2011; Wang et al. 2007, 2013). Mound (2002) indicated that litter-dwelling thrips are particularly diverse in the subtropics and tropics, with up to 50% of thysanopteran species in these regions. For example, almost 50 species of litter thrips were described from a single area of forest 50 km in diameter in southern Brazil (Mound 1977). Few quantitative field studies have been published on litter thrips. The only published quantitative field studies of litter thrips were conducted in subtropical China (Wang et al. 2008; Wang and Tong 2012) and in Australia (Tree and Walter 2012). In China, Wang and Tong (2012) found Thysanoptera constituted more than 1% of total litter-dwelling macroinvertebrate individuals extracted with modified Tullgren funnels. Species richness and abundance of litter-dwelling thrips gradually increased from July to December, and then declined rapidly. Litter-dwelling thrips were found only in the litter layer and upper soil layer (0–5 cm in depth) and were entirely absent in deeper soil layers. Tree and Walter (2012) found

leaf-litter thrips were much more common and diverse in dry sclerophyll forest than in wetter forest types in subtropical southeast Queensland, Australia. The species diversity in soil fauna has been studied in temperate regions for more than 50 years, but with scarcely any mention of thrips (Wallwork 1976; Hattenschwiler et al. 2005). This lack of reference to thrips raises the question whether or not litter-dwelling thrips are distributed only in tropical and sub tropical regions.

To determine whether or not species diversity of litter-dwelling thrips alters at higher latitudes, we collected litter samples from six natural reserves which are located respectively in the temperate, subtropical and tropical zones, along a 4100 km latitudinal gradient in East China. The observations are also interesting from the point of view of understanding geographical scale differences in ecology, and responses of ecosystems to global warming.

## **Material and methods**

### **Locations**

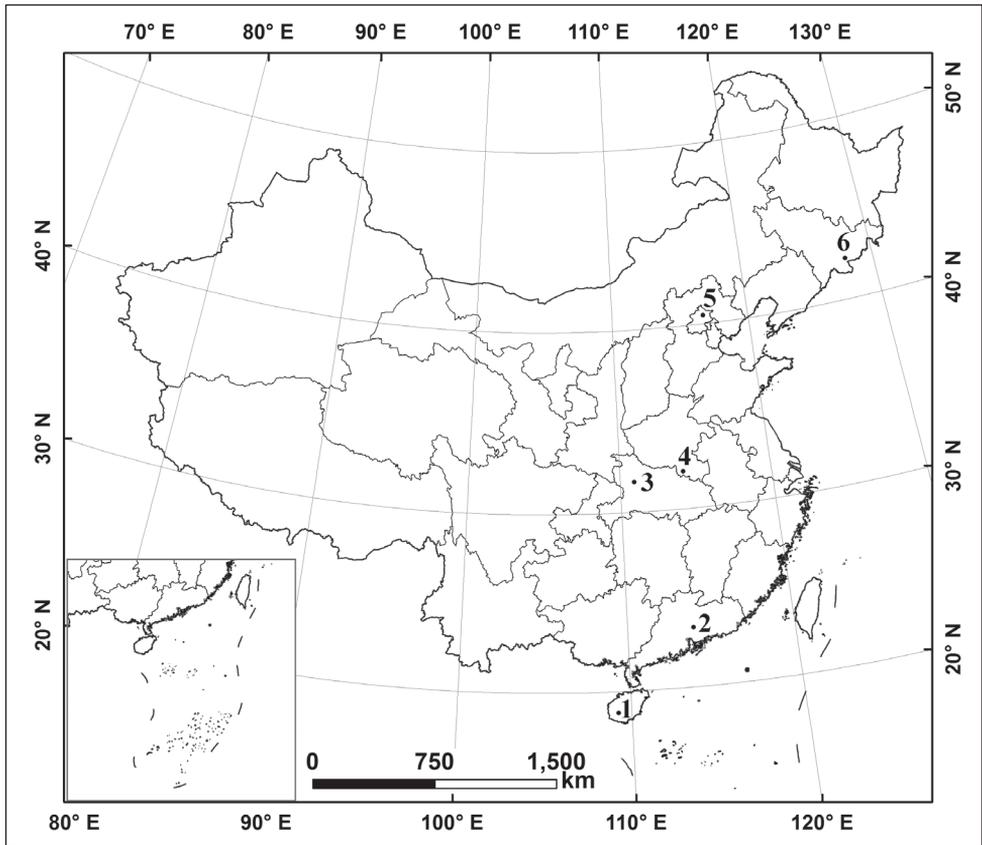
This study was conducted on six different natural reserves along a broad latitudinal gradient China (Figure 1): Wuzhishan Natural Reserve (Hainan Province), Nankunshan Natural Reserve (Guangdong Province), Shennongjia Natural Reserve (Hubei Province), Jigongshan Natural Reserve (Henan Province), Yunmengshan National Forest Park (Beijing), Changbaishan Natural Reserve (Jilin Province). Natural conditions are summarized in Table 1.

### **Sampling**

Wang et al. (2012) suggested that species diversity of litter-dwelling thrips was highest in October and December. Species diversity of litter thrips and other litter macro-invertebrates was quantitatively sampled from six natural reserves in October from 2007 to 2010. In each sampling, 5 plots (10 × 10 m) were randomly selected, and the distance between each sample plot was more than 50 m; 5 quadrat litter samples (50 × 50 cm) were selected in each plot – four in each corner and one in the center. A total of 150 litter samples were then placed in labeled plastic bags and extracted in the laboratory by means of a modified Tullgren funnel.

### **Sorting and identification**

Litter-dwelling thrips and other soil macro-invertebrates were extracted with the modified Tullgren funnels, using 60 W bulbs suspended 10 cm above the top of the samples over 10 hrs until the litter dried and became fragile. Specimens were then preserved in



**Figure 1.** Locations of sampling stations in China. **1** Wuzhishan Natural Reserve, Hainan Province **2** Nankunshan Natural Reserve, Guangdong Province **3** Shennongjia Natural Reserve, Hubei Province **4** Jigongshan Natural Reserve, Henan Province **5** Yunmengshan National Forest Park, Beijing **6** Changbaishan Natural Reserve, Jilin Province.

75% ethanol. All extractions were completed within 3 days. The macro-invertebrate samples were sorted to Order level, and counted under a dissecting microscope. The adults of leaf-litter thrips were identified to species, and the larval stages of thrips were separated under the category of “thrips larvae” and counted separately.

### Data analysis

Species richness, density (individuals/m<sup>2</sup>), relative abundance and frequency were applied to indicate the diversity of litter-dwelling thrips. Relative abundance refers to the total number of specimens for a particular species divided by the total number of all litter thrips, while frequency expresses the number of individuals a species collected in a month, divided by the total number of months. A “dominant group” is defined as

**Table 1.** Natural conditions in the locations of sampling stations.

	1*	2	3	4	5	6
Latitude (N)	18°51'	23°38'	31°25'	31°50'	40°33'	41°55'
Longitude (E)	109°42'	113°50'	110°20'	114°05'	116°40'	127°40'
Annual average temperature (°C)	23	21	14	15	9	3
Annual average precipitation (mm)	2400	2163	1750	1119	700	680
Type of forest	Tropical rain forest	Evergreen seasonal rain forest	Deciduous broad-leaf forest	Deciduous broad-leaf forest	Deciduous broad-leaf forest	Pine and broad-leaf mixed forest
Zone of temperature	Tropic	Subtropics	Subtropics	Subtropics	Temperate	Temperate
Biogeographic region	Oriental region	Oriental region	Oriental region	Palaearctic region	Palaearctic region	Palaearctic region

\*1. Wuzhishan Natural Reserve, Hainan Province; 2. Nankunshan Natural Reserve, Guangdong Province; 3. Shennongjia Natural Reserve, Hubei Province; 4. Jigongshan Natural Reserve, Henan Province; 5. Yunmengshan National Forest Park, Beijing; 6. Changbaishan Natural Reserve, Jilin Province.

having a relative abundance of more than 10%; the relative abundance of “ordinary groups” is between 1% and 10%; “rare group” is less than 1%. The density of each thrips species in each month was the mean of 25 quadrat samples from 5 plots and presented as Mean ± standard errors.

$$\text{Shannon-Wiener diversity index } (H') = -\sum(N_i / N) \ln(N_i / N)$$

$$\text{Simpson dominance index } (D) = \sum(N_i / N)^2$$

$$\text{Pielou evenness index } (J) = H' / \ln S$$

In the above,  $N_i$  is the number of individuals of species  $i$ ;  $N$  is the total number of individuals of all the species;  $S$  is the number of species (Wang et al. 2008). The analyses were carried out using SPSS ver 12.0.

## Results

### Species composition and relative abundance of litter-dwelling thrips

A total of 53,353 individuals of litter-dwelling invertebrate were collected in 150 samples, belonging to 30 groups in 10 classes under 3 phyla. Acarina and Collembola accounted for more than 10.0% of the total individuals of litter invertebrates and were considered to be “the dominant groups”. Relative abundance of litter-dwelling thrips was distinctly different in the different natural reserves (Table 2). It was a common Order of the litter invertebrate assemblage from tropical and subtropical regions, was rare an Order in temperate regions. In Wuzhishan Natural Reserve, litter thrips individuals

**Table 2.** Species composition and density (Means  $\pm$  SE) of litter-dwelling thrips in 6 natural reserves from different latitude (unit: individuals/m<sup>2</sup>).

Species	6	5	4	3	2	1*
<i>Acallurothrips</i> sp.	0.0a	0.0a	0.0a	0.0a	0.0a	0.3 $\pm$ 0.3a**
<i>Adraneothrips russatus</i>	0.0b	0.0b	0.0b	0.0b	0.0b	1.0 $\pm$ 0.7a
<i>Adraneothrips chinensis</i>	0.0a	0.0a	0.0a	3.3 $\pm$ 3.3a	2.3 $\pm$ 1.2a	3.5 $\pm$ 1.5a
<i>Apelaunothrips lienii</i>	0.0d	0.0d	5.5 $\pm$ 2.1bc	7.8 $\pm$ 7.1ab	19.3 $\pm$ 9.5a	1.0 $\pm$ 0.5c
<i>Baenothrips asper</i>	0.0a	0.0a	0.0a	0.0a	0.0a	0.5 $\pm$ 0.5a
<i>Heliiothripoides reticulatus</i>	0.0a	0.0a	0.0a	0.0a	0.0a	0.3 $\pm$ 0.3a
<i>Holothrips</i> sp.	0.0a	0.0a	0.0a	0.3 $\pm$ 0.3a	0.0a	0.0a
<i>Holurothrips morikawai</i>	0.0b	0.0b	0.0b	0.0b	3.0 $\pm$ 2.7a	0.0b
<i>Hoplothrips</i> sp.	0.0d	0.5 $\pm$ 0.3bc	2.3 $\pm$ 2.0ab	5.5 $\pm$ 2.4a	0.0d	1.8 $\pm$ 1.5ab
<i>Hyidiothrips japonicus</i>	0.0b	0.0b	0.0b	0.0b	0.0b	7.5 $\pm$ 3.3a
<i>Karnyothrips flavipes</i>	0.0a	0.0a	0.0a	0.5 $\pm$ 0.3a	1.0 $\pm$ 1.0a	0.3 $\pm$ 0.3a
<i>Psalidothrips ascitus</i>	0.0c	0.0c	42.5 $\pm$ 26.9a	0.0c	12.3 $\pm$ 5.4b	21.3 $\pm$ 18.2ab
<i>Psalidothrips simplus</i>	0.0a	0.0a	0.0a	0.3 $\pm$ 0.3a	5.0 $\pm$ 5.0a	0.0a
<i>Psalidothrips</i> sp.	0.0a	0.0a	0.0a	0.0a	0.3 $\pm$ 0.3a	0.3 $\pm$ 0.3a
<i>Preeriella parvula</i>	0.0b	2.5 $\pm$ 2.2ab	0.0b	71.5 $\pm$ 71.2a	0.5 $\pm$ 0.5ab	0.0b
<i>Stephanothrips japonicus</i>	0.0c	0.0c	4.3 $\pm$ 3.3b	22.3 $\pm$ 8.1a	2.5 $\pm$ 1.1b	1.0 $\pm$ 0.6b
<i>Terthrothrips palmatus</i>	0.0b	0.0b	0.0b	0.0b	0.0b	2.0 $\pm$ 1.2a
<i>Mystrothrips flavidus</i>	0.0b	0.0b	0.0b	0.0b	1.3 $\pm$ 1.3ab	1.8 $\pm$ 0.9a
<i>Thrips</i> sp.	0.0b	0.0b	0.0b	1.8 $\pm$ 0.3a	0.0b	1.6 $\pm$ 0.8a
Thrips larvae	0.0c	0.5 $\pm$ 0.3c	37 $\pm$ 12.3ab	14.8 $\pm$ 10.5b	31.8 $\pm$ 11.7ab	49.3 $\pm$ 7.3a

\*1. Wuzhishan Natural Reserve, Hainan Province; 2. Nankunshan Natural Reserve, Guangdong Province; 3. Shennongjia Natural Reserve, Hubei Province; 4. Jigongshan Natural Reserve, Henan Province; 5. Yunmengshan National Forest Park, Beijing; 6. Changbaishan Natural Reserve, Jilin Province.

\*\*Values in a row followed by the same letters indicate no significant difference at 0.05 level of probability (ANOVA, Tukey HSD) and values with standard errors.

accounting for 5.9% of the litter invertebrates, the relative abundance was maximum, only less than Acarina and Collembola.

In total, 19 species of litter-dwelling thrips (1578 individuals), representing 16 genera and 2 families, were collected during the survey period (Table 2). Most species and genera belonged to the family Phlaeothripidae (18 and 15 respectively); these phlaeothripids live as fungus-feeders in leaf litter. Of the family Thripidae 22 individuals were collected; these thripids are flower-living or leaf-feeding and only enter the litter or soil to pupate.

Species composition and density of fungus-feeding thrips were different in the six natural reserves (Table 2). In Wuzhishan Natural Reserve, 371 individuals of 14 species and 12 genera were collected in leaf litter. Among them, *Psalidothrips ascitus* and *Hyidiothrips japonicus* were dominant species, accounting for 48.6% and 17.1% of the total adult thrips individuals, respectively. *Heliiothripoides reticulatus* and *Terthrothrips palmatus* were collected only in this reserve. In three natural reserves located in subtropics, 10 genera and 12 species were collected: *Preeriella parvula*, *Psalidothrips ascitus*,

**Table 3.** The comparison of diversity indices of fungus-feeding thrips in five natural reserves from different latitude.

Diversity indices	6	5	4	3	2	1*
number of species/plot	0	1.2±0.4 d	3.4±0.5 c	5.4±0.4 b	5.8±0.2 b	8±0.9 a**
Density (mean±SE)	0	3.6±2.4 b	91.6±37.3 a	127.9±59.9 a	78.9±30.3 a	93.0±22.4 a
No. of species	0	2	4	8	10	14
Shannon-Wiener Diversity index $H'$	-	1.149	1.6207	1.995	2.424	2.202
Simpson's dominant index $D$	-	0.476	0.6152	0.638	0.7492	0.659
Pielou's equality index $J$	-	0.725	0.698	0.601	0.7008	0.564

\*1. Wuzhishan Natural Reserve, Hainan Province; 2. Nankunshan Natural Reserve, Guangdong Province; 3. Shennongjia Natural Reserve, Hubei Province; 4. Jigongshan Natural Reserve, Henan Province; 5. Yunmengshan National Forest Park, Beijing; 6. Changbaishan Natural Reserve, Jilin Province.

\*\*Values in a row followed by the same letters indicate no significant difference at 0.05 level of probability (ANOVA, Tukey HSD) and values with standard errors.

*Apelaunothrips lienii*, *Stephanothrips japonicus* were dominant species, accounting for 33.5%, 19.9%, 15.1% and 13.5% of the total adult thrips individuals, respectively. In Yunmengshan, 14 individuals in 2 species, *Preeriella parvula* and *Holothrips* sp., were collected. No leaf-litter thrips were collected in Changbaishan Natural Reserve, the most northern of the six sites.

### Diversity indices of litter-dwelling thrips

According to species number and individuals of each species, Shannon-Wiener diversity index, Simpson dominance index and Pielou evenness index were applied to analyze community structure of fungus-feeding thrips (Table 3). The order on the average species numbers per plot of fungus-feeding thrips was tropics > subtropics > temperate (n=25, p<0.05). Mean density of fungus-feeders per plot in tropics and subtropics was significantly higher than in temperate region (n=25, p<0.05), but the average density was not significantly different between tropical and subtropical zones (n=25, p>0.05). The diversity of fungus-feeding thrips in the tropics and subtropics was much higher than in the temperate area, based on the comparisons of Shannon-Wiener diversity index ( $H'$ ), Pielou evenness index ( $J$ ), and Simpson dominance index ( $D$ ).

### Discussion

Extant insects of the order Thysanoptera include approximately 6000 described species worldwide, classified into nine families (ThripsWiki 2014). At least 2500 species are placed in the families Phlaeothripidae and Merothripidae, and many of these are found in forest litter where they feed on fungi (Mound 2005). The systematics of litter-

dwelling thrips has been well studied by Mound and Palmer (1983), Mound (2013) and Mound and O'Neill (1974). These litter thrips are especially diverse in some areas of the tropics and subtropics, which were proved by some qualitatively extensive surveys with the purpose of extracting abundant specimens to describe new taxa and study morphological variation. For example, almost 50 species in eight genera of litter thrips were described from a single area of forest 50 km in diameter in southern Brazil (Mound 1977). Two merothripid species and 15 phlaeothripid species were recorded from Jinmuji forest, Kanagawa Prefecture, Japan (Okajima and Urushihara 1992). Fifty thrips species, including twenty-six undescribed species, were recovered from various forest types and microhabitats in a single locality of subtropical eastern Australia (Tree and Walter 2012).

In recent years, we conducted a series of investigations by quantitative sampling methods to survey the species diversity of leaf-litter thrips in China. We found these litter-dwelling thrips to be a common group of litter macro-invertebrates, with high species diversity and relative abundance in Guangdong Province of subtropical China. For example, the numbers of these thrips accounted for 3% to 13.5% of total litter macroinvertebrate individuals caught in four different forest types of two natural reserves (Li et al. 2004a, b). In another natural forest, the relative abundance of Thysanoptera was 5.0%, representing 10 genera and 12 species (Wang et al. 2008). In an urban forest remnant, 25 species of 19 genera of leaf-litter thrips were collected, and these constituted 6.5% of total litter macro-invertebrate individuals caught (original totals 1413 thrips out of 21817 individual macro-invertebrates) (Wang et al. 2007; Wang and Tong 2012). In the present work, the relative abundance of Thysanoptera was over 3.0% in four natural reserves from the subtropical and tropical zones, and reached 5.9% in the tropical zone of Wuzhishan Natural Reserve (Hainan Province), only less than Acarina and Collembola. In contrast, it was only 0.3% in the warm temperate zone of Yunmengshan National Forest Park (Beijing) and no individual was collected in mid temperate zone of Changbaishan Natural Reserve (Jilin Province). 14 species and 12 genera of fungus-feeding thrips were collected from leaf litter of tropical China, 10 genera and 12 species in the subtropics, but only 2 species in the warm temperate zone. No species was collected in mid temperate zone. The results indicate that species number and relative abundance increase with decreasing latitude.

In the New World, the fauna of litter thrips is represented primarily by three genera, Eurythrips, Terthrothrips and Tylothrips (Mound 1976, 1977). In contrast, samples taken in the Old World rarely include these genera, whereas species of *Apelaunothrips* and *Adraneothrips* are often abundant, with species of *Psalidothrips* and *Zemiathrips* found commonly in the litter of sclerophyll forests in Australia (Mound 2002; Tree and Walter 2012). A total of 128 species in 43 genera belonging to 2 families of litter thrips were documented from China. Fauna and Zoogeographical analyses indicated that fungus-feeding thrips are diverse in China. *Psalidothrips* and *Apelaunothrips* are the dominant genera, with 9 species and 8 species, respectively. Relative abundance also can provide assemblage composition and fauna characteristics, and refers to the total number of specimens for a particular species divided by the total number of all litter

thrips. *Psalidothrips ascitus* and *Hyidiothrips japonicus* were dominant species in samples from the tropics, accounting for 48.6% and 17.1% of the total adult thrips individuals, respectively. *Heliiothripoides reticulates* and *Terthrothrips palmatus* were collected only in this reserve. In subtropics, *Preeriella parvula*, *Psalidothrips ascitus*, *Apelaunothrips lieni*, *Stephanothrips japonicus* were dominant species, accounting for 33.5%, 19.9%, 15.1% and 13.5% of the total adult thrips individuals, respectively. In the warm temperate zone, a few individuals were collected of *Preeriella parvula* and *Holothrips*.

A total of five distribution patterns can be recognized among the 15 genera of litter-dwelling thrips in six nature reserves. Genera with a Pan-tropical distribution are most abundant, including the following: *Acallurothrips*, *Adraneothrips*, *Baenothrips*, *Holothrips*, *Karnyothrips*, *Preeriella*, *Stephanothrips* and *Terthrothrips*. These genera are found in the tropical and subtropical areas of Asia-Africa-America. *Apelaunothrips* is distributed in the tropical and subtropical areas of Asia-Africa. *Hyidiothrips* and *Psalidothrips* occur in the warmer areas of Asia and America. *Heliiothripoides*, *Holurothrips* and *Mystrothrips* are distributed across tropical or subtropical Asia, being found in China, Japan, Korea and the India-Malaya area. Excluding the genera with cosmopolitan distributions (*Hoplothrips*), almost all litter-dwelling genera are found in tropical and subtropical areas. Differing from geographic distribution patterns at genus level, the 18 species of fungus-feeding thrips were divided into four distribution patterns, according to species currently distribution areas. Endemic to South China distribution: *Apelaunothrips lieni*, *Adraneothrips chinensis* and *Terthrothrips palmatus*. Eastern Asia distribution: *Adraneothrips russatus*, *Holurothrips morikawai*, *Hyidiothrips japonicus*, *Psalidothrips simplus*, *Stephanothrips japonicus* and *Mystrothrips flavidus* recorded in Japan and South China. Tropical Asia distribution: *Heliiothripoides reticulates*, *Psalidothrips ascitus* and *Preeriella parvula* recorded in India-Malaya area or Japan. Tropical Asia, Africa and America disconnected distribution: *Baenothrips asper* and *Karnyothrips flavipes*. These zoogeographic analyses indicate that litter-dwelling thrips possess tropical and subtropical characteristics. Litter-dwelling thrips inhabiting forest litter usually have weak flight ability, some species are even wingless, but individual genera or even species are sometimes found in two disconnected continents. The causes have been discussed by Wang and Tong (2012).

The species richness of litter-dwelling thrips in our quantitative investigation at six locations across a broad latitudinal gradient reveal an increase with decreasing latitude, as reported for many other taxonomic groups of invertebrates, prominent examples include termites (Collins 1989), butterflies (Sime and Brower 1998) and springtails (Sun et al. 2013). However, we also found that the density of litter-dwelling thrips peaked at our mid-latitude sites (Shennongjia Natural Reserve), with no individual collected at the northern extreme. Individuals of oribatid mites, springtails and soil nematodes were richest in the warm temperate regions, and they could be found from polar to equatorial regions (Bardgett and Wardle 2010); a similar conclusion was made concerning leaf-associated aquatic hyphomycetes (Jabiol et al. 2013). The mechanisms underlying such patterns are still not fully understood, but several explanations have been proposed, such as habitat relationship, body size of organisms, solar energy,

temperature and precipitation, etc (Turner 2004; Willig et al. 2003). We think that temperature might be a limiting factor for the distribution of litter-dwelling thrips in the northern temperate zone, particularly areas with snow cover in winter. In tropical regions, particularly complicated climatic conditions lead to dramatic fluctuation among different seasons (Wang and Tong 2012), and this could decrease number of individuals of litter thrips.

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# Review of the Chinese species of the genus *Varma* Distant (Hemiptera, Fulgoromorpha, Tropiduchidae), with description of two new species

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## Abstract

Two new species of *Varma* Distant, 1906, *V. falcata* Chang & Chen, **sp. n.** (China: Guizhou) and *V. lobata* Chang & Chen, **sp. n.** (China: Guizhou) are described and illustrated. The female genitalia of four species including two known species are described and illustrated for the first time. The diagnostic characters of this genus are redefined. A checklist to the species of *Varma* in China is given. The Keys on male and female genitalia to the Chinese species of *Varma* are provided.

## Keywords

Fulgoroidea, morphology, taxonomy, distribution

## Introduction

The tropiduchid genus *Varma* was established by Distant (1906) with *Serida fervens* Walker, 1857 from Borneo as its type species. He described the second species *V. tridens* from Sri Lanka. Then Distant (1909) described one species *V. obliqua* in this genus. Melichar (1914) transferred the genus *Varma* into Tropiduchidae and placed it in the tribe Tropiduchini, added one species *V. distanti* from India. Metcalf (1954) and Fennah (1982) recognised the treatment. In China, as the first record of the genus *Varma*, two species *V. gibbosa* and *V. bimaculata* were described by Wang and Liang (2008). Then Men et al. (2010) added one species *V. serrata* from China. Up to now, seven species have been reported worldwide, of three species recorded in southwestern China.

Much attention were paid to the genus *Varma*, however, little information has been reported on female genitalia of the genus, especially in species identification. In this paper, two new species *V. falcata* Chang & Chen, sp. n. from Guizhou (China) and *V. lobata* Chang & Chen, sp. n. from Yunnan (China) are described and illustrated. The female genitalia of four species including two known species, *V. gibbosa* and *V. serrata* are described and illustrated for the first time, as useful characters for species identification. The diagnostic characters of this genus are redefined. A checklist to the species of *Varma* in China is given. The Keys on male and female genitalia to the Chinese species of *Varma* are provided.

## Material and methods

External morphology was observed under a stereoscopic microscope and dimensions of characters were measured with an ocular micrometer. Measurements are given in millimeters (mm). Abdomens were removed and macerated in 10% KOH overnight, washed in water and then removed to glycerine. Observations and drawings were done under a Leica MZ 12.5 stereomicroscope. Illustrations were scanned with Canon CanoScan LIDE 100 and imported into Adobe Photoshop 8.0 for labeling and plating composition. Photographs of the types were taken with a KEYENCE VHX-1000C. The type specimens are deposited in the Institute of Entomology, Guizhou University, Guiyang, China (GUGC).

Morphological terminology follows that of Bourgoïn and Huang (1990) and Bourgoïn (1993) for male and female genitalia.

## Taxonomy

### Genus *Varma* Distant, 1906

*Varma* Distant, 1906: 330; Distant 1909: 171; Melichar 1914: 117; Wang and Liang 2008: 116.

**Type species.** *Serida fervens* Walker, 1857, by original designation.

**Diagnosis.** Body slender, somewhat dorsoventrally depressed. Head (Figs 1–4, 5, 24) produced in front of eyes. Vertex (Figs 1–4, 5, 24) shorter in middle than broad at base (about 2.1–4.8:1), disc depressed, unicarinate carina, not reaching anterior margin. Frons (Figs 6, 25) unicarinate, longer in middle line than wide than broad (about 1.3–1.5:1). Pronotum (Figs 5, 24) tricarinate, wider than long in middle (about 3.1–5.0:1). Mesonotum (Figs 5, 24) tricarinate, wider than long in middle (about 1.1–1.3:1). Hind tibia with 3 lateral spines, spinal formula of hind leg 6(5)-5-2. Forewing (Figs 1–4, 8, 27) subhyaline, about 2.5 times longer than the widest breadth, corium without granulation, costal cell with various oblique transverse veins, nodal line and subapical line distinct. Male genitalia (Figs 10–15, 29–34) with pygofer asymmetrical, irregularly subquadrate, posterior margin produced various lobes; anal tube (urite X) symmetrical, anal styles (paraproct and epiproct) relative small, not surpassing apex of anal tube; gonostyli asymmetrical, with a strong stout process in left side, with a small process in right side; fused basally, with various median processes in ventral view; aedeagus tubular, expanded apex, with several lobes or band processes.

**Female genitalia.** Gonapophyses VIII (first valvula) (Figs 16, 21, 35, 40) saw-like, strongly sclerotized, with 6–8 distinct teeth on dorsal margin, ventral margin with about 3–4 distinct teeth. Gonapophyses IX (second valvula) (Figs 18, 22, 35, 37, 41) degraded, triangular. Gonoplace (third valvula) (Figs 19, 23, 38, 42) stout, membranous, formed about 10–14 teeth on ventral margin and apical margin (Figs 19, 23, 38, 42). In ventral view, endogonocoxal lobe (Figs 17, 20, 36, 39) not bilaterally symmetrical, in the base of the gonapophyses VIII produced mesad irregular process. Sternite VII with posterior margin depressed or convex (Figs 17, 20, 36, 39).

**Distribution.** Oriental region.

### Checklist of species of *Varma* Distant, 1906 in China

*Varma bimaculata* Wang & Liang, 2008; China (Xizang)

*Varma falcata* Chang & Chen, sp. n.; China (Guizhou)

*Varma gibbosa* Wang & Liang, 2008; China (Xizang)

*Varma lobata* Chang & Chen, sp. n.; China (Yunnan)

*Varma serrata* Men & Qin, 2010; China (Yunnan, Hunan)

## Keys to species of genus *Varma*, 1906 in China

(based on male genitalia, ♂)

- 1 Pygofer with posterior margin produced into a distinct process in right side ..... **2**
- Pygofer without posterior margin produced into a distinct process in right side ..... **3**
- 2 Pygofer with posterior margin produced into a trapezoidal process in right side (see Men and Qin: 263, Fig. 2A, I, J) .....  
..... ***V. serrata* Men & Qin**
- Pygofer with posterior margin produced into a strip in right side (Figs 29, 32, 33)..... ***V. lobata* Chang & Chen, sp. n.**
- 3 Gonostyli with subcircular or subglobose lobe at apical inner margin ..... **4**
- Gonostyli with a falcate lobe at apical inner margin (Fig. 11) .....  
..... ***V. falcata* Chang & Chen, sp. n.**
- 4 Aedeagus with apical part expanded into two hemispherical protuberances, curved through about 180 degree (see Wang and Liang: 118, Figs 8, 9) .....  
..... ***V. gibbosa* Wang & Liang**
- Aedeagus with apical part expanded into a hemispherical protuberance, curved through about 90 degree, then extended into an irregularly contorted scoop-shape plate (see Wang and Liang: 121, Figs 21, 22).....  
..... ***V. bimaculata* Wang & Liang**

(based on female genitalia, ♀)

- 1 Sternite VII with posterior margin project triangularly in middle; endogonocoxal lobe produced mesad irregular trapeziums, more broader in left side, more slender in right side (Fig. 17) ..... ***V. falcata* Chang & Chen, sp. n.**
- Sternite VII with posterior margin formed a shallow pit in middle ..... **2**
- 2 Sternite VII with posterior margin formed a pit in middle about 1/2; endogonocoxal lobe produced mesad irregular triangle, more narrow in left side, more broader in right side (Fig. 36) .. ***V. lobata* Chang & Chen, sp. n.**
- Sternite VII with posterior margin formed a pit in middle less than 1/2 ..... **3**
- 3 Sternite VII with posterior margin formed a narrow and deep pit in middle 1/9; endogonocoxal lobe produced mesad different rods (Fig. 39) .....  
..... ***V. serrata* Men & Qin**
- Sternite VII with posterior margin formed a shallow pit in middle 1/7; endogonocoxal lobe produced mesad irregular protuberances, triangular in left side, falcate in right side (Fig. 20) ..... ***V. gibbosa* Wang & Liang**

Note: this key didn't refer to *V. bimaculata* Wang & Liang, as we didn't have the female specimens.

***Varma bimaculata* Wang & Liang, 2008**

*Varma bimaculata* Wang & Liang, 2008: 120.

**Material examined.** No specimen has been collected by the authors.

**Distribution.** China (Xizang).

***Varma falcata* Chang & Chen, sp. n.**

<http://zoobank.org/37F52044-C2AD-47A3-8512-D810C1F31D28>

Figs 1, 5–15

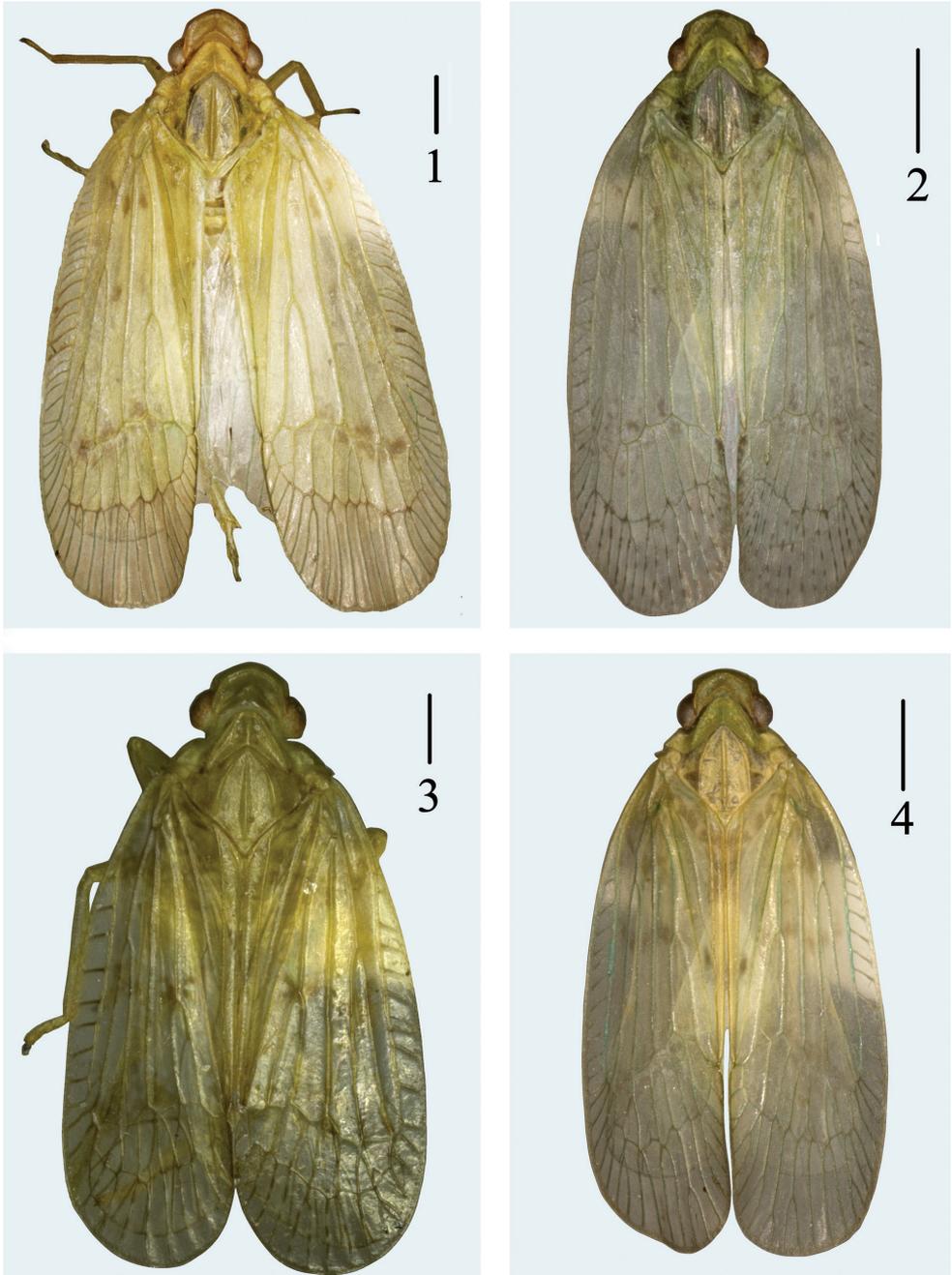
**Type material.** Holotype: ♂, **China:** Guizhou, Dushan, Duliujiangyuan Wetlands (25°50'N, 107°32'E), 12 July 2012, Q.-Z. Song; paratypes: 1 ♂, 4 ♀♀, same data as holotype; 2 ♀♀, Guizhou, Fanjingshan National Nature Reserve (27°44'N, 109°13'E), 22–24 Sept. 2011, X.-F. Yu and Z.-H. Fan; 1 ♀, Fanjingshan National Nature Reserve, 1 June 2002, X.-S. Chen; 1 ♀, Leigongshan National Nature Reserve (26°23'N, 108°04'E), 10 July 2011, Z.-M. Chang.

**Description.** Body length (from apex of vertex to tip of forewings): male 12.1–12.8 mm (N = 2), female 13.0–13.5 mm (N = 4).

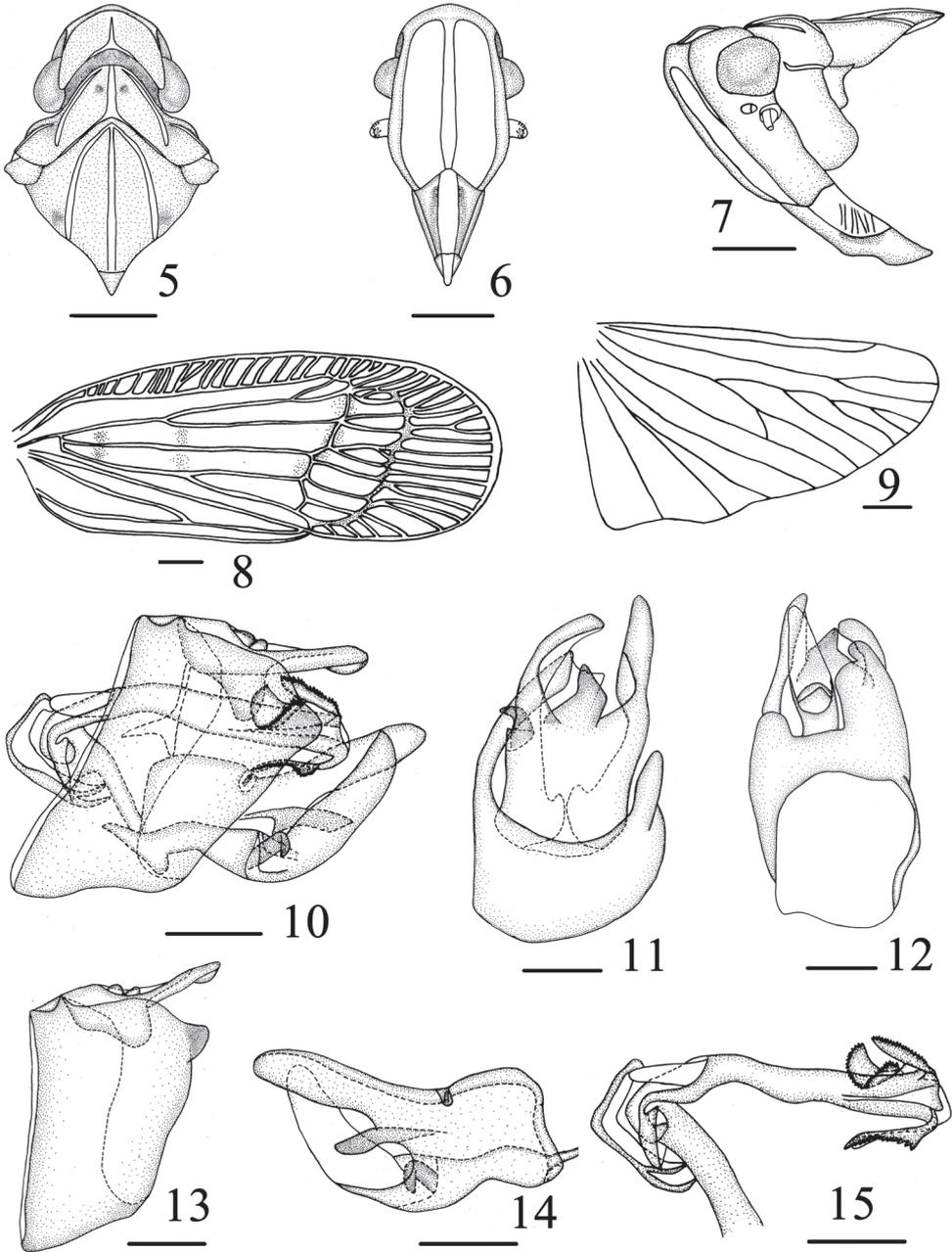
**Coloration.** General colour yellowish green to stramineous yellow. Head and pronotum pale green to pale tawny. Mesonotum pale green or pale ochreous. Abdomen tawny. Forewings pale yellowish green, basal part with two light brownish spots, around nodal line with light brownish fasciae.

**Head and thorax.** Vertex (Fig. 5) broader than long in middle line (2.4:1). Frons (Fig. 6) obviously longer in middle than widest breadth (1.4:1), widest at apical fourth, anterior margin and posterior arch, median carina broad and ridged. Pronotum (Fig. 5) obviously wider than long in middle (3.8:1). Mesonotum (Fig. 5) wider than long in middle (1.1:1). Forewing about 2.4 times longer than the widest, venations as in Fig. 8. Hind wing with venation as in Fig. 9. Spinal formula of hind leg 6-5-2.

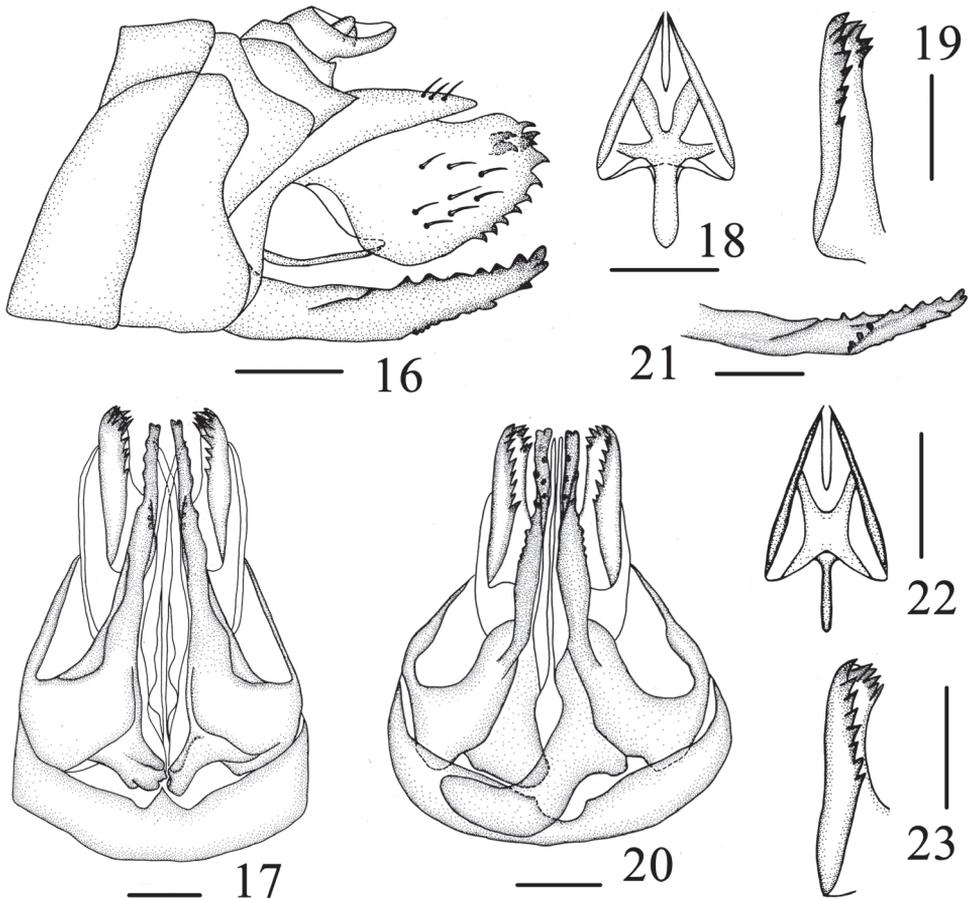
**Male genitalia.** Male genitalia (Figs 10–14) with pygofer not bilaterally symmetrical; in profile left side, irregularly subquadrate, dorsal margins and ventral margin subparallel, anterior margin and posterior margin nearly subparallel, posterior margin near its upper end produced into a short and indistinct lobe; in right side, dorsal margin incline to venter, anterior margin near dorsal 1/3 concave, lateral margins subparallel. Anal tube (urite X) (Figs 12, 13) symmetrical and long, surpassing apex of aedeagus in lateral view, with anal styles short, not surpassing apex of anal tube. In ventral view, gonostyli (Figs 10–12, 14) with basal 2/3 fused together, medially produced into a falcate lobe. Aedeagus (Fig. 15) tubular, relatively long, narrow at base and expanded apex, with three processes, of one band process at lateral ventral margin, of one lobe in dorsal margin, directed anteriorly, of one flexural waviness on the right side, all processes with serrated margins. Periandrium fissure-like, exposed at the apex. Corpus connectivi stout, rod-like.



**Figures 1–4.** Dorsal habitus of *Varma* species. **1** *Varma falcata* Chang & Chen, sp. n.; **2** *Varma lobata* Chang & Chen, sp. n.; **3** *Varma gibbosa* Wang & Liang; **4** *Varma serrata* Men & Qin. Scale bars = 1.0 mm.



**Figures 5–15.** *Varma falcata* Chang & Chen, sp. n. **5** Head and thorax, dorsal view **6** Head, ventral view **7** Head and thorax, lateral view **8** Forewing **9** Hind wing **10** Male genitalia, lateral view **11** Pygofer and gonostyli, ventral view **12** Male genitalia, dorsal view **13** Pygofer and anal segment, left side **14** Gonostyli, right side **15** Aedeagus, left side. Scale bars = 1.0 mm (5–9), 0.5 mm (10–15).



**Figures 16–23.** Female genitalia. **16–19** *Varma falcata* Chang & Chen, sp. n. **16** Female genitalia, lateral view **17** Female genitalia, ventral view **18** Gonapophyses IX, ventral view **19** Gonoplace, ventral view **20–23** *Varma gibbosa* Wang & Liang **20** Female genitalia, ventral view **21** Gonapophyses VIII, lateral view **22** Gonapophyses IX, ventral view **23** Gonoplace, ventral view. Scale bars = 0.5 mm (16–23).

**Female genitalia.** Gonapophyses VIII (first valvula) (Fig. 16) saw-like, strongly sclerotized with 6–7 distinct teeth on dorsal margin, ventral margin with about 4 distinct teeth. Gonapophyses IX (second valvula) (Fig. 18) degraded, triangular. Gonoplace (third valvula) (Fig. 19) stout, membranous, formed 12 teeth on ventral margin and apical margin. In ventral view, endogonocoxal lobe (Fig. 17) in the base of the gonapophyses VIII produced mesad irregular trapeziums, that of left side more broader, paw-like, with 2 small teeth, that of right more slender, lateral margin dented. Sternite VII (Fig. 17) with posterior margin project triangularly in middle.

**Etymology.** The new species is named after the presence of a falcate process at apically inner margin of gonostyli.

**Distribution.** China (Guizhou).

**Remarks.** This new species is similar to *V. serrata* Men & Qin, 2010 in external appearance, but can be distinguished from the latter in the gonostyli with a falcate lobe at apically inner margin (with semicircular lobe in *serrata*) (Fig. 11); posterior margin of pygofer without lobe process near its upper end on right side (with posterior margin with trapezoidal lobe directed caudoventrad on right side in *serrata*) (Figs 10, 13); apical part of the aedeagus bearing one band process at lateral ventral margin, with one lobe in dorsal margin, on the right side of the aedeagal shaft with one flexural waviness (in *serrata*, with apical part of aedeagus bearing a semicircular ribbon-like plate at left side side, on the right side of the aedeagal shaft with a pediform flate plate and wing-shaped lobe) (Fig. 15).

***Varma gibbosa* Wang & Liang, 2008**

Figs 3, 20–23

*Varma gibbosa* Wang & Liang, 2008: 117.

**Material examined.** 2 ♂♂, 1 ♀, **China**, Xizang, 1960m, 22 Aug. 2005, Z.-H. Yang.

**Distribution.** China (Xizang).

**Female genitalia.** Gonapophyses VIII (first valvula) (Fig. 21) saw-like, strongly sclerotized with 7-8 distinct teeth on dorsal margin, ventral margin with 3-4 distinct teeth. Gonapophyses IX (second valvula) (Fig. 22) degraded, triangular. Gonoplace (third valvula) (Fig. 23) stout, membranous, formed 13 or 14 teeth on ventral margin and apical margin. In ventral view, endogonocoxal lobe (Fig. 20) in the base of the gonapophyses VIII produced mesad not bilaterally symmetrical, that of left triangular, apex obtuse, that of right falcate. Sternite VII (Fig. 20) with posterior margin forming a shallow pit in middle 1/7.

**Remarks.** For the female species, Sternite VII with posterior margin of *V. gibbosa* is similar to *V. serrata*, but can be from the latter in the pit of posterior margin more shallow and relative more broader (more deep and narrow in *serrata*), left of endogonocoxal lobe triangular, apex obtuse, that of right falcate (that of left thin rods, that of right slender, with one triangular protrusion in the outer edge, in *serrata*) (Figs 20, 39).

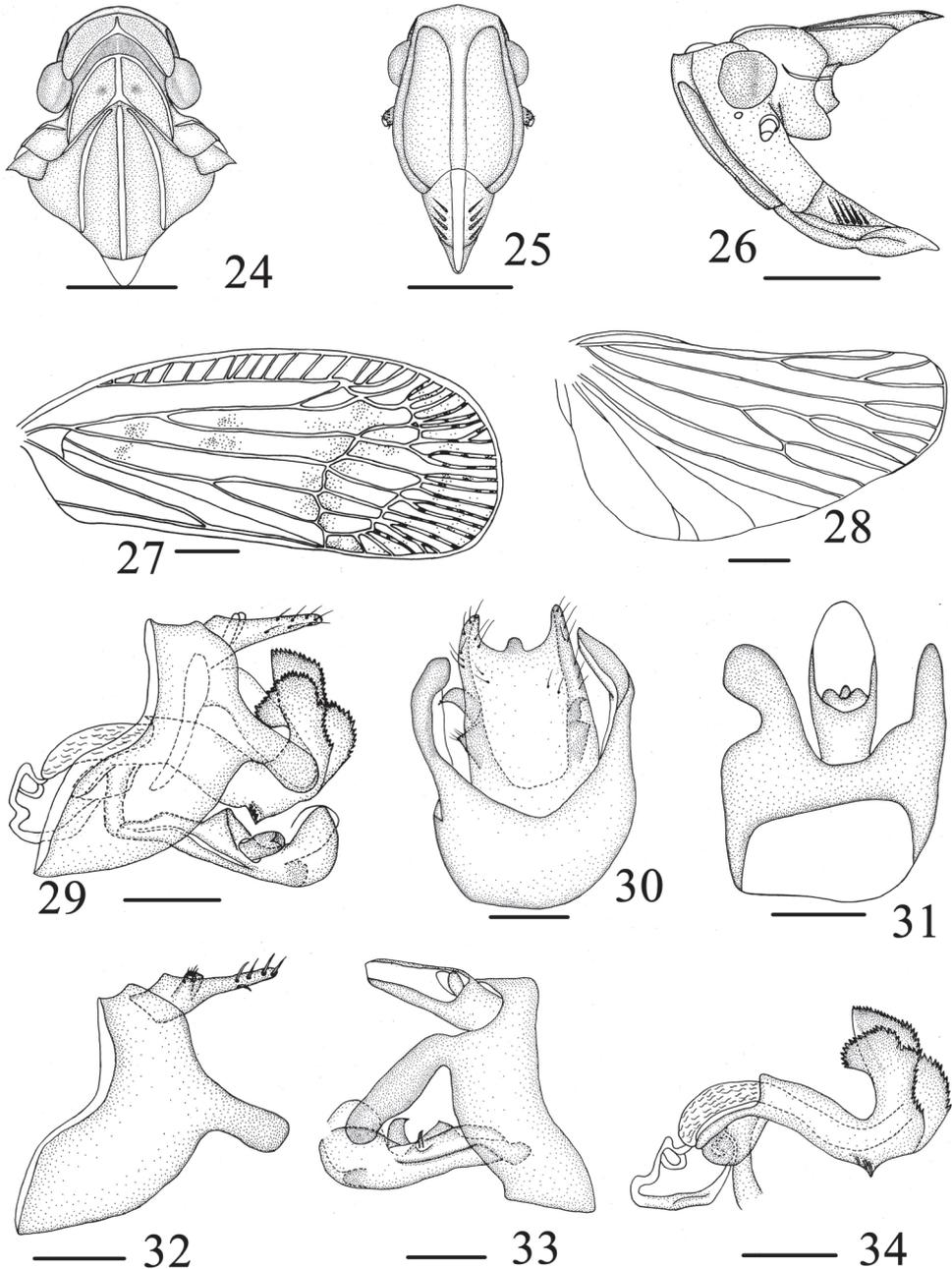
***Varma lobata* Chang & Chen, sp. n.**

<http://zoobank.org/1A64F0A0-1905-4E63-AFCB-46DFDD89C124>

Figs 2, 24–34

**Type material.** Holotype: ♂, **China**: Yunnan, Jinping Fenshuiling Native Nature Reserve (22°46'N, 103°14'E), 7 July 2012, W.-B. Zheng; paratypes: 4 ♂♂, 6 ♀♀, same data as holotype.

**Description.** Body length (from apex of vertex to tip of forewings): male 9.2–9.5 mm (N = 6), female 11.1–11.8 mm (N = 4).



**Figures 24–34.** *Varma lobata* Chang & Chen, sp. n. **24** Head and thorax, dorsal view **25** Head, ventral view **26** Head and thorax, lateral view **27** Forewing **28** Hind wing **29** Male genitalia, lateral view **30** Pygofer and gonostyli, ventral view **31** Male genitalia, dorsal view **32** Pygofer and anal segment, left side **33** Male genitalia, right side **34** Aedeagus, left side. Scale bars = 1.0 mm (24–28), 0.5 mm (29–34).

**Coloration.** General color pale green to greenish-yellow. Vertex, pronotum, mesonotum pale green. Forewings light green, marked with irregular brown spots at the base and middle and around nodal line, with 3-4 ranks of fine speckles and suffused fuscous between apical margin and the first subapical line.

**Head and thorax.** Vertex (Fig. 24) distinctly broader than long in middle line (4.8:1). Frons (Fig. 25) longer in middle than widest breadth (1.3:1), widest at apical fourth. Pronotum (Fig. 24) obviously wider than long in middle (4.5:1). Mesonotum (Fig. 24) wider than long in middle (1.2:1). Forewing about 2.4 times longer than the widest, venations as in Fig. 27. Hind wing with venation as in Fig. 28. Spinal formula of hind leg 6 (5)-5-2.

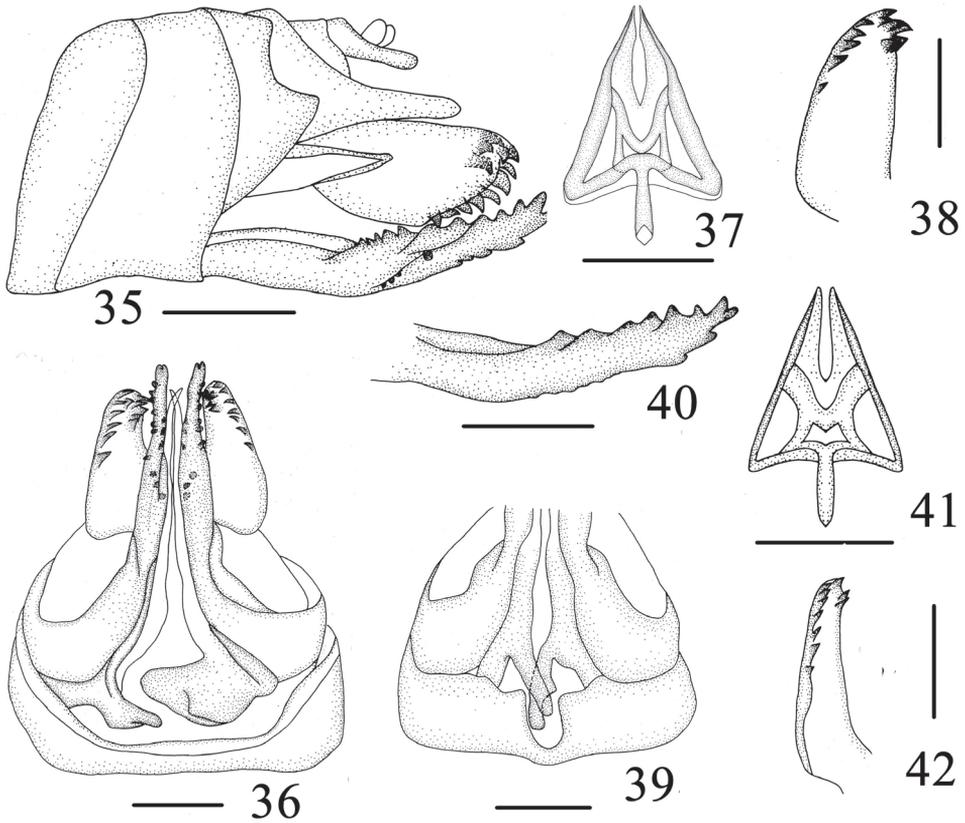
**Male genitalia.** Male genitalia (Figs 29-34) with pygofer not bilaterally symmetrical, in profile left view, irregularly stomach-like, posterior margin produced caudad with a lobe near its upper end; in right side, irregularly subquadrate, posterior margin produced into strip directed caudoventrad (Figs 29, 31, 32). Anal tube (urite X) (Figs 31, 32) symmetrical, not surpassing apex of aedeagus in lateral view, anal styles relatively small, not surpassing apex of anal tube. In ventral view, gonostyli (Figs 29, 30, 33) with basal 3/4 fused together, medially produced into sub-semicircular lobe. Aedeagus (Figs 29, 34) tubular, relatively long, narrow at base and distinctly expanded apex, splitting into two lobe plates, directed into dorsal margins, both with serrated margins, of one prongy in left view, of one sub-oblong lobe in right side, with 3-4 denticulate structure in ventral margins near basal 2/3. Periandrium fissure-like, exposed in middle. Corpus connectivi stout, rod-like.

**Female genitalia.** Gonapophyses VIII (first valvula) (Fig. 35) saw-like, strongly sclerotized with 7 distinct teeth on dorsal margin, ventral margin with 3-4 distinct teeth. Gonapophyses IX (second valvula) (Fig. 37) degraded, triangular. Gonoplace (third valvula) (Fig. 38) stout, membranous, formed 12 or 13 teeth on ventral margin and apical margin. In ventral view, endogonocoxal lobe (Fig. 36) in the base of the gonapophyses VIII produced mesad irregular triangle, that of left more narrow, that of right more broader. Sternite VII (Fig. 36) with posterior margin forming a pit in middle 1/2.

**Etymology.** The name of the new species results from apex of aedeagus, splitted into two lobe plates.

**Distribution.** China (Yunnan).

**Remarks.** This new species can be distinguished from other species in the genus by the following combination of characters: (1) Gonostyli with a sub-semicircular lobe at apically inner margin (Fig. 30). (2) Apex of aedeagus, splitted into two lobe plates, directed into dorsal margins, of one sub-oblong lobe, of one sub-oblong lobe, with 3-4 denticulate structure in ventral margins near basal 2/3 (Fig. 34). (3) Pygofer, irregularly stomach-like in profile left view; right side, posterior margin produced into a strip (Figs 29, 32). (4) Sternite VII with posterior margin forming a pit in middle 1/2 (Fig. 36).



**Figures 35–42.** Female genitalia. **35–38** *Varma lobata* Chang & Chen, sp. n. **35** Female genitalia, lateral view **36** Female genitalia, ventral view **37** Gonapophyses IX, ventral view **38** Gonoplace, ventral view **39–42** *Varma serrata* Men & Qin **39** Female genitalia, lateral view **40** Gonapophyses VIII, lateral view **41** Gonapophyses IX, ventral view **42** Gonoplace, ventral view. Scale bars = 0.5 mm (35–42).

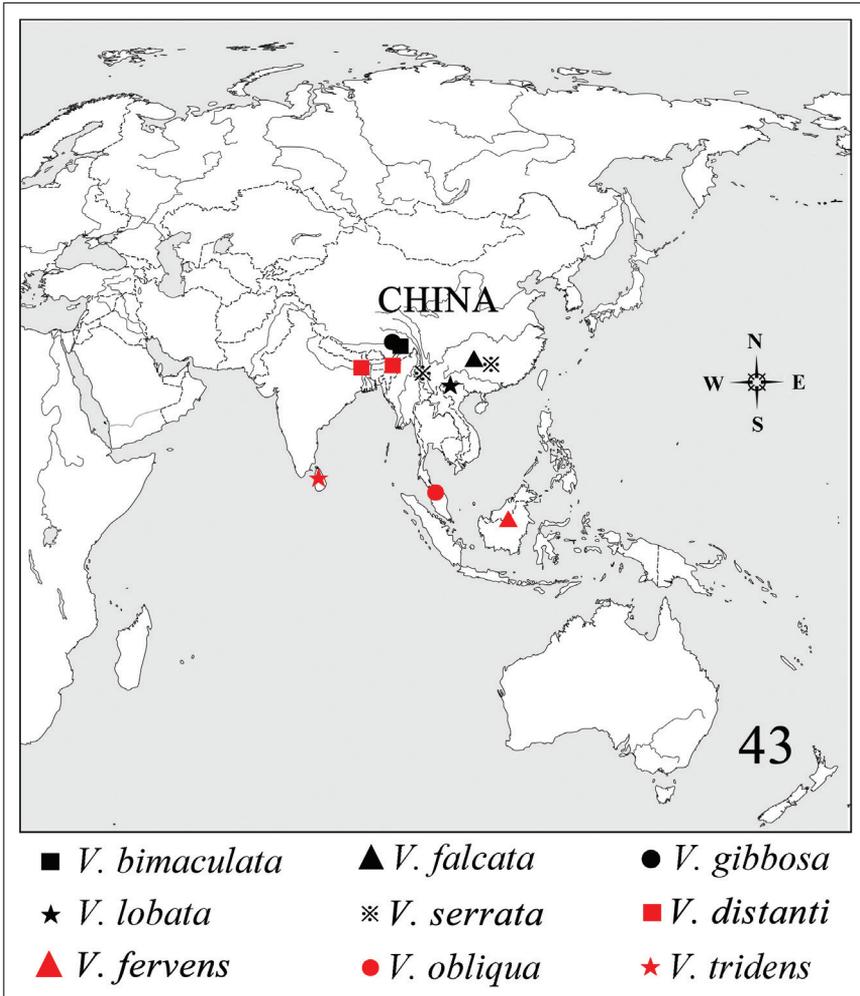
### *Varma serrata* Men & Qin, 2010

Figs 4, 39–42

*Varma serrata* Men & Qin, 2010: 116.

**Material examined.** 2 ♂♂, 3 ♀♀, **China**, Yunnan, Lushui, 1960m, 14 Aug. 2006, Q.-Z. Song; 2 ♀♀, Hunan, Langshan, 5 Oct. 2010, X.-S. Chen; 2 ♂♂, Yunnan, Lushui, 21 July 2012, J.-K. Long.

**Female genitalia.** Gonapophyses VIII (first valvula) (Fig. 40) saw-like, strongly sclerotized with 7 distinct teeth on dorsal margin, ventral margin with 3 distinct teeth. Gonapophyses IX (second valvula) (Fig. 41) degraded, triangular. Gonoplace (third valvula) (Fig. 42) stout, membranous, formed 10 teeth on ventral margin and apical margin. In ventral view, endogonocoxal lobe (Fig. 39) in the base of the gonapophyses



**Figure 43.** Geographic distribution of *Varma* worldwide

VIII produced mesad not bilaterally symmetrical, that of left thin rods, that of right slender, with one triangular protrusion in the outer edge, Sternite VII with posterior margin formed a narrow and deep pit in middle 1/9 (Fig. 39).

**Distribution.** China (Yunnan, Hunan).

**Remarks.** The author examined many species of *V. serrata*, and then found that the forewings marked with very light irregular brown spots at the base and middle and around nodal line (Fig. 4).

### Geographic distribution of *Varma* worldwide

According to the geographic distribution map, all species distributed in Oriental region.

## Discussion

The female genitalia were generally used for higher taxon in the Tropicuchidae family, such Fennah (1982) as important tribes' characters. However, few characters were used in species identification for the instability of the female genitalia, such as the numbers of teeth of gonapophyses VIII and gonoplace. Fortunately, we found that there are steady specific differences in the endogonocoxal lobe and sternite VII in genus *Varma* (Figs 17, 20, 36, 39). These characters were used to record new species in *Leptovanua* Melichar, 1914 (Tropicuchini), *Neocatara* Distant, 1910 (Tropicuchini) (Fennah, 1970). It seems unclear that these characters are suited to others genus in the tribe Tropicuchini for inadequate specimens.

## Acknowledgments

The authors thank Qiong-Zhang Song, Dr Jian-Kun Long, Dr Zai-Hua Yang, Ph. D. Xiao-Fei Yu and Ph. D. Zhi-Hua Fan (Institute of Entomology, Guizhou University, Guiyang, China) for providing materials studied. This research was supported by the National Natural Science Foundation of China (No. 31060290, 31093430, 31160163), and by the International Science and Technology Cooperation Program of Guizhou (20107005).

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# A new species of *Megoura* (Hemiptera, Aphididae) from Japan

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## Abstract

A new species of the genus *Megoura*, *M. lathyricola* **sp. n.**, was collected from *Lathyrus japonicus* subsp. *japonicus* (Leguminosae) in seashore areas of northern and southern Japan. This species is described and illustrated, and a revised key to the identification of the world species of *Megoura* is presented.

## Keywords

Macrosiphini, *Megoura*, *Lathyrus japonicus* subsp. *japonicus*, new species

## Introduction

The genus *Megoura* Buckton 1876, nested within the tribe Macrosiphini of the subfamily Aphidinae (Remaudière and Remaudière 1997), comprises eight valid species described from the Palearctic, Oriental, and Australian regions (Miyazaki 1971; Heie 1995; Blackman and Eastop 2006; Lee et al. 2002; Eastop 2011). The species are

*Megoura lespedezae* (Essig and Kuwana 1918), *Megoura crassicauda* Mordvilko, 1919, *Megoura brevipilosa* Miyazaki, 1971, *Megoura nigra* Lee, 2002 from East Asia, *Megoura dooarsis* (Ghosh & Raychaudhuri, 1969) from the Indian subregion, *Megoura viciae* Buckton, 1876, *Megoura litoralis* Müller, 1952 from Europe, Central Asia and the Middle East, and *Megoura stufkensi* Eastop, 2011 from New Zealand. This genus is characterized by having swollen siphunculi and an association with several genera of Leguminosae (Blackman and Eastop 2006).

Until now, three species of the genus *Megoura* have been reported from Japan; *M. crassicauda*, *M. lespedezae*, and *M. brevipilosa*. Recently, we collected a macrosiphine aphid species from the leguminous plant *Lathyrus japonicus* subsp. *japonicus*, in Hokkaido (northern Japan) and Nagasaki Prefecture (southern Japan). This species has morphological characters in common with the genus *Megoura*, such as swollen siphunculi, smooth head, and antenna approximately as long as body (Miyazaki 1971; Heie 1995). Morphological identification keys and original descriptions of *Megoura* spp. (Miyazaki 1971; Heie 1995; Lee et al. 2002; Eastop 2011) suggest that this species is referable to *M. crassicauda* in Japan. However, the apterous viviparous female of this species is distinguished from *M. crassicauda* by antennal segment III with 40–59 secondary rhinaria, abdominal tergite III with 11–13 setae, pale tibia (except distal 1/9 dark), and pale yellow cauda.

The present paper describes this new species, and provides a revised key to species of *Megoura* of the world.

## Materials and methods

Aphid samples for this study were collected in 2012 on *Lathyrus japonicus* subsp. *japonicus* in Japan. Each sample of aphid colonies was preserved in 80% alcohol, and mounted specimens were prepared in Canada balsam, following methods by Blackman and Eastop (2000). Illustrations for each species were taken by digital camera, Carl Zeiss, AxioCam MRc5 attached on the microscope, Carl Zeiss Microimaging GmbH 37801, Gottingen, Germany. Measurements for each specimen are taken from the digital images by the software, Axio Vision Re. 4.8.

Abbreviations used for descriptions and table are as follows: al. – alate viviparous female, alata; apt. – apterous viviparous female, aptera; Ant. – antennae; Ant.I, Ant.II, Ant.III, Ant.IV, Ant.V, Ant.VI, and Ant.VIb – antennal segments I, II, III, IV, V, VI, and base of VI, respectively; BDAnt.III – basal diameter of antennal segment III; BL – length of body; GP – genital plate; 2HT – second segment of hind tarsus; PT – processus terminalis; SIPH – siphunculi; URS – ultimate rostral segment (segment IV + V).

## Taxonomy

### *Megoura lathyricola* Lee & Akimoto, sp. n.

<http://zoobank.org/2B8624A7-184C-438C-B439-779B72966F5B>

Figs 1, 2, Table 1

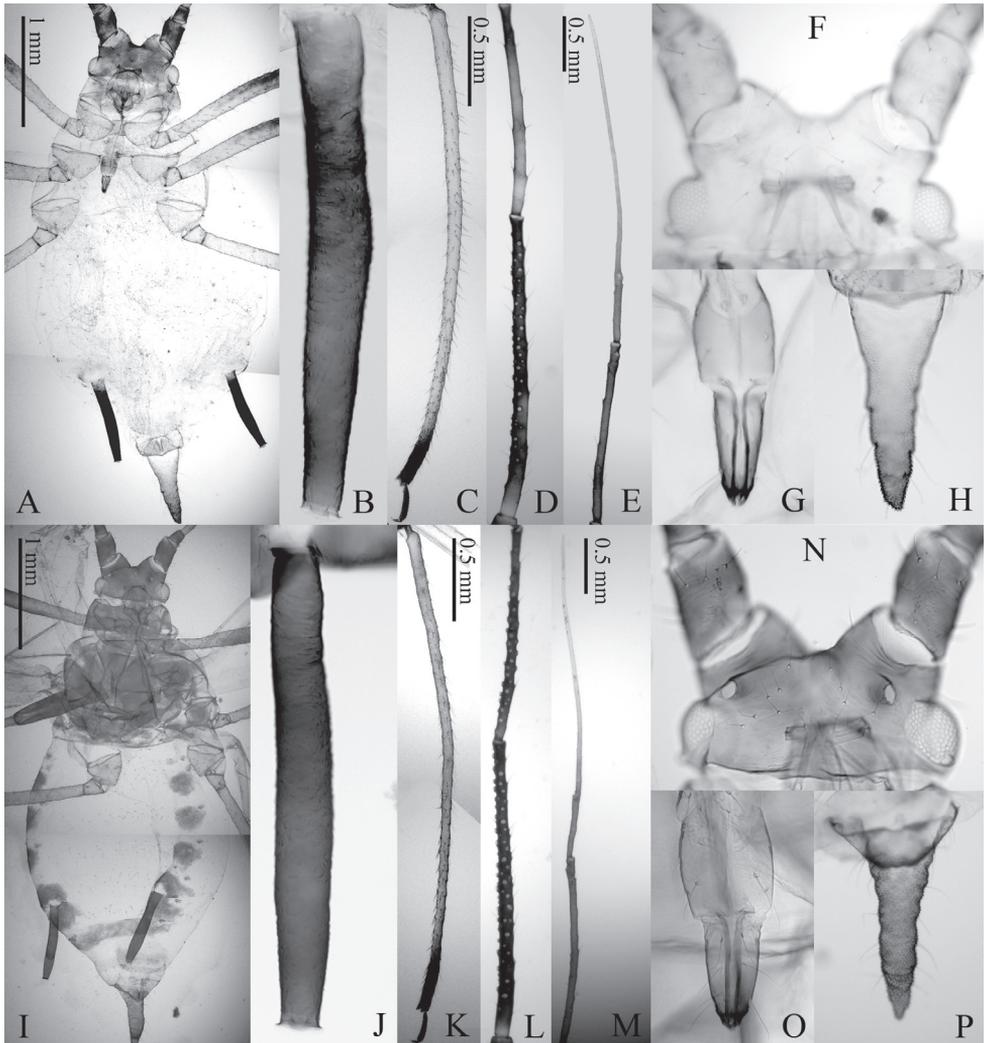
**Holotype.** Apterous viviparous female, Coll#.120605WH26/ap.1, Muroran, Hokkaido, Japan, 05.vi.2012, leg. Wonhoon Lee, on *Lathyrus japonicus* subsp. *japonicus*.

**Paratypes.** 9 apterous viviparous females and 2 alate viviparous females, same data as for holotype; 5 apterous viviparous females, Coll#.120309WH16, Nagasaki, Nagasaki prefecture, Japan, 09.iii.2012, leg. Wonhoon Lee, on *Lathyrus japonicus* subsp. *japonicus*.

The type specimens, including holotype and paratypes, are deposited in the Laboratory of Systematic Entomology, Graduate School of Agriculture, Hokkaido University, Japan.

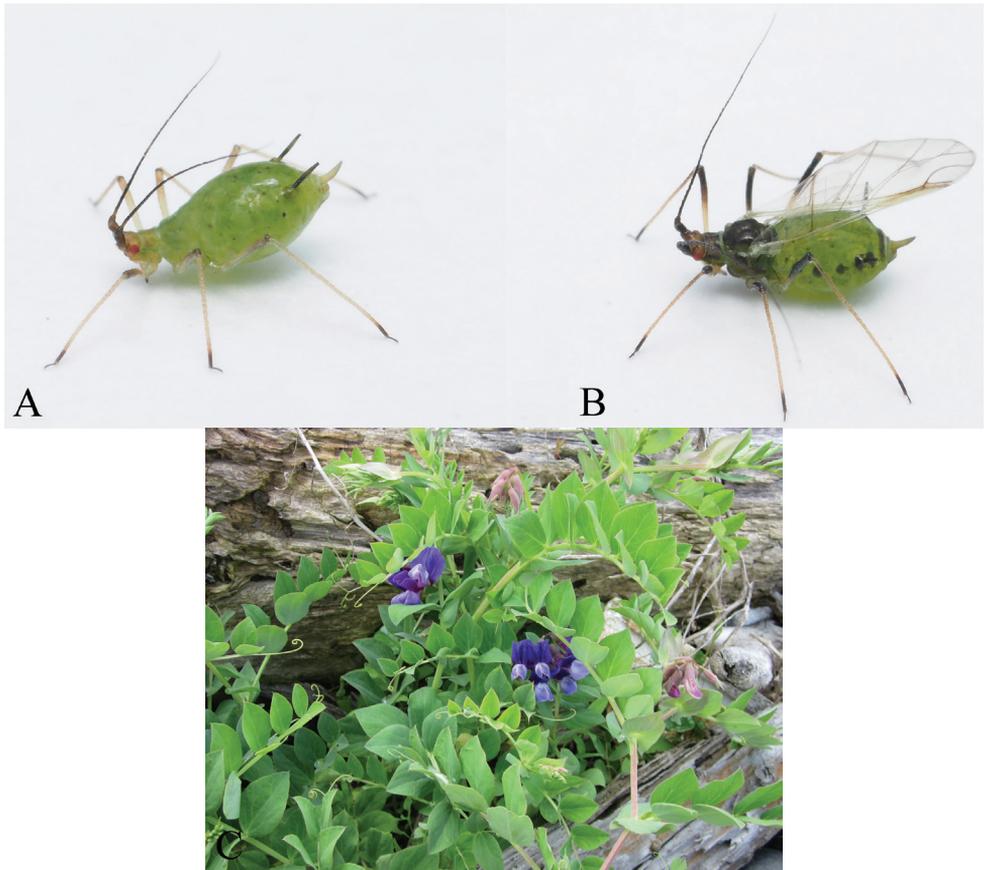
**Etymology.** The specific epithet is composed of the root of the plant genus (lathyr) and the lexeme “col” that, in this case, means ‘living on’.

**Apterous viviparous female.** (Figs 1A–H, 2A) *Color alive:* Head yellowish brown with antennae dark brown, thorax and abdomen pale green. Legs pale yellowish brown except distal 1/9 of tibiae including tarsi dark brown. SIPH dark brown. Cauda pale. *Color of macerated specimens:* Head yellowish brown and antennae dark brown. Rostrum pale, except the tip of URS dark brown. Thorax yellowish brown and abdomen entirely pale. Legs pale except distal 1/9 of tibiae and tarsi dark brown. SIPH dark brown and cauda pale except extreme end. *Morphology:* Body spindle shaped. Head: smooth on ventrum and dorsum including three pairs of acuminate setae. Antennal tubercle well developed with 3–5 setae on both side, frons U-shaped with four setae on vertex, including weakly developed median tubercle. Ant.I smooth; Ant.II granulate; Ant.III weakly imbricate with short setae, bearing 40–59 secondary rhinaria irregularly spaced; Ant.IV imbricate with 12–18 setae with no secondary rhinaria; Ant.V imbricate with 8–13 setae, primary rhinarium ciliate, longest diameter of which is shorter (0.63–0.83 times) than middle width; Ant.VI imbricate with 3–7 short setae on Ant.VIb. Rostrum attaining posterior margin of mesocoxa; mandibular laminae with 4–6 setae on each side; URS longest seta 0.78–1.00 times as long as apical primary ones. Thorax: pronotum smooth with two spinal setae and one marginal seta on anterior margin. Hind coxa weakly spinulose with 6–7 acuminate setae; hind trochanter wide at base, 1.63–1.65 times as long as apical width, bearing three setae; hind femur smooth on basal 1/17, spinulose on apical 16/17 ventrally, bearing short setae, longest seta 0.43–0.48 times as long as basal width of segment; hind tibia smooth, longest seta 0.80–1.07 times as long as middle width of segment; first segment of each tarsus smooth with three setae at apex; 2HT imbricate with 10–11 setae. Abdomen: dorsum smooth, membranous with 11–13 setae on tergite III, 0.37–0.47 times as long as basal width of hind femur. SIPH swollen, weakly spinulose except smooth base, irregularly reticulated on distal end, apex flanged. Cauda elongate, triangular, ventral spinules strong and dense, in groups of one or two; dorsal ornamentation composed of ribbed imbrication.



**Figure 1.** Apterous viviparous female (**A–H**) and Alate viviparous female (**I–P**) of *Megoura lathyricola* sp. n.: **A** whole body of apterous vivipara **B** siphunculus **C** hind tibia and tarsus **D** antennal segments III–IV **E** antennal segments V–VI **F** head focused on dorsum **G** ultimate rostral segment **H** cauda **I** whole body of alate vivipara **J** siphunculus **K** hind tibia and tarsus **L** antennal segments III–IV **M** antennal segments V–VI **N** head focused on dorsum **O** ultimate rostral segment **P** cauda.

**Alate viviparous female.** (Figs 1 I–P, 2B) *Color alive:* Head, antennae and thorax black, abdomen pale green. Abdomen with black patches on tergites III–VI. Legs pale yellowish brown except distal 1/2 of femora and distal 1/9 of tibiae including tarsi dark brown. SIPH dark brown. Cauda pale. *Color of macerated specimens:* Head, antenna, and thorax dark brown. Legs pale except dark distal 1/2 of femora, 1/9 of tibiae and tarsi. Abdomen with marginal sclerites on II–VI segments. SIPH and Cauda dusky.



**Figure 2.** Photographs of *Megoura lathyricola* sp. n. and host plant: **A** apterous viviparous female **B** alate viviparous female **C** *Lathyrus japonicus* subsp. *japonicus*.

Wings pale with veins bordered by narrow dark pigmentation. *Morphology*: Antennae with 60–62 secondary rhinaria irregularly scattered on whole of Ant.III, and 20–32 secondary rhinaria scattered on whole of Ant.IV. Cauda triangular, pointed at apex. SIPH strongly imbricate. Otherwise like apterous viviparous female.

**Distribution and host-plant.** So far collected and observed only on *Lathyrus japonicus* subsp. *japonicus* in Muroran, Hokkaido and Nagasaki, Japan. This plant is distributed only in seashore areas.

**Biology.** This species seems to be rare. Colonies were observed on stem and young leaves of host plants. In nature it appears to be specific to *Lathyrus japonicus*. However a clonal lineage from Nagasaki was readily reared in the laboratory of Systematic Entomology, Hokkaido University under long day conditions by using broad bean seedlings as a host. When the clone was reared at 15 °C and 8L16D, it produced viviparae but no sexual morphs, suggesting that the Nagasaki population of this species is anholocyclic.

**Table I.** Biometric data of *Megoura lathyricola* sp. n.

	Part	Apterous vivipara (n=10)	Alate vivipara (n=2)
		Range(Mean)	Range(Mean)
Length (mm)	BL	4.06–4.47(4.30)	4.13–4.86(4.49)
	Whole antennae	4.11–4.75(4.40)	4.62–4.91(4.76)
	Ant.I	0.20–0.24(0.22)	0.22–0.26(0.24)
	Ant.II	0.11–0.16(0.14)	0.13–0.16(0.14)
	Ant.III	1.09–1.26(1.18)	1.22–1.28(1.25)
	Ant.IV	0.65–0.90(0.80)	0.91–0.96(0.93)
	Ant.V	0.70–0.78(0.74)	0.75–0.82(0.75)
	Ant.VIb	0.22–0.30(0.27)	0.27–0.35(0.31)
	PT	1.01–1.12(1.04)	1.03–1.20(1.11)
	URS	0.13–0.15(0.14)	0.13–0.14(0.14)
	Hind femur	1.38–1.58(1.48)	1.53–1.59(1.56)
	Hind tibia	2.50–2.78(2.60)	2.72–2.81(2.78)
	2HT	0.16–0.21(0.19)	0.19–0.20(0.19)
	SIPH	0.60–0.73(0.68)	0.58–0.66(0.62)
	Cauda	0.56–0.66(0.62)	0.54–0.57(0.55)
	Setae on Ant.III	0.03–0.06(0.05)	0.04–0.05(0.05)
No. of hairs on	Mandibular lamina.	4–6(5)	5–6(6)
	Ant.I	9–18(13)	10–12(11)
	Ant.II	5–7(6)	5–5(5)
	Ant.III	22–33(26)	20–25(22)
	URS (subsidiary)	6–6(6)	6–6(6)
	Abdominal tergite VI between SIPH	5–7(6)	6–6(6)
	Abdominal tergite VIII	6–7(6)	6–6(6)
	Median of genital plate	2–2(2)	2–2(2)
No. of Rhinaria on	Posterior margin of genital plate	17–21(19)	18–18(18)
	Cauda	10–13(12)	13–14(14)
	Ant.III	40–59(48)	60–62(61)
Ratio (times)	Ant.IV	0	20–32(25)
	Whole Antennae / BL	0.96–1.06(1.02)	1.00–1.13(1.06)
	PT / Ant.VIb	3.50–4.75(3.85)	3.41–3.80(3.58)
	PT / Ant.III	0.83–0.95(0.88)	0.84–0.95(0.89)
	URS / 2HT	0.67–0.82(0.75)	0.69–0.76(0.73)
	URS / Ant.VIb	0.43–0.64(0.52)	0.39–0.53(0.46)
	SIPH / BL	0.14–0.16(0.16)	0.12–0.16(0.14)
	SIPH / Ant.III	0.47–0.64(0.58)	0.46–0.54(0.50)
	SIPH / Hind femur	0.39–0.50(0.46)	0.37–0.43(0.40)
	SIPH / Cauda	1.00–1.16(1.09)	1.08–1.15(1.12)
Cauda / Width of cauda	1.92–3.03(2.49)	2.10–2.23(2.17)	

**Key to species of the genus *Megoura* of the world (based on the apterous viviparous female)**

- 1 Median cephalic frontal tubercle well developed, and Ant.III with no secondary rhinaria. Cauda with 5–7 hairs. On the genus *Carmichaelia*. In New Zealand..... ***Megoura stufkensi***
- No median cephalic frontal tubercles, and Ant.III with 0–64 secondary rhinaria. Cauda with more than 10 hairs..... 2
- 2 Cauda dark brown or black. On the genus *Vicia* or *Lathyrus*..... 3
- Cauda pale yellow. Not on the genus *Vicia*..... 5
- 3 Body totally dark brown or black in life. Tibia pale yellow except apical 1/5. URS 0.88–1.00 times as long as 2HT. Ant.I, mandibular lamina, abdominal tergite III, and GP with 13–20, 6–8, 16–21, and 24–33 hairs, respectively. Ant.III with 28–67 secondary rhinaria. On the genus *Vicia* (Leguminosae). In Korea ..... ***Megoura nigra***
- Body green except antenna, legs, SIPH, and cauda black in life. Tibia black or dark brown. URS 0.63–0.87 times as long as 2HT. Ant.I, mandibular lamina, abdominal tergite III, and GP with 8–15, 4–5, 15–18, and 14–23 respectively. Ant.III with 5–42 secondary rhinaria ..... 4
- 4 Ant.III with more than 20 secondary rhinaria which are scattered irregularly over two-thirds of, or throughout the segment. SIPH as long as or longer than cauda. On the genera *Vicia*, *Lathyrus*, *Amphicarpaea*, and *Pisum* (Leguminosae). In Japan, China, India, Korea, Russia (Siberia), and Taiwan..... ***Megoura crassicauda***
- Ant.III with less than 20 secondary rhinaria which are situated on basal half or two-thirds, in a line. SIPH shorter than cauda. On the genera *Vicia* and *Lathyrus* (Leguminosae). In Europe, Central Asia, Middle East, and Ethiopia ..... ***Megoura viciae***
- 5 All legs pale, except that apices of tibiae and tarsi are pale brown ..... 6
- Legs dark brown, or at least fuscous on distal half of femora and tibiae..... 7
- 6 SIPH 0.67–0.95 times as long as cauda. Ant.III with 6–21 secondary rhinaria. PT 2.70–3.70 times as long as Ant.VIb. On the genus *Lathyrus* (Leguminosae). In Denmark, Finland, Germany, Norway, Poland, and Sweden ... ***Megoura litoralis***
- SIPH 1.00–1.16 times as long as cauda. Ant.III with 40–59 secondary rhinaria, PT 3.50–4.75 times as long as Ant.VIb. On *Lathyrus japonicus* subsp. *japonicus* (Leguminosae). In Japan ..... ***Megoura lathyricola* sp. n.**
- 7 URS 0.89–1.17 times as long as 2HT and 0.68–0.88 times as long as Ant. VIb. Antennal tubercle weakly developed. Frons more than twice as wide as median depth. Antenna 0.83–0.94 times length of body. SIPH 1.07–1.31 times as long as Ant.III. On the genera *Lespedeza*, *Cajanus*, *Desmodium*, and *Indigofera* (Leguminosae). In Japan, China, India, Korea, Siberia, Switzerland, and Taiwan..... ***Megoura lespedezae***

- URS 0.71–0.83 times as long as 2HT and 0.47–0.54 times as long as Ant.VIb. Antennal tubercle well developed. Frons V-shaped, as wide as median depth. Antenna at least 1.3 times length of body. SIPH shorter than Ant. III..... 8
- 8 Cauda about 0.50 times as long as SIPH. SIPH with narrow base, basal diameter shorter than middle diameter. Hairs on Ant.III about 0.50 times as long as BDAnt.III. On the genera *Indigofera*, *Hedysarum*, and *Tephrosia* (Leguminosae). In Afghanistan, India, Kashmir, Pakistan, and Thailand ..... ***Megoura dooarsis***
- Cauda more than 0.7 times as long as SIPH. SIPH widest at base. Hair on Ant.III 0.25 times as long as BDAnt.III. On the genus *Lespedeza* (Leguminosae). In Japan and Korea ..... ***Megoura brevopilosa***

## Acknowledgments

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# A new species of *Zagrammosoma* Ashmead (Hymenoptera, Eulophidae) from Qinghai Province, China

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## Abstract

The new species *Zagrammosoma dulanense* Cao & Zhu, **sp. n.**, from Qinghai Province, China, is described and illustrated. All type specimens were reared from the pupae of *Micrurapteryx sophorivora* Kuznetsov & Tristan (Lepidoptera: Gracillariidae), a leafmining moth attacking the plant *Thermopsis lanceolata* R. Br. (Fabaceae). A key to the three known Asian species of *Zagrammosoma* is provided. All specimens are deposited in the Insect Collection, the Institute of Zoology, Chinese Academy of Sciences, Beijing, China.

## Keywords

Eulophidae, *Zagrammosoma dulanense* sp. n., *Micrurapteryx sophorivora*, *Thermopsis lanceolata*, Qinghai

## Introduction

The genus *Zagrammosoma* Ashmead is one of several small genera of the Eulophidae tribe Cirrospilini (Hymenoptera: Chalcidoidea). The members of this genus mainly attack leafminers in the orders Lepidoptera and Diptera (LaSalle 1989), occasionally

Coleoptera (Peck 1951) and Hymenoptera (Ubaidillah et al. 2000). They are predominantly New World in distribution. Noyes (2013) listed 16 species in this genus, with 12 of them known from the Americas (Gordh 1978, LaSalle 1989, Noyes 2013). Of the Old World species, *Z. crowei* (Kerrich) was known from East Africa and Reunion (Noyes 2013), *Z. talitzkii* (Bouček) from Italy and Eastern Europe through to Russia, Kazakhstan and Turkmenistan (Noyes 2013, Radeghieri et al. 2002), and *Z. latilineatum* Ubaidillah from Australia and Indonesia (Ubaidillah et al. 2000).

Noyes (2013) also included *Zagrammosoma variegatum* (Masi) in *Zagrammosoma*. Several authors discussed differences between *Zagrammosoma* and *Cirrospilus*, which are clearly closely related (Gates 2000, Gordh 1978, Hansson and LaSalle 1996, LaSalle 1989, Ubaidillah et al. 2000, Ubaidillah et al. 2003, Zhu et al. 2002). For the most part these authors have placed *variegatum* Masi in the genus *Cirrospilus* as *C. variegatus* (Masi), and this paper follows that classification. It should be noted that a species of *Cirrospilus* determined as *C. nr variegatus* was included in a molecular analysis of Eulophidae relationships (Gauthier et al. 2000), and it consistently clustered with *Cirrospilus* rather than *Zagrammosoma*. This is despite the fact that a morphological analysis of Cirrospilini relationships (Ubaidillah et al. 2003) found that a relationship between *Zagrammosoma* and *C. variegatus* and the closely related *C. afer* (Silvestri) was supported by at least one morphological character. Until further work provides a better understanding of these relationships, this paper follows the definition of *Zagrammosoma* as used or discussed by Schauff et al. (1997), Zhu et al. (2002) and Ubaidillah et al. (2003), which excludes *C. variegatus*.

During a recent field trip to Kunlun Mountains, Qinghai Province, many specimens of a parasitoid species were reared from the pupae of *Micrurapteryx sophorivora* (Lepidoptera: Gracillariidae), a leafminer attacking *Thermopsis lanceolata* R. Br. (Fabaceae). These specimens are described and illustrated here as a new species of the genus *Zagrammosoma*, after comparing them with descriptions (Kerrich 1969, LaSalle 1989, LaSalle 1992, Ubaidillah et al. 2000, Yefremova 1995a, b), or specimens deposited in Natural History Museum (NHM), London, UK and those in the Insect Collection, the Institute of Zoology, Chinese Academy of Sciences (IZCAS), Beijing, China.

A key to the known Asian species of *Zagrammosoma* based on females is also provided.

## Material and methods

Host plants were collected in Qinghai Province, China in late July 2013 and moved to the lab in Beijing to rear specimens of the leafminer moths and parasitoid wasps. Specialists in the Institute of Botany, Chinese Academy of Sciences, identified the plant. All parasitoid specimens were collected and stored in 95% alcohol. Then specimens were mounted on cards for morphological studies and deposited in the Insect Collection, the IZCAS, Beijing, China.

Habitus and head pictures were recorded with a NIKON D7000 digital camera connected to a NIKON SMZ 1500 stereomicroscope. Pictures of appendages (forewings, antennae and legs) were taken by a CANON 550D digital camera connected to a LEICA DM-2500 microscope. All pictures above were stacked with Helicon Focus software.

Morphological terminology and abbreviations follow Gibson (1997). Abbreviations are: SMV, submarginal vein; MV, marginal vein; PMV, postmarginal vein; STV, stigmal vein;  $Gt_n$ , gastral tergites; POL, postocellar length; OOL, ocular-ocellar length. Absolute measurements in millimeters (mm) were used for the body and forewing length. For all other dimensions, relative measurements were used.

Acronyms in this text are as follows: IZCAS, the Institute of Zoology, Chinese Academy of Sciences, Beijing, China; MZBI, Museum Zoologicum Bogoriense, Bogor, Java, Indonesia; NMPC, National Museum (National History), Prague, Czech Republic.

Unless indicated otherwise, all examined specimens are deposited in the Insect Collection, the IZCAS.

## Systematics

### Genus *Zagrammosoma* Ashmead, 1904

*Hippocephalus* Ashmead, 1888: viii. Type species: *Hippocephalus multilineatus* Ashmead; by monotypy; preoccupied by *Hippocephalus* Swainson, 1839 in fishes.

*Zagrammosoma* Ashmead, 1904: 354, 393. Replacement name for *Hippocephalus* Ashmead (not Swainson).

*Zagrammatosoma* Schulz, 1906: 142. Unjustified emendation.

*Mirzagrammosoma* Girault, 1915: 279. Type species: *Mirzagrammosoma lineaticeps* Girault; by monotypy; synonymized by La Salle 1989: 230, 232.

**Diagnosis.** Vertex vaulted and extending above level of compound eyes; funicle 2-segmented; pronotum elongate; notaulus curved and extending to anterior half of axilla; axilla strongly advanced, typically elongate, mostly anterior to scutellum; mesoscutum elongate, longer than scutellum; scutellum with 2 pairs setae, and 2 parallel submedian grooves which are often difficult to discern due to color pattern; forewing often with fuscate areas; propodeum without plicae, but with remnants of a median carina; color at least partly yellow, often with striking patterns, not metallic.

**Biology.** The biology of *Zagrammosoma* has been poorly studied, but its taxonomic host range seems to be quite wide but within a narrow ecological niche. Species are ectoparasitoids, mostly of the larvae or pupae of leafminers from several insect orders, including Lepidoptera and Diptera (LaSalle 1989), occasionally Coleoptera (Peck 1951) and Hymenoptera (Ubaidillah et al. 2000), and in total 15 families in the above four orders (Noyes 2013).

## Checklist of known species of *Zagrammosoma* in Asia

### 1. *Zagrammosoma latilineatum* Ubaidillah, 2000

*Zagrammosoma latilineatum* Ubaidillah, 2000: 223–225, in Ubaidillah et al. (2000).  
Holotype ♀, Indonesia: West Java, Bandung, Pangalengan (MZBI).

**Distribution.** Australia; Indonesia.

**Hosts.** DIPTERA **Agromyzidae:** *Liriomyza huidobrensis*. (Ubaidillah et al. 2000)

### 2. *Zagrammosoma talitzkii* (Bouček, 1961)

*Cirrospilus* (*Zagrammosoma*) *talitzkii* Bouček, 1961: 18–19, 27–28. Holotype ♂, Moldova: Kishinev (NMPC).

*Cirrospilus talitzkii* Bouček, 1961: Kerrich 1969: 196.

*Zagrammosoma talitzkii* (Bouček, 1961): Yefremova 1995b: 50–51.

**Distribution.** Bulgaria; Kazakhstan; Iran; Italy; Moldova; Russia; Turkmenistan; Ukraine; Yugoslavia (Federal Republic); China: Xinjiang.

**Hosts.** LEPIDOPTERA **Bucculatricidae:** *Bucculatrix crataegi*; **Gracillariidae:** *Cameraria ohridella*, *Parornix persicella*, *Phyllonorycter connexella*, *Ph. corylifoliella*, *Ph. malella*, *Ph. saliciphaga*, *Ph. sorbi*, *Ph. spinicolella*; **Heliozelidae:** *Holocacista rivillei*; **Lyonetiidae:** *Leucoptera malifoliella*, *L. sinuella*; DIPTERA **Agromyzidae:** *Liriomyza pseudopygmina*. (Noyes 2013, Radeghieri et al. 2002, Yefremova 1995b)

### *Zagrammosoma dulanense* Cao & Zhu, sp. n.

<http://zoobank.org/693F11F7-D759-4029-A81A-9FC113FA14DC>

Figs 1–3

**Material examined.** Holotype 1 ♀; Paratypes: 8 ♀, 4 ♂. China: Qinghai Province, Dulan County, 2458 Km milestone locality on G109 national highway (35°53.782'N, 97°47.106'E), 3060m; Host moth: *Micrurapteryx sophorivora* (Lepidoptera: Gracillariidae); Host plant: *Thermopsis lanceolata* (Fabaceae); 29.VII. 2013, coll. Huan-Xi CAO.

**Diagnosis.** Antenna (Fig. 3d) with fuscate setae on flagellum and pedicel in dorsal view. Mesosoma (Figs 1a–d) yellow with black patterns and markings except pronotum and lateral lobes of mesoscutum pale yellow. A narrow median black stripe extends the whole length of mesosoma excluding neck. Forewing (Fig. 3e) hyaline with large bare areas and fuscate parastigma and stigmal vein in contrast to light colored marginal and postmarginal veins. Stigma long and slightly curved, with uncus near its apex. This new species can be distinguished from the other Asian species by the black marking



**Figure 1.** Habitus of *Zagrammosoma dulanense* Cao & Zhu sp. n.: **a** body in dorsal view ( $\sigma$ ) **b** body in dorsal view ( $\varphi$ ) **c** body in dorsal view ( $\varphi$ ) **d** body in lateral view ( $\varphi$ ). Scale bar: 0.5 mm.

pattern on the gastral tergites (Figs 1a-d), on which there are three black spots on Gt<sub>6</sub> and Gt<sub>7</sub>, respectively in female, and markings on Gt<sub>7</sub> are reduced into one median black spot in male.

The key provided here will differentiate *Z. dulanense* from other Asian species; it can be distinguished from any New World species with even vaguely similar body coloration by the following characters of the forewing: surface of forewing (Fig. 3e) completely hyaline and without dark markings except for a very small patch near stigma, stigmal vein (particularly at base) and parastigma bordering marginal vein with dark areas in contrast to light colored marginal and postmarginal veins.

**Description. Female.** Body length 2.0–3.1 mm.

**Color.** Body yellow with black stripes and spots (Fig. 1b–d).

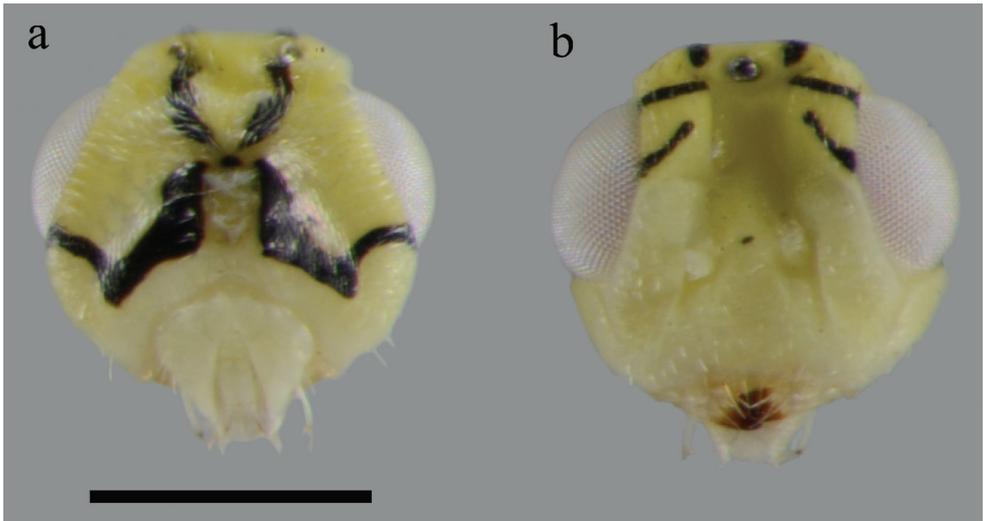
Frons yellow with two sets of short black stripes laterally extending from below the flange of vertex to upper lateral eye margin (Fig. 2b). Occipital foramen with a black spot. Two pairs of dark stripes diverging from occipital foramen, one pair diverging upward to the anterior ocellus, truncated into two pieces by posterior ocelli, and the other pair proceeding ventrally and curving antero-dorsally to meet ventral eye margin (Fig. 2a). Antenna yellow, scape with a oblique black stripe on dorsal surface, pedicel with a black spot basally on dorsal surface (Fig. 3d).

Pronotal collar and lateral lobe of mesoscutum pale yellow. A black stripe extending from base of pronotum to apex of scutellum medially, forming a reverse triangle on dorsellum. Two enlarged dark spots anterolaterally on mesoscutum, which are partially visible through the pronotum which overlaps them. Mesoscutum with dark stripe bordering axilla. Two parallel black stripes on lateral lobe of mesoscutum in lateral view. Acropleuron and upper mesepimeron with a dark stripe respectively; sometimes the one on upper mesepimeron truncated into two short parts. The border of metapleuron covered by dark stripe. Dark stripes along notauli and scuto-scutellar suture. Two dorsolateral dark stripes on scutellum, slightly diverging anteriorly and fused posteriorly. Lateral panel of metanotum with short black curved stripe. Propodeum with a dark stripe along the anterior margin and a W-shaped dark marking below it; the median line of “W” bold basally and apically, reaching the anterior margin.

Metasoma yellow with black coloration pattern (Fig. 1b–d). Black markings on Gt<sub>1</sub>-Gt<sub>5</sub> extend postero-laterally and develop the forms of “W” with straight or arched stripes below them; sometimes these stripes absent. Markings on Gt<sub>6</sub> and Gt<sub>7</sub> reduced to three black spots respectively.

Wings hyaline; vein pale yellow with the exception of fuscate parastigma and STV; SMV with a black line on it; humeral plate and tegula with one dorsal dark spot respectively. Legs (Fig. 3a–c) yellow; middle and hind coxae with dark dorsal spot; hind femur with black stripe on dorsal surface extending from base approximately three quarters the length of femur, and a black spot near apex of femur.

**Head:** Head (Fig. 2a–b) nearly quadrate in anterior view, with numerous short white setae. Mandible brown apically. Vertex with several scattered black setae dorsally, vaulted between compound eyes. Face with small and scattered white setae, difficult to



**Figure 2.** Head (♀): **a** head in posterior view **b** head in anterior view. Scale bar: 0.2 mm.

see due to the coloration pattern. Eyes bare. Toruli placed slightly above the level of lower eye margin. Relative measurements: POL 12, OOL 8.

**Antenna:** Antenna (Fig. 3d) with two anelli, two funicular segments and a 3-segmented club. The first funicle slightly longer than the second segment with ratio of length 11/9; the first funicle slightly longer than its width, the second segment as long as wide. Ratios of the length of three club segments: 8/6/6; the second club segment more transverse. All segments excluding scape and anelli setose with several fuscate setae in dorsal view. Longitudinal sensilla present on all funicular and club segments.

**Mesosoma:** Mesosoma (Fig. 1b–d) with fine reticulate sculpture dorsally and laterally, and several short white setae scattered on the midlobe of mesoscutum. Notaulus curving to meet axilla. Scutellum with 2 pairs of long white setae. Lateral panel of metascutum smooth; dorsellum large, triangular, the tip pointed. Propodeum with fine reticulate sculpture, callus with some white erect setae, spiracle small and round.

**Metasoma:** Metasoma with fine reticulate sculpture, pointed apically. Short white setae uniformly distributed on metasoma. Metasoma subequal in length with mesosoma, and slightly wider. Length ratio of metasoma/mesosoma: 100/105; width ratio of metasoma/mesosoma: 60/55. Petiole very short and transverse, not visible in dorsal view. Three dark cercal setae present, which are slightly different in length. Tips of ovipositor sheath visible dorsally.

**Legs.** Legs (Figs 3a–c) with numerous setae on tibiae and tarsi. Tibial spur on each leg shorter than basitarsus, particularly on fore leg.

**Forewing:** Forewing (Fig. 3e) length 1.5–1.8 mm, with large bare areas extending from base of basal cell to STV except for several admarginal setae on ventral surface of wing below MV. Costal cell with several pale setae on its dorsal surface. SMV with 5–10 dorsal setae, MV with a row of black setae. SMV longer than MV; PMV shorter



**Figure 3.** Appendages (♀): **a** mid leg **b** fore leg **c** hind leg **d** antenna **e** forewing. Scale bar: 0.5 mm.

than STV. Relative lengths of veins: SMV/MV/PMV/STV: 60/40/10/19. Several black setae on STV, stigma long and slightly curved, with uncus near its apex. The triangular area on wing surface between PMV and STV bare. Speculum open. Basal setal line absent. Cubital setal line absent at base, and its three or less setae extend into speculum. Subcubital line very close to the margin of forewing.

**Variation:** Apart from different body sizes of specimens, the main variation is in the color pattern, particularly on propodeum and metasoma. On propodeum, the lateral arms of W-shaped markings may not connect to the posterior transverse marginal stripe. On metasoma, variations include changes in thickness of stripes and whether the black transverse stripes below the W-shaped dark markings exist, and if exist, whether connecting to the W-shaped dark markings. Occasionally, there is a small dark spot between the toruli.

**Male:** Smaller than female. Body length 1.8–2.3 mm. Forewing length 1.3–1.6 mm. Antenna with numerous setae on flagellar segments, more setose than that of female. The significant difference between female and male lies in the pattern of stripes on metasomal tergites, which are often paler and less extensive than that of female (Fig. 1a).  $Gt_7$  shorter than other metasomal tergites by comparison, and markings on it reduced to one black spot. Genitalia protruding in dorsal view.

**Biology:** The new species has been reared from the pupae of *Micrurapteryx sophorivora* Kuznetsov & Tristan (Lepidoptera: Gracillariidae) on *Thermopsis lanceolata* R. Brown (Fabaceae).

Gençer and Seven (2005) reared 6 eulophid species (*Baryscapus nigroviolaceus*, *Cirrospilus pictus*, *Necremnus croton*, *Neochrysocharis arvensis*, *Neochrysocharis formosa*, *Pnigalio* sp.) and one pteromalid (*Pteromalus* sp.) from *Micrurapteryx sophorivora* mining *Robinia pseudoacacia* (Fabaceae) in Turkey.

The host plant is toxic and can cause livestock poisoning, but has also been used as a Chinese medicine plant (Zhu and Kirkbride 2006). Adults emerged from the host moth throughout August 2013, with fewer female specimens reared in September, while three males were collected in October. To our surprise, another female was captured from the dry host plant kept in the lab until mid May, 2014.

**Distribution.** China: Qinghai Province.

**Etymology.** This species is named for the locality in Dulan County, Qinghai Province, China, where the host plant, moth and type specimens were collected.

### Key to the known Asian species of *Zagrammosoma* based on females

Note that some species of *Cirrospilus*, e.g. *C. variegatus*, appears very close to *Zagrammosoma*, and even have a slightly to distinctly vaulted vertex. These species of *Cirrospilus* can be distinguished by having the notaulus straight posteriorly and extending to the scuto-scutellar suture.

- 1 Propodeum almost entirely dark; scutellum without dorsolateral stripes; median dark stripe on mesoscutum wide posteriorly, over half the width of scuto-scutellar margin ..... *Z. latilineatum*
- Propodeum almost entirely yellow but with dark stripes or markings; scutellum with dorsolateral stripes; median dark stripe on mesoscutum narrow, less than half the width of scuto-scutellar margin ..... **2**
- 2 Pronotum and lateral lobes of mesoscutum yellow; posterior margin of pronotum without dark or brown markings; speculum small with setae on dorsal surface of wing surface extending to line of admarginal setae on ventral surface; metasoma with short dark setae; three black spots on  $Gt_6$  in the form of a triangle;  $Gt_7$  with one small black spot ..... *Z. talitzkii*
- Pronotum and lateral lobes of mesoscutum pale yellow; posterior margin of pronotum with enlarged dorsolateral dark or brown spots; speculum large with setae on dorsal surface of wing clearly separated from line of admarginal setae on ventral surface; metasoma with short white setae; three black spots on  $Gt_6$  in a straight line;  $Gt_7$  with three black spots ..... *Z. dulanense* sp. n.

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Foundation to study reference materials of Eulophinae in Natural History Museum, London, UK in 2004–2005.

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# *Carlota*, a new genus of Agrypnini from the Valdivian Forests of Chile (Elateridae, Agrypninae, Agrypnini)

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## Abstract

*Carlota* **gen. n.**, with one included species *C. coigue* **sp. n.**, is described and illustrated from the Valdivian forests of Chile. The relationships of this genus to other Agrypnini from Chile are discussed and generic key for Chilean Agrypninae genera is provided.

## Resumen

Se describe e ilustra *Carlota* **gen. n.**, con una especie *C. coigue* **sp. n.**, de los bosques Valdivianos de Chile. Se discuten las relaciones de este género con otros Agrypnini de Chile y se proporciona una clave para éstos.

## Keywords

Chile, Coleoptera, Elateridae, Agrypninae, Agrypnini, new species, new genus

## Introduction

Up to now, the Chilean Elateridae includes 52 genera and 140 species (Arias-Bohart and Elgueta 2012). The canopy beetle faunas of *Nothofagus* spp., and Araucarian forests show at least 32 yet undescribed Elateridae taxa (Arias et al. 2008). From those representing unknown Elateridae collected by fogging I found several specimens of a new Agrypnini.

## Materials and methods

This study is based on the specimens from multiple collecting trips of the Essig Museum of Entomology, University of California, Berkeley (led by E. T. Arias-Bohart) and private Chilean collections. The type specimens and loan material are indicated in the text. Acronyms of institutions and private collections follow Arnett et al. (1993).

<b>ANIC</b>	Australian Insect Collection, Canberra, Australia
<b>ETA</b>	Elizabeth Arias-Bohart, (private collection), Berkeley, California, USA
<b>FMNH</b>	Field Museum of Natural History, Chicago, Illinois, USA
<b>IRScNB</b>	Collections Nationales Belges d’Insectes et d’Arachnides, Institut royal des Sciences Naturelles de Belgique, Brussels, Belgium
<b>MNHN</b>	Museum National d’Histoire naturelle, Paris France
<b>JEB</b>	Juan Enrique Barriga Tuñon, (private collection), Curicó, Chile
<b>MNNC</b>	Colección Nacional de Insectos, Museo Nacional de Historia Natural, Santiago, Chile
<b>SRC</b>	Sergio Riese, (private collection), Genova, Italy

Specimens from which the genitalia were removed were first relaxed in 10% KOH solution over 1 to 3 days.

For examination of the male genitalia, the last abdominal segments were removed and placed in water with a few drops of soap in a Petri dish and left overnight. Then genitalia were subsequently extracted and placed into a small vial with 90% alcohol, or glued on a card, or on a vial, and pinned under the specimen. Methods outlined by Becker (1958) were followed for examination of the female genitalia. After examination, female genitalia were placed in a small vial with glycerin and pinned under the specimen.

Measurements. Following measurements were made with the aid of a calibrated ocular micrometer as follows: total body length from the frontal margin to elytral apex; pronotal length and maximum width of the pronotum, when both sides are in focus, and elytral length and maximum width of the elytra, when both sides are in focus.

Terminology. Terms for adult morphology follows Platia (1994) and Calder (1996). Wing vein nomenclature follows that of Dolin (1975), Kukalová-Peck and Lawrence (1993, 2004).

Label Information. Places and names of the material studied are from the original spellings from recorded specimen labels. The following symbols are used in the recorded label information as follows:

/ indicating line separation within label, // indicating label separation. Juan Enrique Barriga’s collection labels include the following URL <http://www.coleoptera-neotropical.org>, which I have excluded from the label information.

Drawings were made using a camera lucida on a Leica MZ7 dissecting scope. Type material has been databased with a unique number indicated on the label information consisting of the acronym EMEC and the identification number. For example, the holotype of *Carlota coigue* sp. n., has the unique number EMEC10005989

followed by the repository in brackets. Type information of the described material is available online at <http://essigdb.berkeley.edu>.

## Taxonomy

### *Carlota* gen. n.

<http://zoobank.org/C20C8BB5-58D2-4477-A501-C81F9EE77C5C>

**Type species.** *Carlota coigue* sp. n., here designated.

**Etymology.** The generic name *Carlota* (gender feminine) is dedicated to my mother Carlota Tobar Vega, who has always encouraged me in my study of nature and insects.

**Diagnosis.** This genus differs from all other elaterid genera by the following characters: antennal grooves short, pronotum subquadrate; mesepisternum forming part of mesosternal cavity, mesosternal cavity shape oval; mesosternal posterior region pointed; mesocoxal distance about 4.6 times mesocoxal cavity. Wing venation with R cell short  $MP_{3+4}$  bent towards  $MP_{1-2}$  not branching towards  $MP4+CuA_1$ .

**Description.** Body about 3.72–4.22 times as long as wide, sides subparallel from anterior pronotal sides towards elytral sides, slightly narrowing posteriorly towards elytral apices. Dorsal vestiture short dense, fine, with some erect short well distributed hairs.

Head declined at base, transverse, ratio of median length to greatest postocular width 0.24. Eyes medium sized, protuberant in both sexes, faceted, lacking interfacetal hairs. Supra-antennal ridges strong, fossa shallow. Frontoclypeal region flattened and frontally carinate. Labrum small, transverse, sclerotised, sinuate basally. Antennae in male with antennomeres 3–10 strongly serrate, antennomere 11 elongate, much longer than preceding ones; all antennomeres clothed with long and short semi-erect and erect gold hairs. Female antennae shorter than male antennae.

Prothorax subquadrate, about 0.70–0.90 times as long as greatest width. Sides almost straight or slightly expanded posteriorly, carinate and emarginate, not visible for their entire length viewed dorsally. Posterior angles short and stout, produced posterolaterally. Posterior edge with scutellar notch broad and sharply defined. Disc punctate, clothed with dense hairs. Prosternum more or less flat with deep punctures. Notosternal suture complete, straight for most of its length, open anteriorly; curved posteriorly. Prosternal process narrow near base, then gradually expanded posteriorly, following procoxae in lateral view, extending well behind procoxae. Hypomerion simple, with deep punctures. Procoxae subglobular.

Elytra dark brown or black, about 2.79–3.18 times as long at midline as greatest width and 4.09–4.90 times as long as pronotum. Humeri well developed; parallel-sided anterior 2/3rds, gradually converging posteriorly, apices rounded. Disc with 10 weakly defined puncture rows. Mesoventrite on same plane as metaventrite. Mesocoxae slightly projecting, mesocoxal cavities narrowly separated, open laterally to mesanepisternum. Metacoxae obliquely oriented, with plates not extending to lateral edges of coxae.

Hindwing about 2.83 times as long as wide. Apical field about 0.6 times as long as total wing length, with 2 lightly pigmented oblique linear sclerites. Radial cell well developed, elongate, 3.4 time as long as wide, with inner posterobasal angle forming a right angle. Cross-vein  $r_3$  moderately short, horizontal and arising distally from  $r_4$ , which is mostly linear and complete. Base of RP very long, extending to wing base. R-M loop forming a narrowly acute angle; medial spur slightly curved. Medial field with five free veins.  $MP_{3+4}$  not branching in 2 veins (Figs 14, 16, 17).

Tarsomeres. 1–3 elongate, tarsomere 4 smaller than precedents. Pretarsal claws simple; empodium short, not extending between claws.

Female genitalia: bursa copulatrix globular, 1.51 mm in diameter, with one sclerotised internal structure comb-shape, with numerous spinules, mostly shorts and few longs (Fig. 21).

Aedeagus. Symmetrical, attached to parameres both dorsally and ventrally.

**Distribution.** Chile provinces: Curicó, Ñuble, Malleco, Cautín.

### *Carlota coigue* sp. n.

<http://zoobank.org/F69AB8E3-1F79-4CBE-AF19-B9FA7502C218>

Figs 1, 4, 10, 15, 20, 24–26

**Etymology.** This species is named after the evergreen tree *coigüe* (vernacular name of *Nothofagus dombeyi*) is to be considered a noun in apposition.

**Description.** Holotype ♂: Body brown; integument dull, body length 8.59 mm, width 2.16 mm (Fig. 1).

Head dark brown, deeply inserted into prothorax antenna same color as head. Antennomere 10 reaching apex of posterior pronotal angles, antennomere 3 smaller than antennomere 2, antennomere 5 through eighth similar in length, antennomere 11 about 1.6 times antennomere 10 (Fig. 24). Mandibles curved and acute (Fig. 25).

Prothorax anteriorly black and posteriorly with a reddish triangular area, with long gold semi-decumbent hairs, 1.36 times as long as wide. Punctate, punctures separated by more than one own diameter. Pronotal hypomeron base straight posteriorly.

Scutellum orange at middle. Elytra black or dark brown, 3.04 times as long as wide. Legs brown, vestiture black. Tarsomeres 2 and 4 more or less equal in length, tarsomere 4 only half as long as 1.

Male genitalia. Length 1.89 mm, and 0.35 mm wide. Parameres apex globose with a hook, with at least 3 strong setae (Fig. 26).

**Distribution.** Chile provinces: Curicó, Ñuble, Malleco, Cautín.

**Type material.** HOLOTYPE. On a card, ♂genitalia // 15-CHILE IX Region / Flor del Lago Ranch Villarrica / 39°12'378" / 78°08'182"312m // 12.XII.2003 / Canopy Fogging 60cc/l / Arias et al UCB // HOLOTYPE / *Carlota coigue* ♂ / E. Arias-Bohart 2013 //EMEC10005989// [MNNC]

PARATYPES. On a card //CHILE- ÑUBLE Shangri-lá / 6-11-12, 1998 / col. J. Mondaca // Paratype/ *Carlota coigue* ♂ / E. Arias-Bohart 2013 //EMEC10006002// [MNNC]



**Figure 1.** Adult of *Carlota coigue*.

On a card // abdomen //15-CHILE IX Region / Flor del Lago Ranch Villarrica / 39°12'378" / 78°08'182" / 312m / 12.XII.2003 / Canopy Fogging 60cc/l / Arias et al UCB // Paratype/ *Carlota coigue* ♂ / E. Arias-Bohart 2013 //EMEC10005991// [ANIC]

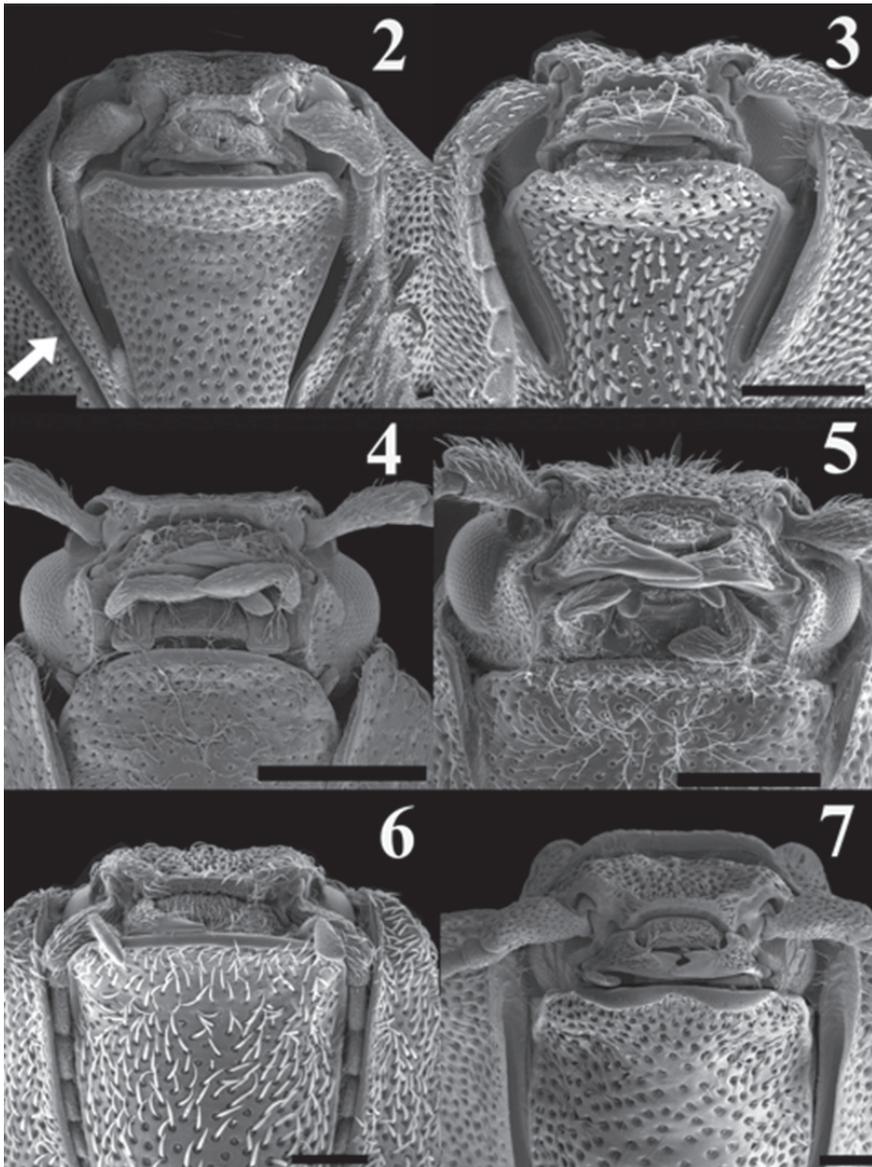
On a card // female genitalia on a vial //15-CHILE IX Region /Flor del Lago Ranch Villarrica/ 39°12'378" / 78°08'182" / 312m / 12.XII.2003 / Canopy Fogging 60cc/l / Arias et al UCB //Paratype/ *Carlota coigue* ♀ / E. Arias-Bohart 2013 // EMEC10005990// [ETA]

On a card //Shangrila /VIII Region/30-10-1988 /Elizabeth Arias // Paratype / *Carlota coigue* ♂ /E. Arias-Bohart 2013 //EMEC10005993// [ETA]

On a pin //Chile Marimenuco /Lonquimay / 10-15.XII.1986 / Coll. L.E. Peña // Paratype /*Carlota coigue* ♂ / E. Arias-Bohart 2013 //EMEC10005996// [ETA]

On a card //CHILE: Cautín P.R.: P.N./ Conguillío, 1.5 Km East/Laguna Captrén, guard sta.1365m, / 38°38'7"S, 71°41.37'W, // 23.xii.1996–5.ii.1997 // *Nothofagus dombeyi* deciduous spp., / *Araucaria*, with / *Chusquea* understory/ FMHD #96-229, flight/ intercept trap. A.New- / ton & M.Thayer 977/FIELD MUS. NAT. HIST. // Paratype /*Carlota coigue* ♂ / E. Arias-Bohart 2013 //EMEC10005994// [FMNH]

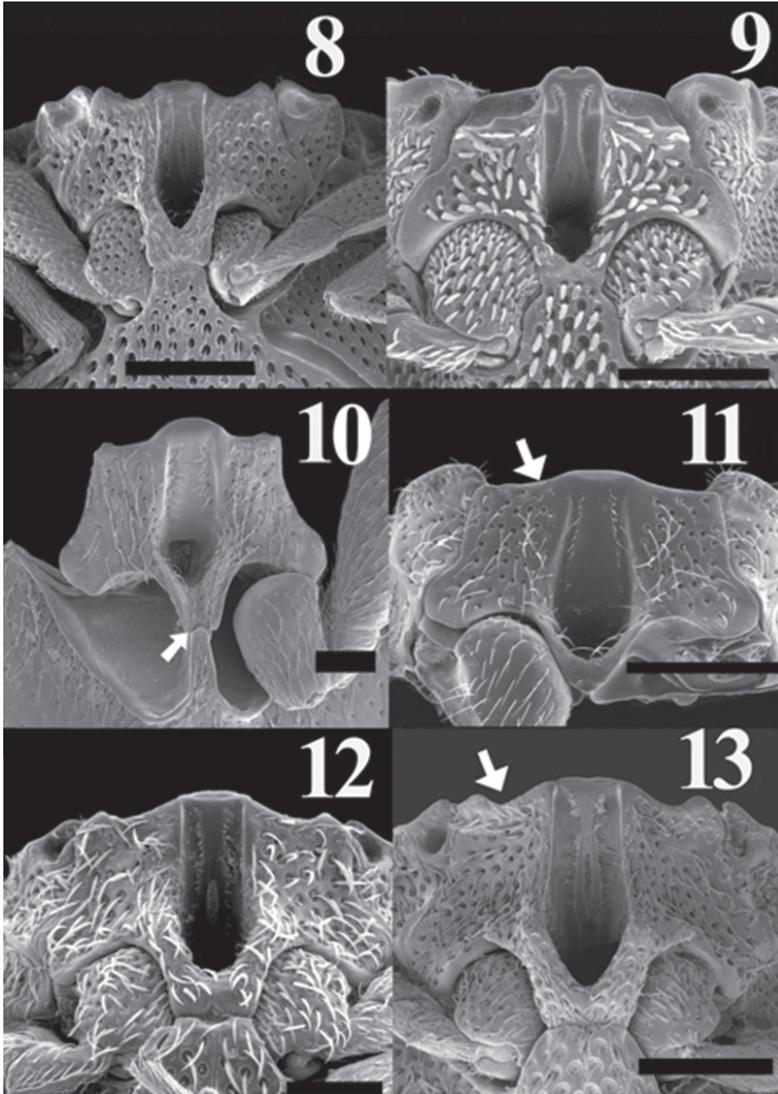
On a point //Chile, prov. Curicó, 15/ km. E. Potrero Grande, / Camino El Relvo, 19/ Leg. JE. Barriga T, / S/N. alpina, N. obliqua/ 36011.14 S700 56.1W // Colección J. E. Barriga //CHILE 163778 // Paratype/ *Carlota coigue* ♂ // E. Arias-Bohart 2013 // EMEC10005998// [IRScBN]



**Figures 2–7.** Scanning electron micrograph of frontal head of: *Acrocryptus ater* (2) *Agrypnus* sp. (Australia) (3) *Candanius* sp. (4) *Carlota coigue* (5) *Dilobitarsus laconoides* (6) *Lacon chilensis* (7). Scale bar = 1 mm.

On a card // male genitalia // Chile Talca 1300 m. /Altos de Vilches/ 26.I.69  
Valencia // Ex-colección / Jorge Valencia / JVCC / Chile 003660 // Colección JEBC  
/ Juan Enrique Barriga-Tuñón / Chile 0204053 // Paratype/ *Carlota coigue* ♂ // E.  
Arias-Bohart 2013 //EMEC10005999// [JEB]

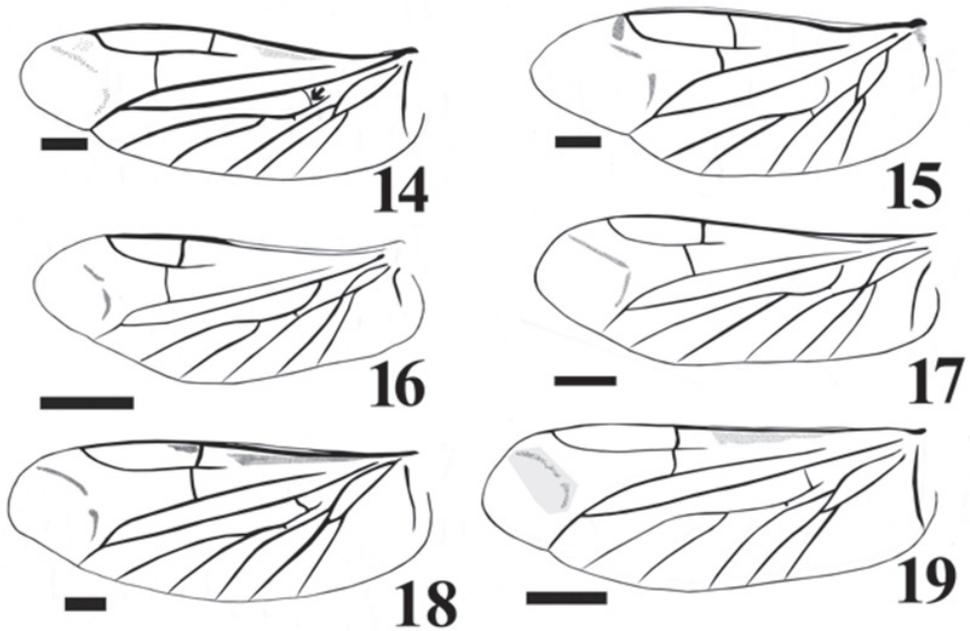
On a card // on a card male genitalia // Chile Arauco / Pichinahuel / 15.I.59 /  
G. Barria // Ex. Colección / Jorge Valencia /JVCC /Chile 003152 /Valencia //Ex-



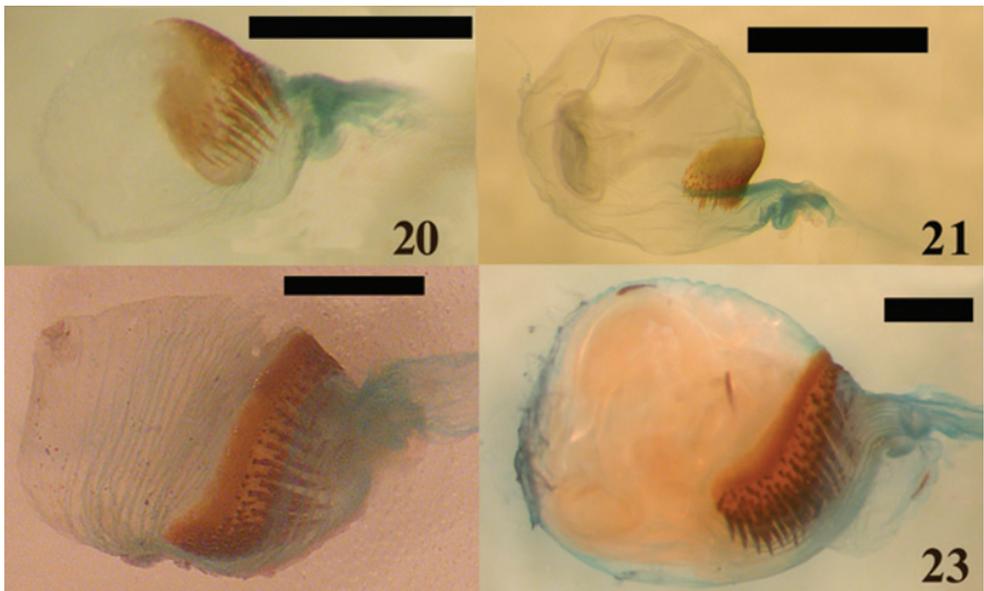
**Figures 8–13.** Scanning electron micrograph of mesoventral cavity of: *Acrocryptus ater* (8) *Agrypnus* sp. (Australia) (9) *Candanius* sp. (10) *Carlota coigue* (11) *Dilobitarsus laconoides* (12) *Lacon chilensis* (13). Scale bar = 1 mm.

colección / Jorge Valencia /JVCC/ Chile 003660 // Colección JEBC /Juan Enrique/ Barriga-Tuñón /Chile 0204684 // Paratype/ *Carlota coigue* ♂ //E. Arias-Bohart 2013 //EMEC100060000// [JEB]

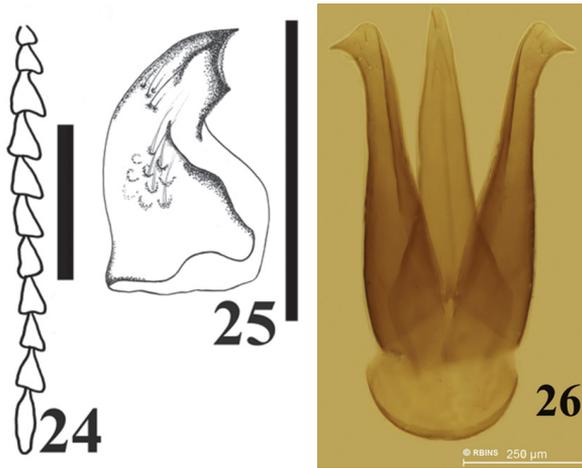
On a point // CHILE prov. Ñuble/ Shangri-lá, 1490 mt 36°52'34"S/ 71°28'3"W, 7 / dic 2008. Fogging Lengua (*Nothofagus pumilio*) / leg J. E. Barriga-Tuñón // Colección / JE Barriga-Tuñón / Chile 122722 // Paratype/ *Carlota coigue* ♂ / E. Arias-Bohart 2013 // EMEC10006001 // [JEB]



**Figures 14–19.** Wing venation illustration of: *Acrocryptus ater* **14** *Agrypnus* sp. (Australia) **15** *Candanius* sp. **16** *Carlota coigue* **17** *Dilobitarsus laconooides* **18** *Lacon chilensis* **19**. Scale bar = 1 mm.



**Figures 20–23.** Female genitalia of *Candanius* sp. **20** *Carlota coigue* **21** *Dilobitarsus laconooides* **22** *Lacon chilensis* **23** Scale bar = 0.5 mm.



**Figures 24–26.** Antennomeres, mandible and male genitalia of *Carlota coigue*. Antennomeres (**24**) mandible (**25**) male genitalia (**26**). Scale bar = 0.5 mm.

On a card // male genitalia // Chile, prov. Curicó, 15/ km. E. Potrero Grande, Puente Morongos, 25/ nov 2003, fogging a/ *Nothofagus dombeyi*/ S36°12'58.1"/ W70°58'37.4/ leg. J. E. Barriga// Colección J. E. Barriga // CHILE 148098 //Paratype / *Carlota coigue* ♂ // E. Arias-Bohart 2013 //EMEC10005997// [MNHN]

On a card, specimen & male genitalia //15- CHILE IX Region /Flor del Lago Ranch Villarrica /39°12'378"/78°08'182"312m / 12.XII.2003 / Canopy Fogging 60cc/l / Arias et al UCB // Paratype /*Carlota coigue* ♂ / E. Arias-Bohart 2013 // EMEC10005992// [SRC]

**Key to separate Chilean genera of Agrypnini**

- 1 Antennal groove short, less than half of length of pronotosternal suture; articulate surfaces of mesosternite not angulate (Fig. 11, white arrow); mesocoxal distance more than 4 times the length of the mesocoxal diameter ..... **2**
- Antennal groove more than half of length of pronotosternal suture; articulate surfaces of mesosternite angulate (Fig. 13, white arrow); mesocoxal distance less than 4 times the length of the mesocoxal diameter..... **3**
- 2 Pronotum elongate, lacking distinctive depressions; prosternal process following procoxae; posterior region of mesosternum excavate (Fig. 10, white arrow) ..... ***Candanius* Hayek**
- Pronotum subquadrate, with distinctive depressions; prosternal process straight; posterior region of mesosternum pointed (Fig. 11) .. ***Carlota* gen. n.**
- 3 Mesosternal cavity length less than three times its width (Fig. 13); tarsomeres lacking ventral lobes..... ***Lacon* Laporte**

- Mesosternal cavity length more than three times its width; tarsomeres with ventral lobe..... **4**
- 4 Antennomeres flabellate (Fig. 2); grooves for anterior, middles, and hind tarsomeres present on propleura, metasternum and abdominal sternite respectively (Fig. 8); mesosternum anteriorly with a small notch... ***Acrocryptus* Candèze**
- Antennomeres serrate (Fig. 6); lacking associated grooves for anterior, middles, and hind tarsomeres; mesosternum anteriorly without a small notch (Fig. 12)..  
..... ***Dilobitarsus* Latreille**

## Discussion

The subfamily Agrypninae is considered one of the most ancient subfamilies in Elateridae (Gurjeva 1969, Dolin 1978). However, even though several workers have treated this subfamily, its placement within the family is still insufficiently settled since most of the characters used to establish genus-level taxa in more advanced subfamilies of Elateridae show high variability within the Agrypninae at both the generic and specific level (Prosvirov and Savitsky 2011).

Hayek (1973) studied the characters to separate the genera of Agrypninae based on the structure of the middle coxal cavity, and was followed by Nakane and Kishii (1956) who also included the size and shape of the second and third antennal segment. Later, Gurjeva (1974) demonstrated the importance of the characters of the prothorax and metathorax, as well as those characters found on the bursa copulatrix as important in establishing natural supraspecific and suprageneric groups. Also, Gurjeva (1974) indicated that the rearward extent of the lateral lobes of the mesosternite was a subfamily character. I also found important the shape of the lateral lobes of the mesosternite, the shape and depth of the groove of the mesothoracic cavity important.

In Chile the tribe Agrypnini has 4 genera *Acrocryptus* Candèze, 1874, *Candanius* Hayek, 1874, *Dilobitarsus* Latreille, 1874, and *Lacon* Laporte, 1838 distributed in 8 species as follows: *Acrocryptus ater* (Philippi, 1873), *Candanius gracillimus* (Candèze, 1889), *Dilobitarsus crux* (Philippi & Philippi, 1860), *D. laconooides* (Fleutiaux, 1907), *D. sulcicollis* (Solier, 1851), *D. vitticollis* (Fairmaire & Germain, 1860), *Lacon chilensis* (Solier, 1851) and *L. fairmairei* (Candèze, 1881).

*Carlota* appears to be closely related to the genus *Candanius* because they share the following characters: short antennal grooves, not angulate articulate surfaces of mesosternite (Fig. 11, white arrow). Mesocoxal distances more than four times the mesocoxal diameter, and wing vein  $MP_{3+4}$  curves towards major vein  $MP_{1+2}$ , without branching in two short veins (Figs 16, 17).

*Carlota* differs from *Candanius* by the following (contrasting characters for *Candanius* in parentheses): posterior prosternal lobe truncate (Fig. 5) (posterior prosternal lobe curved Fig. 4), posterior region of mesosternum pointed (between mesocoxae Fig. 11) (posterior region of mesosternum excavate (between mesocoxae) Fig. 10), wing with two elongate plates (Fig. 17) (wing with two short plates, Fig. 16), prosternal spine

straight (prosternal spine follows procoxae), bursa copulatrix with a sclerotised structure about 0.37 times the bursa copulatrix diameter, (Fig. 21) (bursa copulatrix with a sclerotised structure about 0.68 times the bursa copulatrix diameter, Fig. 20).

*Carlota* differs from *Acrocryptus* by the following (contrasting characters for *Acrocryptus* in parentheses): short antennal grooves not well developed for the reception of the antennae (Fig. 5) (long antennal grooves for the reception of the antennae extending beyond the anterior half of the prosternopleural suture, Fig. 2), lacks grooves on propleura, metasternum and abdominal sternite for anterior, middles, and hind tarsomeres (posses grooves on propleura, metasternum and abdominal sternite for anterior, middles, and hind tarsomeres, Fig. 8), third and fourth tarsal segments without lobes (third and fourth tarsal segments with lobes).

*Carlota* differs from *Dilobitarsus* by the following (contrasting characters for *Dilobitarsus* in parentheses): short antennal grooves not extending beyond the anterior half of the prosternopleural suture, (Fig. 5) (antennal grooves extending beyond the anterior half of the prosternopleural suture, Fig. 6), mesosternal cavity sides anterior half region not parallel, (Fig. 11) (mesosternal cavity sides anterior half region parallel, (Fig. 12), third and fourth tarsal segments without lobes (third and fourth tarsal segments with lobes), wing R cell less than 2 times its width, (Fig. 17) (wing R cell more than 4 times its width, Fig. 18).

*Carlota* differs from *Lacon* by the following (contrasting characters for *Lacon* in parentheses): short antennal grooves not extending beyond the anterior half of the prosternopleural suture, (Fig. 5) (antennal grooves extending beyond the anterior half of the prosternopleural suture, Fig. 7), mesocoxal distance more than 4 times mesocoxal diameter, (Fig. 11) (mesocoxal distance less than 3 times mesocoxal diameter, Fig. 13), anterior region of mesosternum lacking a small notch, (Fig. 11) (anterior region of mesosternum with a small notch, Fig. 13), articulate lobes of mesosternum not angulate, (Fig. 11, white arrow) (articulate lobes of mesosternum angulate, Fig. 13).

*Carlota* most closely approaches the genus *Agrypnus* (studied *Agrypnus* sp. from Australia) which does not occur in Chile. It differs from *Agrypnus* by the following (contrasting characters for *Agrypnus* in parantheses): short antennal grooves, not extending beyond anterior half of the prosternopleural suture, (Fig. 5) (deep antennal grooves extending beyond anterior half of the prosternopleural suture, Fig. 3), anterior region of mesosternum not notched, (Fig. 11) (anterior region of mesosternum notched, Fig. 9), mesosternal cavity length less than 3 times its width, (Fig. 11) (mesosternal cavity length more than 3 times its width, Fig. 9), mesosternal cavity sides not parallel, (Fig. 11) (mesosternal cavity sides parallel, Fig. 9).

Based of the appearance of the prothorax, Hayek (1973) concluded that the retention of *Lacon* and *Dilobitarsus* could not be justified. However, I consider these two genera valid based on the following: *Dilobitarsus* differs from *Lacon* by the following (contrasting characters for *Lacon* in parentheses): walls of anterior half of the mesosternal cavity sides mostly parallel (walls of anterior half of the mesosternal cavity sides divergent), posterior region of the mesosternal cavity subquadrate, (Fig. 12) (posterior region of the mesosternal cavity V-shaped, Fig. 13), tarsomeres with lobes (tarsomeres without lobes), bursa copulatrix subglobular (bursa copulatrix globular), sclerotised structure of bursa

copulatrix about 0.4–0.5 times the diameter of bursa copulatrix, (Fig. 22) (sclerotised structure of bursa copulatrix about 0.3 times the diameter of bursa copulatrix, Fig. 23).

Discovery of the larvae of the above genera will likely help clarify the systematic position of the tribe Agrypnini and its members.

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Patrick Grootaert for access to the Candèze collection, type material and space to conduct my research in the Institut Royal des Sciences Naturelles de Belgique (IRScNB); Julien Cillis for taking the scanning electronic micrograph photo; Yves Laurent and Isabelle Bachy for taking color photos; Jerome Constant for helping with my research at IRScNB.

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# Life beneath the surface of the central Texan Balcones Escarpment: genus *Anillinus* Casey, 1918 (Coleoptera, Carabidae, Bembidiini): new species, a key to the Texas species, and notes about their way of life and evolution

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## Abstract

The Texas fauna of the genus *Anillinus* Casey, 1918 includes three previously described species (*A. affabilis* (Brues), 1902, *A. depressus* (Jeannel), 1963 and *A. sinuatus* (Jeannel), 1963) and four new species here described: *A. acutipennis* Sokolov & Reddell, **sp. n.** (type locality: Fort Hood area, Bell County, Texas); *A. comalensis* Sokolov & Kavanaugh, **sp. n.** (type locality: 7 miles W of New Braunfels, Comal County, Texas); *A. forthoodensis* Sokolov & Reddell, **sp. n.** (type locality: Fort Hood area, Bell County, Texas); *A. wisemanensis* Sokolov & Kavanaugh, **sp. n.** (type locality: Wiseman Sink, Hays County, Texas). A key for identification of adults of these species is provided. The fauna includes both soil- and cave-inhabiting species restricted to the Balcones Fault Zone and Lampasas Cut Plain and adjacent areas underlain by the Edwards-Trinity Aquifer. Based on morphological and distributional data, we hypothesize that four lineages of endogean *Anillinus* species extended their geographical ranges from a source area in the Ouachita-Ozark Mountains to the Balconian region in central Texas. There the cavernous Edwards-Trinity aquifer system provided an excellent refugium as the regional climate in the late Tertiary and early Quaternary became increasingly drier, rendering life at the surface nearly impossible for small, litter-inhabiting arthropods.

Isolated within the Edwards-Trinity aquifer system, these anilline lineages subsequently differentiated, accounting for the currently known diversity. The paucity of specimens and difficulty in collecting them suggest that additional undiscovered species remain to be found in the region.

### Keywords

Coleoptera, Adephaga, Carabidae, Bembidiini, Anillina, *Anillinus*, new species, Texas, cave faunas, soil faunas, Balcones Fault Zone, Edwards-Trinity aquifer, Lampasas Cut Plain

### Introduction

Representatives of the subtribe Anillina are typically litter- or soil-dwelling carabids, but they are not common in caves. Of the approximately 50 anilline species previously described from North America, only four species of *Anillinus* (namely, *A. longiceps* Jeannel (1963a), *A. smokiensis* Sokolov (2011), *A. tombarri* Sokolov (2012), and *A. valentinei* (Jeannel 1963b) and both described species of the genus *Anillaspis* Jeannel can be considered true troglobitic species. In North America, anilline beetles are more common and diverse in the wet and forested areas of the southern Appalachians (42 species of the 56 species known to date from the continent) than in the dry regions to the West of the Mississippi River (where only 14 species have been recorded) (Bousquet 2012; Sokolov 2012; Sokolov and Carlton 2012).

During the last 10 years, the caves of central Texas have been intensely monitored because of conservation issues involving endangered troglobitic species threatened by urban development (see U.S. Fish and Wildlife Service, Department of Interior 2000, Paquin and Hedin 2004, Ledford et al. 2012). Central Texas harbors one of the richer and more distinctive cave faunas of North America and the world (Culver et al. 2003, 2006). More than a thousand cavernicole taxa have been reported to date, including at least 160 cave obligates (troglobites) (Reddell 1994). Troglobitic species are known among schizomids, pseudoscorpions, myriapods, collembolans, thysanurans, diplurans, and crustaceans, but the most impressive radiations of cave obligates are found in spiders, opilionids, and beetles. Troglobitic Coleoptera are represented by Staphylinidae: Pselaphinae (Chandler 1992, Chandler and Reddell 2001, Chandler et al. 2009), Curculionidae (Paquin and Anderson 2009), and Carabidae, particularly members of the genus *Rhadine* (*subterranea* group) (Barr 1974, Reddell and Cokendolpher 2001, 2004, Reddell and Dupérré 2009). During these expeditions, in addition to typical cave dwellers, a small number of anilline carabids have been collected. In approximately 40 years of surveying Texas caves, only 40 specimens of Anillina have been found. Their rarity in collections may reflect habitat preferences that are unlike other troglobites because most surveys in Texas were carried out by experienced biospeleologists, namely the second author [JRR] and his collaborators, who are familiar with the collection of tiny arthropods.

Before the cave survey, the Texas fauna of anillines had included only three species of these tiny eyeless carabids, which were represented in collections by a total of only five specimens. Such diversity is low in comparison with anilline faunas of North

Carolina (14), Tennessee (12), or Alabama (9) (Bousquet 2012; Sokolov 2012; Sokolov and Carlton 2012) and possibly reflects certain difficulties in sampling the endogean microfauna in general and anillines in particular.

The first anilline species from Texas was described as *Anillus affabilis* Brues (1902: 366) from three specimens “collected at Austin, Texas”. According to Brues, all three specimens were taken from ant nests: two of these specimens “were sifted from a nest of *Eciton coecum* Latreille [= *Labidus coecus*], and one from a nest of *Solenopsis geminata* Fabricius”. The author of the description did not consider the species myrmecophilous, but pointed out that the beetles evidently shared their habitats with ants. After that first description, no new species were described from Texas for more than 60 years and only this species was cited for Texas in the first edition of the Catalogue of the Coleoptera of North America (Leng 1920). One more species, *Anillus debilis* LeConte (1853), originally described from California, was added to the Texas fauna in the fourth supplement to Leng’s catalogue (Blackwelder 1939). Obviously erroneous, this reference was copied from Jeannel’s first treatment of endogean bembidiines (Jeannel 1937). In the latter paper, Jeannel transferred all North American anillines, including Texan species, to the genus *Anillinus* Casey. However, later, in his main monograph on the world Anillina (Jeannel 1963a), he changed his view on the taxonomy of the North American fauna. In that monograph, he proposed a multilevel generic arrangement of the world anillines in “divisions” and “séries phylétiques.” Unfortunately, his inability to distinguish between two common genera from the eastern USA, *Anillinus* and *Serranillus* Barr (see Sokolov et al. 2004), led him to interpret the North American anilline genera incorrectly. As a main distinguishing character among the North American lineages, Jeannel (1963a, p. 48) used the number of parameres (one or two) in male genitalia. Accordingly, representatives of *Anillinus*, which Jeannel considered to have only one paramere (“à un seul style”), were incorrectly contrasted with representatives of anillines with the normal aedeagal configurations (i.e., two parameres). We surmise that Jeannel was using members of a *Serranillus* species, males of which lack the right paramere, leaving just the left one (Barr 1995; Sokolov et al. 2004; Sokolov and Carlton 2008, 2012) as his exemplars for genus *Anillinus* rather than true *Anillinus* specimens when he made these comparisons. As a result, Jeannel conceived of two North American lineages whose ranges roughly corresponded to the regions to the East and West of the Mississippi River. For the western fauna of non-troglobitic anillines, a new genus *Anillodes* Jeannel was established, and *A. affabilis* from Texas subsequently changed its taxonomic position for the second time. In addition, Jeannel described two new anillines from Texas, *Anillodes sinuatus* Jeannel and *Micranillodes depressus* Jeannel, each based exclusively on a single female. The holotype of the latter species supposedly possessed a labium with the mentum and submentum fused and had shortened elytra, which prompted Jeannel to erect a new genus for this species. This is how California and Texas anillines, technically both “western” but otherwise quite distinct from one another, came to be included in one genus, *Anillodes*. A few years ago, while preparing his revised Catalogue of Geadephaga of America, north of Mexico, (Bousquet 2012), Yves Bousquet examined types of the Texas species of Anil-

lina and judged them to be congeneric with the eastern *Anillinus* species and returned *A. affabilis* to that genus. He also transferred *A. sinuatus* and *M. depressus* (l.c.) to *Anillinus*. Currently, therefore, the Texas anillines are represented by three species in the genus *Anillinus*: *A. affabilis*, *A. depressus* and *A. sinuatus*.

Our preliminary investigation of the Texas Anillina collected in caves showed that material at hand could not be identified by reference to the existing original descriptions and, therefore, more thorough taxonomic study was needed. This paper presents the results of our taxonomic study of all the Texas representatives of Anillina known to the authors to date. The question of relationships between *Anillinus* and *Anillodes* is beyond the scope of this paper.

## Material and methods

This study is based on examination of 39 specimens of Anillina from Texas, representing seven species, four of which are described as new. Most of the specimens originated from the collection of the Texas Memorial Museum, The University of Texas at Austin, Austin, Texas, USA (TMM). Types and a few additional specimens were borrowed from the U. S. National Museum of Natural History (NMNH), Smithsonian Institution, Washington, DC, and the Museum of Comparative Zoology (MCZ), Harvard University, Cambridge, MA. Specimens from this study, including types, have also been deposited in collections at the California Academy of Sciences, San Francisco (CAS), and the Canadian National Collection, Ottawa, Ontario, Canada (CNC). Verbatim label data are given for type specimens of all newly described taxa, with label breaks indicated by a slash (“\”), and photographs of labels from types of previously described species are also included.

**Measurements.** All specimens were measured electronically using a Leica M420 microscope equipped with a Syncroscopy AutoMontage Photomicroscopy system (SYNCROSCOPY, Synoptics Ltd.). Measurements for various body parts are encoded as follows: LH = length of head, measured along midline from anterior margin of labrum to the virtual line, connecting posterior supraorbital setae; WH = width of head, at level of anterior supraorbital setae; W<sub>Pm</sub> = maximal width across pronotum; W<sub>Pa</sub> = width across anterior angles of pronotum; W<sub>Pp</sub> = width across posterior angles of pronotum; LP = length of pronotum from base to apex along midline; WE = width of elytra, at level of 4th umbilicate setae; LE = length of the elytra, from apex of scutellum to apex of left elytron; SBL = standardized body length, a sum of LH, LP and LE. SBL measurements are given in mm; others are presented as nine ratios: mean widths-WH/W<sub>Pm</sub> and W<sub>Pm</sub>/WE and body parts-W<sub>Pa</sub>/W<sub>Pp</sub>, W<sub>Pm</sub>/W<sub>Pp</sub>, W<sub>Pm</sub>/LP, WE/LE, LE/SBL, WE/SBL and LP/LE. All values are given as mean ± standard deviation.

**Illustrations.** Digital photographs of the dorsal habitus of new species were taken with the AutoMontage system using a Leica M420 microscope. Line drawings of selected body parts were made using a camera lucida on an Olympus BX 50 microscope. Scanning electron micrographs were made with coating on an ESEM FEI Quanta 200.

Dissections. Most of the specimens we examined were already dissected by previous investigators, and genitalia of these specimens were preserved in microvials with glycerol, pinned beneath the specimen. Where necessary, dissections were made by present authors using standard technique. Genitalia were dissected from the abdomens of specimens previously softened in boiling water for 20-30 minutes. Contents of the abdomen were cleared using boiling 10% KOH for 2-3 minutes to remove internal tissues, and then washed in hot water before examination. After examination, genitalia were mounted on plastic transparent boards in dimethylhydantoin formaldehyde resin (DMHF) and pinned beneath the specimen.

Type material. The authors investigated type material of all three previously described Texan species of anillines.

Terms. Terms used in this presentation follow Sokolov et al. (2004), Sokolov and Carlton (2008) and Sokolov (2013).

Species ranking. Species recognition is in accordance with our previous approach (Sokolov et al. 2004).

Descriptions. The scheme of descriptions follows that of Ball and Shpeley (2005, 2009).

## **Taxonomic treatment**

### ***Anillinus* Casey, 1918**

*Anillinus* Casey, 1918: 167.

For generic synonymy, see Bousquet (2012: 699).

**Type species.** *Anillinus carolinae* Casey, 1918.

**Recognition.** All examined specimens of Texan *Anillina* are characterized by the following combination of characters: Head totally covered with microsculpture (Fig. 2A–C) comprised of irregular, nearly isodiametric sculpticells. Anterior margin of labrum and clypeus straight. Frontal area flat with minute tubercle (ft) medially near frontoclypeal suture. Fronto-lateral carinae distinct and long. Primary head setae include a pair of clypeal (cs), a pair of frontal (fs) and two pairs of supraorbital (ass and pss) setae. Labium (Fig. 3A–B) with mental tooth; mentum and submentum separated by mental-submental suture (ms). Glossal sclerite (gsc) with distinct paraglossae (pg) laterally and with two setae apically. Maxillary palps (Fig. 2A–C) with short 4th palpomere (mp4), which is 0.2–0.3 length of palpomere 3 (mp3). Pronotum (Fig. 2D–F) of various proportions, totally covered with microsculpture (which is pronounced in most specimens, but present only as very fine microlines visible only at a certain angle in some specimens), with two long primary lateral setae (middle, ls, and basal, bs) on each side. Elytra (Fig. 2G–J) totally covered with microsculpture, with basal margination (bm) distinct and long, with scutellar, three discal, apical, and the series umbilicata setae. Scutellar and discal setae of similar size and approximately three times longer than surrounding vestiture. In most species,

last two (8th and 9th) pores (eo8 and eo9) of umbilicate series much closer to each other than 7th (eo7) pore is to 8<sup>th</sup> (not so only in *A. depressus* (Jeannel)). Abdomen with ventrite 5 of male with two and of female with four setae along the posterior margin. Aedeagi of males of all examined species with two parameres (Fig. 6), the typical configuration for most Anillina.

The arrangement of discal setae of elytra and the presence of two parameres in male aedeagi allow us to place all investigated species into the genus *Anillinus*. Beetles at hand vary in habitus from slightly to markedly elongate ( $WE/SBL \leq 0.38$ ), possess pronota with a rather narrow basal margin ( $WP_a/WP_p \geq 1.00$ ), and are completely covered with microsculpture dorsally (Fig. 2A–J). This combination of features allows us to place all of them in group 1 of endogean species of *Anillinus* (Sokolov et al. 2004).

**A key for identification of adults of the genus *Anillinus* from Texas**

- 1 Larger beetles on average (ABL range 1.60–2.00 mm); pronotum with basal margin more or less straight, posterior angles not shifted forward; elytral umbilicate series of pores with 8<sup>th</sup> and 9<sup>th</sup> pores geminate (Fig. 2G–I, eo8 and eo9)..... **2**
- Smaller beetles on average (ABL < 1.50 mm); pronotum with basal margin oblique laterally, posterior angles shifted forward (Fig. 1C); elytral umbilicate series of pores with 8<sup>th</sup> and 9<sup>th</sup> pores disassociated, 8<sup>th</sup> pore situated approximately equidistant from 7<sup>th</sup> and 9<sup>th</sup> pores (Fig. 17, p. 57, Jeannel 1963a) ..... **A. depressus (Jeannel)**
- 2 Body markedly elongate, subparallel, with head, pronotum and elytra of approximately equal width (Fig. 4E–F); width ratios of body parts: Hd/Pnrt>0.78, Pnrt/Eltr>0.85; pronotum more elongate ( $W_{pm}/LP < 1.25$ ), with shallow basilateral sinuation before the nearly rectangular (90–100°) posterior angles (Fig. 2E–F) ..... **3**
- Body slightly elongate, more ovoid, with narrower head and more oval and wider elytra (Fig. 5A–D); width ratios of body parts: Hd/Pnrt<0.78, Pnrt/Eltr<0.85; pronotum more transverse ( $W_{pm}/LP > 1.27$ ), lateral margins varied ..... **4**
- 3 Apex of elytron widely concave with a long curved spine on the outer margin of incision (Fig. 2J, 5E); female spermatheca with distal part of cornu (dpc) only slightly dilated (Fig. 7G) ..... **A. acutipennis Sokolov & Reddell, sp. n.**
- Apex of elytron EITHER truncate OR shallowly incised, without spine laterally (Fig. 2H–I, 5F); female spermatheca with distal part of cornu (dpc) markedly dilated (Fig. 7E) ..... **A. forthoodensis Sokolov & Reddell, sp. n.**
- 4 Pronotum with microsculpture distinct at any angle, with lateral margins more or less rectilinearly constricted towards slightly obtuse (100–110°) posterior angles (as in Fig. 2D); beetle from the territories to the north of Bexar County ..... **5**
- Pronotum with fine microsculpture visible on disc only at certain angles, lateral margins with shallow basilateral sinuation before the nearly rectangular (90–100°) posterior angles (Fig. 1B, Fig. 5B); beetle from Bexar County ..... **A. sinuatus (Jeannel)**

- 5 Male with abdominal ventrites modified as in Fig. 3D; male metafemora with small spine at middle of posterior edge (Fig. 4D); median lobe of male aedeagus without protuberance on dorsal margin (Fig. 6A); spermatheca of female with distal part of cornu (dpc) markedly dilated (Fig. 7C); habitus as in Fig. 1A..... ***A. affabilis* (Brues)**
- Male with abdominal ventrites simple (Fig. 3C); spermatheca of female varied.. **6**
- 6 Metafemora of male modified, triangularly dilated medially (Fig. 4E); median lobe of male aedeagus with protuberance (dp) on dorsal side, without spinose ventral sclerite (Fig. 6G, J); spermatheca of female with distal part of cornu markedly dilated (Fig. 7D); habitus as in Fig. 5C.....  
.....***A. wisemanensis* Sokolov & Kavanaugh, sp. n.**
- Metafemora of male unmodified, fusiform (Fig. 4G); median lobe of male with dorsal side evenly rounded, without dorsal protuberance extended beyond the general contour, and with large spinose ventral sclerite (vs) in the inner sac (Fig. 6K); spermatheca of female with distal part of cornu only slightly dilated (Fig. 7F); habitus as in Fig. 5D.....  
.....***A. comalensis* Sokolov & Kavanaugh, sp. n.**

***Anillinus acutipennis* Sokolov & Reddell, sp. n.**

<http://zoobank.org/7E00D63B-F269-4A2A-97F9-45D5ABFDAB07>  
Figs 2C, F, J, 3B, 5E, 7G, 8

**Type material.** HOLOTYPE, a female, deposited in CAS, point-mounted, dissected, labeled: \ TX: Bell Co., Talking Crows Cave, Fort Hood, 4.V.2006, J. Fant, M. Reyes \ Texas Memorial Museum Invertebrate Zool Coll #45.781 \ Holotype *Anillinus acutipennis* Sokolov & Reddell 2014 [red label] \ . CAS Type No. 18870 \ . PARATYPES: 2 females, both dissected; one, in CNC, labeled: \ TX: Bell Co., Hidden Pit Cave, Fort Hood, 27.X.2007, J. Reddell, M. Reyes \ Texas Memorial Museum Invertebrate Zool Coll #60.107 \ ; one, in TMM, labeled: \ TX: Hays Co., Wiseman Sink, 10mi, 2.IV.1995, A. G. Grubbs, C. Jordan \ Texas Memorial Museum Invertebrate Zool Coll #27.148 \ . Both paratypes also labeled: \ Paratype *Anillinus acutipennis* Sokolov & Reddell 2014 [yellow label] \ .

**Type locality.** U.S.A., Texas, Bell County, Fort Hood area.

**Etymology.** The specific epithet is a Latinized adjective in the masculine form and is derived from the Latin adjective *acutus* meaning "acute, sharpened" and the Latin noun *penna* meaning "feather, wing". The epithet refers to the spinose apex of elytron in members of the new species.

**Recognition.** Adults of this new species are distinguished easily from those of other Texan species of the genus by the following combination of external characters: markedly elongated habitus, distinctly elongate pronotum with shallow basolateral sinuation, and incised elytral apex with a distinct spine.

**Description.** Medium-sized for genus (SBL range 1.62–1.84 mm, mean 1.74±0.116 mm, n=3).

Habitus. Body form (Fig. 5E) subdepressed, subparallel, markedly elongate (WE/SBL  $0.33 \pm 0.009$ ), head large for genus compared to pronotum (WH/WPm  $0.80 \pm 0.006$ ), pronotum wide in comparison to elytra (WPm/WE  $0.88 \pm 0.013$ ).

Color. Body rufotestaceous, appendages testaceous.

Microsculpture. Distinct over all dorsal surfaces of head, pronotum and elytra, with slightly transverse polygonal meshes of more or less scaly appearance on elytra.

Head. Labium (Fig. 3B). Mental tooth present; mentum and submentum separated by suture. Glossal sclerite with distinct paraglossae laterally and with two setae apically.

Prothorax. Pronotum (Fig. 2F) relatively long (LP/LE  $0.42 \pm 0.016$ ) and markedly elongated (WPm/LP  $1.23 \pm 0.080$ ), with lateral margins shallowly sinuate and moderately constricted posteriorly (WPm/WPp  $1.28 \pm 0.020$ ). Anterior angles indistinct, posterior angles nearly rectangular ( $90\text{--}100^\circ$ ). Width between anterior and posterior angles of approximately equal length (WPa/WPp  $1.02 \pm 0.024$ ). Basal margin straight.

Elytra (Fig. 2J). Widely depressed along suture, comparatively short (LE/SBL  $0.57 \pm 0.004$ ) and narrow for genus (WE/LE  $0.59 \pm 0.020$ ), with traces of 4–5 striae. Humeri distinct, rounded, in outline forming obtuse angle with longitudinal axis of body. Lateral margins subparallel, slightly divergent at basal fourth, evenly rounded to apex in apical fourth, without subapical sinuation. Vestiture of elytra short (less than one-third length of discal setae). Apex of elytron deeply emarginate, the notch with a distinct spine laterally.

Male unknown.

Female genitalia. Spermatheca with distal part of cornu only slightly dilated, gradually tapered to proximal part. Nodus short, ramus undifferentiated (Fig. 7G).

**Geographical distribution.** This species has been found only in two remote areas of Bell (Lampasas Cut Plain) and Hays (Balcones Fault Zone) Counties, Texas (Fig. 8, white stars).

**Way of life.** This species has been found only in caves. The specimens from caves in Bell County were taken in darkness on the underside of rocks shallowly embedded in soil.

**Relationships.** In general habitus and in the modified apex of the elytra, members of this new species closely resemble *A. forthoodensis* adults, described below; however, they are more similar to members of *A. comalensis*, also described below, in the shape of the spermatheca. In the absence of males, the relationships of this species to the other Texan anillines is unclear. The presence of a spine on the lateral margin of the apex of the elytron is unique to this species among the known *Anillinus* species of Texas.

### *Anillinus affabilis* (Brues)

Figs 1A, 3D, 4D, 5A, 6A–C, 7B–C, 8

*Anillus affabilis* Brues, 1902: 366. Leng 1920

*Anillinus affabilis* (Brues), Jeannel 1937; Erwin and House 1978; Bousquet 2012

*Anillodes affabilis* (Brues), Jeannel 1963a

**Type material.** *Anillus affabilis* Brues, 1902: 366. Lectotype (Fig. 1A), designated by Erwin and House (1978: 233), a male, in NMNH, glued on a hair, dissected,

and labeled: \ schmitti [handwritten] \ Type [typed] \ COTYPE [typed red label] \ Austin Texas [handwritten] \ HSB dissect of int. 1932 [handwritten] [these first five labels mounted on a single card] \ Anillus affabilis Brues 1902 Mann Coll. 1932 [red handwritten label with male symbol] \ LECTOTYPE [male symbol] *Anillinus affabilis* (Brues) By Erwin 78 \. Two paralectotypes: one female, also in NMNH, labeled: \ Austin Texas [printed] \ E. caecum [handwritten] \ type [typed with blue ink] \ TYPE [typed red label] \ ADP 115719 \ *Anillodes affabilis* Brues R, Jeannel det. 19 \ USNM TM #2067637 \ Paralectotype *Anillus affabilis* Brues recognized by Sokolov & Kavanaugh 2014 [printed yellow label] \; one male, in MCZ, labeled: \ Austin Tex \ Type [white label] \ H. C. Fall Collection \ *Anillus affabilis* Brues \ Paralectotype *Anillus affabilis* Brues recognized by Sokolov & Kavanaugh 2014 [printed yellow label]

**Notes on nomenclature and types.** In his original description, Brues (1902) noted that he had examined three specimens of this species, all from Austin, Texas. In 1978, the paralectotype specimens noted above were unknown to Erwin and House (1978: 233) but they have been located in the MCZ and NMNH since then.

**Recognition.** Females of *A. affabilis* are practically indistinguishable from females of *A. wisemanensis*, described below. From adults of other Texan species of the genus, those of *A. affabilis* can be distinguished by the following combination of external characters: large size, comparatively narrow and transverse pronotum with rectilinearly constricted lateral margins, rather wide and long elytra with rounded apices; and males can be further distinguished by the minute spine on the posterior edge of metafemora and shape of the median lobe.

**Redescription.** Medium-sized for genus (SBL range 1.73–1.96 mm, mean  $1.87 \pm 0.120$  mm,  $n=3$ ).

**Habitus.** Body form (Figs 1A, 5A) subdepressed, subparallel, slightly elongate (WE/SBL  $0.38 \pm 0.010$ ), head normally proportioned for genus (WH/WPm  $0.76 \pm 0.026$ ), pronotum moderately narrow in comparison to elytra (WPm/WE  $0.78 \pm 0.007$ ).

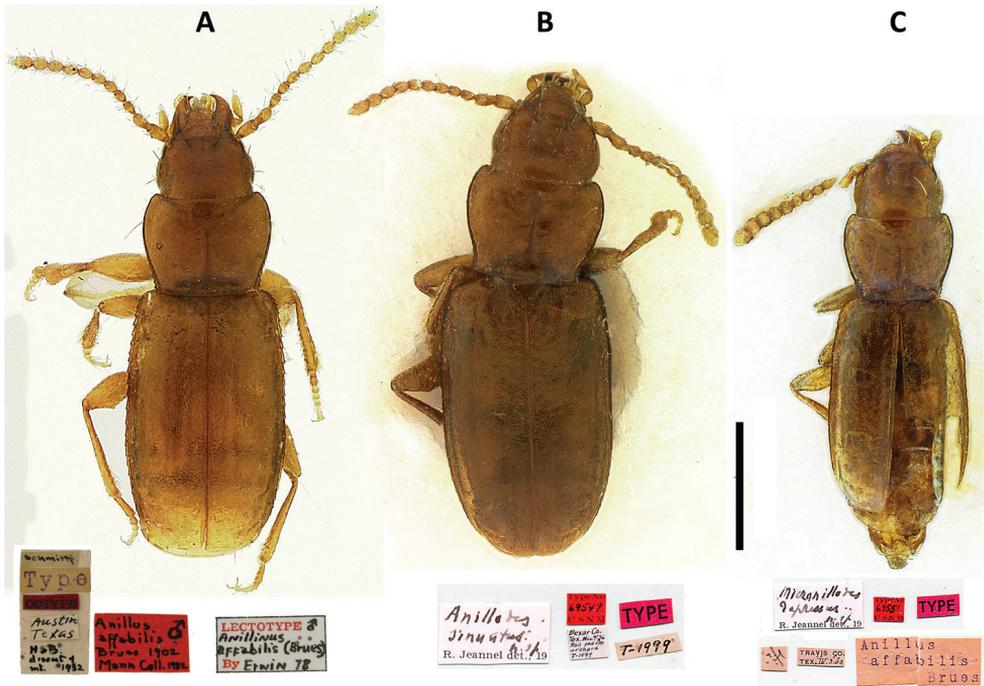
**Color.** Body rufotestaceous or brunneorufous, appendages testaceous.

**Microsculpture.** Distinct over all dorsal surfaces of head, pronotum and elytra, with slightly transverse polygonal meshes of more or less scaly appearance on elytra.

**Prothorax.** Pronotum of normal length (LP/LE  $0.39 \pm 0.012$ ) and slightly transverse for genus (WPm/LP  $1.31 \pm 0.016$ ), lateral margins almost rectilinear and moderately constricted posteriorly (WPm/WPp  $1.32 \pm 0.008$ ). Anterior angles indistinct, posterior angles slightly obtuse ( $100$ – $110^\circ$ ). Width between anterior and posterior angles of equal length (WPa/WPp  $1.00 \pm 0.026$ ). Basal margin almost straight.

**Elytra.** Widely depressed along suture, of normal length (LE/SBL  $0.58 \pm 0.008$ ) and typical width for genus (WE/LE  $0.66 \pm 0.029$ ), with traces of 4–5 striae. Humeri distinct, rounded, in outline forming right angle with longitudinal axis of body. Lateral margins subparallel, slightly divergent at basal fourth, evenly rounded to apex in apical fourth, without subapical situation. Vestiture of elytra short (less than one-third length of discal setae). Apex of elytron rounded.

**Legs.** Male protarsomere 1 markedly dilated apico-laterally with rows of adhesive setae ventrally. Male hind legs modified: metafemora with minute tooth at middle along posteroventral margin (Fig. 4D).



**Figure 1.** Images of type specimens of previously described Texas *Anillina* species. **A** *Anillus affabilis* Brues, lectotype; **B** *Anillodes sinuatus* Jeannel, holotype **C** *Micranillodes depressus* Jeannel, holotype. Scale = 0.5 mm.

Abdomen. Abdominal ventrites 3 and 4 of males each with a pair of protuberances at the places of setal attachments (Fig. 3D). Last visible abdominal ventrite of male slightly depressed (Fig. 3D).

Male genitalia. Median lobe of aedeagus (Fig. 6A) with short basal lobe, long arcuate shaft, and strongly enlarged apex, broadly rounded at tip. Dorsal margin strongly sclerotized along almost all its length. Ventral margin enlarged along entire length from apex to basal orifice, bearing numerous poriferous canals. Dorsal sclerite in form of a semicircular blade-like structure with characteristic basal prolongations. Without distinct ventral sclerites, but with few sclerotized fields in apicoventral area. Dorsal membranous field with small spines located dorsally from dorsal sclerite. Enlarged apical area of median lobe with a dark spine-like structure. Right paramere slightly enlarged, long and narrow, with numerous (>8) long setae (Fig. 6C), approximately equal in length to length of the paramere. Left paramere slightly enlarged apically and greatly so basally, with translucent keel and large lateral process comparable in size to paramere itself (Fig. 6B), without long setae.

Female genitalia. Gonocoxite 2 unguiform (Fig. 7B), rather long, with moderately curved blade and narrowly rounded apex, with nematiform and two ensiform setae, the lateral of which is thicker than the medial one. Laterotergite with 9–10 setae. Sper-

matheca (Fig. 7C, sp) with distal part of cornu (dpc) markedly dilated and abruptly narrowed to the proximal part (ppc). Nodus (n) short, ramus undifferentiated.

**Geographical distribution.** This species is known only from Travis County, Texas (Fig. 8, black triangle), in the vicinity of the Balcones Fault Zone. In addition to the lectotype and paralectotype, we have examined a total of five specimens (3 males and 2 females), all dissected: one male and one female labeled: \ TX: Travis Co., Tooth Cave, 24.V.1992, J. Reddell \ Texas Memorial Museum Invertebrate Zool Coll #27.145 \; one male and one female, in CNC, labeled: \ TX: Travis Co., Tooth Cave, 6.VI.1992, J. Reddell \ Texas Memorial Museum Invertebrate Zool Coll #27.146 \; one male, in TMM, labeled: \ TX: Travis Co., Three-Holer Cave, 18.VIII.1990, J. Reddell, M. Reyes \ Texas Memorial Museum Invertebrate Zool Coll #27.144 \.

**Way of life.** All newly collected beetles were found in caves on the underside of rocks shallowly embedded in soil. Specimens of the type series were sifted from ant nests (Brues 1902).

**Relationships.** The shape of the spermatheca in females and the armature of the internal sac and type of ventral enlargement of the median lobe in males suggest a likely relationship with *A. forthoodensis*.

***Anillinus comalensis* Sokolov & Kavanaugh, sp. n.**

<http://zoobank.org/39FE83DE-4E8E-4A42-9008-2C6E3EF8EFC9>

Figs 4G, 5D, 6K–M, 7F, 8

**Type material.** HOLOTYPE, a male, deposited in CAS, point-mounted, dissected, labeled: \ TX: Comal Co., 7mi W New Braunfels, 27.I.1995, A. G. Grubbs \ Texas Memorial Museum Invertebrate Zool Coll #27.151 \ Holotype *Anillinus comalensis* Sokolov & Kavanaugh 2014 [red label] \ CAS Type No. 18871 \. PARATYPES: 2 females, one in CNC and one in TMM, both dissected, labeled same as holotype, except each with the following label: \ Paratype *Anillinus comalensis* Sokolov & Kavanaugh 2014 [yellow label].

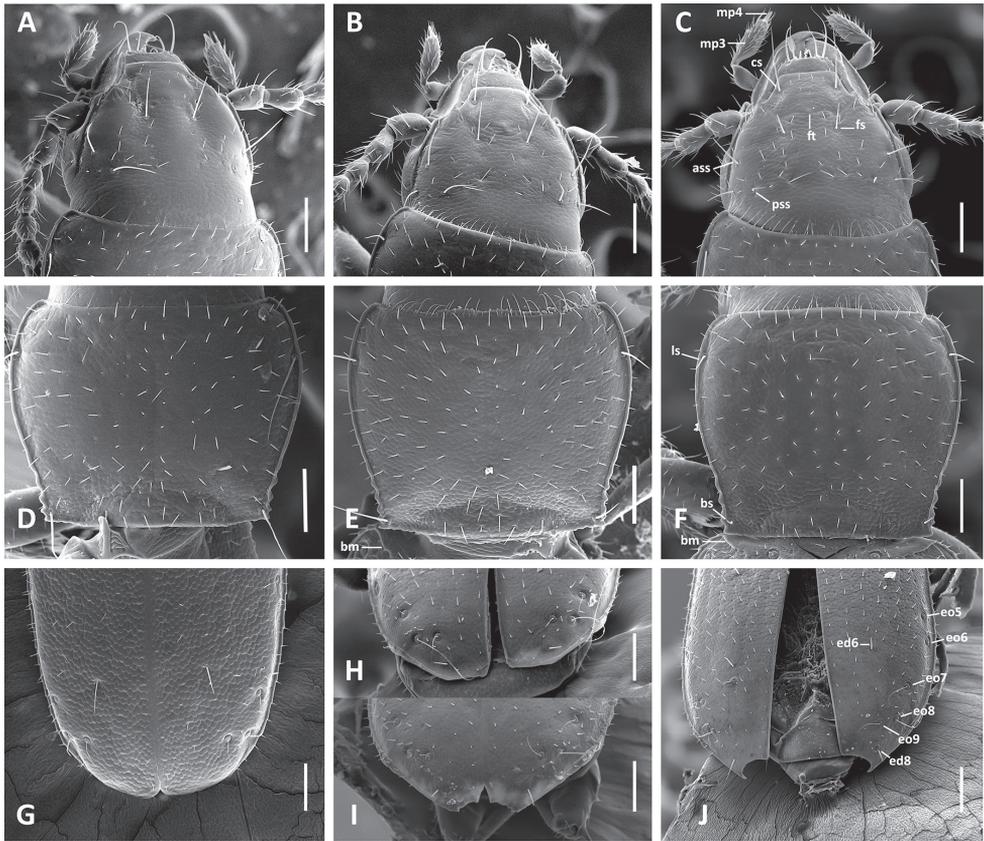
**Type locality.** U.S.A., Texas, Comal County, 7mi W New Braunfels.

**Etymology.** The specific epithet is a Latinized adjective in the masculine form based on the name of Comal County, from which the new species is described.

**Recognition.** Adults of this new species are distinguished from those of other Texan species of the genus by the following combination of external characters: slightly ovoid and narrow elytra, rather short and transverse pronotum and rounded apex of elytron; and males are further distinguished by the unmodified hind legs.

**Description.** Medium-sized for genus (SBL range 1.72–1.86 mm, mean  $1.78 \pm 0.072$  mm,  $n=3$ ).

Habitus. Body form (Fig. 5D) subdepressed, slightly ovate, slightly elongate (WE/SBL  $0.37 \pm 0.002$ ), head normally proportioned for genus (WH/WPm  $0.76 \pm 0.015$ ), pronotum rather narrow in comparison to elytra (WPm/WE  $0.80 \pm 0.015$ ).



**Figure 2.** SEM images of body parts, dorsal aspect, of *Anillinus* species. **A–C** Head: **A** *A. wisemanensis* (TEXAS, Hays County, Wiseman Sink) **B** *A. forthoodensis* (TEXAS, Bell County, Talking Crows Cave) **C** *A. acutipennis* (TEXAS, Bell County, Talking Crows Cave) **D–F** Pronotum: **D** *A. wisemanensis* (TEXAS, Hays County, Wiseman Sink) **E** *A. forthoodensis* (TEXAS, Bell County, Talking Crows Cave) **F** *A. acutipennis* (TEXAS, Bell County, Talking Crows Cave) **G–J** Apical half of elytra: **G** *A. wisemanensis* (TEXAS, Hays County, Wiseman Sink) **H** *A. forthoodensis* (TEXAS, Bell County, Bell Cave) **I** *A. forthoodensis* (TEXAS, Bell County, Talking Crows Cave) **J** *A. acutipennis* (TEXAS, Bell County, Talking Crows Cave). ass – anterior supraorbital seta; bm – basal margination; bs – basilateral pronotal seta; cs – clypeal seta; ed6 – 3d discal seta; ed8 – apical seta; eo5–9 setae from the umbilical series; fs – frontal seta; pss – posterior supraorbital seta; ft – frontal tubercle; ls – midlaterall pronotal seta; mp3 – maxillary palpomere 3; mp4 – maxillar palpomere 4. Scale bars = 0.1 mm.

Color. Body rufotestaceous, appendages testaceous.

Microsculpture. Distinct over all dorsal surfaces of head, pronotum and elytra, with slightly transverse polygonal meshes of more or less scaly appearance on elytra.

Prothorax. Pronotum (as in Fig. 2D) relatively short (LP/LE  $0.37 \pm 0.022$ ) and markedly transverse (WPM/LP  $1.31 \pm 0.046$ ), with lateral margins almost rectilinear and moderately constricted posteriorly (WPM/WPp  $1.29 \pm 0.027$ ). Anterior angles indistinct, posterior angles slightly obtuse ( $100\text{--}110^\circ$ ). Width between anterior and posterior angles of equal length (WPa/WPp  $1.00 \pm 0.037$ ). Basal margin almost straight.

Elytra (as in Fig. 2G). Widely depressed along suture, comparatively long (LE/SBL  $0.61 \pm 0.010$ ) and narrow for genus (WE/LE  $0.61 \pm 0.010$ ), with traces of 4-5 striae. Humeri distinct, rounded, in outline forming right angle with longitudinal axis of body. Lateral margins subparallel, slightly divergent at basal fourth, evenly rounded to apex in apical third, without subapical sinuation. Vestiture of elytra short (less than one-third length of discal setae). Apex of elytron rounded.

Legs. Male protarsomere 1 markedly dilated apico-laterally with adhesive setae ventrally. Male hind legs unmodified (Fig. 4G).

Abdomen. Ventrite 5 of male without depression.

Male genitalia. Median lobe of aedeagus (Fig. 6K) with short basal lobe (bl), long arcuate shaft (sh), and enlarged apex, rounded at tip. Dorsal margin strongly sclerotized along basal two thirds of the shaft length. Ventral margin enlarged in apical half, with numerous poriferous canals on wall of shaft medially. Dorsal sclerite (ds) in form of a curved blade-like structure with very short basal prolongations. Ventral sclerite (vs) in form of semicircular plate narrow in middle and abruptly widened at both ends, surfaces of which are totally spinose. Distinct spines are absent from internal sac. Enlarged apical area (aa) of median lobe with a dark spine-like structure (ss). Right paramere enlarged, very short and wide with numerous (>8) long setae (Fig. 6M) with length approximately equal to length of paramere. Left paramere of normal shape (Fig. 6L), without long setae.

Female genitalia. Spermatheca with distal part of cornu only slightly dilated, gradually tapered to the proximal part. Nodulus short, ramus undifferentiated (Fig. 7F).

**Geographical distribution.** This species is known only from the type locality in the New Braunfels area, Comal County, Texas (Fig. 8, white diamond), in the Balcones Fault Zone.

**Way of life.** The type specimens were taken from the underside of limestone rocks in talus.

**Relationships.** The unusual structure of the male median lobe and unmodified hind legs of males suggest that this species is not closely related to any of the other Texan anillines.

### *Anillinus depressus* (Jeannel)

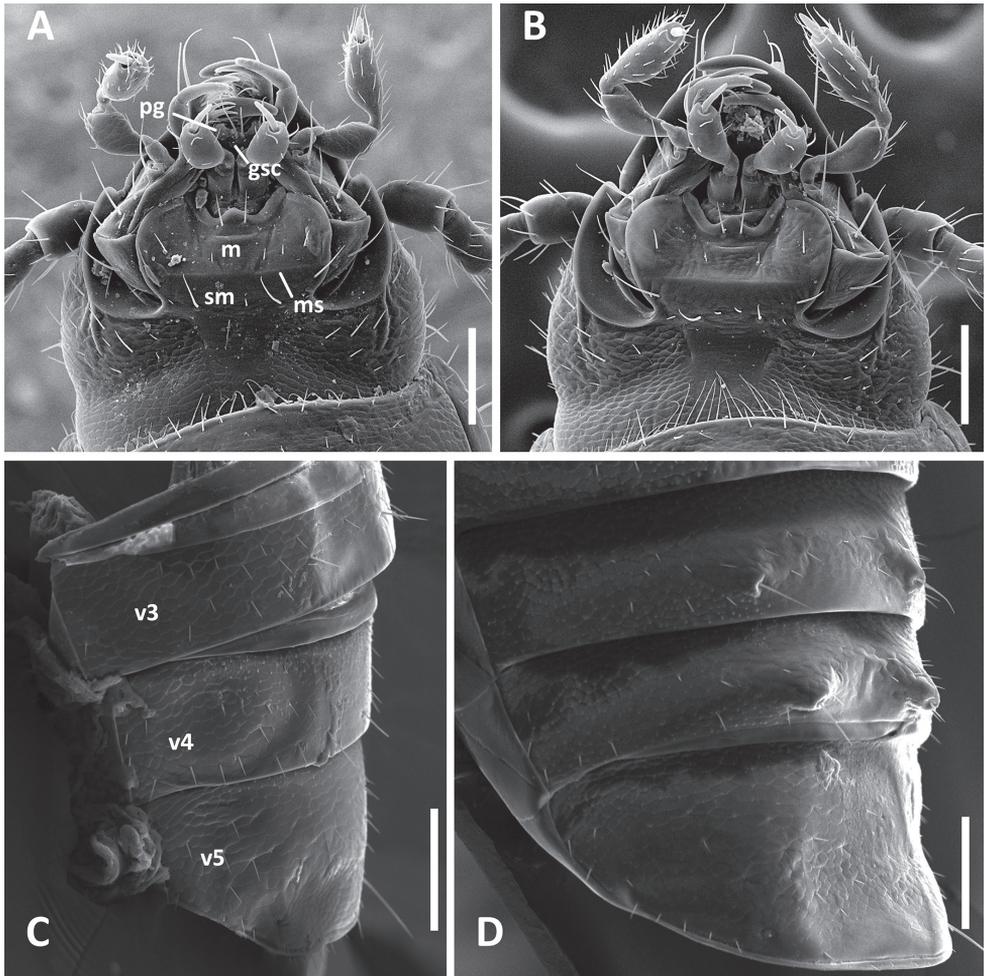
Figs 1C, 8

*Micranillodes depressus* Jeannel 1963a: 58. Holotype, a female, in NMNH, glued on cardboard and labeled as in Fig. 1C.

*Anillinus depressus* (Jeannel), Bousquet 2012

**Recognition.** Adults of *A. depressus* are distinguished easily from those of other Texan species of the genus by the following combination of external characters: small size, markedly elongated habitus, laterally oblique pronotal basal margin and simple (i.e., neither truncated nor incised elytral apex).

**Redescription.** Small-sized for genus (SBL 1.45 mm).



**Figure 3.** SEM images of structural features of *Anillinus* species. **A–B** Head capsule, ventral aspect: **A** *A. forthoodensis* (TEXAS, Bell County, Talking Crows Cave) **B** *A. acutipennis* (TEXAS, Bell County, Talking Crows Cave) **C–D** Abdominal ventrites 3-5, males, latero-ventral aspect: **C** *A. forthoodensis* (TEXAS, Bell County, Talking Crows Cave) **D** *A. affabilis* (TEXAS, Travis County, Tooth Cave). gsc – glossal sclerite; m – mentum; ms – mental-submental suture; pg – paraglossa; sm – submentum; v3-v5 – abdominal ventrites. Scale bars = 0.1 mm.

**Habitus.** Body form (Fig. 1C) subdepressed, subparallel, elongate (WE/SBL 0.34), head large for genus compared to pronotum (WH/WPm 0.83), pronotum wide in comparison to elytra (WPm/WE 0.85).

**Color.** Body rufotestaceous, appendages testaceous.

**Microsculpture.** Present over all dorsal surfaces of head, pronotum and elytra, but much finer on head and pronotum than on elytra.

**Head.** Labium with mental tooth present; mentum and submentum separated by suture.

Prothorax. Pronotum relatively long (LP/LE 0.41) and slightly transverse (W<sub>Pm</sub>/LP 1.29), with lateral margins almost rectilinear and strongly constricted posteriorly (W<sub>Pm</sub>/W<sub>Pp</sub> 1.33). Anterior angles indistinct, posterior angles slightly obtuse (100–110°). Width between posterior angles less than between anterior angles (W<sub>Pa</sub>/W<sub>Pp</sub> 1.10). Basal margin oblique laterally, so posterior angles noticeably shifted forward.

Elytra. Widely depressed along suture, of normal length (LE/SBL 0.57) and narrow for genus (WE/LE 0.61), with traces of 4–5 striae. Humeri distinct, rounded, in outline forming right angle with longitudinal axis of body. Lateral margins subparallel, slightly divergent at basal fourth, evenly rounded to apex in apical third, without subapical sinuation. Umbilicate series with 9 pores, 8<sup>th</sup> and 9<sup>th</sup> of which not geminate. Apex of elytron rounded with distinct sutural angle.

Genitalia not examined.

**Geographical distribution.** The single known specimen of this species was collected in Travis County, Texas (Fig. 8, black diamond), in the vicinity of the Balcones Fault Zone.

**Way of life.** No precise data provided in original description or on labels associated with the holotype.

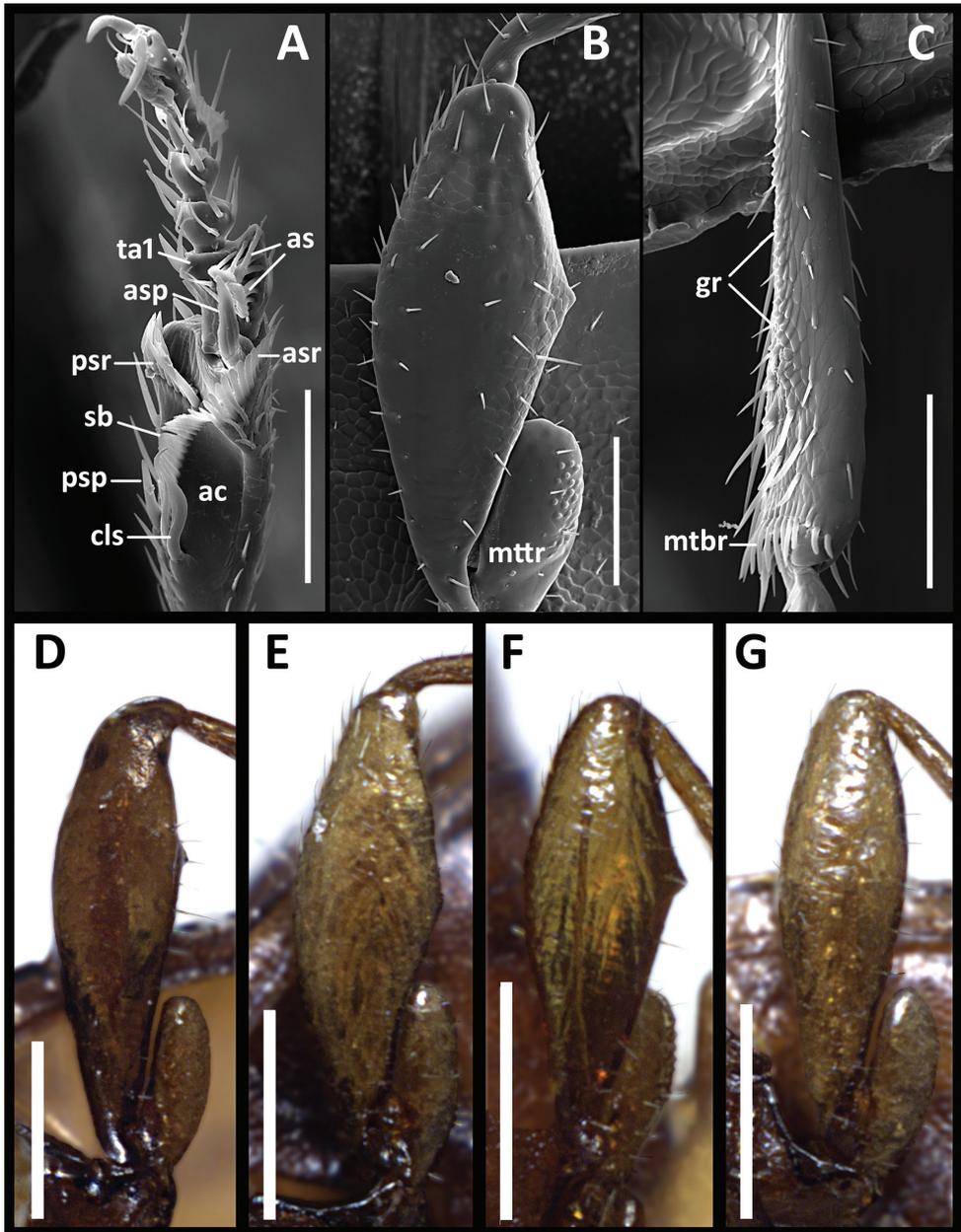
**Relationships.** Contrary to Jeannel's description (1963a), the type specimen possesses a distinct mental-submental suture on the labium and normal, not shortened, elytra [although the apical half of the right elytron is missing]. Chaetotaxy of the elytra cannot be investigated because of their poor condition, but Jeannel cited and illustrated three discal setae for the specimen. If so, then this specimen can be treated as a representative of *Anillinus*, as was done by Bousquet (2012). Configuration of the last pores of the umbilicate series may be of low importance for a separate generic status of the specimen, because it is known that this character is variable within "good" genera of anillines (Giachino and Vailati 2011). The small size and reduction of microsculpture on the foreparts of the body of its members make this species morphologically distinct from other Texan anillines. Perhaps, this combination of characters reflects adaptations for living in a rather different environment in comparison with the other species.

***Anillinus forthoodensis* Sokolov & Reddell, sp. n.**

<http://zoobank.org/A5899D9D-93A5-45A0-BC9E-E13A8A7EBED6>

Figs 2B, E, H–I, 3A, C, 4A–C, F, 5F, 6N–P, 7A, E, 8

**Type material.** HOLOTYPE, a male, deposited in CAS, point-mounted, dissected, labeled: \ TX: Bell Co., Talking Crows Cave, Fort Hood, 4.V.2006, J. Fant, M. Reyes \ Texas Memorial Museum Invertebrate Zool Coll #45.781 \ Holotype *Anillinus forthoodensis* Sokolov & Reddell 2014 [red label] \ CAS Type No. 18872. PARATYPES: 4 males and 3 females; two males and one female, in TMM, labeled same as holotype; one male, in CNC, labeled: \ TX: Bell Co., Talking Crows Cave, Fort Hood, 2 June 2005, J. Fant, J. Reddell, M. Reyes \ Texas Memorial Museum Invertebrate Zool Coll #38.153 \; one female, in TMM, labeled: \ TX: Bell Co., Nolan Creek Cave, Fort Hood, 27.IV.2007, J.



**Figure 4.** Structural features of legs of males of *Anillinus* species. *A. forthoodensis* (TEXAS, Bell County, Talking Crows Cave): **A** left protibia **B** left metafemur **C** left metatibia **D–G** Left metafemora: **D** *A. affabilis* (TEXAS, Travis County, Tooth Cave) **E** *A. wisemanensis* (TEXAS, Hays County, Wiseman Sink) **F** *A. forthoodensis* (TEXAS, Bell County, Talking Crows Cave) **G** *A. comalensis* (TEXAS, Comal County, 7mi W New Braunfels). ac – antennal cleaner; as – articulo-setae; asp – anterior spur; asr – anterior setal row; cls – clip seta; gr – granulation; mtbr – metatibial brush; mttr – metatrochanter; psp – posterior spur; psr – posterior setal row; sb – setal band; ta1 – tarsomere 1. Scale bars: **A–C** = 0.1 mm; **D–G** = 0.2 mm.

Fant, J. Reddell \ Texas Memorial Museum Invertebrate Zool Coll #55.333 \; one male and one female, in TMM, labeled: \ TX: Bell Co., Bell Cave, Fort Hood, 4 March 2010, J. Fant \ Texas Memorial Museum Invertebrate Zool Coll #70.872 \. All paratypes also labeled: \ Paratype *Anillinus forthoodensis* Sokolov & Reddell 2014 [yellow label] \.

**Type locality.** U.S.A., Texas, Bell County, Fort Hood area.

**Etymology.** The specific epithet is a Latinized adjective in the masculine form based on Fort Hood, the U. S. military post located in Texas, from the surroundings of which the new species is described.

**Recognition.** Adults of this new species are distinguished easily from those of other Texan species of the genus by the following combination of external characters: small size, markedly elongate habitus, distinctly elongate pronotum with shallowly sinuate lateral margins, and truncate apex of elytron.

**Description.** Medium-sized for genus (SBL range 1.65–1.73 mm, mean  $1.69 \pm 0.040$  mm,  $n=4$ ).

Habitus. Body form (Fig. 5F) subdepressed, subparallel, markedly elongate (WE/SBL  $0.33 \pm 0.010$ ), head large for genus compared to pronotum (WH/WPm  $0.79 \pm 0.022$ ), pronotum wide in comparison to elytra (WPm/WE  $0.88 \pm 0.031$ ).

Color. Body rufotestaceous, appendages testaceous.

Microsculpture. Distinct over all dorsal surfaces of head, pronotum and elytra, with slightly transverse polygonal mesh of more or less scaly appearance on elytra.

Head. Labium (Fig. 3A) with mental tooth; mentum and submentum separated by suture. Glossal sclerite with distinct paraglossae laterally and with two setae apically.

Prothorax. Pronotum (Fig. 2E) relatively long (LP/LE  $0.43 \pm 0.027$ ) and markedly elongate (WPm/LP  $1.21 \pm 0.024$ ), with lateral margins shallowly sinuate and moderately constricted posteriorly (WPm/WPp  $1.29 \pm 0.016$ ). Anterior angles indistinct, posterior angles nearly rectangular ( $90$ – $100^\circ$ ). Width between anterior and posterior angles of approximately equal length (WPa/WPp  $1.03 \pm 0.012$ ). Basal margin slightly convex.

Elytra (Fig. 2H–I). Widely depressed along suture, of normal length (LE/SBL  $0.56 \pm 0.010$ ) and narrow for genus (WE/LE  $0.59 \pm 0.022$ ), with traces of 4–5 striae. Humeri distinct, rounded, in outline forming obtuse angle with longitudinal axis of body. Lateral margins subparallel, slightly divergent at basal fifth, evenly rounded to apex in apical fourth, without subapical sinuation. Vestiture of elytra short (less than one-third length of discal setae). Apex of elytron truncate (Fig. 2H, 6 specimens out of 7 investigated) or shallowly emarginate (Fig. 2I, 1 female from 7 investigated).

Legs. Male protarsomere 1 markedly dilated apico-laterally with two rows of adhesive setae ventrally (Fig. 4A). Male hind legs modified: trochanters with many minute bumps scattered across ventral surface (Fig. 4B), metafemora triangularly dilated along posteroventral margin with a small tooth at tip of dilation (Fig. 4B, F), and metatibiae with granulate posterior margin (Fig. 4C).

Abdomen. Ventricle 5 of male with medial depression (Fig. 3C).

Male genitalia. Median lobe of aedeagus (Fig. 6N) with short basal lobe, long rectangularly bent shaft, and enlarged apex, broadly rounded at tip. Dorsal margin strongly sclerotized along almost all its length. Ventral margin enlarged along entire



**Figure 5.** Habitus images of *Anillinus* species. **A** *Anillinus affabilis* (TEXAS, Travis County, Tooth Cave) **B** *Anillinus sinuatus* (TEXAS, Bexar County) **C** *Anillinus wisemanensis* (TEXAS, Hays County, Wiseman Sink), holotype; holotype **D** *Anillinus comalensis* (TEXAS, Comal County, 7mi W New Braunfels), paratype **E** *Anillinus acutipennis* (TEXAS, Bell County, Hidden Pit Cave), paratype **F** *Anillinus forthoodensis* (TEXAS, Bell County, Talking Crows Cave), holotype. Scale bar = 0.5 mm.

length to basal orifice, with numerous poriferous canals. Dorsal sclerite in form of a semicircular blade-like structure with characteristic basal prolongations. Without distinct ventral sclerites. Dorsal membranous field with numerous small spines lo-

cated dorsally from dorsal sclerite. Enlarged apical area of median lobe with a dark spine-like structure. Right paramere enlarged, long and wide with numerous (>8) long setae (Fig. 6P), with length approximately two-thirds of length of the paramere. Left paramere wide, slightly enlarged apically and basally (Fig. 6O), without long setae.

Female genitalia. Gonocoxite 2 (Fig. 7A) unguiform (gc2), rather long, with slightly curved blade (bl) and narrowly rounded apex, with nematiform (ns) and two ensiform setae, with the lateral (les) of these thicker than the medial (mes). Laterotergite (lt) with 9–10 setae. Spermatheca with distal part of cornu markedly dilated. Nodus short, ramus undifferentiated (Fig. 7E).

**Geographical distribution.** This species is known only from several caves distributed in the Fort Hood area, Bell County, Texas (Fig. 8, white quadrangle), Lampasas Cut Plain.

**Way of life.** This species has been found only in caves. Specimens were taken in darkness on the underside of rocks shallowly embedded in soil.

**Relationships.** The medially depressed abdominal ventrite 5, the enlargement of the ventral margin of the median lobe and the presence of small spines on the dorsal membranous field in the internal sac of both *A. forthoodensis* and *A. affabilis* males suggest that they are the closest relatives among the Texan anillines.

### *Anillinus sinuatus* (Jeannel)

Figs 1B, 5B, 6D–F, 8

*Anillodes sinuatus* Jeannel 1963a: 57. Holotype, a female, deposited in NMNH, glued on cardboard and labeled as in Fig. 1B.

*Anillinus sinuatus* (Jeannel), Bousquet 2012

**Recognition.** Adults of *A. sinuatus* are distinguished from those of other Texan species of the genus by the following combination of external characters: large size, pronotum with long and shallow basilateral sinuations and microsculpture on pronotum much finer than on head and elytra; and males are further distinguished by the minute spine on the posterior edge of metafemora and shape of the median lobe.

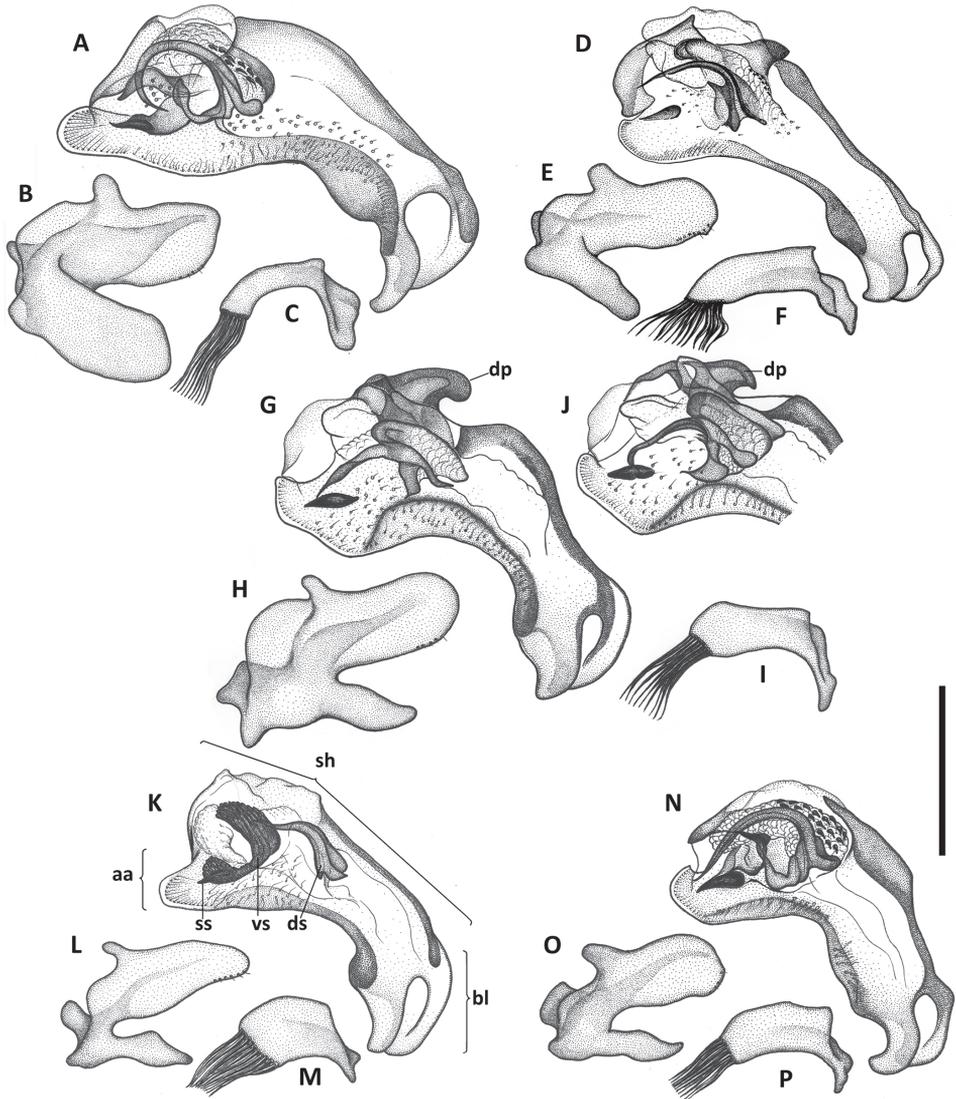
**Redescription.** Medium-sized for genus (SBL range 1.81–1.84 mm, mean  $1.83 \pm 0.019$  mm,  $n=2$ ).

Habitus. Body form (Fig. 1B, 5B) subdepressed, subparallel, slightly elongate (WE/SBL  $0.37 \pm 0.007$ ), head normally proportioned for genus (WH/WPm  $0.77 \pm 0.009$ ), pronotum rather narrow in comparison to elytra (WPm/WE  $0.81 \pm 0.008$ ).

Color. Body rufotestaceous, appendages testaceous.

Microsculpture. Distinct over all dorsal surfaces of head and elytra. Pronotum with much finer microsculpture, almost indistinct on disc and only at certain angles.

Prothorax. Pronotum of normal length (LP/LE  $0.40 \pm 0.004$ ) and slightly transverse for genus (WPm/LP  $1.31 \pm 0.019$ ), lateral margins with long and shallow sin-



**Figure 6.** Illustrations of male aedeagus of *Anillinus* species. *Anillinus affabilis* (TEXAS, Travis County, Tooth Cave): **A** median lobe, right lateral aspect **B** left paramere, left lateral aspect **C** right paramere, right lateral aspect. *Anillinus sinuatus* (TEXAS, Bexar County) **D** median lobe, right lateral aspect **E** left paramere, left lateral aspect **F** right paramere, right lateral aspect. *Anillinus wisemanensis* (TEXAS, Hays County, Wiseman Sink) **G** median lobe, right lateral aspect **H** left paramere, left lateral aspect **I** right paramere, right lateral aspect. *A. wisemanensis* (TEXAS, Bell County, Talking Crows Cave) **J** median lobe, right lateral aspect. *Anillinus comalensis* (TEXAS, Comal County, 7mi W New Braunfels) **K** median lobe, right lateral aspect **L** left paramere, left lateral aspect **M** right paramere, right lateral aspect. *Anillinus forthoodensis* (TEXAS, Bell County, Talking Crows Cave) **N** median lobe, right lateral aspect **O** left paramere, left lateral aspect **P** right paramere, right lateral aspect. aa – apical area; bl – basal lobe; dp – dorsal protuberance; ds – dorsal sclerite; sh – shaft; ss – spine-like structure; vs – ventral sclerite. Scale = 0.2 mm.

uation before posterior angles, moderately constricted posteriorly (WPm/WPp  $1.33 \pm 0.024$ ). Anterior angles indistinct, posterior angles nearly rectangular ( $90\text{--}100^\circ$ ). Width between anterior and posterior angles of approximately equal length (WPa/WPp  $1.03 \pm 0.020$ ). Basal margin almost straight.

Elytra. Widely depressed along suture, of normal length (LE/SBL  $0.58 \pm 0.008$ ) and typical width for genus (WE/LE  $0.64 \pm 0.003$ ), with traces of 5-6 striae. Humeri distinct, rounded, in outline forming right angle with longitudinal axis of body. Lateral margins subparallel, slightly divergent at basal fourth, evenly rounded to apex in apical fourth, without subapical sinuation. Vestiture of elytra short (less than one-third length of discal setae). Apex of elytron rounded.

Legs. Male protarsomere 1 markedly dilated apico-laterally with rows of adhesive setae ventrally. Male hind legs modified: metafemora with minute tooth at middle along posteroventral margin.

Abdomen. Abdominal ventrites of males unmodified.

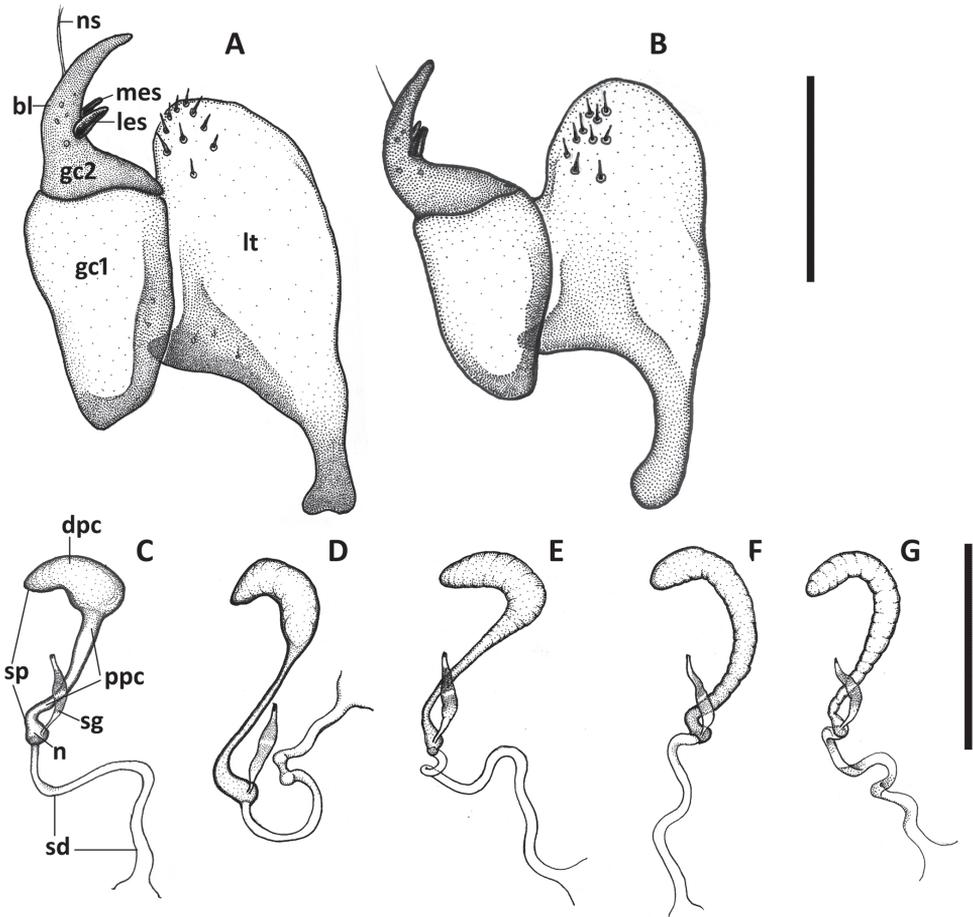
Male genitalia. Median lobe of aedeagus (Fig. 6D) with short basal lobe, long curved shaft, and enlarged apex, broadly rounded at tip. Dorsal margin strongly sclerotized along almost all its length, with rather large protuberance directed backwards and situated before apical orifice. Ventral margin enlarged only apically, where it bears numerous poriferous canals. Dorsal sclerite in form of a semicircular blade-like structure with short basal prolongations. Without distinct ventral sclerites. Dorsal membranous field with two very small spines located dorsally from dorsal sclerite. Enlarged apical area of median lobe with a dark spine-like structure. Right paramere slightly enlarged, long, of moderate width with numerous (>8) long setae (Fig. 6F), their length shorter than length of paramere. Left paramere enlarged apically and basally, where it forms a translucent convex keel (Fig. 6E), without long setae.

Female genitalia. Not investigated.

**Geographical distribution.** This species is known only from Bexar County, Texas (Fig. 8, black quadrangle), in the vicinity of the Balcones Fault Zone. In addition to the holotype, we have examined a total of 2 specimens (one male and the fragmentary remains of one female): one male (dissected), in NMNH, labeled: \ BexarCo. Tex. May 5 1938 T-11135 38-8191 \ From soil of peach orch. \ T-11135 \ USNM \ *Anillinus sinuatus* n. sp R. Jeannel det., 19 \ *Anillodes sinuatus* J. det. T.L.Erwin 96 \; one female (presumably the same species, represented only by two legs [right middle and hind legs]) on points, in NMNH, labeled: \ Bexar Co. Tex. Feb. 9. 1938 T-9056 38-2676 \ From soil of peach orchard \ T-9056 \ USNM \.

**Way of life.** All specimens at hand were extracted from soil during sampling surveys in peach orchards.

**Relationships.** The armature of the internal sac and the presence of the dorsal protuberance on the median lobe suggest a close relationship with *A. wisemanensis*, described below.



**Figure 7.** Illustrations of female genitalia of *Anillinus* species. Ovipositor sclerites: **A** *Anillinus forthoodensis* (TEXAS, Bell County, Talking Crows Cave) **B** *A. affabilis* (TEXAS, Travis County, Tooth Cave). Spermatheca: **C** *Anillinus affabilis* (TEXAS, Travis County, Tooth Cave) **D** *Anillinus wisemanensis* (TEXAS, Hays County, Wiseman Sink) **E** *Anillinus forthoodensis* (TEXAS, Bell County, Talking Crows Cave) **F** *Anillinus comalensis* (TEXAS, Comal County, 7 mi W New Braunfels) **G** *Anillinus acutipennis* (TEXAS, Hays County, Wiseman Sink). bl – blade of gonocoxite 2; dpc – distal part of cornu; gc1 – gonocoxite 1; gc2 – gonocoxite 2; les – lateral ensiform seta; lt – laterotergite; mes – medial ensiform seta; n – nodulus; ns – nematiform seta; ppc – proximal part of cornu; sd – spermathecal duct; sg – spermathecal gland; sp – spermatheca. Scale bars: A, B = 0.1 mm; C-G = 0.2 mm.

***Anillinus wisemanensis* Sokolov & Kavanaugh, sp. n.**

<http://zoobank.org/A2AB931C-A7FA-4F55-BCB7-473FABB599E4>

Figs 2A, D, G, 4E, 5C, 6G–I, 7D, 8

**Type material.** HOLOTYPE, a male, deposited in CAS, point-mounted, dissected, labeled: \ TX: Hays Co., Wiseman Sink, 28.IV.1995, A. G. Grubbs \ Texas Memorial Museum Invertebrate Zool Coll #27.149 \ Holotype *Anillinus wisemanensis* Sokolov & Kavanaugh 2014 [red label] \ CAS Type No. 18873 \ . PARATYPES: 1 male and

3 females, all dissected; one male and one female, in TMM, labeled: \ TX: Hays Co., Wiseman Sink No 2, 10mi W San Marcos, 22.IV.1995, A. G. Grubbs \ Texas Memorial Museum Invertebrate Zool Coll #27.150 \; one female, in TMM, labeled: \ TX: Hays Co., Wiseman Sink, 10mi, 2.IV.1995, A. G. Grubbs, C. Jordan \ Texas Memorial Museum Invertebrate Zool Coll #27.148 \; one female, in CNC, labeled: \ TX: Hays Co., Wiseman Sink, 30.IV.1995, A. G. Grubbs \ Texas Memorial Museum Invertebrate Zool Coll #27.147 \. All paratypes also labeled: \ Paratype *Anillinus wisemanensis* Sokolov & Kavanaugh 2014 [yellow label] \.

**Type locality.** U.S.A., Texas, Hays County, Wiseman Sink.

**Etymology.** The specific epithet is a Latinized adjective in the masculine form based on Wiseman Sink, the caves from which the type specimens were obtained.

**Recognition.** Females of *A. wisemanensis* are virtually indistinguishable from those of *A. affabilis*. Adults of this new species are distinguished from those of other Texan species of the genus by the following combination of external characters: only slightly transverse pronotum with rectilinearly constricted lateral margins, comparatively wide and short elytra, and rounded elytral apices; and males are further distinguished by the triangularly dilated metafemora and distinctive dorsal protrusion of the median lobe.

**Description.** Medium-sized for genus (SBL range 1.68–1.90 mm, mean  $1.77 \pm 0.110$  mm,  $n=4$ ), specimens from Bell County slightly larger (SBL range 1.81–1.93 mm,  $n=2$ ).

**Habitus.** Body form (Fig. 5C) subdepressed, subparallel, slightly elongate (WE/SBL  $0.36 \pm 0.010$ ), head normally proportioned for genus (WH/WPm  $0.76 \pm 0.015$ ), pronotum moderately wide in comparison to elytra (WPm/WE  $0.82 \pm 0.012$ ).

**Color.** Body brunneorufous, appendages testaceous.

**Microsculpture.** Distinct over all dorsal surfaces of head, pronotum and elytra, with slightly transverse polygonal meshes of more or less scaly appearance on elytra.

**Prothorax.** Pronotum (Fig. 2D) of normal length (LP/LE  $0.39 \pm 0.017$ ) and of normal proportions for genus (WPm/LP  $1.28 \pm 0.032$ ), lateral margins almost rectilinear and moderately constricted posteriorly (WPm/WPp  $1.29 \pm 0.025$ ). Anterior angles indistinct, posterior angles slightly obtuse ( $100\text{--}110^\circ$ ). Width between anterior and posterior angles of equal length (WPa/WPp  $1.01 \pm 0.028$ ). Basal margin almost straight.

**Elytra** (Fig. 2G). Widely depressed along suture, of normal length (LE/SBL  $0.58 \pm 0.007$ ) and rather narrow for genus (WE/LE  $0.61 \pm 0.013$ ), but specimens from Bell County with slightly wider elytra (WE/LE  $0.64 \pm 0.004$ ), traces of 4-5 striae evident. Humeri distinct, rounded, in outline forming right angle with longitudinal axis of body. Lateral margins subparallel, slightly divergent at basal fourth, evenly rounded to apex in apical third, without subapical sinuation. Vestiture of elytra short (less than one-third length of discal setae). Apex of elytron rounded.

**Legs.** Male protarsomere 1 markedly dilated apico-laterally with rows of adhesive setae ventrally. Male hind legs modified: metafemora triangularly dilated along posteroventral margin (Fig. 4E), and metatibiae with granulated posterior margin.

**Abdomen.** Ventrite 5 of male unmodified.

**Male genitalia.** Median lobe of aedeagus (Fig. 6G) with short basal lobe, almost rectangularly bent long shaft, and strongly enlarged apex, characteristically angulate ventrally and narrowly rounded at tip. Dorsal margin strongly sclerotized along al-

most all its length, with large protuberance directed backwards and situated before apical orifice. Ventral margin enlarged along all length, but most widely in apical half and then gradually tapered to basal orifice. Numerous poriferous canals on the ventral margin and medial walls of the shaft. Dorsal sclerite in form of a curved blade-like structure with characteristic basal prolongations. Without distinct ventral sclerites or spines. Enlarged apical area of median lobe with a dark spine-like structure. Specimens from Bell County demonstrate slightly different shape of dorsal protuberance and basal prolongations of dorsal sclerite (Fig. 6J). Right paramere enlarged, long and wide with numerous (>8) long setae (Fig. 6I) approximately equal in length to length of paramere. Left paramere wide, markedly enlarged in basal area, where it forms a translucent wide keel (Fig. 6H), without long setae.

Female genitalia. Spermatheca with distal part of cornu markedly dilated. Nodus short, ramus undifferentiated (Fig. 7D).

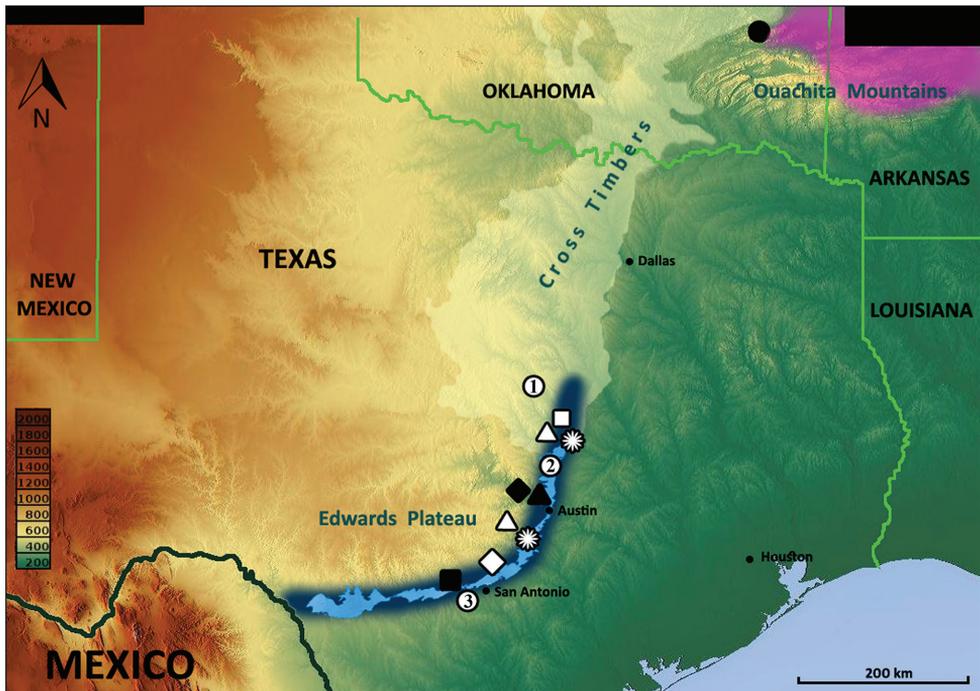
**Geographical distribution.** This species is known from two widely separated localities in Bell (Lampasas Cut Plain) and Hays (Balcones Fault Zone) Counties, Texas (Fig. 8, white triangles). In addition to the type series, we have examined two male specimens, both dissected, labeled: \ TX: Bell Co., Talking Crows Cave, Fort Hood, 19.VI.2003, J. Reddell, M. Reyes \ Texas Memorial Museum Invertebrate Zool Coll #55.559 \ [These specimens correspond to the new species in all respects, except in their being of slightly larger size, in having slightly wider elytra and in the degree of development of some features of the median lobe structure].

**Way of life.** This species has been found only in caves. Specimens from Fort Hood, Bell County, were taken in darkness from the underside of rocks shallowly embedded in soil.

**Relationships.** The shape of the spermatheca in females and the enlarged left paramere and shape of the dorsal sclerite of the median lobe in males suggest a possible but remote relationship with *A. affabilis*.

### Unidentified material

We are unable to associate definitively the following six specimens, all in TMM, with any of the seven species included above: one female labeled: \ TX: Coryell Co., Lucky Day Cave, Fort Hood, 27.VI.2009, J. Fant, J. Reddell, M. Reyes \ Texas Memorial Museum Invertebrate Zool Coll #70.013 \; one female labeled: \ TX: Bell Co., Sponge Bob Pot, Fort Hood, 17.II.2009, J. Fant, M. Warton \ Texas Memorial Museum Invertebrate Zool Coll #69.724 \; one male labeled (aedeagus lost): \ TX: Williamson Co., Lobo's Lair, 13.IX.1991, J. Reddell & M. Reyes \ Texas Memorial Museum Invertebrate Zool Coll #27.142 \; one female labeled: \ TX: Williamson Co., Lobo's Lair, 1.IX.1991, W. Elliot, J. Reddell, M. Reyes, M. Warton \ Texas Memorial Museum Invertebrate Zool Coll #27.126 \; one female (pronotum broken, ovipositor sclerites and spermatheca lost) labeled: \ TX: Bexar Co., Up the Creek Cave, 14.XI.1995, J. Cokendolpher, J. Reddell, M. Reyes \ Texas Memorial Museum Invertebrate Zool Coll



**Figure 8.** Locality records for *Anillinus* species: *A. acutipennis* – white stars; *A. affabilis* – black triangle; *A. comalensis* – white diamond; *A. depressus* – black diamond; *A. forthoodensis* – white quadrangle; *A. lescheni* – black circle; *A. sinuatus* – black quadrangle; *A. wisemanensis* – white triangles; *A. spp.* – white circles (1 – Bell and Coryell Counties; 2 – Williamson County; 3 – Bexar County). Violet color – range of the western *Anillinus* species in Arkansas and Oklahoma (Sokolov et al. 2004). Light blue color – recharge zone of the Edwards Aquifer, dark blue color – the Balcones Escarpment, topographic expression of the Balcones Fault Zone (Woodruff and Abbot 1986). Contour of the Cross Timbers ecological region (highlighted) were taken from Wikipedia: [http://en.wikipedia.org/wiki/Cross\\_Timbers](http://en.wikipedia.org/wiki/Cross_Timbers). Elevation scale bar is given in meters.

#27.141 \; one female (in poor condition, only head, pronotum and abdominal ventrites are present, ovipositor sclerites and spermatheca lost) labeled: \Zara-3873: TX: Bexar Co., Holy Smoke Cave, 10.XII.2008, P. Sprouse, S. Zappitello \.

Females from Coryell and Bell Counties (Fig. 8, white circle with a “1”) and Bexar County (Fig. 8, white circle with a “3”) are distinguished from those of all known species in having markedly transverse pronota (WPm/LP 1.33–1.37). At the same time, specimens from Coryell and Bexar Counties possess elytra of normal width for the genus (WE/LE 0.63–0.65), whereas one female from Bexar County has narrower than typical elytra (WE/LE 0.59). The two specimens from Williamson County (Fig. 8, white circle with a “2”) belong to a new species, but in the absence of genitalia from the male specimen and the presence of only one female, we consider a description of this species premature. Additional material is needed to clarify the taxonomic position of these unidentified specimens.

## Evolutionary aspects

New findings have increased the total number of *Anillinus* species recorded from Texas to seven. The discovery of these four new species allows us to suggest some hypotheses about different aspects of their taxonomy and evolution.

The external structural features of the species lead us to include them in one morphological group of totally microsculptured endogean species, but the forms of male and female genitalia exhibit a wide range of variation, suggesting that as many as four lineages may be involved: 1, the *A. affabilis-forthoodensis-sinuatus-wisemanensis* lineage; and three monobasic lineages – 2, the *A. depressus* lineage, 3, the *A. comalensis* lineage, and 4, the *A. acutipennis* lineage. Based on the shape of the median lobe and armature of the internal sac, *A. affabilis*, *A. forthoodensis*, and *A. wisemanensis* belong to a lineage of endogean species that is widely distributed across the geographical range of the genus. A configuration of male genitalia similar to the Texan species has been seen for the Appalachian *moseleyae*-group of species (Figs 11–12, p. 4, Sokolov 2011), *A. aleyae* Sokolov & Watrous (Fig. 2, p. 540, Sokolov and Watrous 2008) from southern Missouri, and *A. lescheni* Sokolov & Carlton (Fig. 30, p. 194, Sokolov et al. 2004) from eastern Oklahoma. Without a doubt, among the listed species, members of the last-named species are most similar to the Texan *Anillinus*. *Anillinus lescheni* members share with Texas specimens not only structural features of the median lobe, but also the type of metafemoral and metatibial modifications in males. Female genitalia remain mostly uninvestigated among endogean *Anillinus*, but dilation of the distal part of the cornu in the spermatheca, which is characteristic of *A. affabilis*, *A. forthoodensis*, and *A. wisemanensis*, is unusual for litter species but also has been seen in *A. aleyae* females (Fig. 5, p. 540, Sokolov and Watrous 2008) from southern Missouri. Based on similarities in the structure of hind legs of males, the shape of the median lobe and armature of the internal sac in males and the configuration of the spermatheca in females, we hypothesize that the Texan species are most closely related to and perhaps derived from species of the western Ouachita and Ozark Mountains fauna. However, this hypothesis can only be tested by a comprehensive phylogenetic analysis of genus *Anillinus*, which has not yet been undertaken.

The known distribution of Texan *Anillina* extends along the Balcones Fault Zone from San Antonio in the south to Georgetown in the north. Additional populations occur on the Fort Hood Military Installation in the Lampasas Cut Plains to the north (Fig. 8). With the likely exception of *A. sinuatus* at San Antonio and the possible exception of *A. depressus* in Travis County, all are known from caves or talus slopes in the Edwards Limestone. *Anillinus sinuatus* was collected from "peach orchards" which are not usually planted on limestone; therefore, this species may have been collected from south or east of the Balcones Fault Zone.

This virtually linear distribution of the Texan species of *Anillinus* reflects the fact that beneath the Balcones Fault Zone lie a number of underground water resources known as the Edwards-Trinity aquifer system of Texas (Ryder 1996). For endogean organisms, living more in the vertically- than horizontally-oriented world,

this underground world of vast water resources provides a good opportunity to escape from the unacceptably dry climatic conditions at the above-ground periphery of their ranges. The Edwards-Trinity aquifer system harbors a diverse stygobiontic arthropod fauna (Holsinger 1967; Barr and Spangler 1992) with, for example, unique species of diving beetles (Dytiscidae) (Young and Longley 1976; Spangler and Barr 1995; Miller et al. 2009; Jean et al. 2012). Possibly, subterranean aquifer systems surrounded by highly porous and fractured limestones also harbor a special subterranean anilline fauna, which is analogous to epigeal “streamside” bembidiine complexes of species and is confined to the damp rock interspaces and other crevices surrounding underground water bodies. This fauna is exceptionally difficult to sample and usually escapes sampling by investigators. However, from time to time its representatives can be collected in caves or even on the surface under rocks or in the soil after heavy rains or by using special methods of sampling.

Although the Fort Hood Military Installation is separated from the cavernous deposits of the Balcones Fault Zone by about 60 km of non-cavernous deposits, the same genera containing troglobites occur in both areas. This indicates that the ancestral species of troglobites ranged throughout the entire area. Both areas contain the same basic vegetation type and presumably were suitable habitat for the same litter-dwelling and endogean species that gave rise to the troglobites. The Fort Hood region belongs to the Lampasas Cut Plain, a subdivision of the Cross-Timbers ecological region (Gould 1975), which marks the western habitat limit of many mammals (Goetze and Nelson 2009), fishes (Hubbs 1957) and insects (Carlton 1990) and is also a transitional zone for many plants (Hatch et al. 1990) and animals whose ranges extend northward and eastward from the oak woodlands of Central Texas to the oak forests of the western Ouachita. Practically speaking, the Fort Hood region connects the modern range of Texas *Anillina* with the range of *A. lescheni* in Oklahoma (Fig. 8), and we hypothesize that, in a previous time, probably during or just prior to the late Tertiary or early Quaternary, when the regional environment began to dry (Graham 1999), this region served as a main route for the expansion of the eastern anillines deep into the southwest. The comfortable conditions of the Balcones Fault Zone, with its rich underground water resources, appear to have triggered a new round of speciation of endogean anillines in Texas. Without doubt, unseen and unknown underground connections and barriers in the region have shaped the modern distributions of species and driven their evolution. If so, we can expect further discoveries of these hard-to-collect, enigmatic beetles both along the Balcones Fault Zone and around the Edwards-Trinity Aquifer area, and perhaps also in the Cross-Timbers region, where *Anillina* species have not yet been reported.

In summary, we hypothesize that four lineages of endogean, totally microsculptured *Anillinus* extended their geographical ranges from their source area in the Ouachita-Ozark Mountains to the Balconian region in central Texas. There, they encountered the cavernous Edwards-Trinity aquifer system that provided an excellent refugium as the regional climate in the late Tertiary and early Quaternary became increasingly drier, rendering the near-surface conditions too dry to sustain the life of small litter-inhabiting arthropods. Isolated within the cool damp layers of limestone

penetrated by the Edwards-Trinity aquifer system, these anilline lineages differentiated, but to what extent is not known. One of them is represented by four species; each of the others might have remained monobasic, although it seems likely that they too differentiated within their Texan refugium.

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# Diversity and altitudinal distribution of Chrysomelidae (Coleoptera) in Peregrina Canyon, Tamaulipas, Mexico

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## Abstract

The Chrysomelidae (Coleoptera) is a highly speciose family that has been poorly studied at the regional level in Mexico. In the present study, we estimated species richness and diversity in oak-pine forest, Tamaulipan thorny scrub and in tropical deciduous forests in Peregrina Canyon within the Altas Cumbres Protected Area of the northeastern state of Tamaulipas, Mexico. Sampling of Chrysomelidae consisted of five sweep net samples (200 net sweeps) within each of three sites during four sample periods: early dry season, late dry season, early wet season, and late wet season. Species were identified and total numbers per species were recorded for each sample. A total of 2,226 specimens were collected belonging to six subfamilies, 81 genera and 157 species of Chrysomelidae from the study area. Galerucinae was the most abundant subfamily with 1,828 specimens, representing 82.1% of total abundance in the study area. Lower abundance was recorded in Cassidinae (8.5%), Eumolpinae (3.6%), Cryptocephalinae (2.2%), Chrysomelinae (2.2%), and finally Criocerinae (1.3%). The highest species richness was also presented in the subfamily Galerucinae with 49% of the total obtained species followed by Cassidinae (20%), Cryptocephalinae (9.7%), Eumolpinae (9.7%), Chrysomelinae (6.5%) and Criocerinae (5.2%). The most common species were *Centralaphthona fulvipennis* Jacoby (412 individuals), *Centralaphthona diversa* (Baly) (248), *Margaridisa* sp.1 (219), *Acallepitrrix* sp.1 (134), *Longitarsus* sp.1 (104), *Heterispa vinula* (Erichson) (91), *Epitrrix* sp.1 (84) and *Chaetocnema* sp.1 (72). Twenty-two species were doubletons (1.97% of total abundance) and 52 were singletons (2.33%). The estimated overall density value obtained was 0.0037 individuals/m<sup>2</sup>. The greatest abundance and density of individuals were recorded at the lowest elevation site. However, alpha diversity increased with increasing altitude. Similarity values were less than 50% among

the three sites indicating that each site had distinct species assemblages of Chrysomelidae. The highest abundance was obtained during the late dry season, whereas diversity indices were highest during the early wet season. The present work represents the first report of the altitudinal variation in richness, abundance, and diversity of Chrysomelidae in Mexico. These results highlight the importance of conservation of this heterogeneous habitat and establish baseline data for Chrysomelidae richness and diversity for the region.

### Keywords

Chrysomelidae, leaf beetles, species richness, abundance, altitude, Northeast Mexico

### Introduction

Chrysomelidae is one of the largest families within the order Coleoptera, with over 35,000 species described worldwide (Jolivet et al. 2009). In Mexico, about 2,174 species are known (Ordóñez-Reséndiz et al. 2014), although the actual number is probably considerably greater. The family is also an economically important group due to their predominantly phytophagous feeding habits (Ding et al. 2007, Meissle et al. 2009). This feeding characteristic and their generally high abundance also make leaf beetles an important component of food webs and a major component of tropical herbivore guilds (Farrell and Erwin 1988, Basset and Samuelson 1996) as well as being an important food item for other organisms (Eben and Barbercheck 1996).

The great species richness of Chrysomelidae and their role as a phytophagous functional group make the Chrysomelidae a potentially useful indicator group for: 1) biodiversity of a region (Farrell and Erwin 1988, Kalaichelvan and Verma 2005, Baselga and Novoa 2007, Aslan and Ayvaz 2009), 2) environmental quality (Linzmeier et al. 2006), and 3) as a taxon for monitoring changes in natural areas (Staines and Staines 2001, Flowers and Hanson 2003). However, the use of this family as such has not been adequately explored. In addition, the general lack of published studies of the species richness and diversity of Chrysomelidae in Mexico (Burgos-Solorio and Anaya-Rosales 2004, Andrews and Gilbert 2005, Niño et al. 2005, Furth 2006, Furth 2009), makes it difficult to compare the particular ecological characteristics and biogeographical distribution patterns of this family with other taxa in the country.

Recent climatic and environmental changes create an ecological imbalance that threatens biodiversity. It is vital that baseline data is available through faunistic inventories along elevational gradients to record and predict how organisms alter distributions and adapt to environmental changes (Maveety et al. 2011). This is especially so for Mexico where altitude is often associated with marked changes in the richness and abundance of species (Peterson et al. 1993), producing rapidly changing distribution patterns along altitudinal gradients (Hodkinson 2005).

The present study was conducted in the Cañon of the Peregrina within Altas Cumbrés Protected Area (Vargas et al. 2001) within the northeastern state of Tamaulipas, Mexico. This protected area is located in one of the 15 panbiogeographic nodes in the country. These nodes have unique characteristics which make them centers of higher species richness with high conservation priority (Morrone and Márquez 2008) making

the study area an excellent site for analysis of biodiversity and altitudinal distribution of Chrysomelidae in northern Mexico.

The objectives of the present study were: 1) determine the species richness of Chrysomelidae in Peregrina Canyon, Tamaulipas, Mexico; 2) conduct the first site-specific evaluation of diversity for this taxon in northeast Mexico; and 3) analyze the variation of species richness, abundance and diversity of the family along an altitudinal gradient during different seasons within the study area.

## **Methods**

### **Study area**

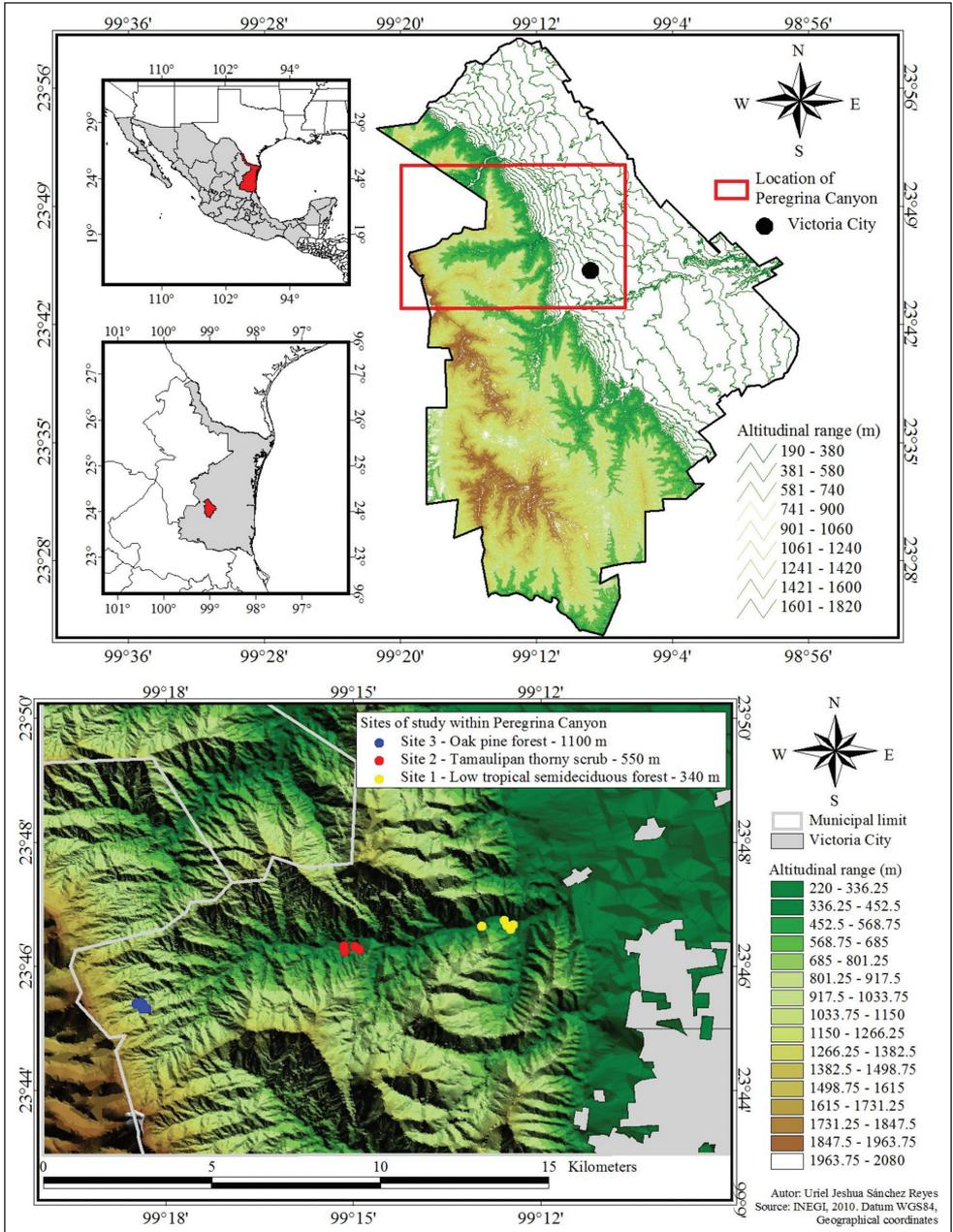
The Peregrina Canyon (Canyon San Felipe or Liberty), is located in the northwest portion of municipality of Victoria, Tamaulipas, along the San Felipe River (Figure 1). The area is located in the Sierra Madre Oriental and is part of Altas Cumbres Protected Area, considered a Special Zone subject to Ecological Conservation established by state decree in 1997 (Vargas et al. 2001). The study area belongs to one of the 15 panbiogeographic nodes present in the country due to the overlap of three biotic provinces: Tamaulipas, Sierra Madre Oriental, and Mexican Gulf (Morrone and Márquez 2008). The altitude within the study area ranges from 340 to 1600 m. The climate of the region is warm and subhumid with summer rains; the mean annual temperature is 18 to 24.3 °C and the mean total annual rainfall is 717.3 mm to 1058.8 mm (Almaguer-Sierra 2005).

### **Site location**

Three sites were established within which five quadrants of 2500 m<sup>2</sup> (50×50 m) were delineated in representative vegetation at each site. Site 1 had the lowest elevation at 340 m and consisted of low tropical semideciduous forest (23°45.30'N; 99°18.39'W). Site 2 was located at an intermediate altitude at 550 m where the plant community consisted of Tamaulipan thorny scrub (23°46.32'N; 99°14.96'W). Site 3 was the highest site at 1100 m with the vegetation composed of oak-pine forest (23°46.62'N; 99°12.55'W).

### **Collection and processing of specimens**

Sampling was conducted using a standard entomological sweep net of 40 cm diameter. Individual samples consisted of 200 sweeps of the shrub and herbaceous vegetation in each quadrant. The contents of the net were emptied into a 2000 cm<sup>3</sup> plastic bag, adding 60% ethanol and an indelible label with corresponding data. Samples



**Figure 1.** Location of Peregrina Canyon in Tamaulipas, Mexico, and location of sampling sites along study area.

were collected at each site from 10:00 to 14:00 hrs. Five samples (one sample for each quadrant, 200 net sweeps) were taken within each of three sites (one site per day), at four different dates in each of the four seasons of the year (early dry season,

EDR, December-February; late dry season, LDS, March-May; early wet season, EWS, June-August; and late wet season, LWS, September-November) between January and December 2009, for a total of 240 samples.

Processing of the samples was performed in the laboratory in the following manner. First, the contents of each plastic bag (sample) were placed in a plastic tray with water, and the more voluminous plant remains (wood fragments, branches, stems, leaves) were removed. A sieve ALSA (0.175 mm) was then used to filter the sample, and the reduced contents placed in a petri dish and observed under a stereoscopic microscope for extraction of all chrysomelid beetles. These were separated and mounted on paper points according to standard entomological technique. All specimens are stored in the collection of the Facultad de Ingeniería y Ciencias at the Universidad Autónoma de Tamaulipas, Ciudad Victoria, Tamaulipas, Mexico.

### **Taxonomic determination**

The identification of the specimens was performed using the available literature on Chrysomelidae (Wilcox 1965, White 1968, Wilcox 1972, Scherer 1983, White 1993, Flowers 1996, Riley et al. 2002, Staines 2002). Where possible, the material was compared with identified specimens deposited in the collection of Chrysomelidae of the Facultad de Ingeniería y Ciencias, Universidad Autónoma de Tamaulipas. Those specimens that could not be identified to the species level were compared with other unidentified specimens and grouped into morphospecies. The designation of “species” in this study includes both morphospecies and determined species. The classification used in this work corresponds to latest taxonomic categories proposed by Riley et al. (2003), except for the subfamily Bruchinae not included in this study.

### **Data analysis**

Abundance was calculated using the number of individuals per species collected at each site, season and for the entire study area. Species abundance was divided into five categories: 1) very common (more than 70 individuals); 2) common (11 to 70); 3) rare (10 to three specimens); 4) doubletons (two specimens); and 5) singletons (one specimen only). As a measure of species richness, we used the number of species present throughout the Peregrina Canyon, in each of the three altitudinal strata analyzed, and in each season. To estimate the potential number of species (total, site, and season), the nonparametric estimators Chao 1 and Jackknife 1 were used. These estimators were chosen because: 1) we did not assume a previous abundance distribution model, 2) they are robust when calculating minimum estimate of species richness, 3) their use is recommended as a recurrent measure in analysis of biodiversity, 4) Chao 1 is based on abundance data, or singletons and doubletons, and Jackknife 1 (incidence) is based on uniques, or species found in only one sample (Magurran 2004, Hortal et

al. 2006, Gotelli and Colwell 2010), and 5) Jackknife indices tend to be conservative estimators, so the use of both Chao 1 and Jackknife 1 can give an estimated range of species richness (Silva and Coddington 1996). The estimators were calculated with 100 randomizations without replacement using the software EstimateS 8.2 (Colwell 2009) based on the number and abundance of species found per sampling unit (quadrant). Sampling efficiency was also measured by using Clench model, through the coefficient of determination ( $R^2$ ) and the slope of the species accumulation curve, which measures the inventory quality. Their calculation was based on the number of samples (quadrants) in the entire study area, site and season; the procedure was performed in the program STATISTICA 8.0 (StatSoft Inc. 2007) based on the method described by Jiménez-Valverde and Hortal (2003). We also calculated overall density, or number of chrysomelid beetles per square meter for future comparisons and was calculated for the entire study area and for each site and season.

After testing for normality of the data, we used the nonparametric Kruskal Wallis and Mann-Whitney tests to analyze the differences in abundance and number of species among the three sites and between different seasons (PAST version 1.94b, Hammer et al. 2001) using as independent variables the total number of specimens and species per sample unit (quadrant).

Alpha diversity for the whole study area and by site and season was calculated using the Simpson diversity index ( $1/D$ ) and the Shannon diversity index ( $H'$ ) (Magurran 2004), using EstimateS 8.2. Differences of diversity values between sites and seasons were analyzed using PAST version 1.94b (Hammer et al. 2001). SHE analysis of diversity was conducted to decompose the Shannon diversity value in a measure of species richness and evenness, to allow the interpretation of changes in diversity (Magurran 2004). As a beta diversity measure, Bray-Curtis similarity index (Sorensen's quantitative index; Magurran 2004) was used among the sites and seasons, using EstimateS 8.2; these data were used to build a distance matrix for an agglomerative cluster analysis, using the Ward's method as amalgamation algorithm calculated using STATISTICA 8.0. A Spearman correlation test was applied between precipitation and temperature data with ecological parameters (abundance and species richness) using STATISTICA 8.0. Precipitation and temperature data were obtained from a local meteorological station localized in Peregrina Canyon.

## Results

### Abundance, richness and diversity of Chrysomelidae in Peregrina Canyon

A total of 2,226 specimens of Chrysomelidae were collected from 240 samples from May 2009 to April 2010, belonging to six subfamilies, 81 genera and 157 species (Table 1). Galerucinae was the most abundant subfamily with 1,828 specimens, representing 82.1% of total abundance in the study area. Lower abundance was recorded in Cassidinae (8.5%), Eumolpinae (3.6%), Cryptocephalinae (2.2%), Chrysomelinae (2.2%), and finally Criocerinae (1.3%). The highest species richness was also presented

**Table 1.** Taxonomic list and abundance of Chrysomelidae by season and site in Peregrina Canyon, Tamaulipas, Mexico. N = Total abundance; 1 = Low tropical semideciduous forest, 340 m; 2 = Tamaulipan thorny scrub, 550 m; 3 = Oak-pine forest, 1100 m.

	Dry Season						Wet Season						N
	Early (Dec - Feb)			Late (Mar - May)			Early (Jun - Aug)			Late (Sep - Nov)			
	1	2	3	1	2	3	1	2	3	1	2	3	
<b>CASSIDINAE Gyllenhal, 1813</b>													
<b>Tribu Chalepini Weise, 1910</b>													
<i>Anisostena pilatei</i> (Baly, 1864)				1	1		1						3
<i>Brachycoryna pumila</i> Guérin-Méneville, 1844	1	3		4	1		5						14
<i>Chalepus bellulus</i> (Chapuis, 1877)													5
<i>Chalepus digressus</i> Baly, 1885				1									1
<i>Euprionota aterrima</i> Guérin-Méneville, 1844								1					1
<i>Glyphuroplata</i> sp. 1				1									1
<i>Heterispa vinula</i> (Erichson, 1847)	1	6		1	20	8	1	29	1	10	12	2	91
<i>Octotoma championi</i> Baly, 1885				2									2
<i>Octotoma intermedia</i> Staines, 1989					1								1
<i>Sumitrosis inaequalis</i> (Weber, 1801)		2			2			1					5
<i>Sumitrosis pallescens</i> (Baly, 1885)						1							1
<i>Sumitrosis rosea</i> (Weber, 1801)				1	1		1		3	2			8
<i>Sumitrosis</i> sp. 1								1		1			2
<i>Sumitrosis</i> sp. 2											1		1
<i>Xenochalepus (Neochalepus) chapuisi</i> (Baly, 1885)				1									1
<i>Xenochalepus (Xenochalepus) omogerus</i> (Crotch, 1873)								1	1				2
<b>Tribu Cassidini Gyllenhal, 1813</b>													
<i>Charidotella bifossulata</i> (Boheman, 1855)						1	3	1					5
<i>Charidotella (Chaerocassis) emarginata</i> (Boheman, 1855)									1				1
<i>Charidotella sexpunctata</i> (Fabricius, 1781)							3	1					4
<i>Charidotella tuberculata</i> (Fabricius, 1775)				2									2
<i>Charidotis auroguttata</i> Boheman, 1855					1								1
<b>Tribu Cassidini Gyllenhal, 1813</b>													
<i>Charidotella tuberculata</i> (Fabricius, 1775)				2									2
<i>Charidotis auroguttata</i> Boheman, 1855					1								1
<i>Coptocycla (Psalidonota) texana</i> (Schaeffer, 1933)								2					2
<i>Microctenochira punicea</i> (Boheman, 1855)				1		2			2				5
<i>Microctenochira varicornis</i> (Spaeth, 1926)						1							1
<i>Microctenochira vivida</i> (Boheman, 1855)				1		1							2
<i>Helocassis crucipennis</i> (Boheman, 1855)						9		3	1		1		14
<i>Helocassis testudinaria</i> (Boheman, 1855)				1			1	1	2				5
<b>Tribu Mesomphaliini Hope, 1840</b>													
<i>Chelymorpha pubescens</i> Boheman, 1854				1									1
<i>Hilarocassis exclamationis</i> (Linnaeus, 1767)								1					1
<i>Ogdoecosta juvenca</i> (Boheman, 1854)								3	1	2			6
<b>Tribu Ischyrosomychini Chapuis, 1875</b>													
<i>Physonota alutacea</i> Boheman, 1854								1					1

	Dry Season						Wet Season						N
	Early (Dec - Feb)			Late (Mar - May)			Early (Jun - Aug)			Late (Sep - Nov)			
	1	2	3	1	2	3	1	2	3	1	2	3	
<b>CHRYSOMELINAE Latreille, 1802</b>													
<b>Tribu Chrysomelini Latreille, 1802</b>													
<b>Subtribu Doryphorina Motschulsky, 1860</b>													
<i>Calligrapha fulvipes</i> Stål, 1859								1					1
<i>Calligrapha</i> sp. 1								1					1
<i>Calligrapha</i> sp. 2				2									2
<i>Calligrapha suffriani</i> Jacoby, 1882								1					1
<i>Labidomera suturella</i> Chevrolat, 1844							1	3	3				7
<i>Zygogramma piceicollis</i> (Stål, 1859)	1												1
<b>Subtribu Chrysomelina Latreille, 1802</b>													
<i>Chrysomela texana</i> (Schaeffer, 1919)				2			3						5
<i>Phaedon cyanescens</i> Stål, 1860							1						1
<i>Plagiodera semivittata</i> Stål, 1860	3			3	1				1	2	2		12
<i>Plagiodera thymaloides</i> Stål, 1860	1	2			5	1				9			18
<b>CRIOCERINAE Latreille, 1807</b>													
<b>Tribu Lemini Heinze, 1962</b>													
<i>Lema balteata</i> LeConte, 1884								1					1
<i>Lema</i> sp. 1						2					1	1	4
<i>Neolema quadriguttata</i> White, 1993				2		1	1						4
<i>Neolema</i> sp. 1					1								1
<i>Neolema</i> sp. 2					1	1							2
<i>Neolema</i> sp. 3				2		1						1	4
<i>Oulema</i> sp. 1				4		3			2			3	12
<i>Oulema</i> sp. 2										1			1
<b>CRYPTOCEPHALINAE Gyllenhal, 1813</b>													
<b>Tribu Cryptocephalini Gyllenhal, 1813</b>													
<b>Subtribu Cryptocephalina Gyllenhal, 1813</b>													
<i>Cryptocephalus duryi</i> Schaeffer, 1906								1				2	3
<i>Cryptocephalus</i> sp. 1	1												1
<i>Cryptocephalus umbonatus</i> Schaeffer, 1906								2		1	1		4
<i>Diachus auratus</i> (Fabricius, 1801)			5			8			2				15
<b>Subtribu Pachybrachina Chapuis, 1874</b>													
<i>Pachybrachis</i> sp. 1	1									1			2
<i>Pachybrachis</i> sp. 2		1			1								2
<i>Pachybrachis</i> sp. 3		1			1	1		1					4
<i>Pachybrachis</i> sp. 4		2									1		3
<i>Pachybrachis</i> sp. 5										2			2
<i>Pachybrachis</i> sp. 6												1	1
<i>Pachybrachis</i> sp. 7					1						1		2
<b>Tribu Clytrini Lacordaire, 1848</b>													
<b>Subtribu Clytrina Lacordaire, 1848</b>													
<i>Anomoea rufifrons</i> Chevrolat, 1837								1	4				5
<b>Subtribu Megalostomina Chapuis, 1874</b>													
<i>Coscinoptera scapularis scapularis</i> (Lacordaire, 1848)								1					1

	Dry Season						Wet Season						N
	Early (Dec - Feb)			Late (Mar - May)			Early (Jun - Aug)			Late (Sep - Nov)			
	1	2	3	1	2	3	1	2	3	1	2	3	
<i>Coscinoptera victoriana</i> L. Medvedev, 2012								1					1
<b>Subtribu Babiina Chapuis, 1874</b>													
<i>Babia tetraspilota</i> LeConte, 1858							2						2
<b>Tribu Chlamisini Gressitt, 1946</b>													
<i>Chlamisus texanus</i> (Schaeffer, 1906)				3									3
<i>Neochlamisus</i> sp. 1								1					1
<b>EUMOLPINAE Hope, 1840</b>													
<b>Tribu Eumolpini Hope, 1840</b>													
<i>Brachypnoea</i> sp. 1				9		9							18
<i>Brachypnoea</i> sp. 2				9	2	2			1				14
<i>Chalcophana cincta</i> Harold, 1874									1			4	5
<i>Colaspis melancholica</i> Jacoby, 1881								1					1
<i>Colaspis</i> sp. 1											1		1
<i>Colaspis townsendi</i> Bowditch, 1921										4			4
<i>Tymnes</i> sp. 1				1				1		1			3
<i>Zenocolaspis inconstans</i> Bechyné, 1997										3			3
<b>Tribu Adoxini Baly, 1863</b>													
<i>Fidia albovittata</i> Lefèvre, 1877						1							1
<i>Xanthonia</i> sp. 1		1	5	1		3					1		11
<i>Xanthonia</i> sp. 2		3											3
<i>Xanthonia</i> sp. 3					1	4							5
<i>Xanthonia</i> sp. 4				1		7							8
<i>Xanthonia</i> sp. 5	1	1											2
<b>Tribu Typophorini Chapuis, 1874</b>													
<i>Typophorus nigrinus</i> (Fabricius, 1801)										1			1
<b>GALERUCINAE Latreille, 1802</b>													
<b>Tribu Alticini Newman, 1835</b>													
<i>Acallepitrix</i> sp. 1	2			35	8	82	1	2	3			1	134
<i>Acallepitrix</i> sp. 2	1	1		15	1	3	2		3				26
<i>Acallepitrix</i> sp. 3	3			3	1	2		3	2	5	4	2	25
<i>Acallepitrix</i> sp. 4						4			4				8
<i>Acallepitrix</i> sp. 5									1				1
<i>Acrocylum dorsalis</i> Jacoby, 1885					1								1
<i>Alagoasa bipunctata</i> (Chevrolat, 1834)				1				1			1		3
<i>Alagoasa decemguttatus</i> (Fabricius, 1801)				1	2	1		4	1			1	10
<i>Alagoasa</i> sp. 1					1	4							5
<i>Asphaera abdominalis</i> (Chevrolat, 1834)								8	2			2	12
<i>Asphaera</i> sp. 1								13	1				14
<i>Asphaera</i> sp. 2								1					1
<i>Asphaera</i> sp. 3								1					1
<i>Asphaera</i> sp. 4				1									1
<i>Blepharida rhois</i> (Forster, 1771)					1								1
<i>Centralaphthona diversa</i> (Baly, 1877)	6	80	6	1	52	30		14		33	25	1	248
<i>Centralaphthona fulvipennis</i> (Jacoby, 1885)	309	1		42				3		56		1	412

	Dry Season						Wet Season						N
	Early (Dec - Feb)			Late (Mar - May)			Early (Jun - Aug)			Late (Sep - Nov)			
	1	2	3	1	2	3	1	2	3	1	2	3	
<i>Chaetocnema</i> sp. 1	27	12	12	9	9			2			1		72
<i>Chaetocnema</i> sp. 2			1	1	1	5							8
<i>Chaetocnema</i> sp. 3	5	5	2		1	7		3	2				25
<i>Derocrepis</i> sp. 1				5									5
<i>Derocrepis</i> sp. 2						2							2
<i>Disonycha antennata</i> Jacoby, 1884								1					1
<i>Disonycha glabrata</i> (Fabricius, 1781)				5	1			1			1		8
<b>Tribu Alticini cont</b>													
<i>Disonycha stenosticha</i> Schaeffer, 1931								1		1			2
<i>Epitrix</i> sp. 1	20	7		15	9		7		1	20	2	3	84
<i>Epitrix fasciata</i> Blatchley, 1918	2				2				1			2	7
<i>Epitrix</i> sp. 3			2			2					1	7	12
<i>Glenidion</i> sp.1		1							1				2
<i>Heikertingerella</i> sp. 1						1				1			2
<i>Heikertingerella</i> sp. 2			4										4
<i>Heikertingerella variabilis</i> (Jacoby, 1885)	4			1		1				1			7
<i>Longitarsus</i> sp. 1	8	36		25	14	8	2	9	2				104
<i>Longitarsus</i> sp. 2								1					1
<i>Longitarsus</i> sp. 3	1	1											2
<i>Longitarsus</i> sp. 4				1									1
<i>Longitarsus</i> sp. 5	1	2		8	8			2					21
<i>Lupraea</i> sp. 1			1							13		18	32
<i>Lupraea</i> sp. 2										8			8
<i>Lupraea</i> sp. 3										16	1	7	24
<i>Lupraea</i> sp. 4										26	6	1	33
<i>Lysathia</i> sp. 1				1									1
<i>Margaridisa</i> sp. 1	52	2	3	61	27		37	5		29	3		219
<i>Margaridisa</i> sp. 2	1						1			1		3	6
<i>Monomacra</i> sp. 1	5	4		2	5		3	2		5	3	4	33
<i>Monomacra</i> sp. 2						6							6
<i>Monomacra</i> sp. 3				1									1
<i>Omophoita cyanipennis octomaculata</i> (Crotch, 1873)								4			2		6
<i>Orthaltica</i> sp. 1						5							5
<i>Orthaltica</i> sp. 2			1										1
<i>Parchicola</i> sp. 1	2									1			3
<i>Phyllotreta</i> sp. 1	3	1	2	1	1								8
<i>Plectrotetra</i> sp. 1					3	13		2					18
<i>Scelidopsis rufofemorata</i> Jacoby, 1888				1									1
<b>Tribu Alticini cont</b>													
<i>Sphaeronychus fulvus</i> (Baly, 1879)			1			1			2	1			5
<i>Strabala</i> sp. 1					1								1
<i>Syphrea</i> sp. 1		2		10	8		1	1					22
<i>Syphrea</i> sp. 2				1	2	6		1	1	1	1		13

	Dry Season						Wet Season						N
	Early (Dec - Feb)			Late (Mar - May)			Early (Jun - Aug)			Late (Sep - Nov)			
	1	2	3	1	2	3	1	2	3	1	2	3	
<i>Systema contigua</i> Jacoby, 1884					1	19		7					27
<i>Systema</i> sp. 1				1									1
<i>Walterianella signata</i> (Jacoby, 1886)					2			1					3
<b>Tribu Galerucini Latreille, 1802</b>													
<b>Grupo Coelomerites Chapuis, 1875</b>													
<i>Coraia subcyanescens</i> (Schaeffer, 1906)				1				1	2	1			5
<i>Derspidea cyaneomaculata</i> (Jacoby, 1886)											1		1
<i>Trirhabda</i> sp. 1						1							1
<b>Grupo Schematizites Chapuis, 1875</b>													
<i>Ophraea rugosa</i> Jacoby, 1886						1			1				2
<b>Tribu Luperini Chapuis, 1875</b>													
<b>Subtribu Diabroticina Chapuis, 1875</b>													
<b>Grupo Diabroticites Chapuis, 1875</b>													
<i>Acalymma vittatum</i> (Fabricius, 1775)						1		1					2
<i>Diabrotica balteata</i> LeConte, 1865				1				1	1				3
<i>Diabrotica porracea</i> Harold, 1875						1							1
<i>Diabrotica underwoodi</i> Bowditch, 1911				1		7		2					10
<i>Gynandrobrotica lepida</i> (Say, 1835)	5		1	13	9	5		1	4	1		1	40
<b>Grupo Cerotomites Chapuis, 1875</b>													
<i>Cerotoma atrofasciata</i> Jacoby, 1879				1									1
<i>Cerotoma ruficornis</i> (Olivier, 1791)				1									1
<i>Cyclotrypema furcata</i> (Olivier, 1808)								3			4		7
<i>Neobrotica sexmaculata</i> Jacoby, 1887								1					1
<i>Neobrotica tampicensis</i> Blake, 1966									2				2
<b>Subtribu Luperina Chapuis, 1875</b>													
<b>Grupo Monoleptites Chapuis, 1875</b>													
<i>Calomicrus</i> sp. 1		1											1

in the subfamily Galerucinae with 49% of the total obtained species followed by Cassidinae (20%), Cryptocephalinae (9.7%), Eumolpinae (9.7%), Chrysomelinae (6.5%) and Criocerinae (5.2%).

Eight species were categorized as “very common” in the Peregrina Canyon, each with greater than 70 specimens and accounted for 61.22% of the total abundance. These very common species were *Centralaphthona fulvipennis* Jacoby (412 individuals), *Centralaphthona diversa* (Baly) (248), *Margaridisa* sp.1 (219), *Acallepitrax* sp.1 (134), *Longitarsus* sp.1 (104), *Heterispa vinula* (Erichson) (91), *Epitrix* sp.1 (84) and *Chaetocnema* sp.1 (72). Twenty-five species were considered common, constituting 22.66% of the total number of chrysomelids. Fifty species were considered rare (263 specimens) by occupying 11.8% of the total abundance. Twenty-two species were doubletons (1.97% of total abundance) and 52 were singletons (2.33%). The estimated density value obtained was 0.0037 individuals/m<sup>2</sup> (Table 2).

**Table 2.** Richness, abundance and diversity parameters of Chrysomelidae in the Peregrina Canyon, Tamaulipas, Mexico. S obs = Observed richness; N = Abundance; Dst = Density; S est = Estimated richness; R<sup>2</sup> = Clench model determination coefficient; 1/D = Simpson diversity index; H' = Shannon diversity index.

Ecological Parameter	Site			Season				Total
	Low tropical semideciduous forest	Tamaulipan thorny scrub	Oak-pine forest	Dry		Wet		
				Early (Dec-Feb)	Late (Mar-May)	Early (Jun-Jul)	Late (Aug-Nov)	
S obs †	85a	96ab	84b	43c	96a	84b	56bc	157
N †	1123a	641b	464c	696c	822a	304b	406bc	2228
Dst	0.0056	0.0032	0.0023	0.0046	0.0054	0.002	0.0027	0.0037
<b>S est</b>								
Chao 1	119.13	196.04	140.89	49.05	132	134.7	84.41	218.45
Jackknife 1	126.48	150.31	123.5	55.78	137.3	130.22	84.52	216.75
<b>Clench</b>								
R <sup>2</sup>	0.997	0.998	0.999	0.998	0.998	0.999	0.999	0.997
S est	128.49	171.80	133.91	57.70	143.46	175.59	94.85	212.41
Slope	0.368	0.532	0.395	0.187	0.539	0.729	0.385	0.178
<b>Diversity ‡</b>								
1/D	5.95a	10.12b	19.26c	4.28d	17.31a	24.66b	13.92c	14.6
H'	2.73a	3.24b	3.67c	2.17d	3.49a	3.78b	3.06c	3.54

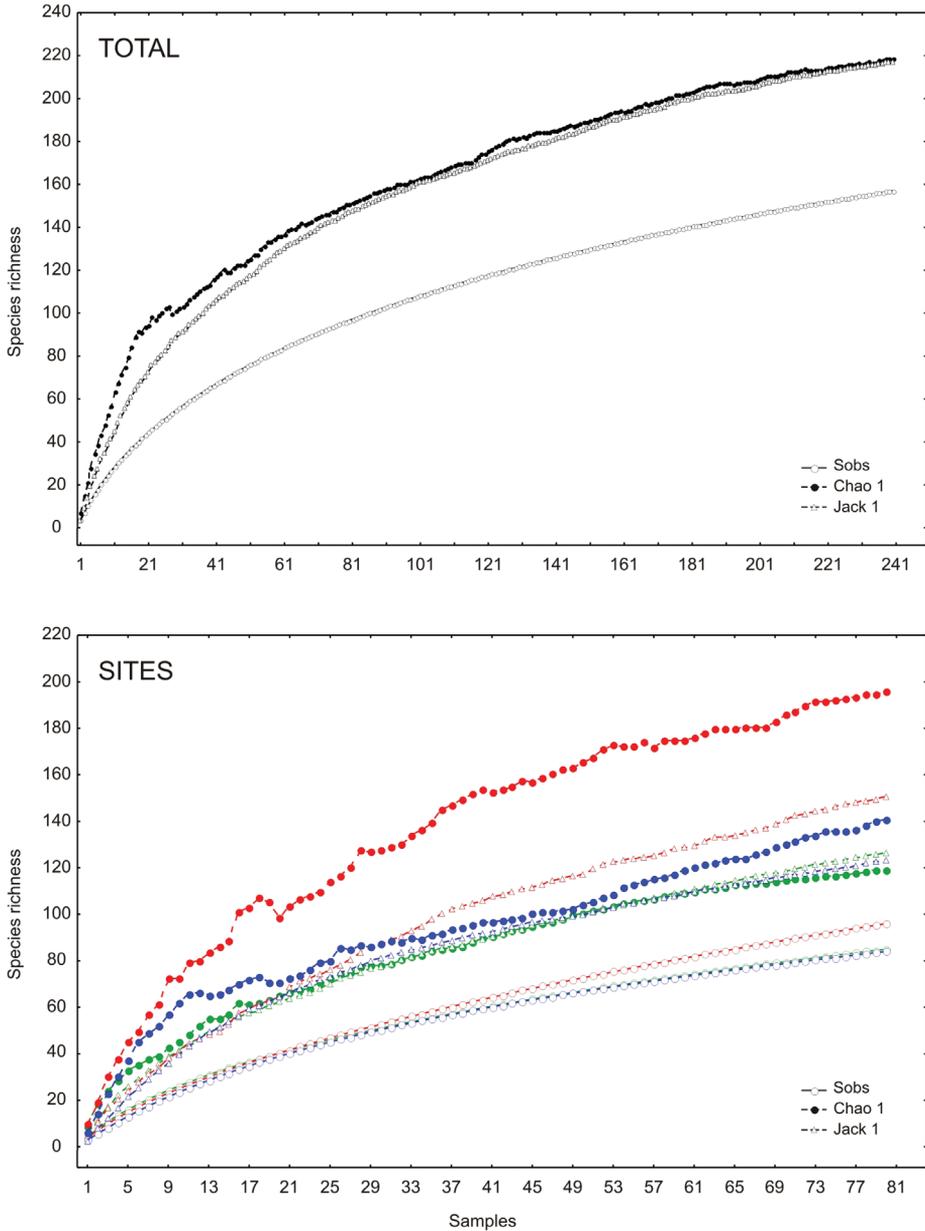
† Values with different letters within rows are significantly different using Kruskal-Wallis and Mann-Whitney Tests: abundance between sites,  $K=15.92$ ,  $DF=2$ ,  $p=0.0003$ ; richness between sites,  $K=8.17$ ,  $DF=2$ ,  $p=0.0157$ ; abundance between seasons,  $K=42.42$ ,  $DF=3$ ,  $p=0.000$ ; richness between seasons,  $K=50.15$ ,  $DF=3$ ,  $p=0.000$ .

‡ Diversity values with different letters within rows are significantly different at  $p<0.05$ , using permutation and bootstrap tests in PAST program.

The richness estimators indicated that the total number of chrysomelid species in the study area was between 216 and 218 species (Table 2, Figure 2) suggesting that the observed total of 157 species represented 71.86 to 72.43% of the actual richness. The data showed a good fit to the Clench model ( $R^2 = 0.99$ ), with a registered proportion of species of 73.91% and a slope close to 0.1. Total diversity values of Chrysomelidae in Peregrina Canyon were 14.58 for the Simpson index and 3.53 for the Shannon index (Table 2). The SHE analysis shows that changes in Shannon diversity value are attributed to increase and stability of species richness curve (Figure 3).

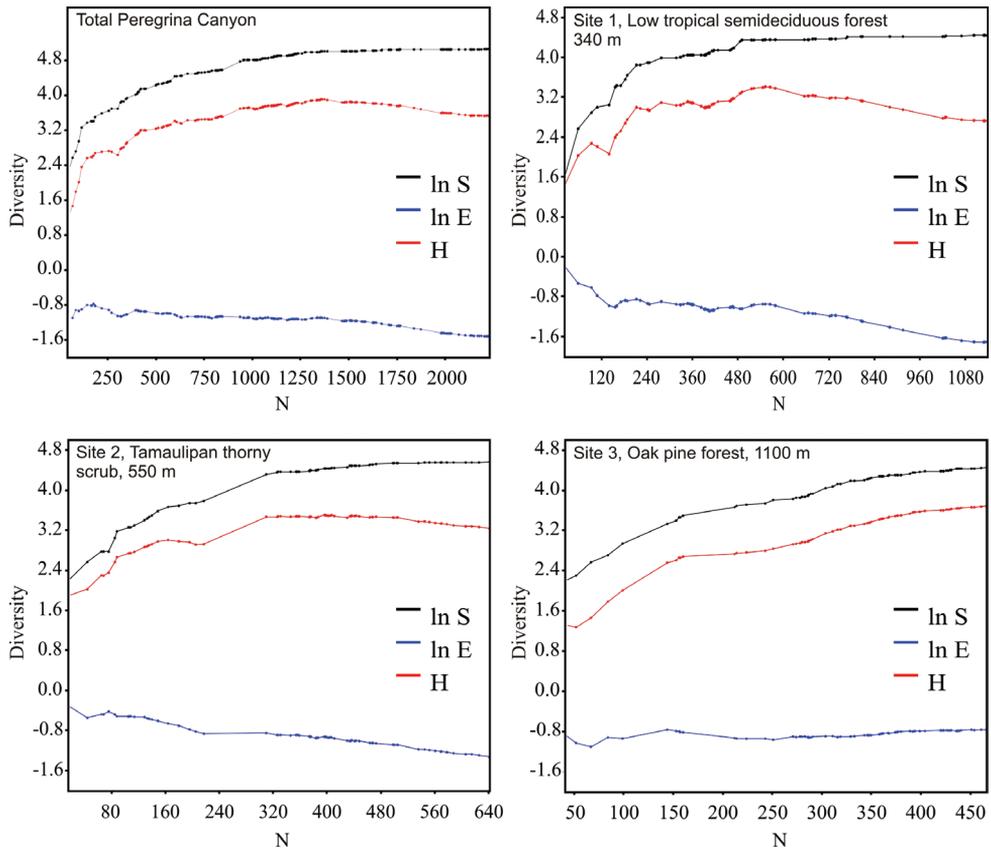
### Altitudinal variation of Chrysomelidae

The abundance of chrysomelid beetles was significantly different among the three sites (Table 2). The greatest abundance and density (individuals per square meter) were recorded at the lowest elevation site, and decreased with increasing altitude (Table 2). The middle altitude site (Site 2) had the greatest number of species (Table 2). The number



**Figure 2.** Species accumulation curves by altitudinal site in the Peregrina Canyon, Tamaulipas, Mexico. Upper graphic: accumulation curves for all study area. Lower graphic: site 1 (green color), site 2 (red color) and site 3 (blue color).

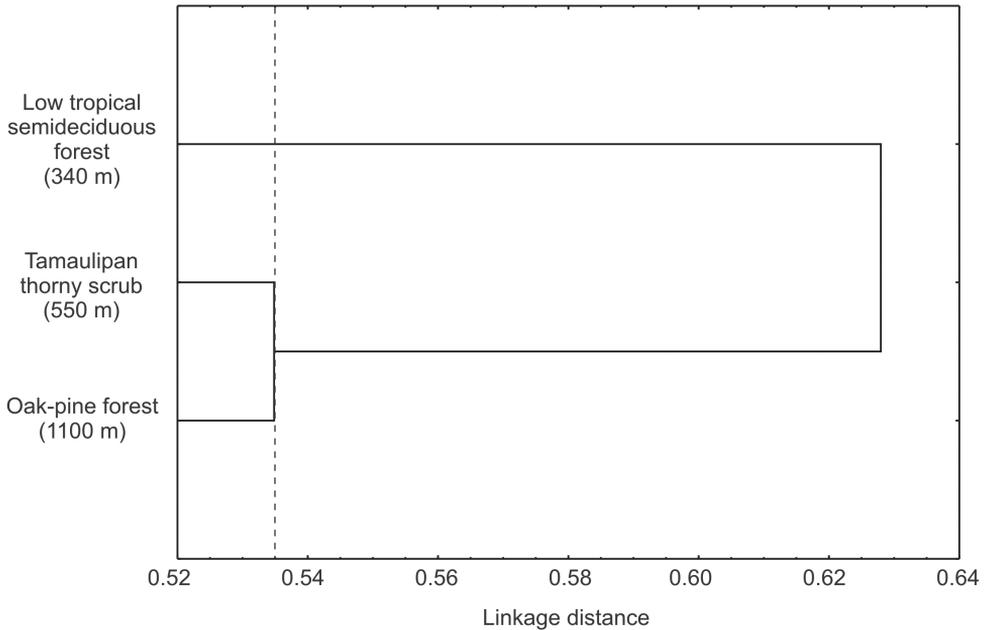
of species significantly differed only between the lowest and the highest altitudinal strata (Site 1 and Site 3; Table 2). In the low altitude site, 85 species were recorded which represented between 67.2 to 71.35% of the estimated richness (minimum and maximum)



**Figure 3.** SHE analysis of diversity for the Peregrina Canyon and for each one of altitudinal sites.  $\ln S$  natural logarithm of species richness;  $\ln E$  natural logarithm of evenness;  $H$  diversity (Shannon index).

with the models used. In the second site, the number increased to 96 species (48.96 to 63.86% of the estimate) and at the highest site, 84 species were recorded (59.62 to 68.01% of the estimate) (Figure 2). A determination coefficient greater than 0.99 was obtained for all sites, indicating a good fit of the Clench model to the data obtained at each site, but the slope calculated was greater than 0.1 in all sites (Table 2).

Alpha diversity at the three sites differed significantly ( $p < 0.05$ ) with indices increasing progressively with increasing altitude (Table 2). Lower diversity values in both sites 1 and 2, were a result of a reduction in evenness and a more or less stable number of species with the increase of samples. In site 3, diversity increases as evenness remained constant and the number of species increased with sample numbers (Figure 3). Of the 157 species recorded in the Peregrina Canyon, 34 were distributed along the entire altitudinal gradient, 40 were recorded only in two sites, and 83 were unique to one of the three sites. Of these, 29 were exclusively from Site 1, 34 for Site 2, and 20 for Site 3 (Table 1). Similarity values were in all cases less than 50%; according to the cluster analysis, each of the three sites was an independent group, containing distinct species assemblages of Chrysomelidae (Figure 4).

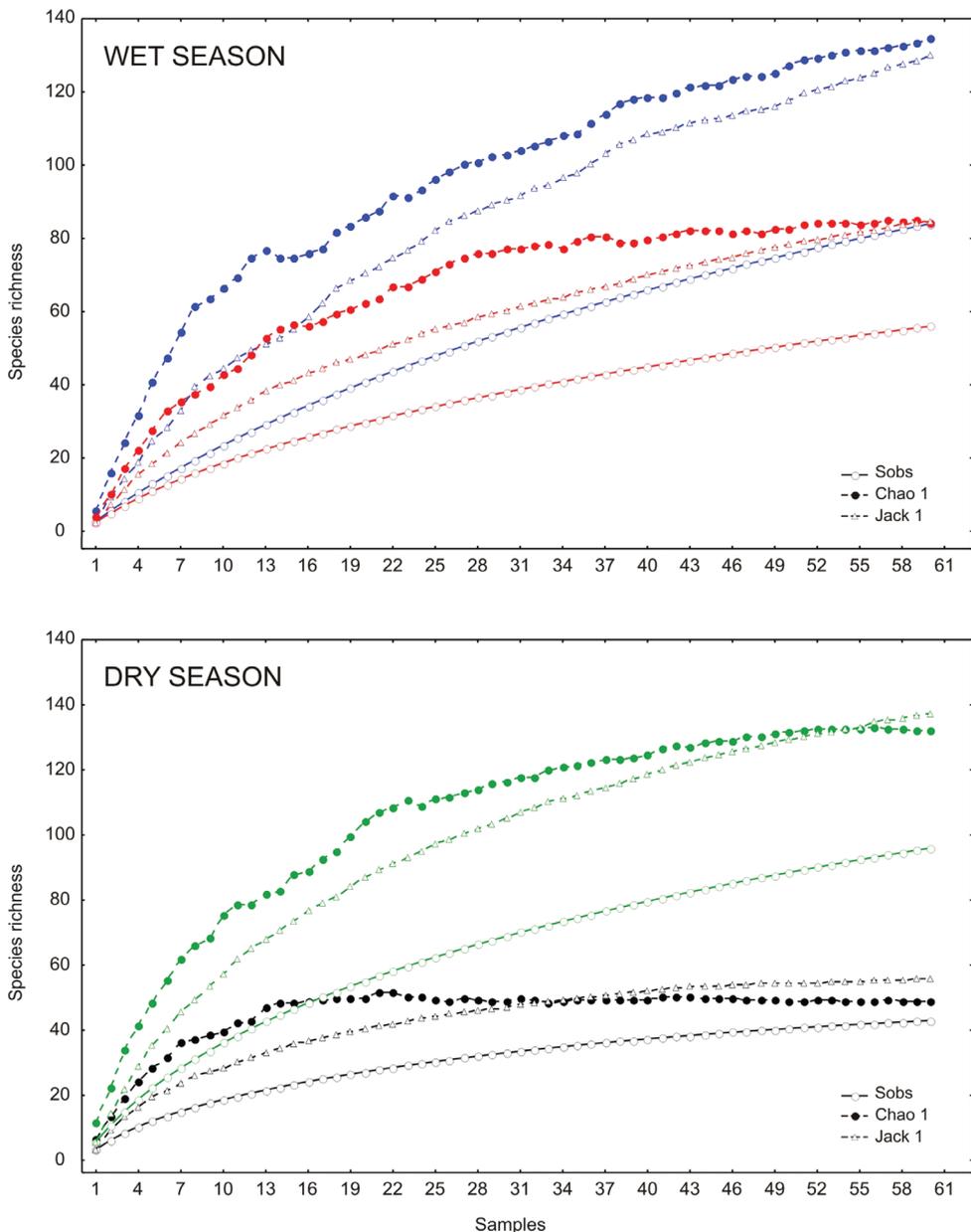


**Figure 4.** Cluster analysis from sites in the Peregrina Canyon, Tamaulipas, Mexico.

### Seasonal variation of Chrysomelidae

General abundance of Chrysomelidae was greater in the dry season than the wet season. Late wet season was not significantly different from early dry and wet seasons; the rest of comparisons between seasons were significantly different. The highest abundance was obtained during the late dry season, with 822 individuals. Fewer individuals were found during the early dry season (696 specimens), and late and early wet seasons, 406 and 302, respectively. Density for seasons followed the same pattern as the abundance, being late dry season the period with higher densities of chrysomelid beetles (Table 2). The number of species collected per season declined as the year progresses. During late dry season, 96 species were recorded, representing between 69.91 and 72.72% of the estimated richness for that season; 84 species were found in early wet season (62.36 to 64.5% of estimated richness), while the number decreases to 56 species in late wet season (66.25 to 66.34%) and 43 species in early dry season (77.08 to 87.66%) (Table 2; Figure 5). Determination coefficients based on the Clench model was higher than 0.99 for all seasons, while the slope values were above 0.1 (Table 2). Higher temperatures and precipitation were found within both wet seasons (Figure 6). High correlation values were present between temperature and richness, and between precipitation and abundance. Abundance was negatively correlated with precipitation, while species richness was positively correlated with maximum temperature. Other comparisons were not significant (Table 3).

In contrast to abundance, the Shannon and Simpson indices indicated the highest diversity during the early wet season. Lower values of diversity occurred in late dry sea-

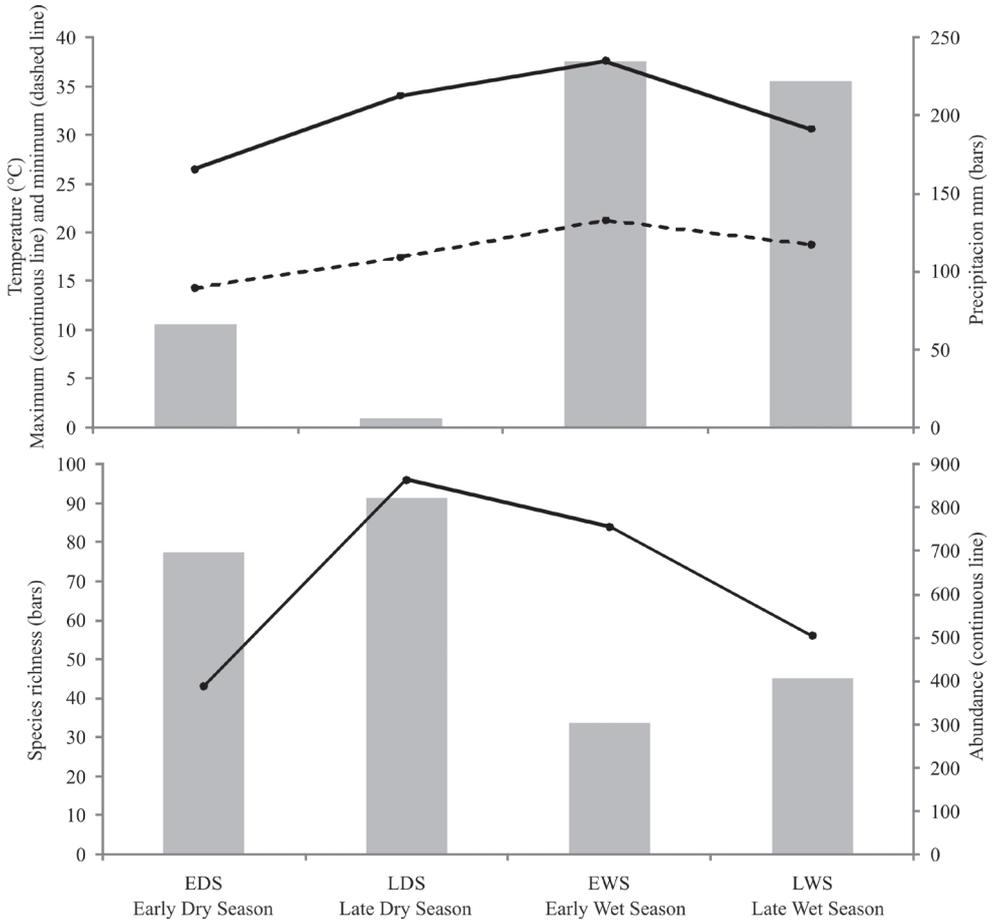


**Figure 5.** Species accumulation curves by season in the Peregrina Canyon, Tamaulipas, Mexico. Upper graphic: Early wet season (blue color) and late wet season (red color). Lower graphic: Early dry season (black color) and late dry season (green color).

son, followed by late wet and early dry seasons. Based on diversity indices, all seasons were statistically different ( $p < 0.05$ ) (Table 2). Reduction in diversity value at early dry season was originated by the drop in evenness with the increase of samples. The rest of

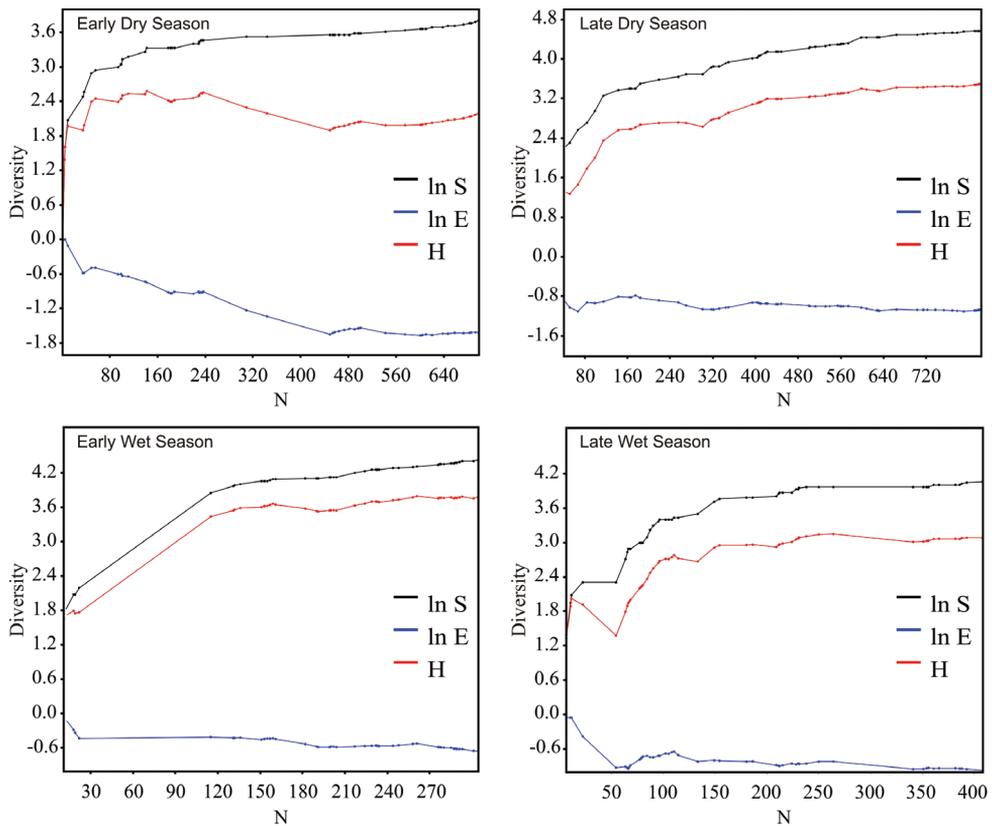
**Table 3.** Spearman rank order correlations of abundance and species richness of Chrysomelidae with precipitation and temperature in Peregrina Canyon; marked (\*) correlations are significant at  $p < 0.05$ .

	Abundance	Richness
Precipitation	-0.769*	0.112
Max °C	0.321	0.842*
Min °C	-0.066	0.587



**Figure 6.** Variation of Chrysomelidae with precipitation and temperature during 2009 in Peregrina Canyon.

year, evenness values, remained constant with the increase of samples in each season (Figure 7). Of the total species recorded in the annual period, only 13 were present throughout the year, and 23 were registered in three seasons, 37 in only two, and 84 were unique to a single season. From these exclusive species, 38 were recorded in late dry season, 26 in early wet season, 12 in late wet season, and only eight in early dry season (Table 1). Bray Curtis index established the greatest similarity between early



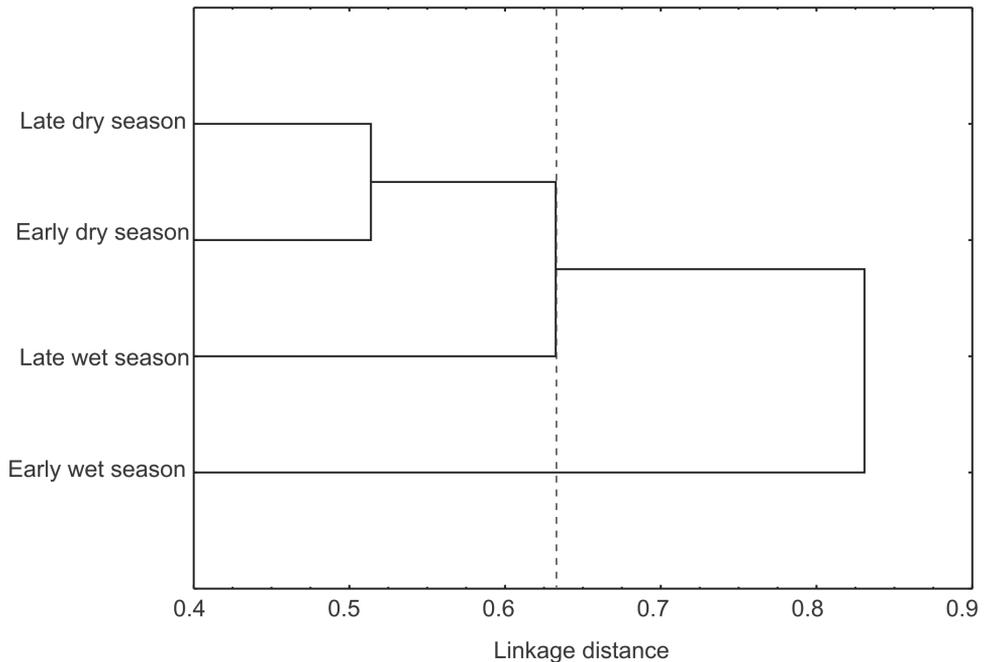
**Figure 7.** SHE analysis of diversity for each season in the Peregrina Canyon.  $\ln S$  natural logarithm of species richness;  $\ln E$  natural logarithm of evenness;  $H$  diversity (Shannon index).

and late dry seasons (45.1%), and in descending order were presented late wet and early dry seasons (38.8%), late dry and late wet seasons (37.9%), late dry and early wet seasons (36.3%), early and late wet seasons (35.6%) and early wet and early dry seasons (25.7%). The cluster analysis showed the formation of three groups according to the composition of species in each season: the first group consists of the species present in early and late dry seasons, the second group corresponds to late wet season species, and the last group was the early wet season species (Figure 8).

## Discussion

### Species richness in Peregrina Canyon

There are few studies of the richness and diversity of Chrysomelidae in Mexico with which the present study can be compared. Deloya and Ordóñez (2008) reported 136 species in fragments of cloud forest, in the state of Veracruz, while Niño et al. (2005)



**Figure 8.** Cluster analysis from seasons in the Peregrina Canyon, Tamaulipas, Mexico.

presented a checklist of 128 species for Biosphere Reserve El Cielo in the state of Tamaulipas, which also included cloud forest vegetation as well as tropical deciduous habitats. Considering that both authors used similar methods to that applied in this research, the 157 species found in this study is noteworthy for its greater richness. This may be a result of the three distinct habitats sampled despite the greater aridness of two of these (thorn scrub and oak forest) when compared to the habitats sampled by Deloya and Ordóñez (2008) and Niño et al. (2005). There are still other studies in Mexico where the species richness or diversity has been analyzed; however, temporal and spatial scale were greater, principally in those studies that were checklists in complete states (Andrews and Gilbert 2005) and natural areas of greater extension (Ordóñez-Reséndiz and López-Pérez 2009, Ordóñez-Reséndiz et al. 2011), or also for all the country and for only one subfamily or tribe, such Chrysomelinae (Burgos-Solorio and Anaya-Rosales 2004), Alticini (Furth 2006, Furth 2009), Cassidinae (Martínez-Sánchez et al. 2010) and Clytrini (Medvedev et al. 2012). Also these studies have been made with very different methodologies and different approaches than in this study which precludes a direct comparison with the results presented here.

Using the latest higher classification scheme of Riley et al. (2003), six subfamilies are formally reported in this study (Table 1). Galerucinae had the greatest number of species which is in accordance with subfamily species totals worldwide (Riley et al. 2002) and in other studies with Chrysomelidae in different parts of the world, including Mexico (Kalaichelvan and Verma 2005, Niño et al. 2005). The 157 species present in this work

represent the 7.22% of the 2,174 reported species for México (Ordóñez-Reséndiz et al. 2014), which is a notable percentage considering the small area sampled in this study.

According to both non-parametrics estimators used, our data represent a sampling efficiency superior to 70%. Similarly, Clench model indicated a percentage superior to 70% and a slope close to 0.1, indicating both data accuracy and the reliability of the study (Jimenez-Valverde and Hortal 2003). However, richness estimators indicates that the number of species is greater, thus a complementary method of sampling, such as canopy fogging (Basset and Samuelson 1996, Novotny et al. 1999, Basset 2001, Charles and Basset 2005, Vig and Markó 2005), malaise traps (Flowers and Hanson 2003), or further sweep net samples (Sackmann 2006, Pedraza et al. 2010), would increase the number of species found, as well as reducing the number of singletons and doubletons.

Alpha diversity of Chrysomelidae in Peregrina Canyon was high, and represents one of the first known studies of site specific data for Mexico. Margalef (1972) notes that Shannon index values are typically between 1.5 and 3.5, and rarely exceed a value of 4. Based on this scale, it can be established that Chrysomelidae diversity in the study area is high (Shannon = 3.53). These results can be explained in part by the geographic location of the study area; Peregrina Canyon is located in one of the 15 panbiogeographic nodes of Mexico, within the Sierra Madre Oriental. According to Morrone and Márquez (2008), these areas are centers for high biological diversity, representing the confluence of different biotic provinces. In this case, Peregrina Canyon is in the union of Tamaulipan, Sierra Madre Oriental and Mexican Gulf biotic provinces, thus presenting influences of both temperate and tropical faunas, which harbors high numbers of species in the area and the typical pattern for tropical faunas, with a high percentage of singletons and doubletons (Silva and Coddington 1996, Furth et al. 2003). This confluence of the biotic provinces is evidenced by the biogeographic distribution of the collected species. Considering the distribution for the identified species and the range of the genera for morphospecies, a total of 71 species (both morphospecies and identified species) in this study, (45%) were principally of Neotropical distribution (some ranging up to southern states of USA, but with their major distribution through Mexico and south into Central America and South America). This distribution is shared by many biotic groups of the Mexican Gulf region (Morrone 2005). Another 24 species (15%) had typical Nearctic distribution (Mexico north into the United States and Canada) which in Mexico includes the Tamaulipan province that extends north into Texas. Finally, 56 species (36%) have distributions throughout the American continent (including North, Central and South America), whereas 6 species (4%) were restricted to Mexico and possibly restricted to or have originated within the Sierra Madre Oriental province. Further study of the biogeographical distributions of the Chrysomelidae of Mexico is sorely needed.

### **Altitudinal and seasonal variation of Chrysomelidae**

We present the first record of the altitudinal variation in richness, abundance, and diversity of Chrysomelidae in Mexico. In our study, greater species richness was found in the

intermediate altitudes, which is a similar result to that found by Fernandez et al. (2010) with Staphylinidae, where the number of species increased from first to second altitudinal strata, and then decreased slightly in the highest part of the gradient. Greatest species richness in intermediate altitudes has also been documented in Alticini (Chrysomelidae) (Furth 2009), as well as dung beetles (Celi et al. 2004) and in some species of Scarabaeinae (Escobar et al. 2005). Intermediate areas represent an area of overlap in species distributions, which could explain the higher species richness in this site. Richness estimators in each site indicated inventory completeness of less than 70%, with higher slopes values for Clench model, which indicated a relatively incomplete inventory for each site (Jimenez-Valverde and Hortal 2003). This is due to the high number of doubletons and singletons for each site which influenced the estimators used.

Decreasing abundance with increasing altitude has been observed in several studies with other insects, such as necrophilic entomofauna (Sanchez-Ramos et al. 1993) and ground beetles (Semida et al. 2001). In contrast to abundance, in this study there was a progressive and significant increase in diversity with altitude, which was directly related to the altitudinal abundance recorded in each site. In the first site, the abundance was very high, with some species concentrated in large numbers (e.g., *C. fulvipennis*), thus reducing diversity. By contrast, in the higher elevation site, the Chrysomelidae community is represented by a more equitative number of individuals, decreasing dominance and thus increasing values of both diversity indices. This is confirmed by the SHE analysis, where the evenness remain constant and the species richness increases progressively with the increasing samples, being this pattern very different than the other two sites. However, in a similar study with a different phytophagous group, Apiionidae (Curculionoidea), Jones et al. (2012) found the opposite pattern with increasing abundance with altitude but decreasing diversity, in the El Cielo Biosfera Reserve, in Tamaulipas, Mexico. Also, Flowers and Hanson (2003) found that both species richness and diversity of Alticini (Chrysomelidae) had lower values on higher altitudes in Costa Rica. However, the pattern found in our study can be explained by the vegetation composition and the plant density in the sampled area, which was higher in the semideciduous tropical forest site, with a greater number of herbaceous plants in the understory. This characteristic is clearly an important factor for Chrysomelidae, because species are almost exclusively phytophagous, with species often highly specialized and thus directly influenced by the composition of the vegetation and the presence and abundance of their host plants (Ribeiro et al. 1994, Řehounek 2002, Aslan and Ayvaz 2009, Flinte et al. 2011, Linzmeier and Ribeiro-Costa 2013).

Novotny et al. (2006) present evidence that the single most important factor contributing to high species diversity of insects in the tropics is the diversity of plants. This would seem to be simplest explanation for the differences in richness, diversity and abundance with altitude of leaf beetles in the present study. Although the abiotic factors that change with altitude, such as precipitation, temperature, air currents, and solar radiation (Lawton et al. 1987, Barry 2008) can certainly affect some aspects of the biology of Chrysomelidae, the single most important factor in the abundance and diversity of these beetles is clearly the presence of their host plants (Ribeiro et al. 1994,

Aslan and Ayvaz 2009, Şen and Gök 2009, Flinte et al. 2011). Each site in the present study has markedly different plant communities with different species compositions, densities and vegetation structure. This was reflected in equally different communities and abundances of leaf beetles among the three sites, with less than 50% similarity in species among sites. Adding to the vegetation differences were anthropogenic activities (grazing, logging) observed around some of the quadrants where sampling was carried out. Moderate disturbance can increase overall plant production and diversity (Connell 1978, Huston 1979), and would have a similar effect on leaf beetles (Şen and Gök 2009). Plants within disturbed vegetation patches are often colonizing species, and so they represent young leaves and less chemical defenses (Wolda 1978, Jolivet 1988, Novotny and Basset 1998) which would favor high abundance of species within some genera of Galerucinae, such as *Centralaphtona* Bechyné & Bechyné, *Chaetocnema* Stephens, *Epitrix* Foudras and *Longitarsus* Berthold. The increase in abundance and species richness as a result of the disturbance of vegetation has been observed in other studies with beetles (Dagobert et al. 2008, Sánchez-Reyes et al. 2012), including Chrysomelidae (Linzmeier and Ribeiro-Costa 2009), because by altering the species composition of a plant community, also alters species composition and abundance of phytophagous beetles (Wąsowska 2004).

On a temporal scale, the Chrysomelidae community followed a markedly seasonal pattern, where the dry season was the most favorable for collection of this group in the study area (greatest abundance and species richness). This is a pattern that was also found in the subtropical region where the higher captures of insects occur in the dry season. Linzmeier and Ribeiro-Costa (2008, 2013) found the major activities of Chrysomelidae during spring/summer, before the rains. Nummelin and Borowiec (1991) in Uganda, also found the peak densities of chrysomelid beetles (subfamily Cassidinae) at the beginning of the dry season after the long rains. Jones et al. (2012) found the greatest richness, diversity and abundance of Apionidae (Curculionoidea) during the dry season in northeastern Mexico. In our study, the greatest number of species and individuals were recorded during the late dry season, resulting in a constant evenness with the increase of the samples; also, the diversity value significantly higher obtained at the early wet season was originated by the high number of species and the drop in abundance value, which can be reflected also in the SHE analysis, where evenness remains constant at the increase of the samples.

Results presented here can be partially explained by the indirect effect of precipitation and temperature on the abundance and species richness, respectively. In this study, abundance increases significantly as precipitation decreases, while species richness increases significantly with an increasing in the maximum temperature. Influence of high temperature present during the wet season has been observed in other studies with Chrysomelidae in tropical areas (Linzmeier and Ribeiro-Costa 2008, 2013). There are several reasons that are related to precipitation and temperature and which can explain the seasonal differences. First, it is probable that many of the leaf beetles are in larval stages during the wet season, and hence lesser abundance of adults was obtained during that season, because we did not collect immatures. At the start of the rainy season,

plant density increases which represents greater food availability and new leaf tissues are more palatable for developing immatures (Wolda 1978, Jolivet 1988, Novotny and Basset 1998, Linzmeier and Ribeiro-Costa 2008, 2013). Second, with greater foliage during the wet season, the foliar area in general increases dramatically which results in populations being more “diluted” among the foliage. Thus, the chances of collecting individuals per sweep is reduced because of the great area of foliage. And third, many leaf beetles pass the dry season as adults in high concentrations in microhabitats unrelated to their host plant and vegetation type. There is evidence that beetles will fly away from dry habitats to wetter ones during the dry season, especially to riparian vegetation (Janzen 1973). However, the life-cycles of each species determines the pattern seen in the Chrysomelidae community, and thus an analysis of each species, their host plant and specific behavior needs to be taken in account (Linzmeier and Ribeiro-Costa 2013).

Although our data only considered a single canyon, beta diversity between sites at different altitudes was high. Similarity values obtained for all comparisons of sites were below 50%. Among the sites there was greater similarity of the first two altitudinal sites, with the lower similarity at the higher site. This pattern apparently reflects the greater difference between the tropical and temperate affinities of the vegetation and associated chrysomelids between the lower sites (Neotropical affinities) with the higher site (Nearctic affinities). Similarly, all comparisons between seasons had a similarity less than 50%, and a high number of exclusive species to each season. This pattern of low similarity indicates a significant turnover of species with altitude, which could be caused by the environmental heterogeneity of the area reflected in the different vegetal communities along the altitudinal gradient, which is observed in the three groups formed by the site cluster, and also the three groups (group 1: LWS and EDS; group 2: EWS; group 3: LDS) that were formed in seasonal cluster. However, we also found high values of alpha diversity for each of the sites and analyzed seasons, which suggests that biotic and abiotic factors present at each site and for each station generates unique conditions for certain species of chrysomelid beetles.

Our results highlight the importance of conservation of a heterogeneous habitat which can generate unique species compositions of highly diverse taxa, such as Chrysomelidae. Results presented here establish baseline data for Chrysomelidae richness and diversity for the region and can serve as a reference study for future work on the potential use of Chrysomelidae as indicator group of community diversity in natural areas. However, further studies are still needed to analyze the importance of environmental factors in the distribution and phenology of Chrysomelidae species and possible changes to expect due to climate change.

## **Conclusions**

A total of 2,226 specimens were collected belonging to six subfamilies, 81 genera and 157 species of Chrysomelidae from the study area. The greatest abundance and density of individuals were recorded at the lowest elevation site; however, alpha diversity

increased with increasing altitude, and species richness was higher at intermediate altitude. Similarity values were less than 50% among the three sites indicating that each site had distinct species assemblages of Chrysomelidae.

The highest abundance and species richness was obtained during the late dry season, whereas diversity was higher during the early wet season. Geographical location of the study area plus different vegetal compositions from the three sites sampled could be the principal reason for the variation here found in Chrysomelidae communities with altitude and season. Also, precipitation and temperature may influence the Chrysomelidae community in study area; however, both abiotic factors affect directly the vegetal composition which is assumed to be the principal factor in determining leaf beetle species composition and abundance.

The present work is one of the first specific area studies of Chrysomelidae conducted in Mexico, in which both altitude and season are analyzed. The information presented here provides baseline data that allow for comparisons of the diversity and species richness of Chrysomelidae on a regional and national scale. This information could be used as an initial step to analyze the potential use of Chrysomelidae as an indicator group of biodiversity in Mexico.

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