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The spider-like katydid *Arachnoscelis* (Orthoptera: Tettigoniidae: Listroscelidinae): anatomical study of the genus

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Abstract

This paper provides some observations on the anatomy of the neotropical katydid *Arachnoscelis arachnoides* Karny (Insecta: Orthoptera: Tettigoniidae). *Arachnoscelis* is a genus of predaceous katydids that comprise species that resemble spiders in their general body appearance. The type species, *A. arachnoids*, was described in 1891 from a single male collected in Colombia. Following the original description, these creatures were never found again, and were thought to have gone extinct or mistakenly assigned to the type locality. But between 1891 and 2012 four more species were described and incorrectly assigned to *Arachnoscelis* based on a similarity of body form. In this paper we present an anatomical comparaison of *Arachnoscelis* and its relatives, and propose that *Arachnoscelis* should be treated as a monotypic genus. This implies that other species previously described in *Arachnoscelis*, should be placed in different genera.

key words: ultrasound, predator, Colombia, stridulation, bushcricket

Introduction

Small, slim, long-legged katydids (Insecta: Orthoptera: Tettigoniidae) resembling spiders (Fig. 1) are grouped in the genus *Arachnoscelis* Karny (Karny, 1911). Five species have been assigned to this genus based on general body resemblance to the type species *A. arachnoides*. However no attempt to review and validate these assumptions has been undertaken. In this paper we study the biomechanics of sound production of *A. arachnoides*, and present an anatomical comparative analysis of all species presently assigned to *Arachnoscelis*. A more reliable report of the distribution of the type species is provided.

Arachnoscelis was described by Karny (Karny, 1911) as a monotypic genus, his type species, *A. arachnoides*, was described earlier from an adult male from Colombia by Joseph Redtenbacher (Redtenbacher, 1891) as *Listroscelis arachnoides*. Except for a few taxonomic reviews, these predaceous katydids have rarely been studied in detail. The only known specimen of *A. arachnoides* is the male studied by Redtenbacher and Karny. Since 1891 these animals have apparently not been collected or studied again. Some taxonomists even believed they had gone extinct, or that the type locality, was incorrect (Theodore Cohn, personal comm.). The peculiar spider-like anatomy has lead to taxonomists including other Neotropical similar spider-like katydids in *Arachnoscelis*. Four additional species from Central America (Bowen-Jones, 1994; Hebard, 1927; Randell, 1964) and two more from South America (Gorochov, 2012; Nickle, 2002) were described and assigned to *Arachnoscelis*. Montealegre-Z *et al.* (2006) reported another spider-like species of katydid wrongly identified as *Arachnoscelis* sp. from Colombia. This species uses the mechanism of elastic energy to produce a very unusual ultrasonic call consisting of a tone peaking at ca 130kHz, the highest tonal mating call ever recorded in nature.

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Recently the authors found a region in Colombia where the type species, *A. arachnoids*, is relatively abundant, offering a unique opportunity to study these exotic creatures. We, therefore, attempt to clarify some taxonomic and distribution aspects of the genus.

Methods

Specimens and locality. Locality: Colombia, Boyacá, Coper, Vereda Turtur, Sector San Ignacio. 5°25'32.51"N. 74° 0'9.07"O., elevation 1561 m. Coper belongs to the west province of the Departamento de Boyacá, and is located 133 Km from Tunja (the capital of Boyacá). Elevation lies between 600 m and 2600 m above sea level. Average temperature is 23°C and the annual rainfall 3,152 mm, therefore, three different thermal floors are identified: warm 171 Km^2; temperate 17 km^2; and cold 14 km^2. Coper has an area of 202 km^2. Specimens (5 males and 1 female) were collected at night between the 25th and the 30th of October, 2009 and transported to Palmira, Colombia, for acoustic recordings and experiments using a custom-built acoustic room.

Anatomical measurements. For morphological measurement specimens were preserved frozen (-24 ºC) in individual vials; a small amount of formalin was injected in the body to stop *rigor mortis* and help to preserve coloration. The stridulatory file has been shown to have taxonomic and acoustic importance (Montealegre-Z, 2005; Walker & Carlysle, 1975), thus it is used here from both perspectives. Stridulatory structures were measured from Scanning Electron Microscope (SEM) pictures. The wings of two specimens were dissected and placed directly in the microscope sample chamber without the need of gold or carbon coating. Measurement of inter-tooth spacing was carried out using the dimension tool of Corel Draw X4 (Corel Inc. Ottawa, Ont., Canada) and SEMs photographs as indicated by (Montealegre-Z & Mason, 2005; Montealegre-Z *et al.*, 2006). Other morphological measurements were obtained using a Mitutoyo digimatic caliper (China), sensitive to 0.01mm. Wing venation nomenclature follows Bethoux (2012).

Results

Morphological characterization of the genus and its relation to other spider-like katydids

Arachnoscelis Karny 1911

Karny. 1911. Verh. der Zoologisch-Botanischen Gesellsch. Wien 61:334–347
Karny. 1912. Genera Insectorum 131:3
Bruner, L. 1915. Annals of the Carnegie Museum 9(3–4):363
Randell. 1964. Canadian Ent. 96:1608
Gorochov. 1995[1994]. Zoosystematica Rossica 3(2):202
Otte, D. 1997. Orthoptera Species File 7:80
Nickle. 2002. J. Orth. Res. 11(2):127
Gorochov. 2007. Zoosystematica Rossica 16(2):210
Gorochov. 2012. Trudy Zoologicheskogo Instituta 316(4):287

Redescription of the genus. Head elongated in males. Male mandibles well developed, mandible elongated. Head, and mandibles of the female of normal appearance (Fig. 2). Males and females with notoriously large maxillary palps. **Legs:** Fore tibia distally decurved with 5 pairs of movable spines on the ventral surface (Fig. 3); tympanal area on the proximal part of fore tibia inflated, with a pair of tympanal openings that are antero-distally elongated, spacious, and asymmetrical; the anterior opening is narrower than the posterior one. Distal margin of both tympanal openings rounded, proximally this margin is acute. **Wings:** Male brachypterous, tegmina reduced to the size of the stridulatory area (Figs. 1A, and 4A–E). Massive vein (formed by the merging of several veins), curves towards the anal area, ends blunt and weakly connects to CuPaa2 through the narrow handle vein (h in Fig. 4E) and vein CuPaa2+CuPaß. The wing shows a large soft area between M+CuA end and CuPaa2 (Fig. 4E). Tympanal slits elongated, relatively broad and asymmetrical (Fig. 5A). Scraper area subquadrate, as large as the mirror area. **Genitalia:** Male subgenital plate broad with a broad v-shape notch, with two distinct styli. Female subgenital plate elongated, upturned, with distal bifurcation (Fig. 5B).

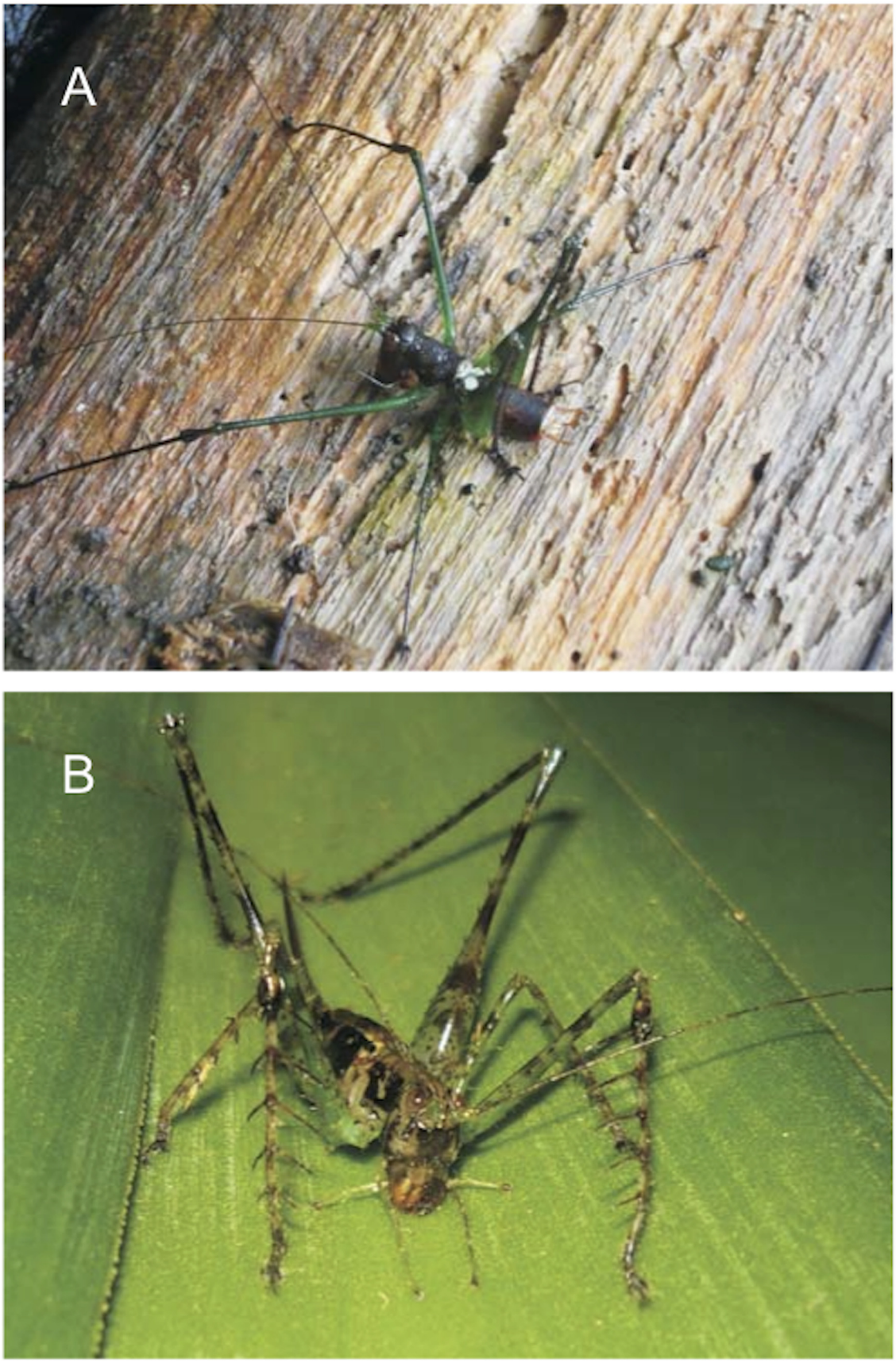

FIGURE 1. *Arachnoscelis arachnoides* habitus; **A**. Male; **B**. Female.

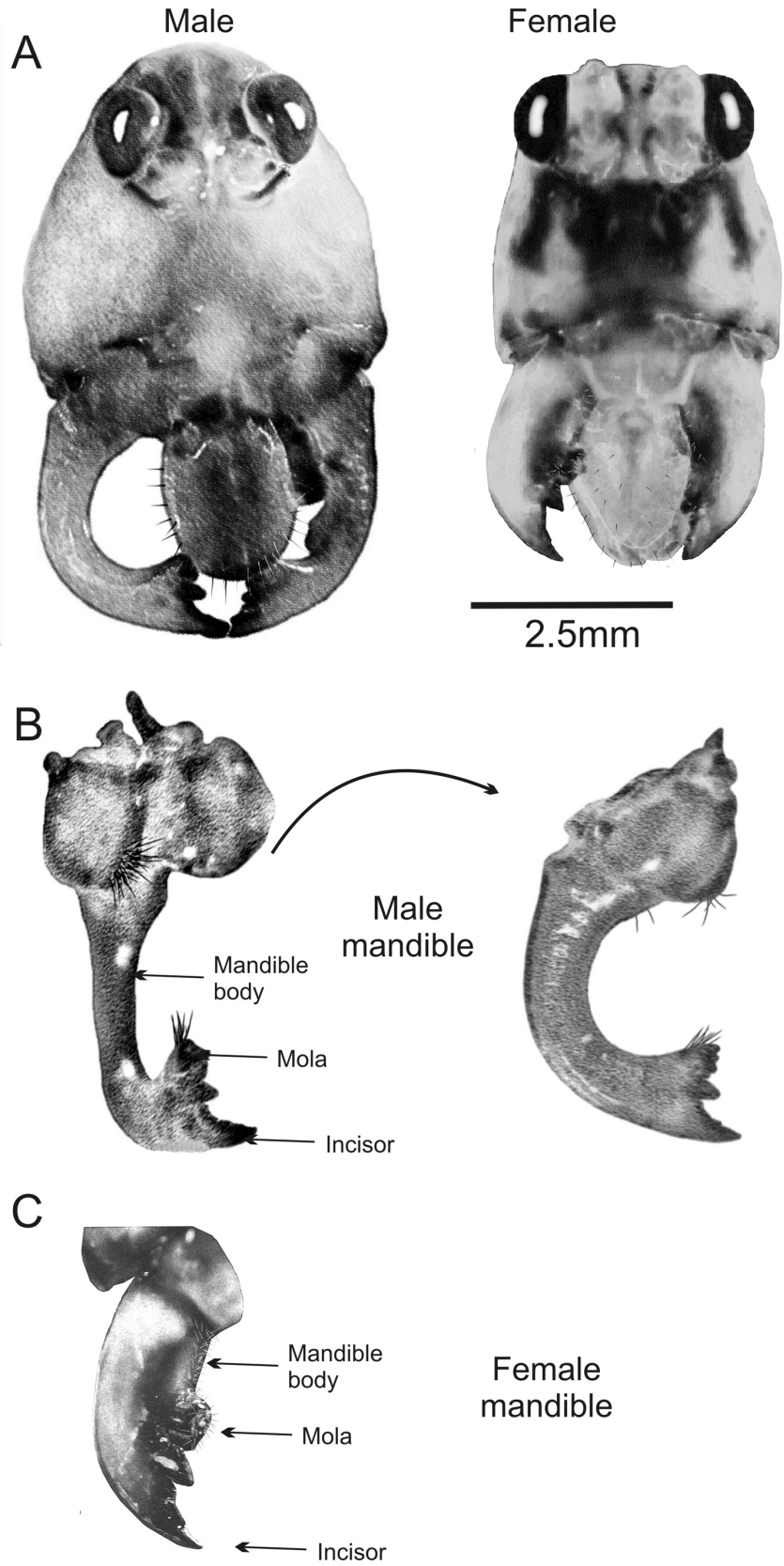

FIGURE 2. Distinguishing structures of the head of *Arachnoscelis arachnoides*: **A.** rostrum of a male and a female; **B**. Male right mandible seen from internal and dorsal view; **C**. Isolated right mandible of the female in dorsal view. B and C illustrate mandible sexual dimorphism in the head structure; note the conspicuous enlargement of the mandible body in males.

FIGURE 3. *Arachnoscelis arachnoides*, female habitus.

Arachnoscelis arachnoides

Redtenbacher. 1891. Verh. der Zoologisch-Botanischen Gesellsch. Wien 41:230, 232 >> *Listroscelis arachnoides*
Giglio-Tos. 1898. Boll. Musei Zool. Anat. Comp. R. Univ. Torino 13(311):93 >> *Listroscelis arachnoides*
Saussure & Pictet. 1898. Biologia Centrali-Americana 1:403 >> *Listroscelis arachnoides*
Kirby, W.F. 1906. A Synonymic Catalogue of Orthoptera (Orthoptera Saltatoria, Locustidae vel Acridiidae) 2:288 >> *Listroscelis arachnoides*
Otte, D. 1997. Orthoptera Species File 7:80 >> *Arachnoscelis arachnoides*
Chamorro-Rengifo, Cadena-Castañeda, Braun, Montealegre-Z., Romero, Serna Marquez & Gonzales. 2011. Zootaxa 3023:14 >> *Arachnoscelis arachnoides*

Redescription. **Head.—**Mandible body enlarged, curved latero-ventrally in males but reduced with normal appearance in females. Both male and female with a well developed tooth between the molar and incisor (Fig. 2). **Wings.—**Both mirrors ovoid (Fig. 4AE), right mirror area of 0.51 mm^2, left mirror smaller, 0.42 mm^2. **Stridulatory file** bearing 62–64 teeth. Measured from the anal side of the file, inter-tooth spacing rapidly and consistently increases in the first third of file length from ca. 14µm to 40µm, decreases during the second third from ca. 40µm to 10 µm, and slowly decreases from 10µm to 5 µm in the last third (Fig. 4C). **Abdomen.—**Male tenth tergite unspecialized, showing only two diffident lobes separated by a broad shallow notch (Figs. 5C, and 6A). Titilators delicately elongated, highly sclerotized and acuminate, projected upwards and protruding from the terminalia contour (Fig. 5C). Male cerci elongated and incurved, with distal tooth projected inward (Figs. 5B and 6A). Male subgenital plate basally expanded, bearing a broad v-shape notch and two distinct styli; the plate extends to the mid distance of the cerci (Fig. 5B). **Female** subgenital plate elongated and distally upcurved, bearing two distinct diverging lobes separated by a V-shaped notch (Fig. 5B).

Coloration. Sexual dimorphism is also observed in the coloration pattern (Fig. 1AB).

Male coloration. Scapus and first flagellar segment, and femora smaragdine (the brilliant crystalline green of the emerald) (Fig. 1A). Tibiae fulvous. Rostrum, clypeus and labrum fuscotestaceous, no facial marks present. Pronotum and abdomen brunneus. Tegmina albus-argentum (pearly). Abdominal tergum with two pale subtriangular spots which cover the first and second tergites; half a spot lays on the first tergite and the other half on the second tergite; the half on the first tergite is amber, while that on the second tergite become olivaceous or smaragdine.

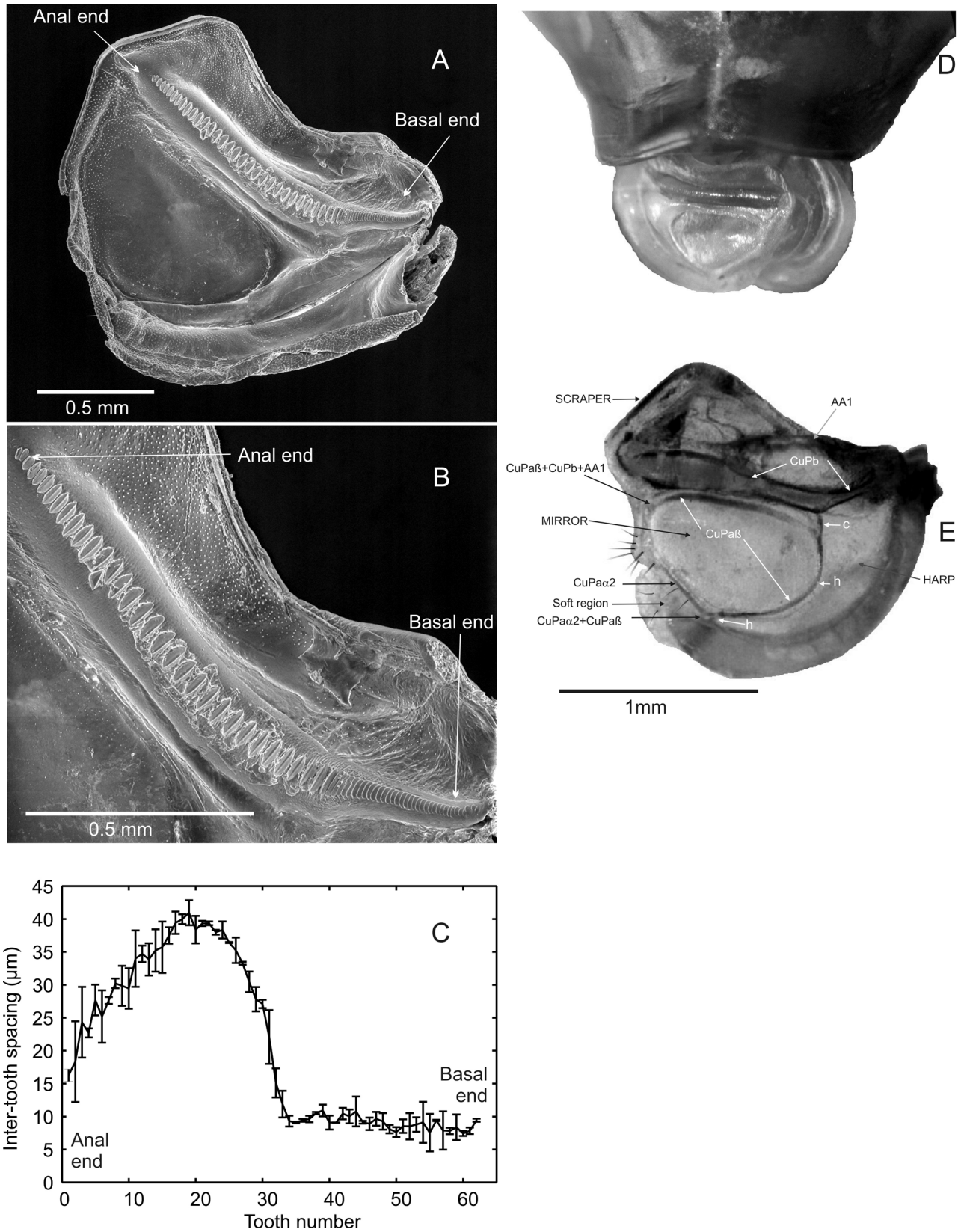

FIGURE 4. The stridulatory file of *Arachnoscelis arachnoides*: **A**. The entire left tegmen in ventral view showing the stridulatory file and mirror; **B**. A close up view of the file. **C**. Average inter-tooth spacing measured from two males. Error bars indicate one standard error; **D**. Male tegmina in resting position; **E**. Right tegmen illustrating venation pattern. Venation nomenclature follows Bethoux (2012).

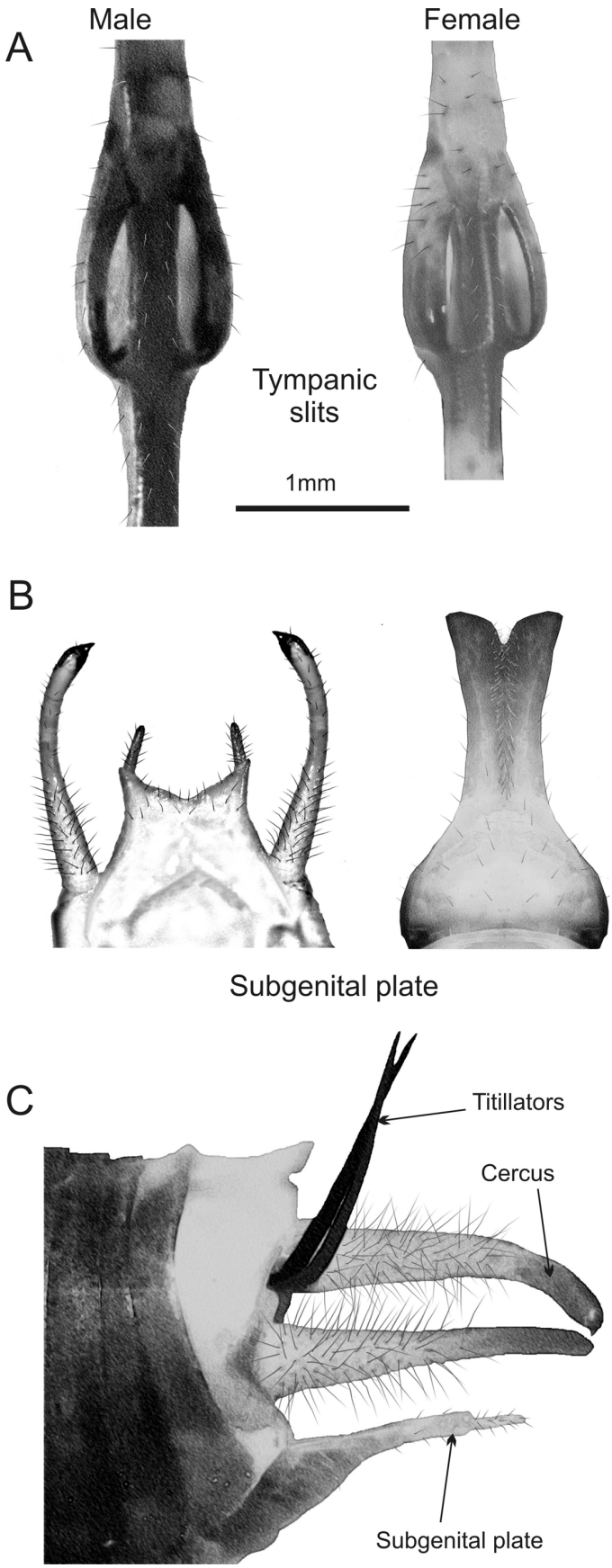

FIGURE 5. Distinguishing structures between males and females: **A**. Proximal part of the left tibia showing tympanal slits; **B**. Subgenital plates of males and females in ventral view. The male diagram also depicts cerci and styli; **C**. Lateral view of the male terminalia showing cerci, subgenital plate and titillators.

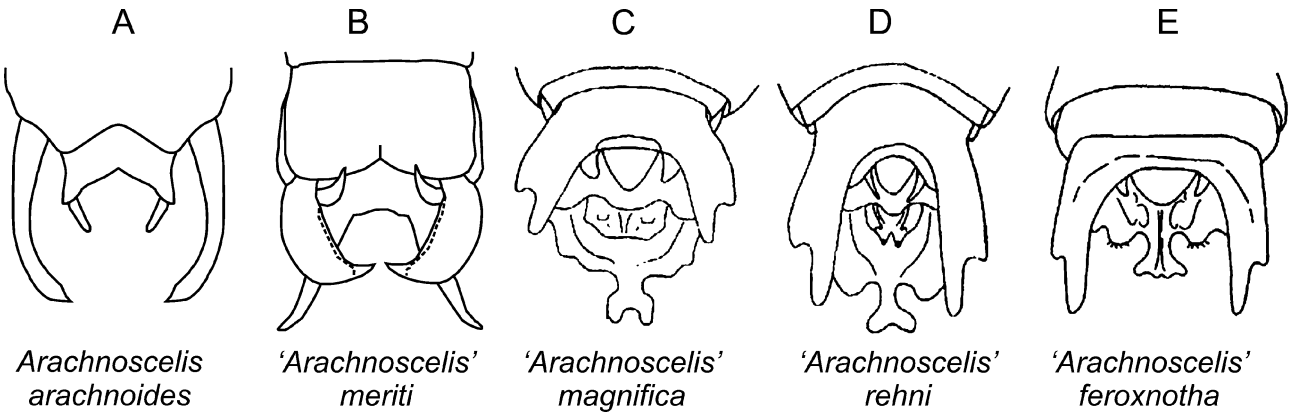

FIGURE 6. Comparative anatomy of the male terminalia between *Arachnoscelis* and other related species: B redrawn from Nickle (2002); C–E redrawn from Bowen-Jones (1994).

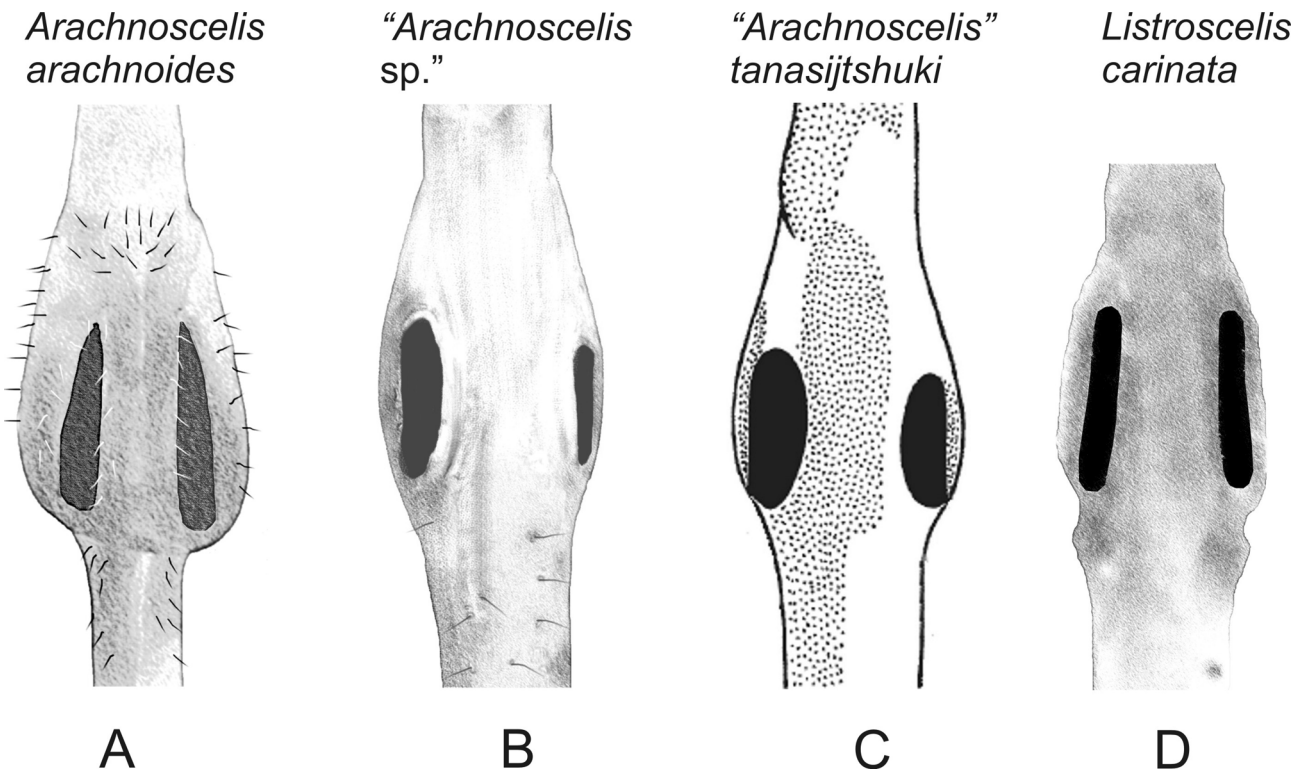

FIGURE 7. Comparative anatomy of the right tympanal slits between *Arachnoscelis* and other related species: **A**. Tympanal region of a female *A. arachnoides*; **B**. Tympanal region of the female of the most ultrasonic arthropod found in the animal kingdom and incorrectly identified as *Arachnoscelis* sp. by Montealegre-Z et al (2006); **C**. Tympanal region of the female '*Arachnoscelis' tanasijtshuki*, (Modified from Gorochov (2012)); **D**. Tympanal region of a female *Listroscelis carinata*..

Female coloration. Female body highly mottled (Fig. 1B). Occiput amber with two short brunneus strips between the eyes and two additional brunneus lines on each side, which continue anteriorad and delineate the eye sockets. Pronotal disk amber, pronotal lobes irregularly covered with a brunneus-atrous macula. Limbs resinous-amber with irregular suffusions of brunneus dots and spots. All femora with two distinct bracelets of the same brunneus tone on distal half. Abdominal pleura atrous and abdominal terga ambar. Subgenital plate and cerci ambar, ovipositor fulvous.

Material examined. Neotype: 1♂, Colombia, Boyacá, Coper, Vereda Turtur, Sector San Ignacio, elevation 1561 m. April 20, 2008, (O. Cadena-Castaneda). *Allotype*: 1 ♀, Colombia, Boyacá, Coper, Vereda Turtur, Sector San Ignacio, elevation 1561 m. April 20, 2008 (O. Cadena-Castaneda). *Paratypes*: 5♂, Colombia, Boyacá, Coper,

Vereda Turtur, Sector San Ignacio, elevation 1561 m. Oct. 25–29, 2009 (O. Cadena-Castaneda & F. Montealegre-Z); 2♂ January 15, 2013 (O. Cadena-Castaneda).

Depositories. COLOMBIA: Museo Universidad Distrital Francisco José de Caldas, Bogotá DC (MUD), Museo de Entomología Universidad del Valle, Cali (MEUV), Museo de Entomología Instituto de Ciencias Naturales, Bogotá DC (ICN).

TABLE 1. Morphological measurement of the specimens examined. Only the left side appendages were measured. Measurements given in millimetres.

	M-1	M-2	M-3	M-4	M-5	Type specimen*	Female
Body	15.6	17.7	18.1	17.2	17.2	13.2	18.6
Pronotum	4.1	4.1	4.6	4.2	4.1	4.2	4.2
Tegmina	1.32	1.35	1.51	1.48	1.37	1.53	0.31
Fore femur	15.6	15.0	16.9	17.1	15.2	17.1	11.5
Fore tibia	18.2	18.7	20.9	19.9	18.8	20.0	13.5
Mid femur	10.0	8.8	10.9	11.0	10.2	11.0	8.5
Mid tibia	10.8	10.3	11.4	11.2	10.9	11.5	9.6
Hind femur	20.5	20.6	22.0	22.1	21.0	22.3	19.8
Hind tibia	20.5	20.9	22.7	21.5	21.7	23.0	20.6
Cercus	3.0	3.1	3.2	3.1	3.1	3.1	1.3
Ovipositor	--	--	--	--	--	--	13.3
Subgenital plate	2.3	2.3	2.5	2.3	2.2	2.4	4.7

* Original specimen described by Redtenbacher (1891).

Discussion

As pointed out previously, the systematic position of *Arachnoscelis* is obscure. This genus has been traditionally included into the subfamily Listroscelidinae, however, Gorochov (1995b) transferred it to the tribe Phisidini of the subfamily Meconematinae on the basis of a certain similarity in the structure of tympanal organs. Gorochov (2012) described *A. tanasijtshuki* and based on this species highlighted the fact that *Arachnoscelis* spp. have a distinct inflation in the proximal part of fore tibia, which is provided with a pair of oval (not very narrow) tympanal openings; this tibia also lacks any distinct concavity on the inner and outer sides near the distal edge of tympanal openings (Fig. 7C).

We show here that the tympanal cavities of *A. arachnoides* do not match with Gorochov (2012) description (Fig. 7) and that this author was inaccurate in assigning his species (*A. tanasijtshuki*) to *Arachnoscelis* (as other authors did), without careful comparison with the holotype and/or type species. Although the tympanal slits and inflation of *A. arachnoides* depart well from *A. tanasijtshuki* and other similar South American species (Fig. 7), the elongated slits suggest that *A. arachnoides* is more similar to some Listroscelidinae in this regards (for instance *Listroscelis carinata* (Fig. 7). However, we do not consider the tympanal structure as a strong enough character to move genera across subfamilies. Based on the tympanal slits anatomy *A. tanasijtshuki* is more similar to other species that have been incorrectly assigned to *Arachnoscelis* (e.g., Gorochov, 2012; Montealegre-Z *et al.*, 2006) (compare panels B and C in Fig. 7).

Gorochov (2012) also mentioned the structure of the mandible as a relevant character. In Listroscelidinae, the strong specialization of male mouthparts leads to the development of a long hook (perhaps the incisor) at the apex of one of male mandibles, and this is observed in *Arachnoscelis arachnoides* (Fig. 2). The female *A. arachnoides* exhibits mandible morphology equivalent to that of the male (mola, incisors, etc), except that the mandible body in males is highly elongated and modified (Fig. 2BC). We highlight the fact that sexual dimorphism in mandible structure shown by *Arachnoscelis* is also observed in other non-related groups of Tettigoniidae (e.g., Pseudophyllinae: *Gnathoclita sodalis*, *Dicranostomus* spp., *Disceratus* spp.; Listroscelidinae: *Listroscelis* sp.), and wetas, and is, therefore. a clear case of convergent evolution. Large mandibles in males are usually associated with

male aggression and fights (Gwynne, 2001). For *A. arachnoides* we do not have information on male interactions, and at least fights were not observed in caged males.

Our morphological analysis (Figs. 6 and 7) suggests that *Arachnoscelis* should be treated as a monotypic genus, with *A. arachnoides* being the only species known so far. This implies that the other species described within *Arachnoscelis* (*A. magnifica, A. rehni, A. feroxnotha, and A. tanasijtshuki*) should be allocated in other genera, pending revision. The structure of the male genitalia suggests that the Central American species could be part of one generic lineage (Fig. 6C–E), while the South American species (see Fig. 6AB) seem to be part of one or more lineages. The anatomy of the stridulatory structures of males *A. magnifica, A. rehni, A. feroxnotha, and A. tanasijtshuki* suggest these insects all use ultrasonic channels above 70 kHz for acoustic communication, as confirmed in other undescribed species of these groups (Montealegre-Z *et al.* 2006). Therefore, the mechanics of stridulation is likely to be similar across these species.

Acknowledgements

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