Morphology, density and population fluctuation of new records of orthopterans associated with four agroecosystems

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ABSTRACT

Objective: To determine orthopterans taxonomically, to calculate the population dynamics and fluctuation based on collections carried out in four agroecosystems in the Experimental Unit of the "Presidente Juárez" Agrobiology School in Uruapan, Michoacán, Mexico.

Design/methodology/approach: The research was conducted from August to December 2019. The agroecosystem was divided into four sectors, and for each sector a hectare of land with different crops was assigned. A completely randomized experimental design was established, with four treatments and five repetitions. Five collections were made in each sector, every 14 days. The field information was analyzed with the SAS software ver. 3.8, with Tukey's means comparison test (0.05).

Results: Two thousand hits were carried out with an entomological net and 2024 orthopterans were collected. The outstanding genera and species were: *Schistocerca nitens*, *Sphenarium purpurascens* and *Achurum sumichrasti*.

Limitations on study/implications: Only five months of the year were evaluated, so the species determined can vary in their relative abundance.

Findings/conclusions: New records were found in seven families, 19 genera and 16 species: *Acanthorintes tauriformis*, *Achurum sumichrasti* (Saussure, 1861); *Aidemona azteca* (Saussure, 1861); *Arphia conspersa* Scudder, 1875; *Brachystola mexicana* Bruner, 1906; *Ceuthophilus pallidipes* Tomás, 1872; *Conocephalus cinereus* Thunberg, 1815; *Dichromorpha prominula* (Bruner, 1904); *Ducetia japónica* (Thunberg, 1815); *Gryllus* spp., Linnaeus, 1758; *Melanoplus differentialis* (Thomas, 1865); *Neoconocephalus triops* (Linnaeus, 1758); *Rhammatocerus viatorius* (Saussure, 1861); *Schistocerca nitens* (Thunberg, 1815); *Sphenarium purpurascens* (Charpentier, 1841); *Stilpnochlora azteca* (Saussure, 1859); *Taeniopoda stali* Bruner, 1907; *Pyrgocorypha* spp., Stal 1873; and *Stenopelmatus* spp., Burmeister, 1838.

Keywords: Acridididae, Tettigoniidae, Pyrgomorphidae, *Schistocerca*, *Sphenarium*, *Achurum*.

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INTRODUCTION

Insects are ideal indicators for environmental monitoring, since it is possible to understand the conservation and/or deterioration of natural environments, diversity and taxonomic wealth, through them (Guzmán *et al.*, 2016). Scientifically, Othoptera have received greater attention as pest species (O'Neill *et al.*, 2003). From the agricultural point of view, grasshoppers and locusts

(Orthoptera: Acrididae) make significant attacks on various crops in many parts of the world (Maiga *et al.*, 2008). In the crops, they defoliate plants, thus reducing their photosynthetic capacities (Easwaramoorthy *et al.*, 1989). In livestock production, grasshoppers are the most abundant herbivores in grasslands, and they often consume more vegetation than the livestock (Branson and Haferkamp, 2014). From the forestry point of view, *Gryllus assimilis* (F. 1775) (Orthoptera: Gryllidae), is a pest of *Eucalyptus* spp. (Myrtaceae) (Silva *et al.*, 2013), where adults and nymphs commonly damage young plants (Barbosa *et al.*, 2009), and occasionally the seeds (Silveira *et al.*, 2014). As urban pests, knowledge about biodiversity of orthopterans is limited, although they represent a potential risk since they attack sport golf fields and gardening areas in hotel facilities (Artabe *et al.*, 2009). For this reason, the objective of this study was to determine the species of Orthoptera morpho-taxonomically, as well as the fluctuation and population density in four agroecosystems, in the Experimental Unit of the "Presidente Juárez" Agrobiology School, which depends on the Universidad Michoacana de San Nicolás de Hidalgo, México.

MATERIALS AND METHODS

Geographic location

The study was carried out from August to December 2019, in the Experimental Unit of the "President Juárez" Agrobiology School, municipality of Uruapan, Michoacán, Mexico; located between 19° 22' 31" North and 102° 01' 33" West at 1610 masl (Google Earth, 2024) (Figure1).

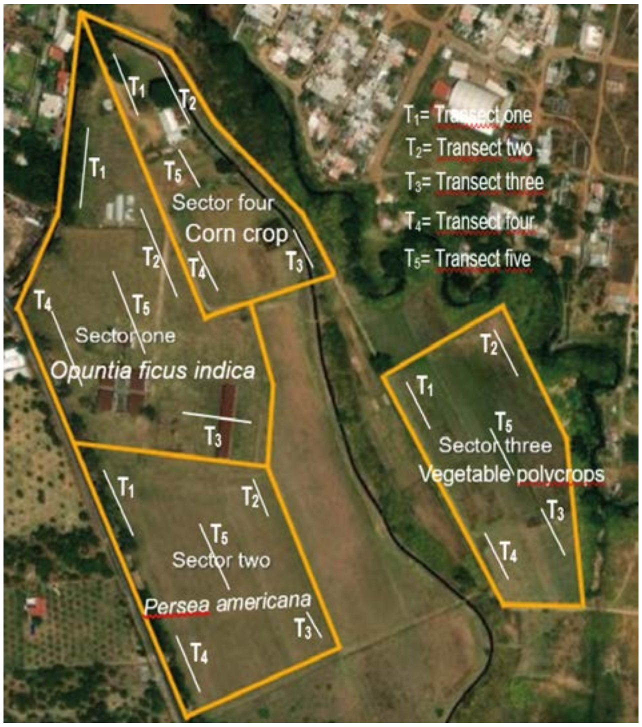

Figure 1. Geographic location of the Experimental Unit of the "Presidente Juárez" Agrobiology School and the sectors for collection (Google Earth, 2024).

Experimental site

Through a completely randomized experimental design, four sectors were chosen. Sector I: with nopal crop (*Opuntia ficus-indica* L.); sector II: orchard with avocado (*Persea americana* Mill. Var Hass); sector III: vegetable polycrops broccoli (*Brassica oleracea* var. Itálica P.), bean (*Phaseolus vulgaris* L.), squash (*Cucurbita pepo* L.); sector IV: corn crop (*Zea mays* L.). In each sector, a systematic sampling was conducted every 14 days during a period of five months (Castillo-Márquez, 2002).

Collection of orthopterans

Five transects were randomly marked in each sector (Figure 1), each transect measured ten meters, and one hit was made with an entomological net in each meter. There were 500 hits per sector, with a total of 2000 hits in the four sectors during each collection. For the collection of orthopterans, entomological vials were used with screw tap, alcohol at 70%, and lethal chamber with ethyl acetate. The samples were labeled and then transported to the laboratory BIO-CHRYS S. P. R. of R. L. of C. V., for their taxonomic determination.

Processing of orthopterans

In the BIO-CHRYS laboratory, the specimens collected were mounted and labeled with entomological pins of number one and two. In some specimens, the male genitalia were obtained. Stereoscopic and biological microscopes were used, both of Zeigen® brand, and a RoHS® digital microscope. To macerate the tegmina and genitalia, a glass vial with metal cap was used, and 5 mL^{-1} of potassium hydroxide at 10% were added, and then the bain-marie technique was applied for 15 min.

Identification of orthopterans

The orthopterans were grouped by morphospecies, to later perform their genus and species determination, based on the information in the database Orthoptera Species File (Otte, 1994), as well as the use of taxonomic keys of different sources of information: Karny (1938); Hebard (1941); Chopard (1951); Emsley (1970); Thomas (1873); McNeill (1897); Scudder (1897); Naskrecki (2000); Pomares (2002); Rowell (2013); and Gorochov and Cadena (2016). The taxonomic determination was the responsibility of Dr. Francisco Javier Avendaño Gutiérrez and Engineer Leticia Vázquez Ortiz. Photographs were captured of the traits with taxonomic value with the microscopes previously mentioned. The photographic camera used was AmScope® version x64, 2020, as well as a RoHS® 500X digital microscope.

Population fluctuation and dynamics

To analyze the density of orthopterans, the field information was captured in the Microsoft Excel software version 23H2 and a database was generated. The number of orthopterans collected was interpreted by sector and capture dates. Finally, with the help of the SAS Version 3.8 software, the Analysis of Variance was calculated with Tukey's means comparison test with α=0.05.

RESULTS AND DISCUSSION

Taxonomic determination of orthopterans

The number of Ensifera and Caelifera collected was 2024, which were distributed in seven families, 19 genera and 16 species (Figure 2) (Table 1).

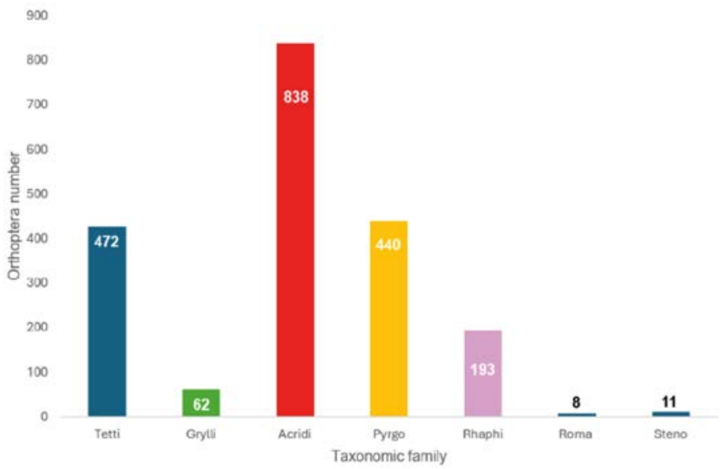

Figure 2. Families of orthopterans collected. Tetti=Tettigoniidae, Grylli=Gryllidae, Acridi=Acrididae, Pyrgo=Pyrgomorphidae, Rhaphi=Rhaphidophoridae, Roma=Romaleidae, and Steno=Stenopelmatidae.

Table 1. Genera and species of Orthoptera collected in the Experimental Unit of the Agrobiology School, 2019.

Location	Taxonomic distribution of orthoptera			
	Suborder	Family	Genus	Species
Experimental unit	Ensifera	Tettigoniidae	*Acanthorintes*	*tauriformis*
			Conocephalus	*cinereus*
			Ducetia	*japonica*
			Neoconocephalus	*triops*
			Stilpnochlora	*azteca*
			Pyrgocorypha	spp.
		Gryllidae	*Gryllus*	spp.
	Caelifera	Acrididae	*Achurum*	*sumichrasti*
			Arphia	*conspersa*
			Aidemona	*azteca*
			Dichromorpha	*prominula*
			Melanoplus	*differentialis*
			Rhammatocerus	*viatorius*
			Schistocerca	*nitens*
		Pyrgomorphidae	*Sphenarium*	*purpurascens*
		Rhaphidophoridae	*Ceuthophilus*	*pallidipes*
		Romaleidae	*Taeniopoda*	*stali*
			Brachystola	*mexicana*
		Stenopelmatidae	*Stenopelmatus*	sp.

Next, the morphotaxonomic characteristics of 15 genera and 13 species were exemplified.

Acanthorintes tauriformis

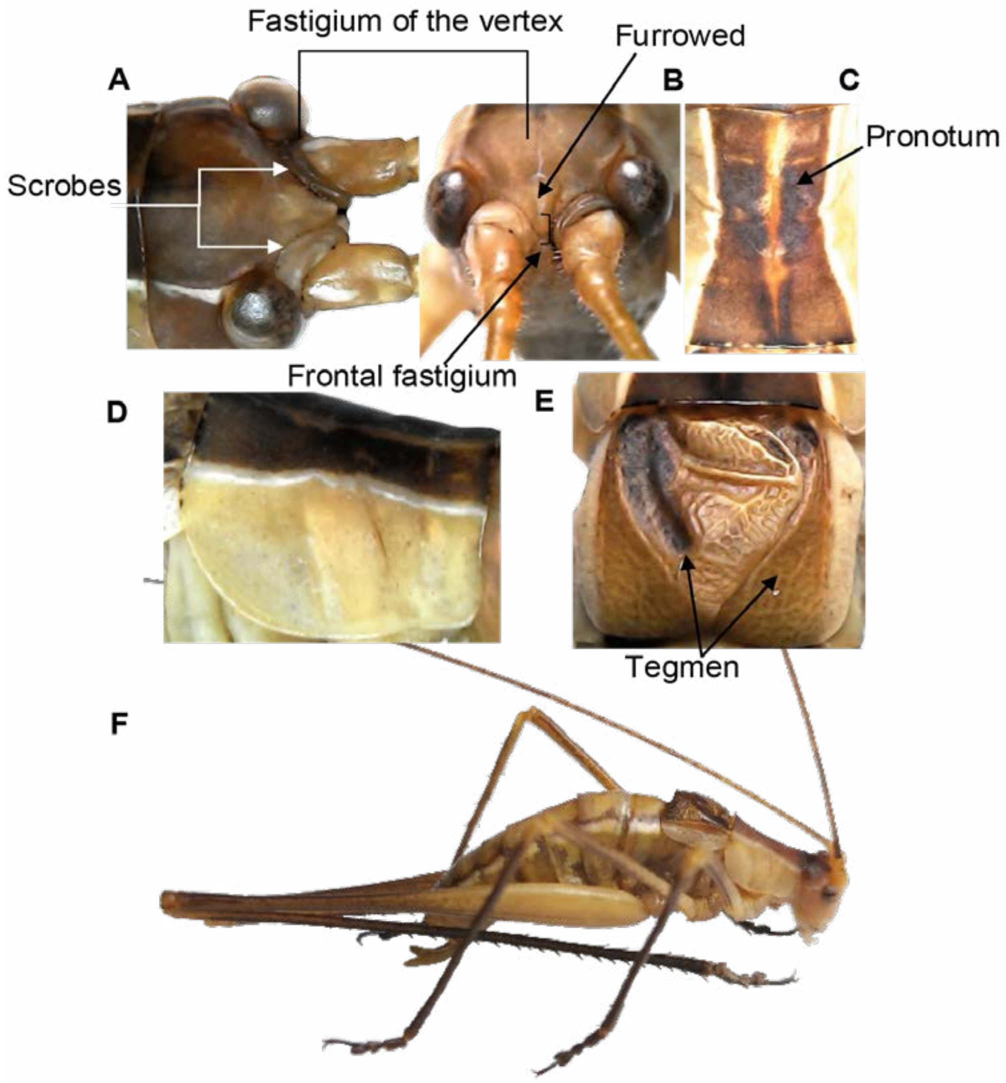

Figure 3. A-F: *Acanthorintes tauriformis*. Male (♂): A. Scrobes and head with declining occiput towards the fastigium, B. Fastigium of the vertex, slightly compressed, with the weakly furrowed dorsum, without touching the frontal fastigium, C. Dorsal view of the pronotum, D. Lateral view of the pronotum, E. More reduced tegmina than the pronotum, F. Moderately thin body shape, lateral view.

Acanthorintes tauriformis

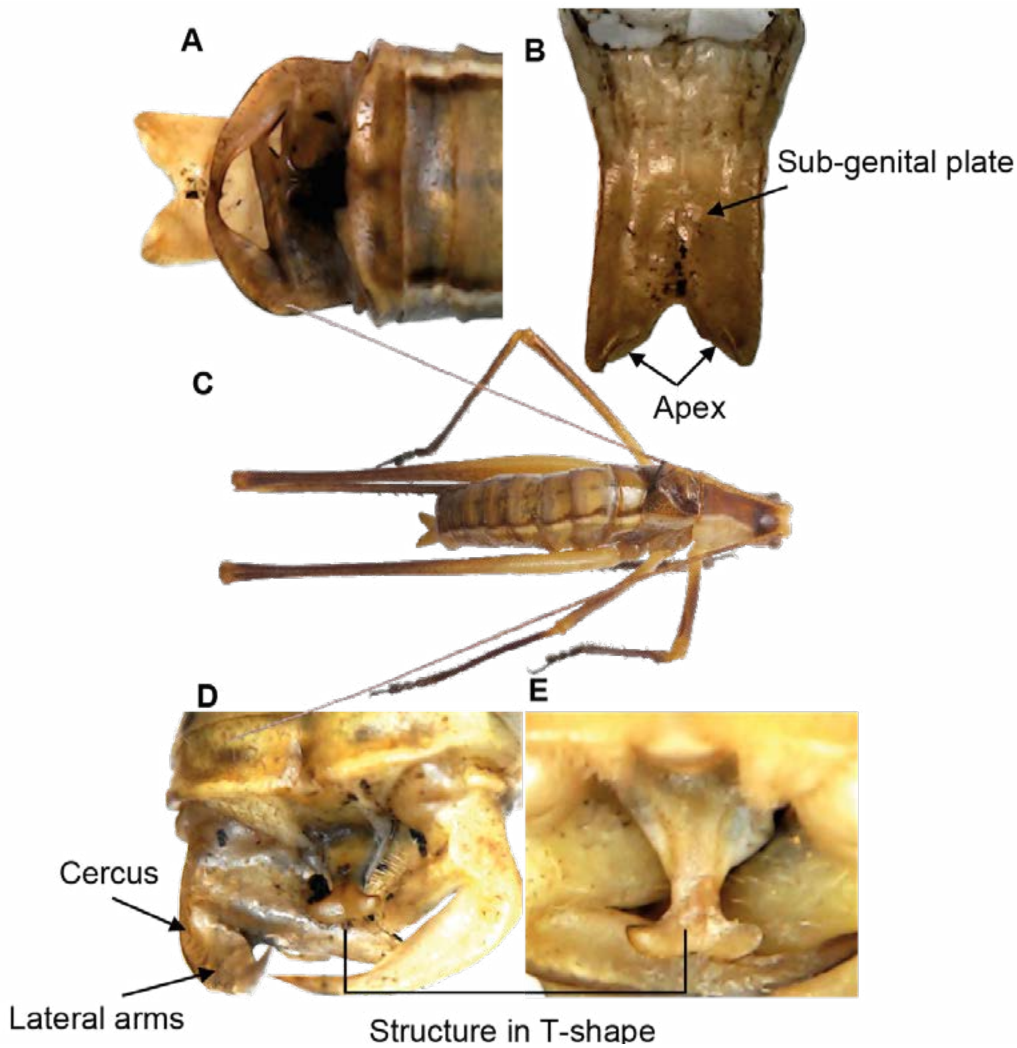

Figure 4. A-E: *Acanthorintes tauriformis*. Male (♂). A. Apex of the abdomen, dorsal profile, B. Subgenital plate, with long concave lateral margins and "doubly emarginated" apex, slightly convex internal margins of the apical slot, C. Complete dorsal body view, D. The cercus with strongly upwards lateral arms, E. Structure in T-shape in the proximity of the apex of the supra-anal plate.

Conocephalus cinereus

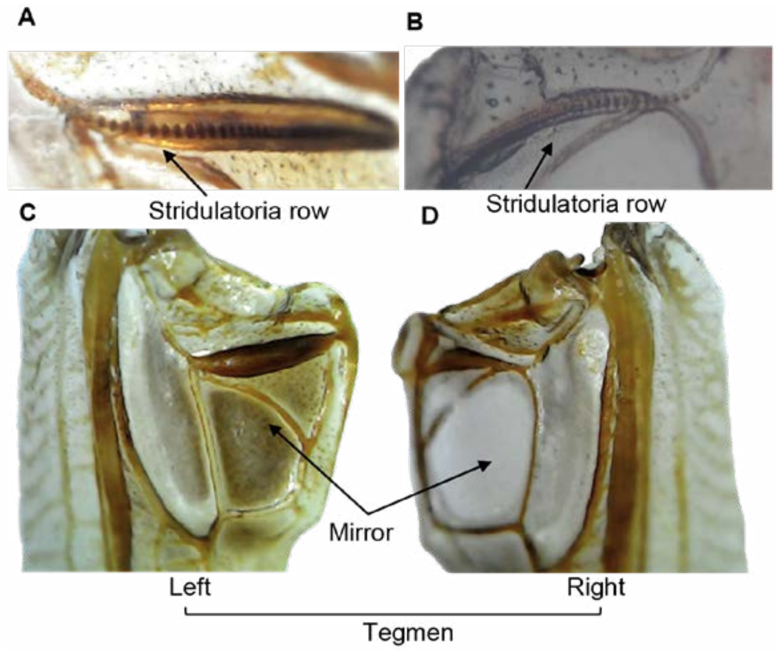

Figure 5. A-D: *Conocephalus cinereus*. Male (♂): A. Stridulation row with 44-45 thick teeth, B. Stridulation row of the right tegmen ventral view, C. Left mirror of the stridulatory apparatus, D. Right tegmen.

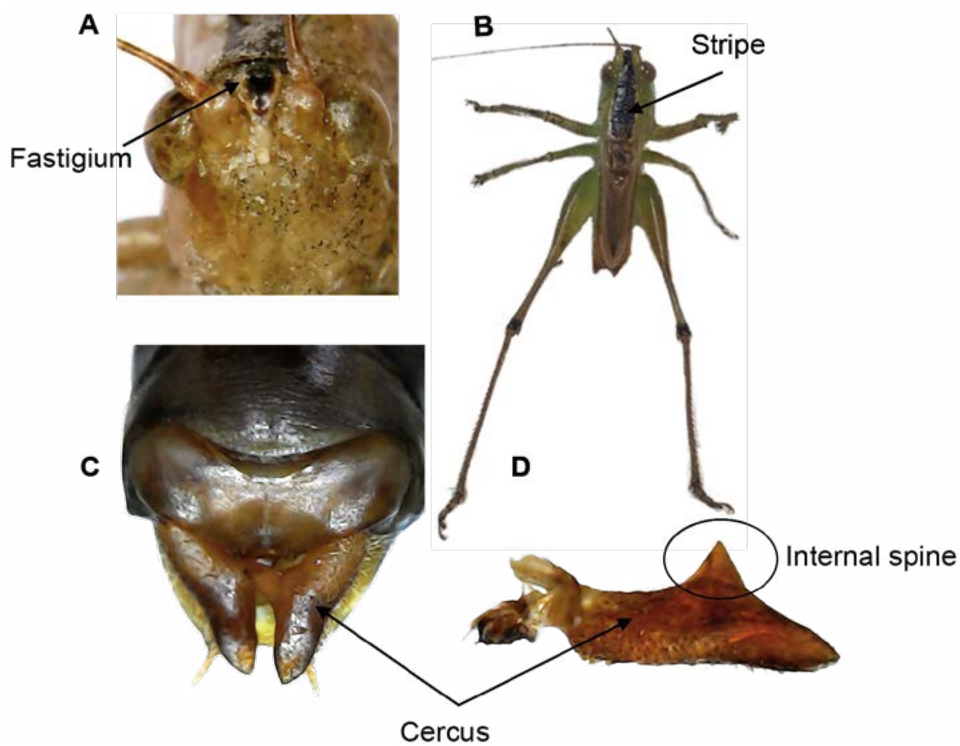

Figure 6. A-D. *Conocephalus cinereus*. Male (♂): A. The apical portion of the fastigium of the vertex tends to be slightly expanded laterally and measures from 2/3 to 3/4 of the scape width, B. Complete body dorsal view, dark brown stripe on the superior part of the head and the pronotum, C and D. Cercus with internal spine, dorsal view.

Conocephalus cinereus

Figure 7. *Conocephalus cinereus*. Thunberg, 1815 Female (♀). Narrow ovipositor, straight to weakly curved; clearly shorter than the posterior femur.

Neoconocephalus triops

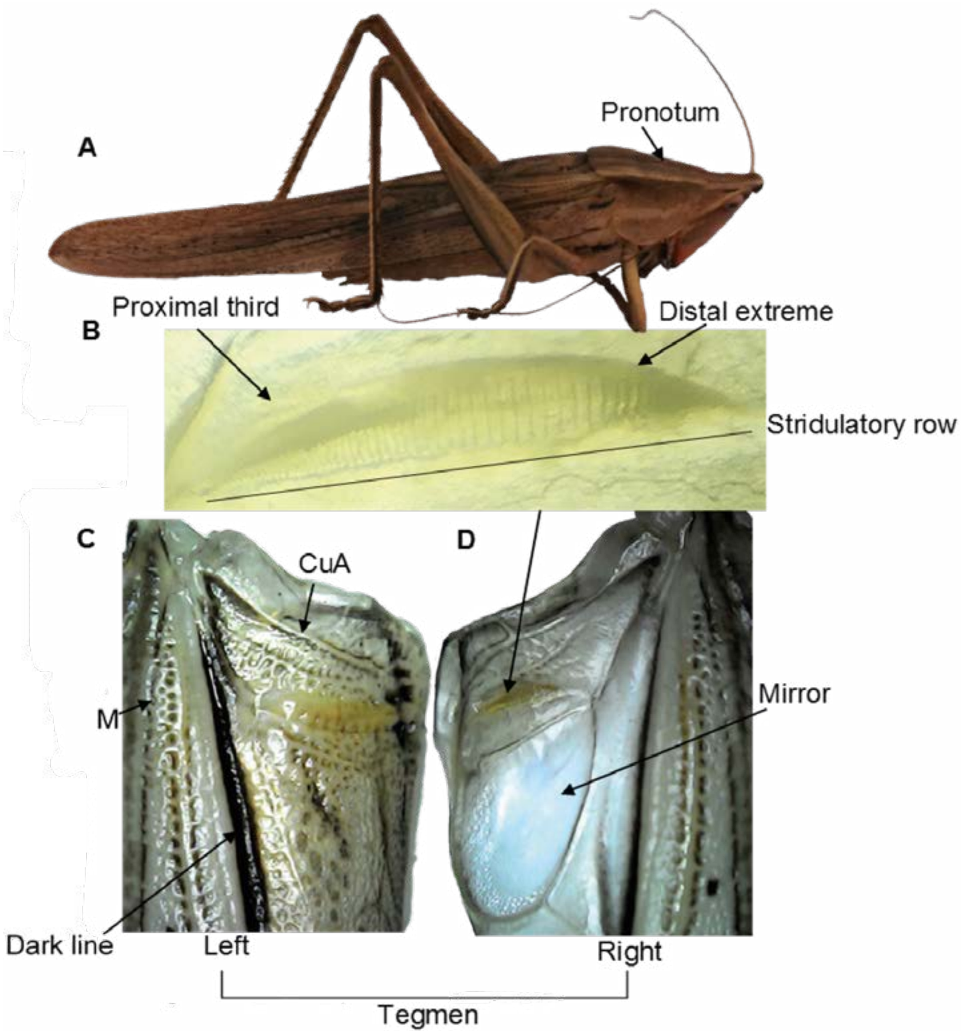

Figure 8. A-D: *Neoconocephalus triops*. Male (♂): A. Complete body lateral view. Pronotum with round appearance, B. Stridulation row with 65-86 teeth; thinner and more spaced teeth in the third proximal of the row, compared to the thickest and less spaced teeth of the distal extreme, C. Base of the left tegmen. Stridulatory area of the wing in most with short and black longitudinal line, parallel to the M+CuA veins, D. Mirror of the oval stridulator.

Neoconocephalus triops

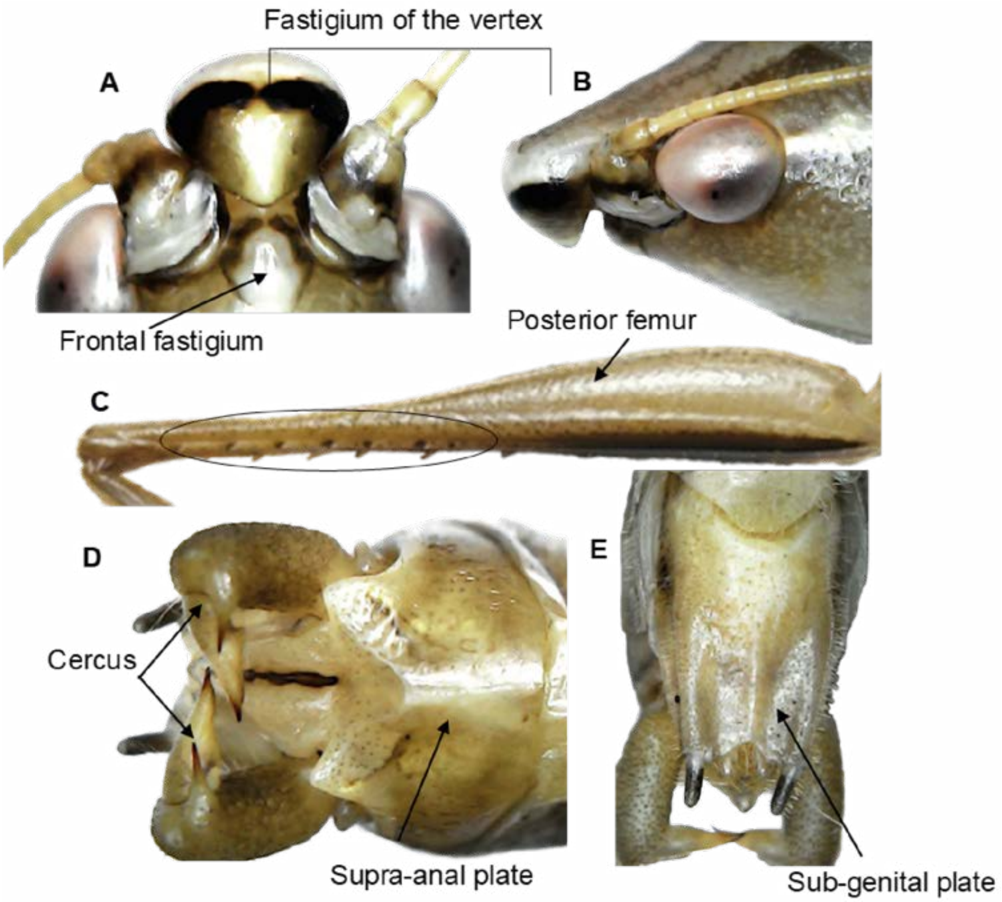

Figure 9. A-E: *Neoconocephalus triops*. Male (♂): A. Fastigium of the large vertex and generally wider rather than long, with round apex, on the frontal part with a weakly defined white band, generally accompanied by a dark thin line, fastigium of vertex separated from the frontal fastigium by a narrow space; blunt frontal fastigium, B. Fastigium lateral view, C. Caudal femur with small spines and dark marks in its base, D. Cercus dorsal view, E. Sub-genital plate.

Stilpnochlora azteca

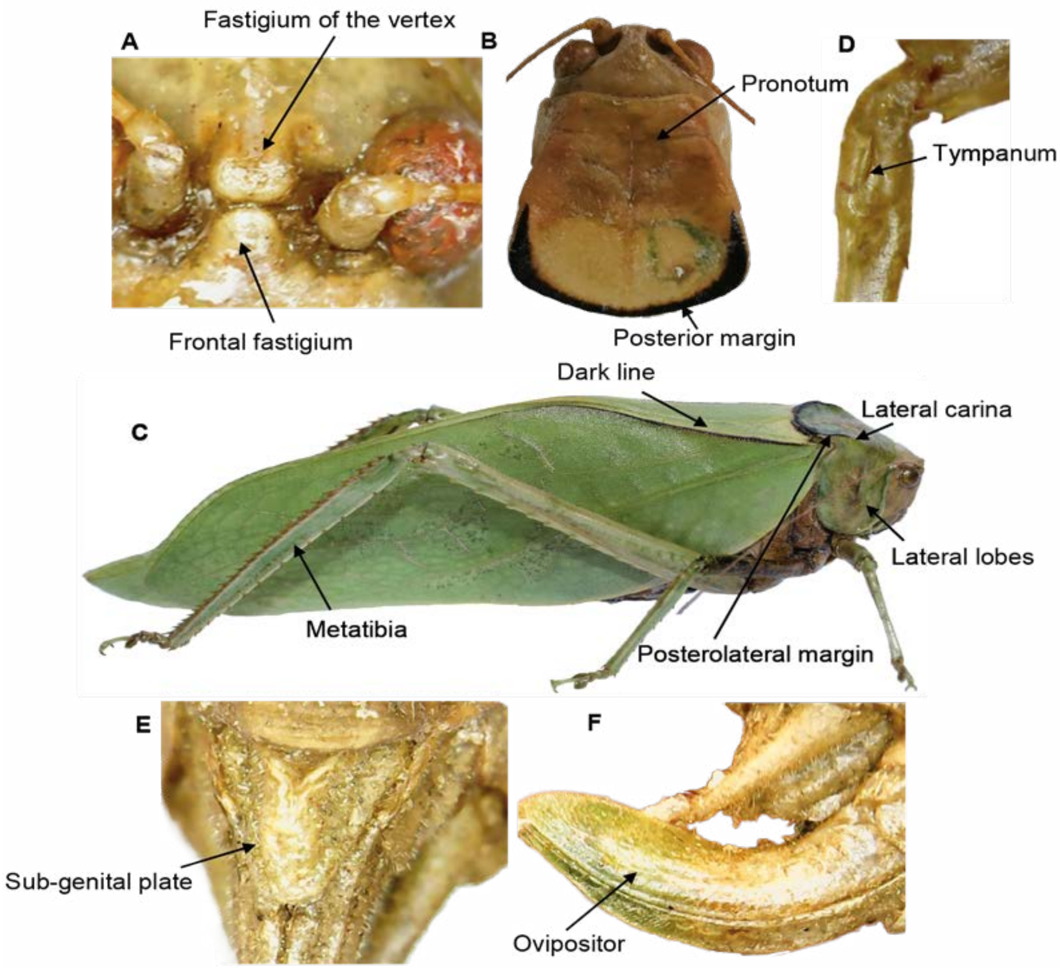

Figure 10. A-F: *Stilpnochlora azteca*. Female (♀), A. Fastigium of the strongly flexed vertex, apically swollen, furrowed in the middle dorsal part; robust and blunt frontal fastigium, B. Pronotum dorsal view, C. Complete body lateral view, approximate size of 95 mm. Lateral lobes that are much deeper rather than wide; anterior round lateral carina, giving the pronotum a curved appearance, D. Tympanum, E. Triangular subgenital plate, ventral view, F. Short ovipositor, raised at 65°, apically pointy, lateral view.

Stilpnochlora azteca

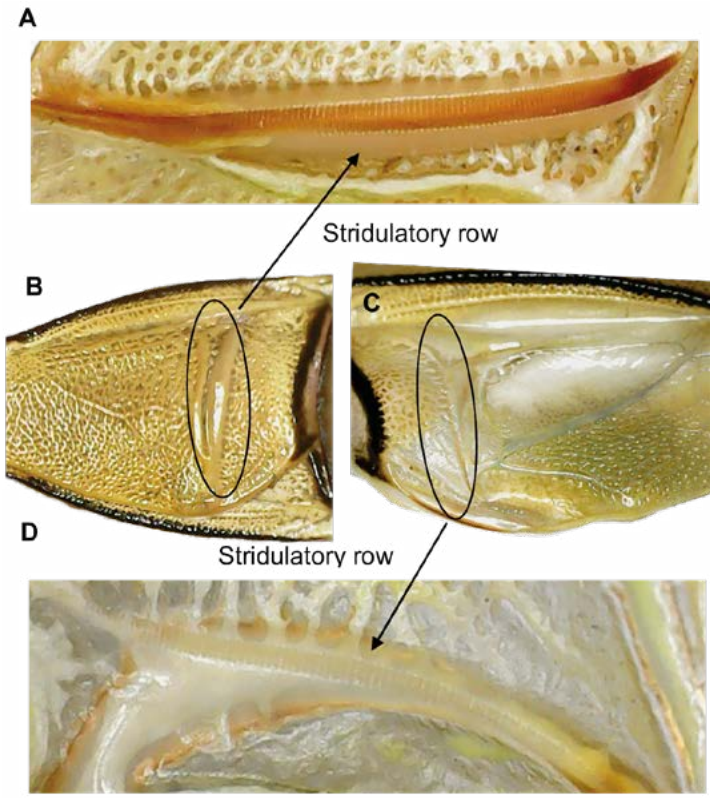

Figure 11. A-D: *Stilpnochlora azteca*. Male (♂): A. Internal face of the left tegmen; stridulation row approximately 61 mm long, with approximately 200 apparently functional teeth, B. Stridulatory apparatus dorsal view, C. Internal face of the stridulation row.

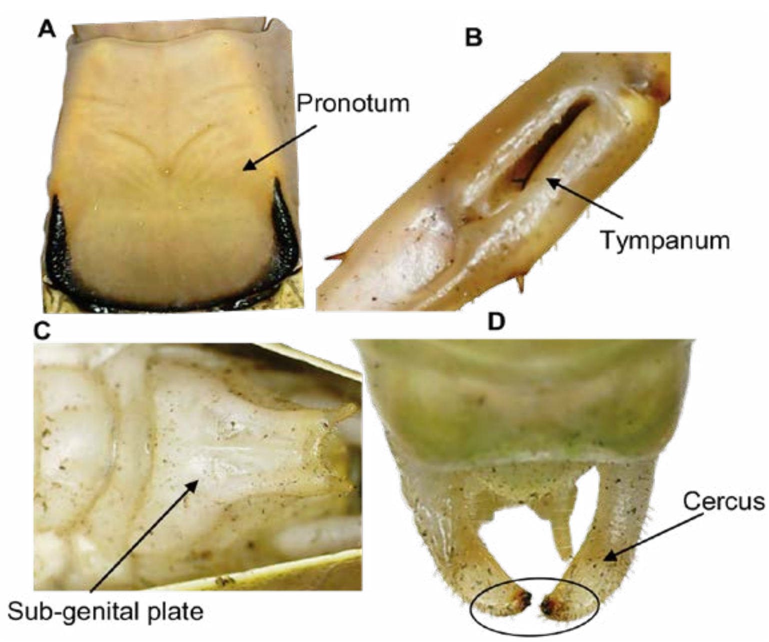

Figure 12. A-D: *Stilpnochlora azteca*. Male (♂): A. Pronotum dorsal view, B. Tympanum on the base of the anterior tibia, C. Articulated sub-genital plate, D. Cercus that end in a pair of similar blunt spines.

Pyrgocorypha **sp.**

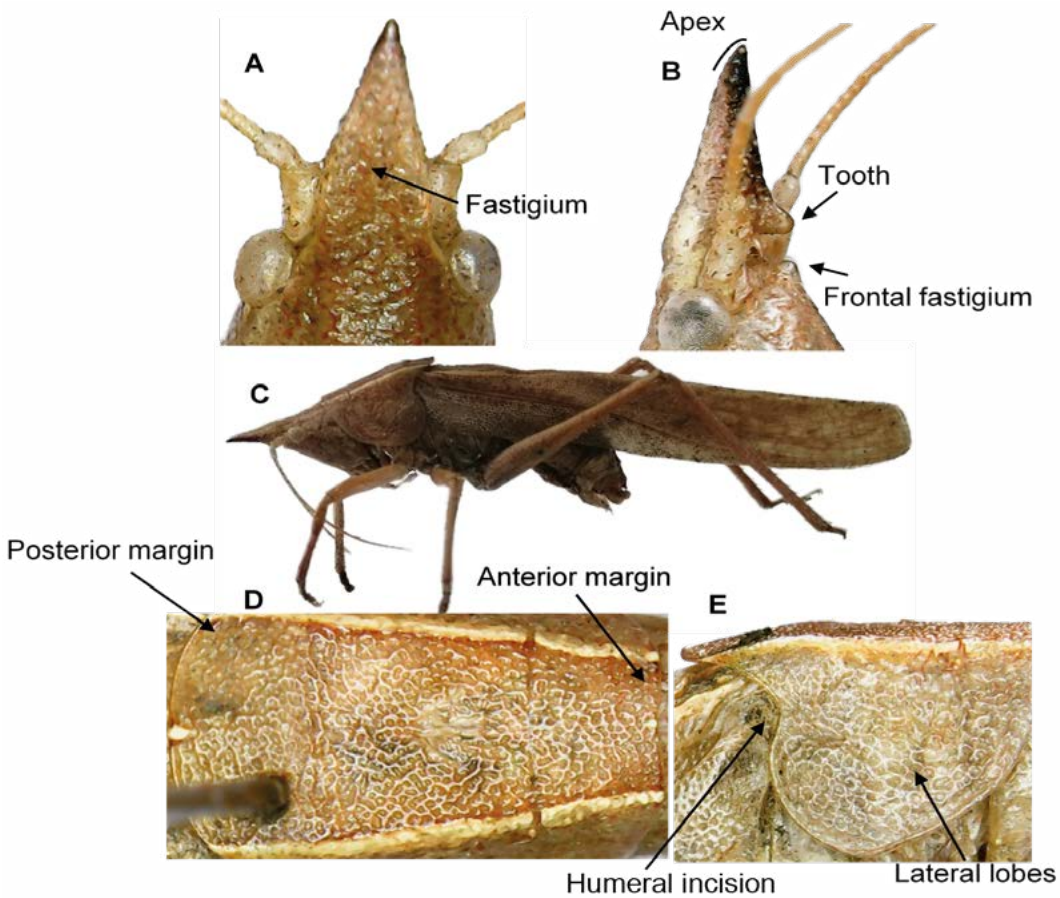

Figure 13. A-E: *Pyrgocorypha* sp. Male (♂): A. Fastigium of the strongly projected vertex, triangular in dorsal view, B. Apex of the fastigium often with a small hook and base with one tooth, separated from the front fastigium by a deep space, C. Complete body lateral view, D. Dorsal surface of the moderately granulated pronotum, flat or weakly convex; straight anterior dorsal margin, posterior straight to weakly convex, E. Lateral lobes with broadly rounded posterior angle and with well-developed humeral incision.

***Pyrgocorypha* sp.**

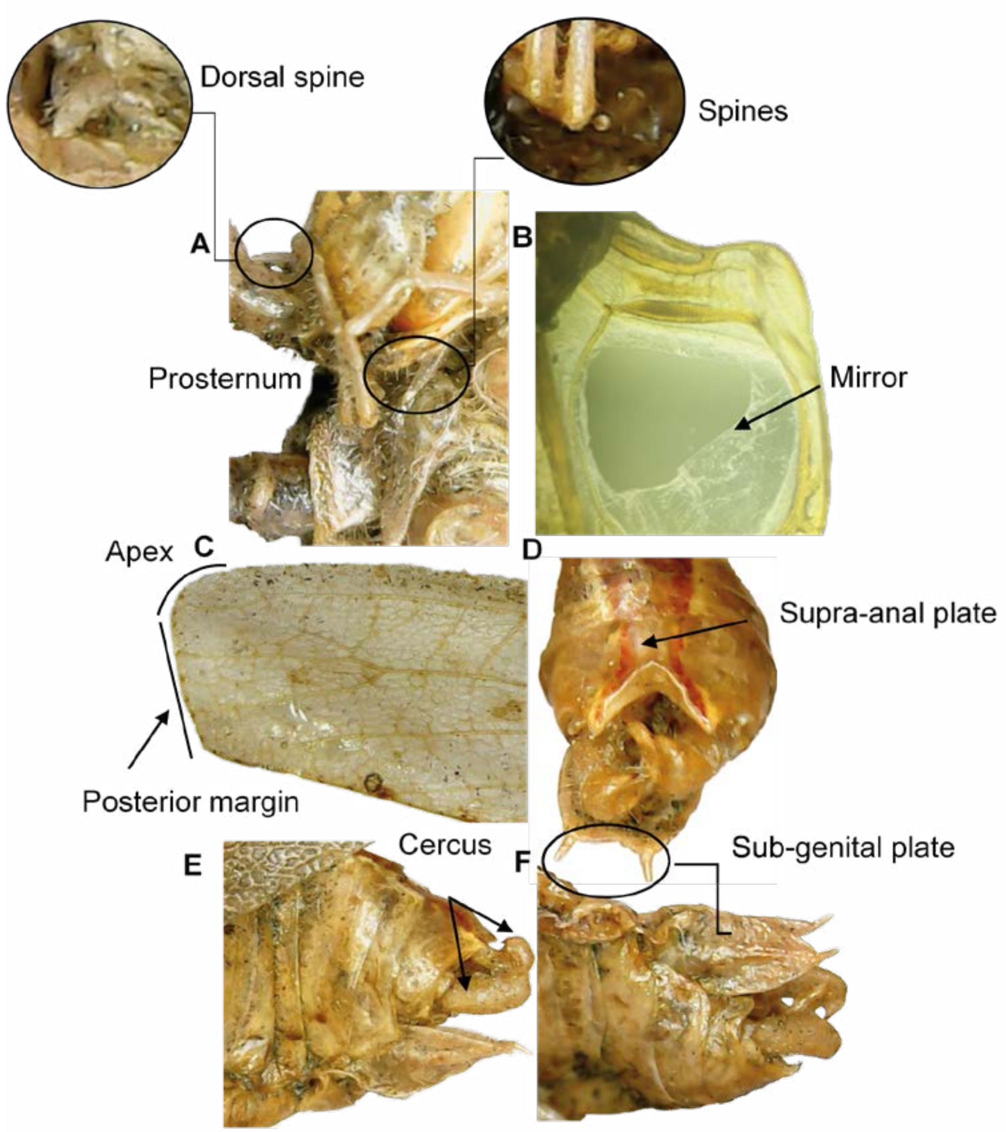

Figure 14. A-F: *Pyrgocorypha* sp. Male (♂): A. Anterior coxa with elongated spine projected forward, prosternum armed with two thin spines, B. Mirror of the right tegmen nearly circular, in ventral view, C. Posterior margin of the anterior straight wings with the rounded apex, D. Small, triangular supra-anal plate, E. Cercus lateral view, F. Sub-genital plate with a pair of styles, straight posterior margin, weakly emarginated or with a deep triangular incision.

***Pyrgocorypha* sp.**

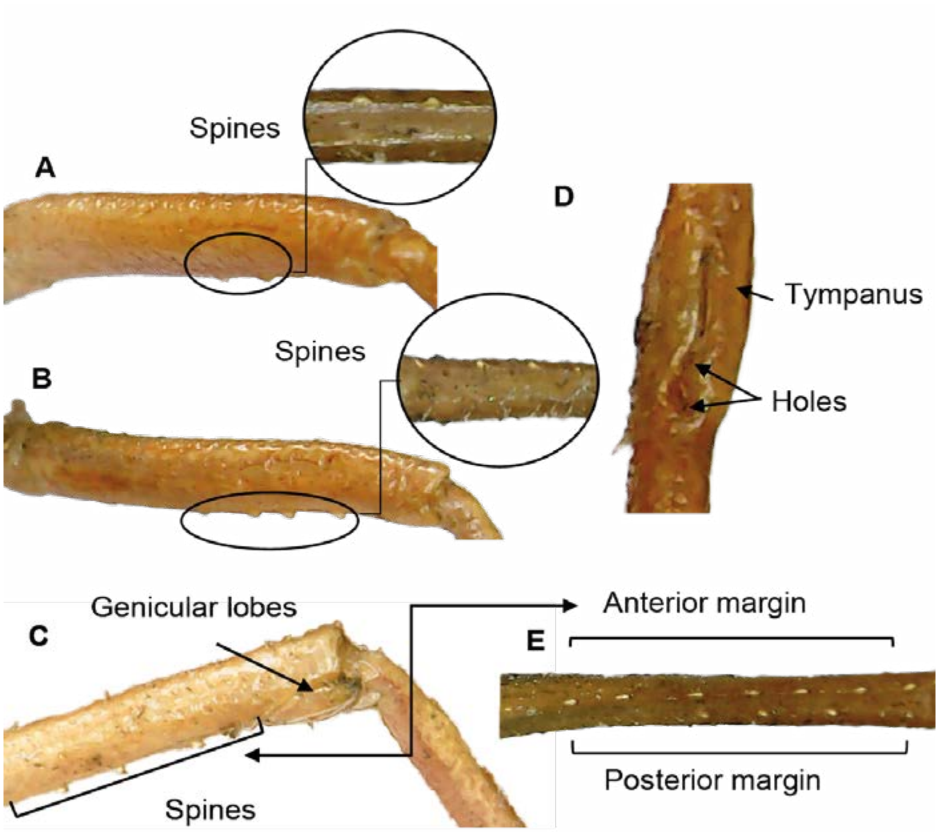

Figure 15. A-E: *Pyrgocorypha* sp. Male (♂): A and B. Anterior and middle femurs with ventral spines in anterior margins, C and E. Posterior femurs with spines in both ventral margins and genicular lobes, D. Tympanum of the anterior tibia closed bilaterally, slightly swollen tympanus area, with a pair of small holes under the tympanus fissures.

Achurum sumichrasti

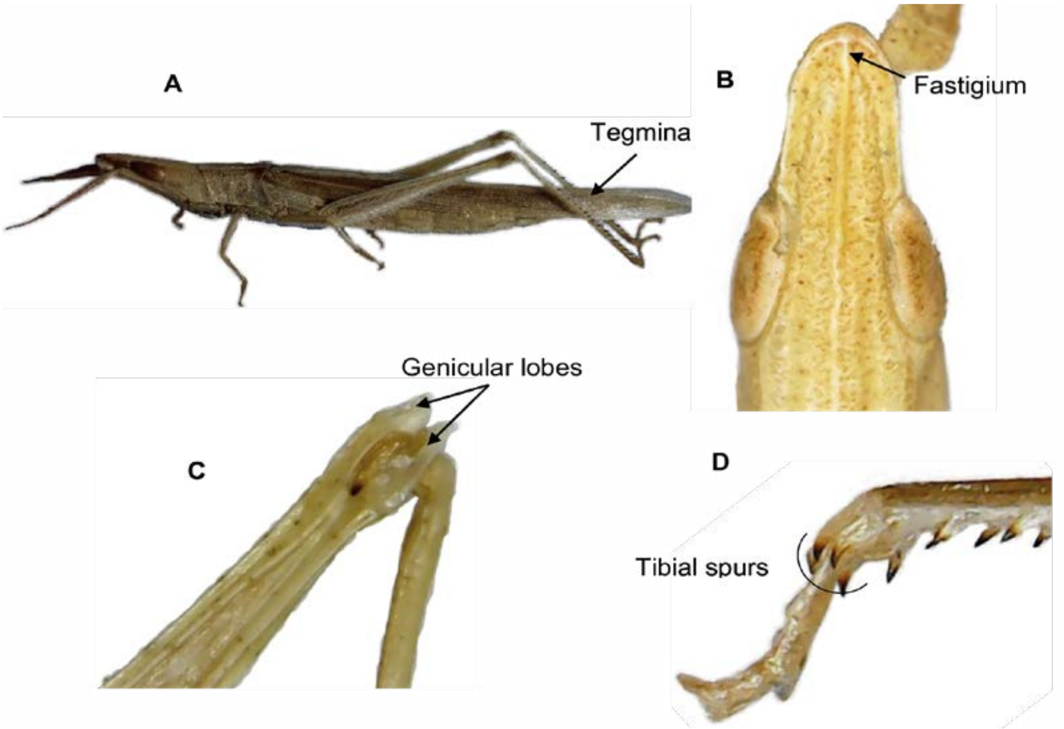

Figure 16. A-D: *Achurum sumichrasti*. Male (♂): A. Complete body lateral view, completely developed tegmina that extend beyond the tip of the abdomen, B. Long fastigium dorsal view, C. Superior and/or inferior elongated genicular lobes, D. Unequal posterior external and internal tibial spurs.

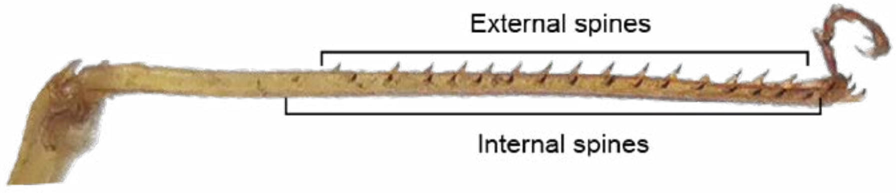

Figure 17. *Achurum sumichrasti*. Female (♀): Posterior tibia with 14-16 external, 16-17 internal spines.

Arphia conspersa

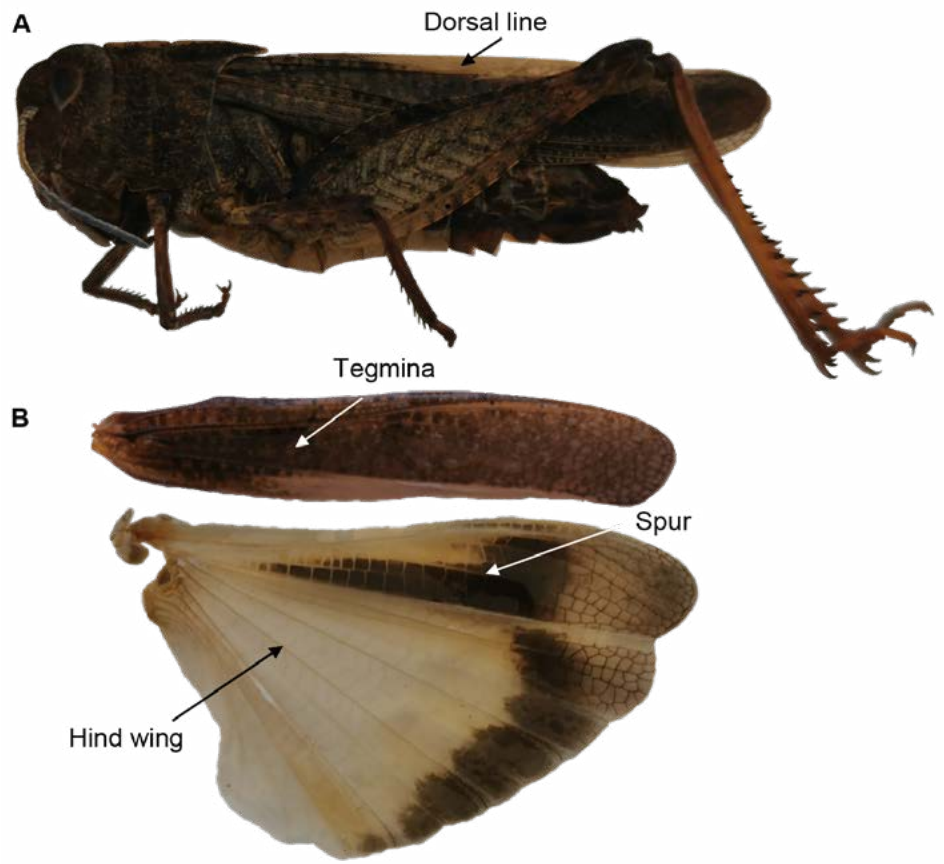

Figure 18. A and B: *Arphia conspersa*. Female (♀): A. Dorsal line of pale color, B. Disc of the posterior wings generally yellow, sometimes pink, with black spur that extends nearly to the base of the wing.

Arphia conspersa

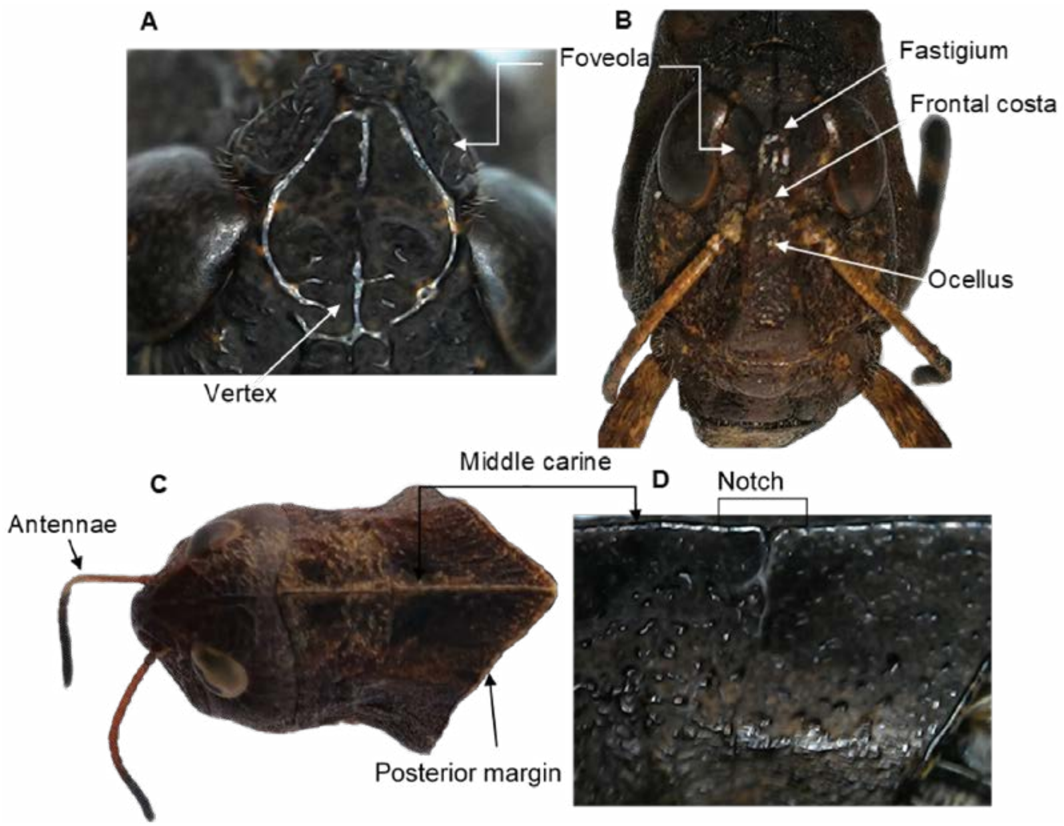

Figure 19. A-D: *Arphia conspersa*. Male (♂): A. Rounded vertex, B. The frontal costa is strongly held between the antennae, truncated fastigium, where it tends to be bifaveolated or with a middle carina. Thin antennae, gradually widening towards the tip, C. The dorsal posterior margin of the pronotum forms an acute angle, D. The middle carina of the pronotum slightly with a furrow near the middle.

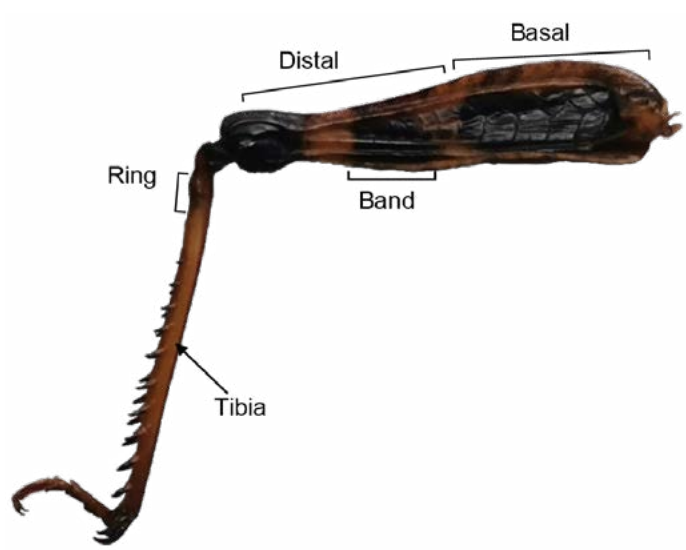

Figure 20. *Arphia conspersa*. Male (♂). Robust posterior femurs, internal face of black color in the basal half. In the yellow distal half with a black band. Light yellow posterior tibia, with dark ring in the third apical.

Aidemona azteca

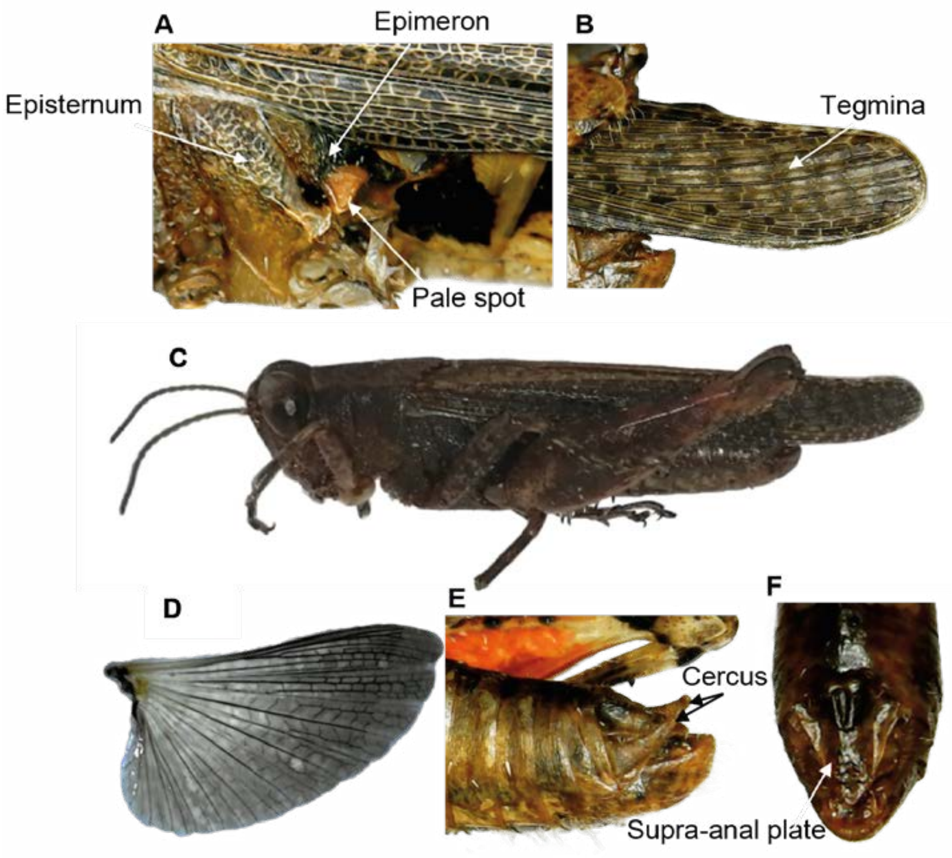

Figure 21. A-F: *Aidemona azteca*. Male (♂). A. Pale spot on the meta-thoracic epimeron on the base of the posterior leg, B. Tegmina larger than the length of the posterior femurs, C. Complete body lateral view, D. Clear posterior wing in its base and distal gray cloudy, E. Cercus of the male flattened on the base, with thin apices, directed towards the middle line, F. Sub-triangular supra-anal plate with round apex, furrowed in the middle basal line, but not divided transversally.

Aidemona azteca

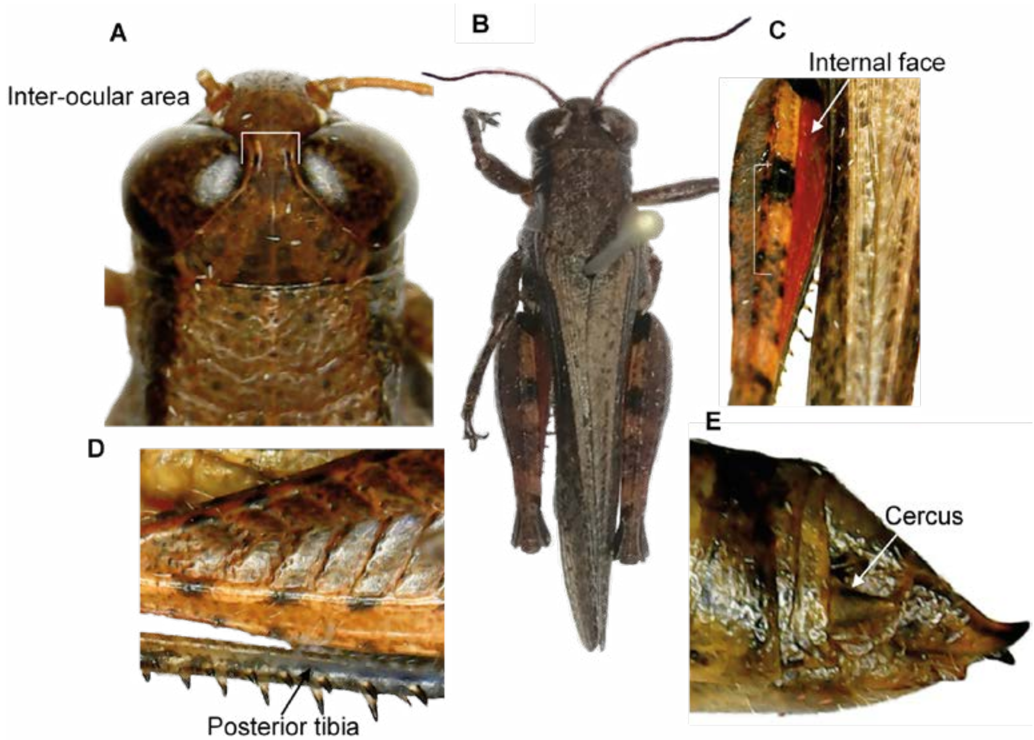

Figure 22. A-E: *Aidemona azteca*. Female (♀). A. Small head with prominent eyes, narrow inter-ocular area, B. Complete body dorsal view, C. Posterior femur with two darker transversal bands in the dorsal area, marginal ventral area, and internal red-orange face, D. Posterior blue tibia, E. Cercus lateral view.

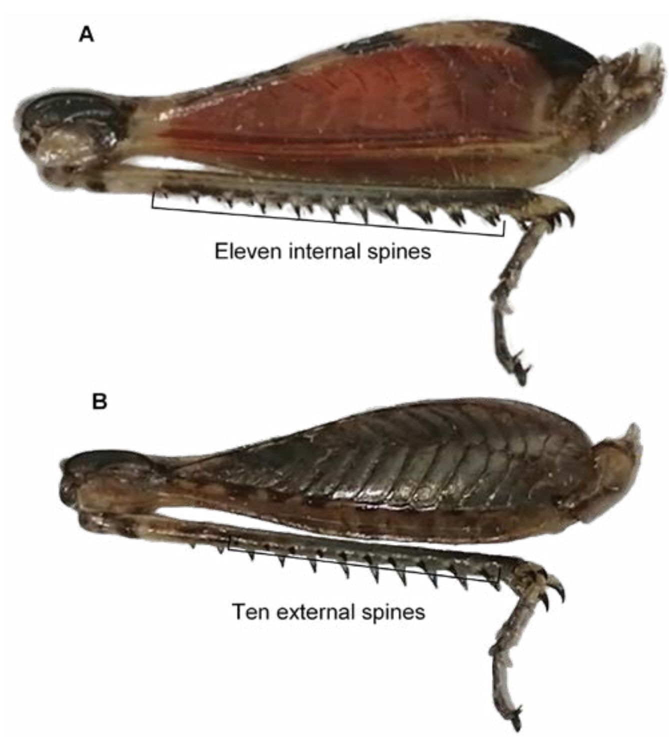

Figure 23. A and B: *Aidemona azteca*. Male (♂). A. Posterior tibia with eleven internal and ten external spines.

Dichromorpha prominula

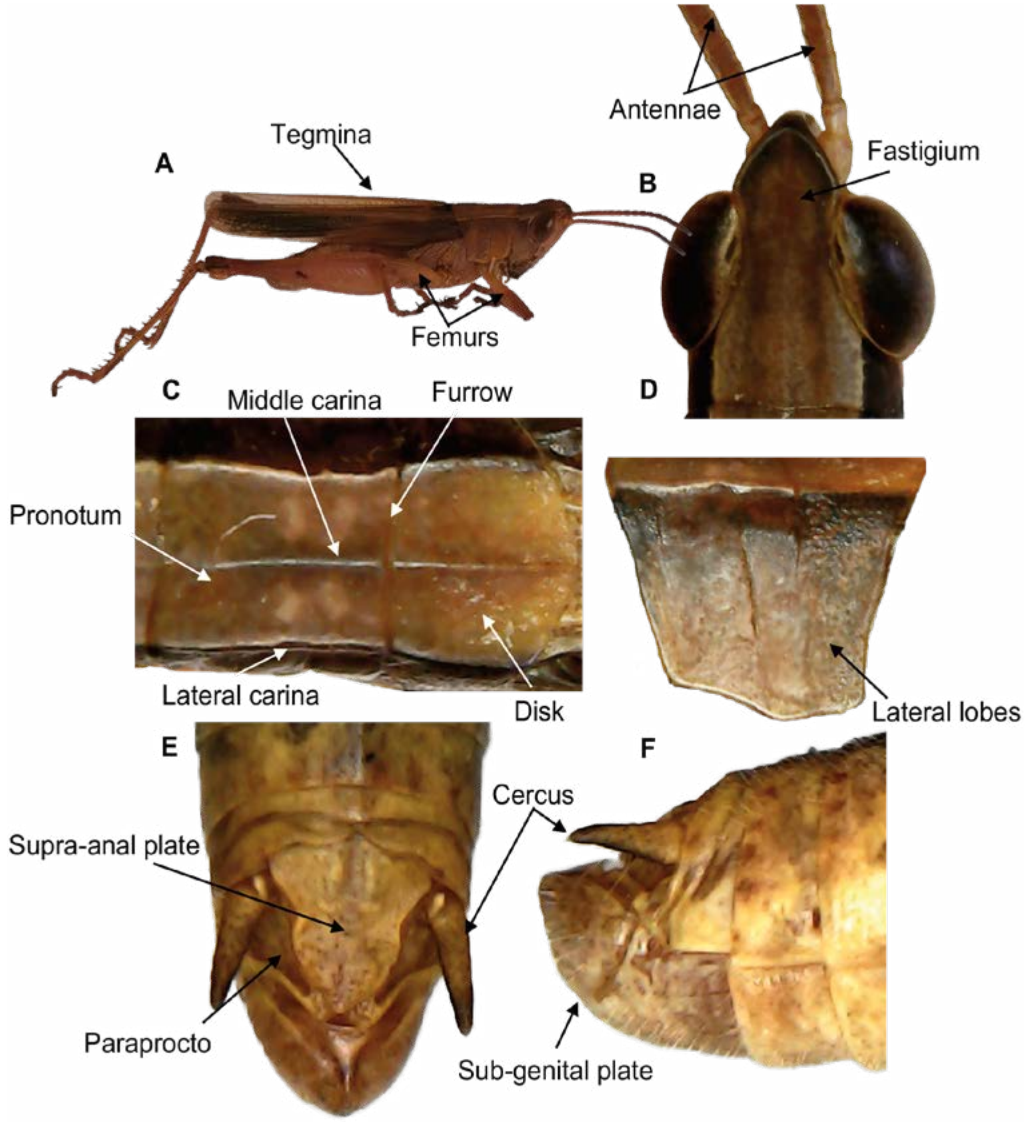

Figure 24. A-F: *Dichromorpha prominula*. Male (♂): A. Complete body lateral view, femurs of anterior and middle legs clearly engrossed. Long and narrow tegmina, exceeding towards the posterior femurs, B. Slightly ensiform antennae in the base. The anterior internal margin of the round fastigium, C. The pronotum disk is simple with three carinas, nearly straight and parallel, cut by one or two transversal furrows, D. The lateral lobes of the pronotum are perpendicular, E. Supra-anal sub-triangular plate, with round apex, slightly shorter than the paraproctos, F. Narrow sub-genital plate with round tip, with silks. Simple cercus, straight with blunt tips.

Melanoplus differentialis

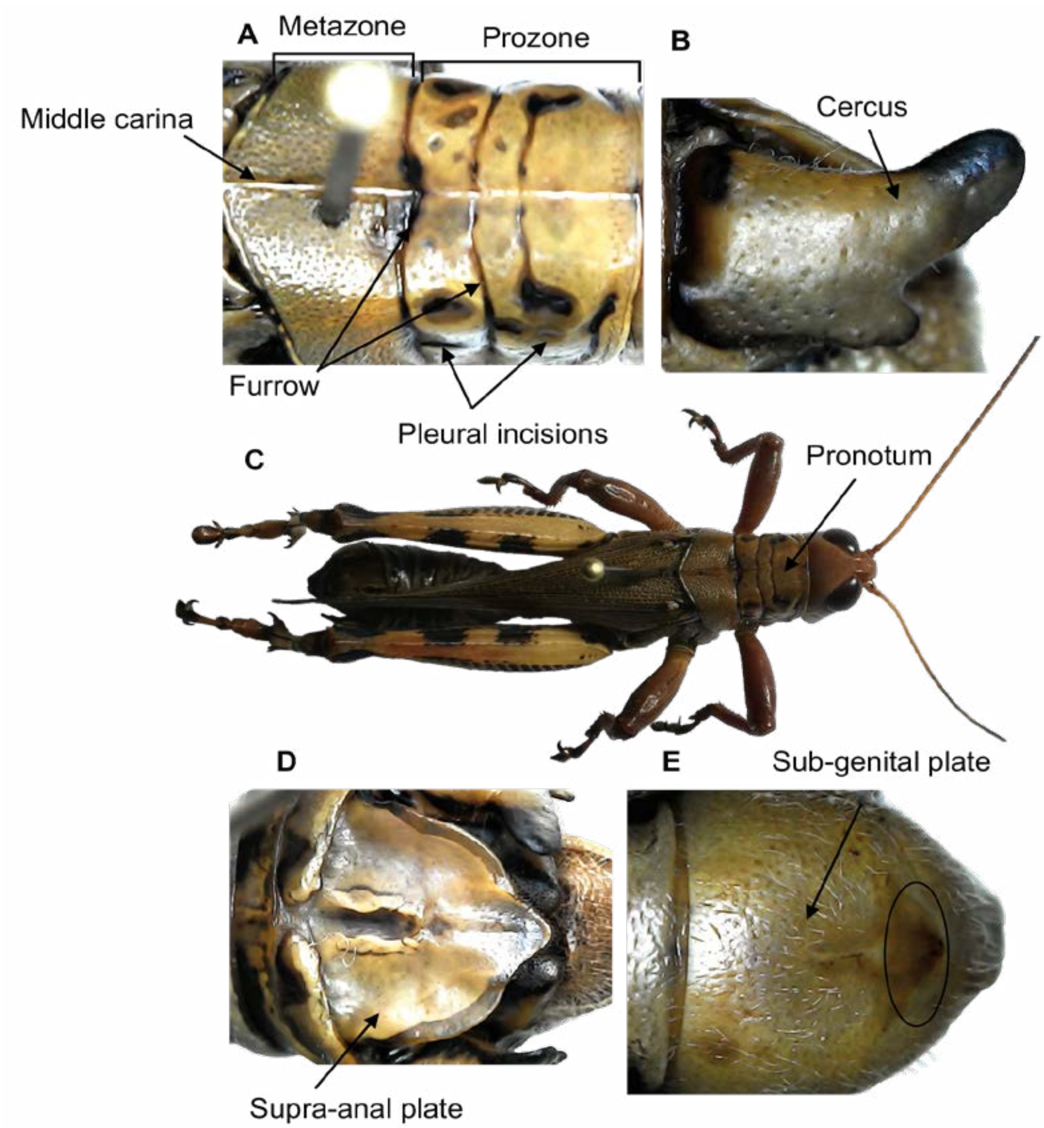

Figure 25. A-E: *Melanoplus differentialis*. Male (♂): A. Pronotum with transversal furrow and dark pleural incisions. Flat disk of the pronotum or nearly flat, distinct middle carina and sharp in metazone, less visible in the frontal half of the prozone, slightly longer prozone than the finely coarse metazone, B. Cercus, lateral view, C. Complete body dorsal view, D. Wide supra-anal plate, the sides of the rounded apical third and oblique on the back, E. Short sub-genital plate, wide, in the middle of the engrossed apical margin, slightly prolonged upwards, rarely with a weak notch.

Melanoplus differentialis

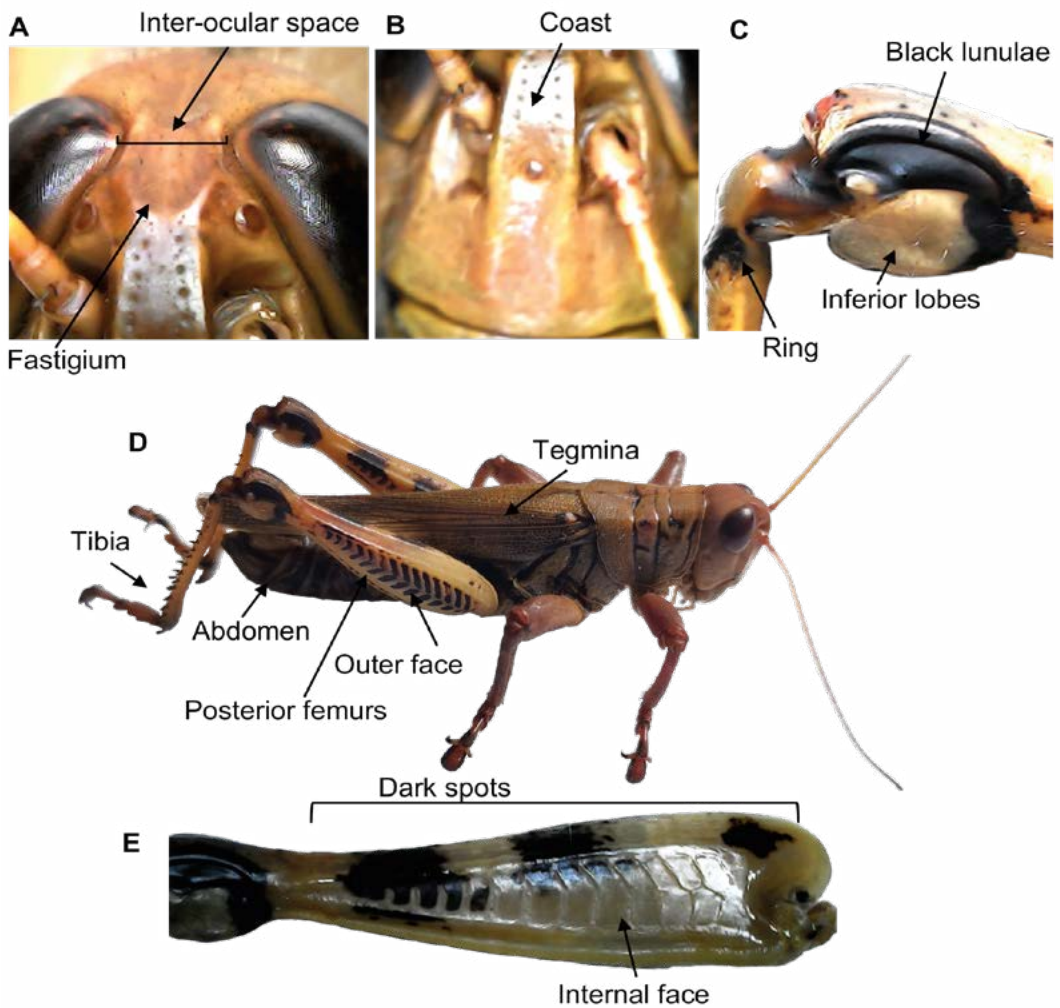

Figure 26. A-E: *Melanoplus differentialis*. Male (♂): A. Inter-ocular space twice or more times the length of the first antenna articulation; fastigium of soft, concave slope, broad but not deep, B. Wide frontal side, furrowed and broad under the ocellus, less distinctively in the female, C. Patella with black lunulae, their inferior exterior lobes of bright yellow color, D. Complete body lateral view. Tegmina exceeding to the tips of the posterior femurs in both sexes. Posterior yellow tibias, with narrow black basal ring and black spines, E. Posterior femurs of pale or bright yellow color, the superior margin with three dark oblique patches, F. Internal face of the posterior femurs, with inferior margin of yellow color.

Rhammatocerus viatorius

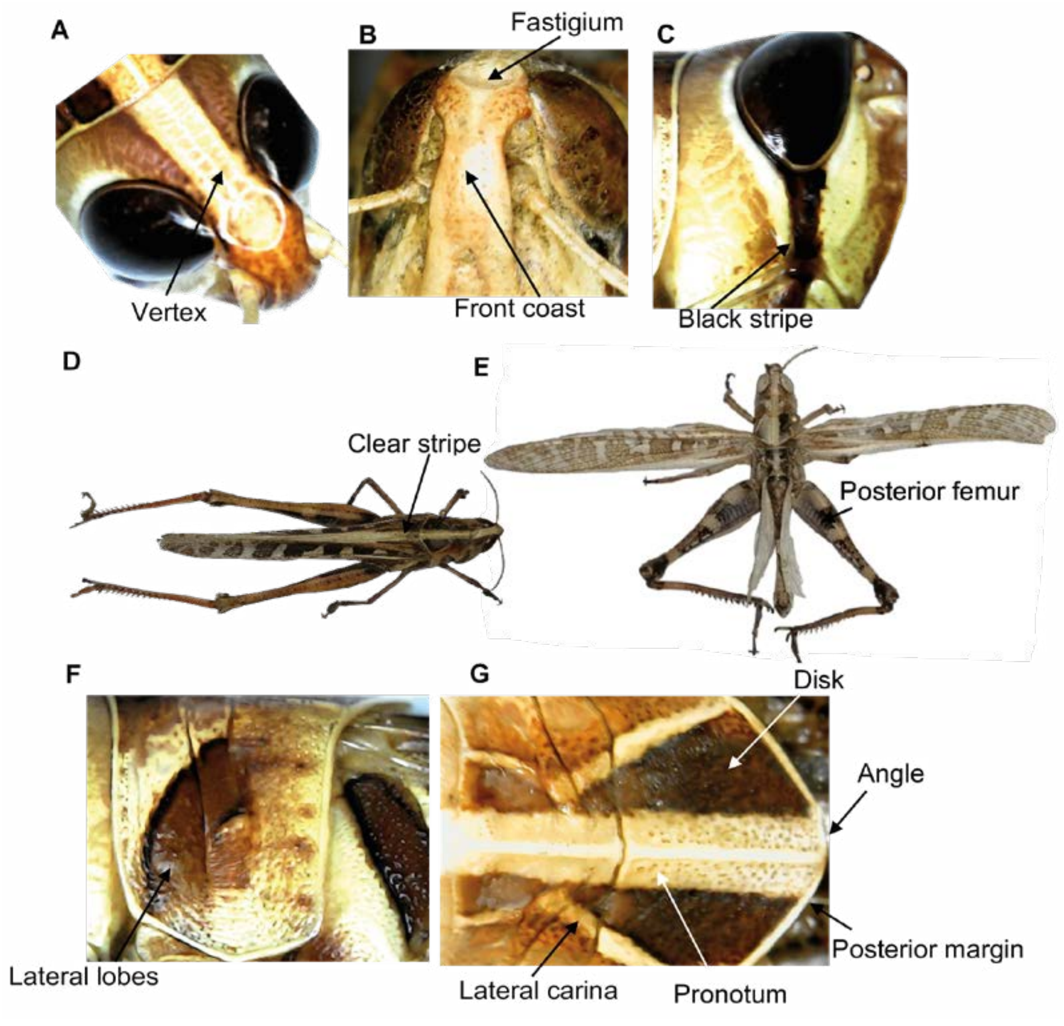

Figure 27. A-G: *Rhammatocerus viatorius*. Male (♂): A. Narrow head; horizontal vertex, B. Round fastigium, concave semi-circular fastigial depression. Strongly arched costa, prominent on the superior part, convex in the inferior part, C. Flexed, convex face and with a dark brown or black spot in the center of the lateral lobe, D. Female (♀) complete body dorsal view, with one light stripe that goes from the fastigium along the head, pronotum, dorsal field of the tegmina, and pro-thoracic lobes, E. Compressed body, F. Pronotum with dark lateral lobes, G. Dorsal view of the pronotum with constrictive lateral carinas of light color, forming a mark of hourglass shape. Disk of the dark pronotum, posterior angled margin.

Rhammatocerus viatorius

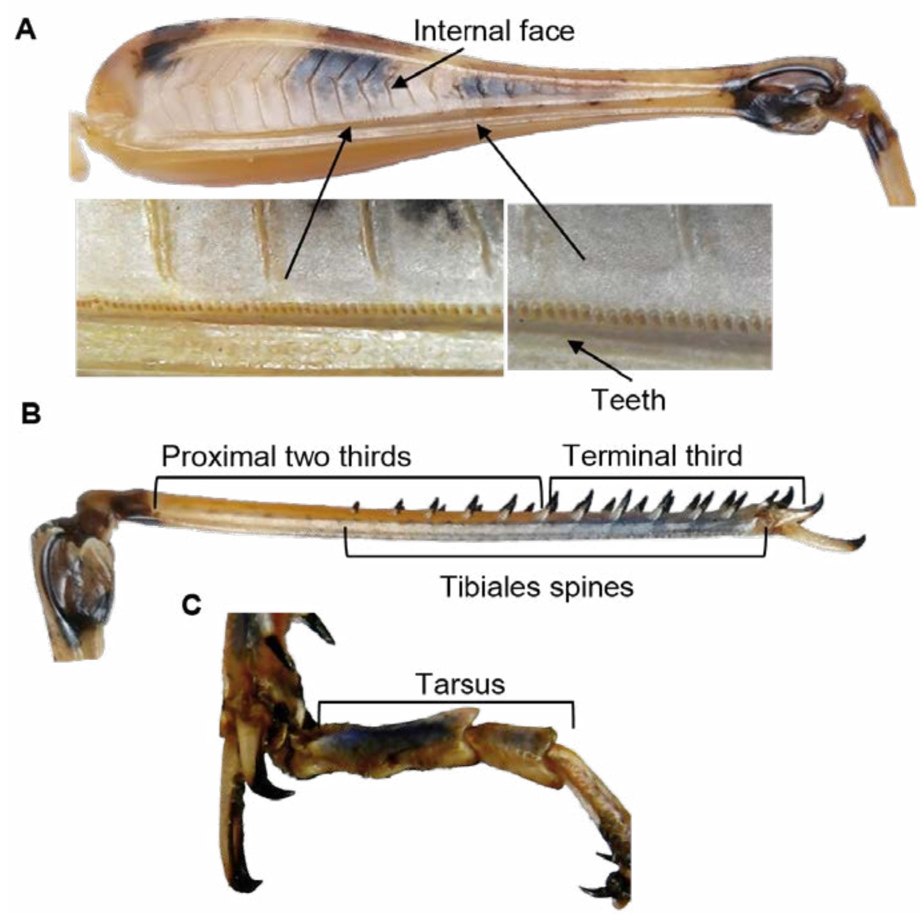

Figure 28. A-C: *Rhammatocerus viatorius*. Male (♂): A. The internal face of the posterior blue or yellow femurs, with three dark spots. Stridulated ridge with approximately 70 teeth, B. Posterior tibia with two thirds proximal yellow or orange color, with the terminal third slightly shaded in blue or gray, C. Blue tarsus dorsally, with the last light brown tarsomere.

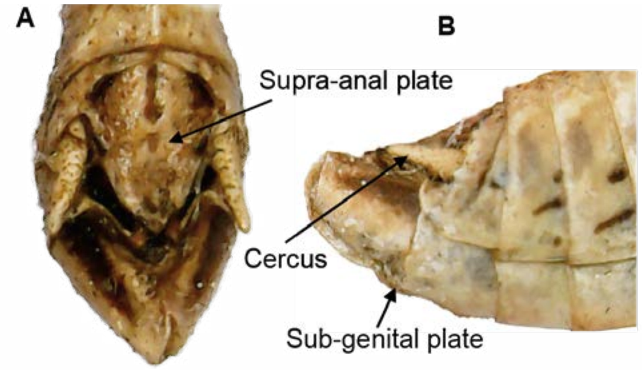

Figure 29. A and B: *Rhammatocerus viatorius*. Male (♂): A. Triangular supra-anal plate; longer cercus than the supra-anal plate, B. Whole sub-genital plate with a sharp tip, which is obliquely directed upwards in the lateral view.

Sphenarium purpurascens

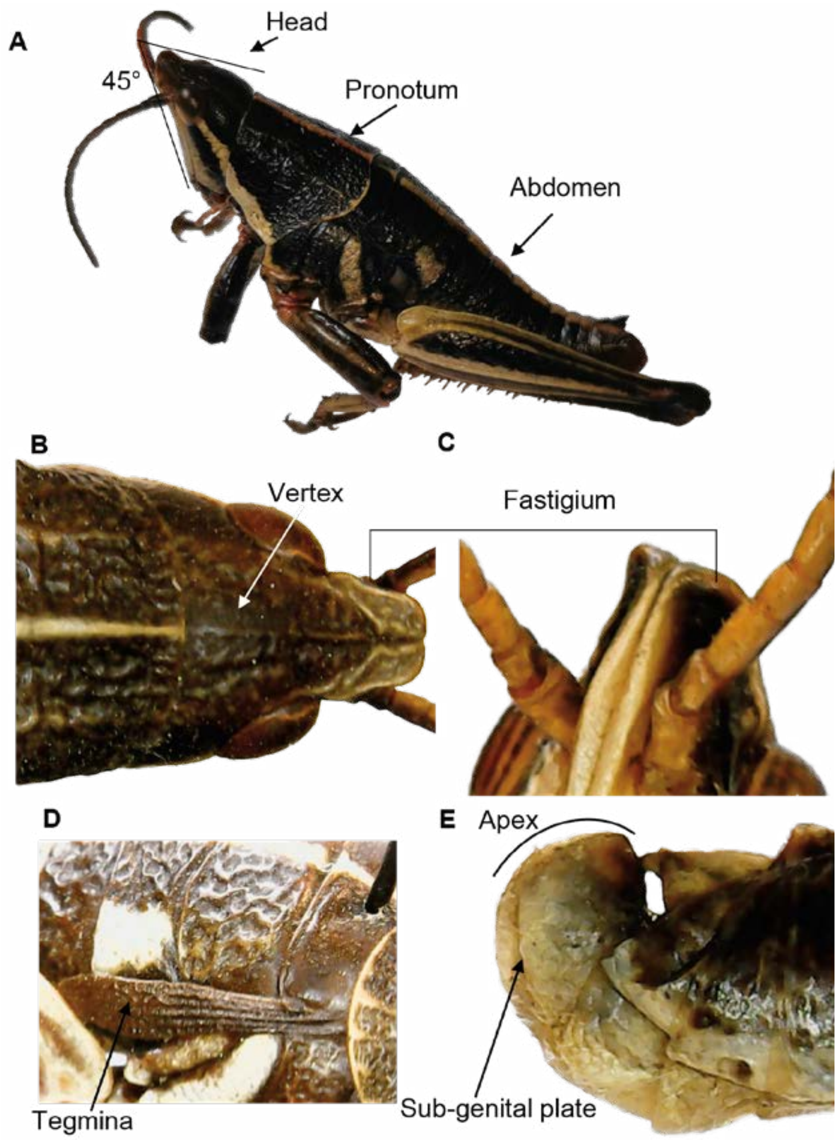

Figure 30. A-E: *Sphenarium purpurascens*. Male (♂): A. Complete body lateral view. Flexed face approximately at 45 degrees, wider in the inferior part than in the superior, sub-triangular compressed, B and C. Rounded vertex, wide and blunt fastigium, divided by an imprinted line, D. Tegmina in shape of spatula, narrow, reaching the second abdominal segment, E. Round sub-genital plate with apex curved upwards.

Sphenarium purpurascens

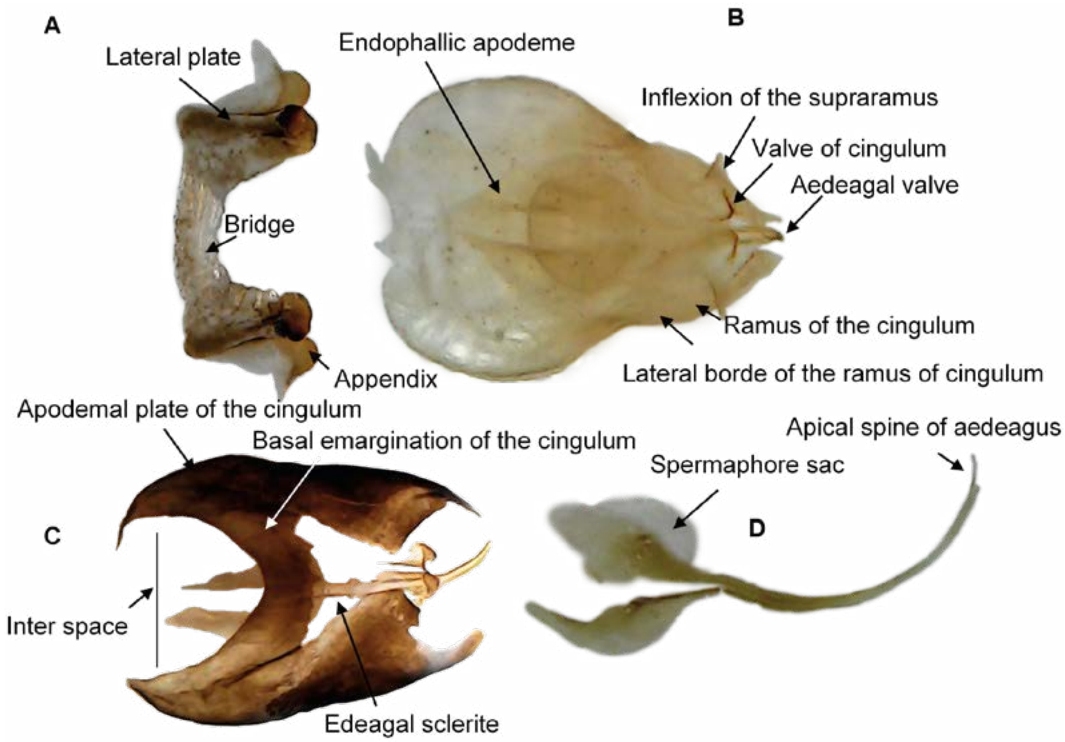

Figure 31. A-D: *Sphenarium purpurascens.* Genital structures of the Male (♂): A. Epiphallus with the bridge as long as the length of the lateral plates, B and C. Ectophallus and its main structures in dorsal view, D. Endophallus in lateral view.

Taeniopoda stali

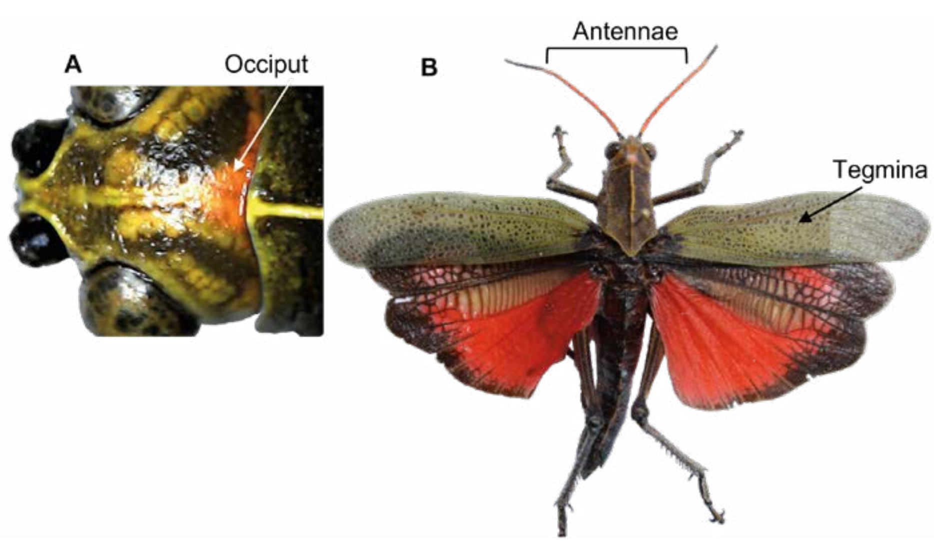

Figure 32. A and B: *Taeniopoda stali.* Female (♀): A. Posterior part of the occiput with a small red surface in the middle, B. The veins on the tegmina are deep green color, inter-vein separations with small areas of dark brown color. Antennae of intense red color.

Brachystola mexicana

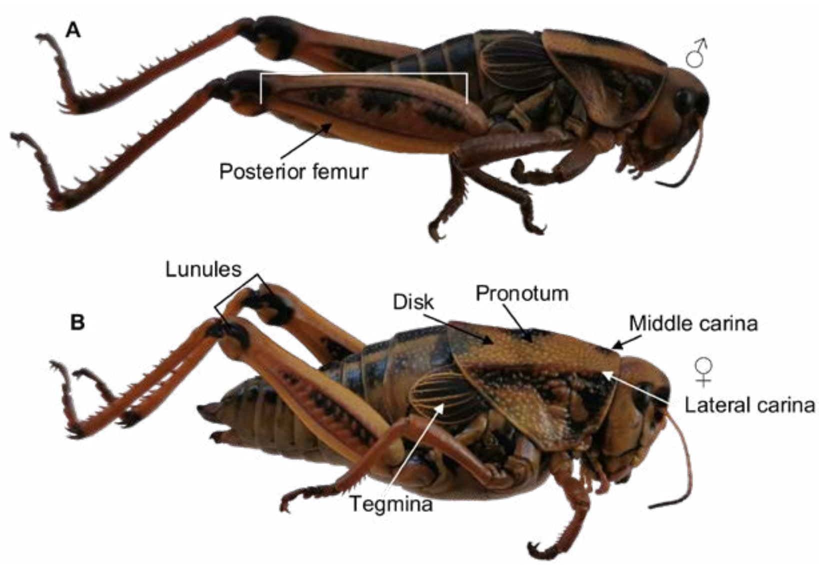

Figure 33. A and B: *Brachystola mexicana*. A. Male (♂), posterior femurs with three dark patches on the external face; one basal, one medium and another apical, dark internal face. Patella with black lunules, B. Female (♀): circular tegmina, small, of dark color with pale veins. Broad pronotum, lateral margins with very marked angle, anterior lobe with compressed disk, bulky on the posterior lobe. Prominent middle carina; prominent and strongly divergent lateral carina.

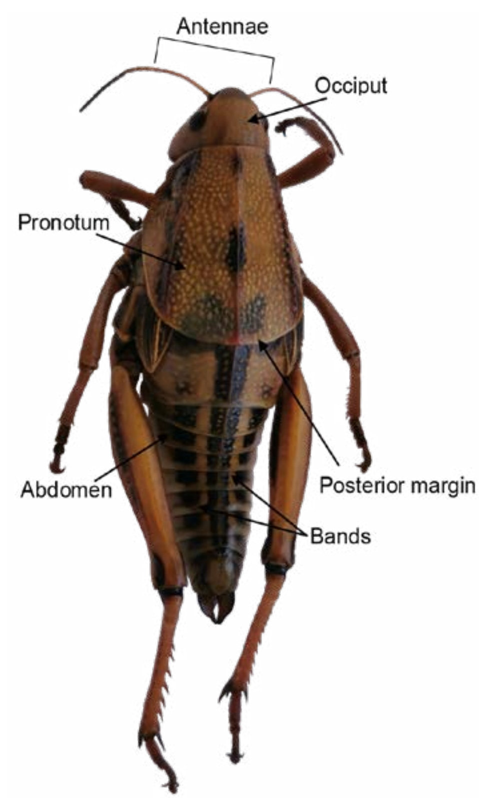

Figure 34. *Brachystola mexicana*. Female (♀): Short antennae, they reach the middle of the pronotum. Pronotum with broadly rounded posterior margin. Short abdomen on the base, thinning quickly in the middle and distal part. Dorsum of the abdomen with two pale bands, one on each side close to the middle of the body.

Brachystola mexicana

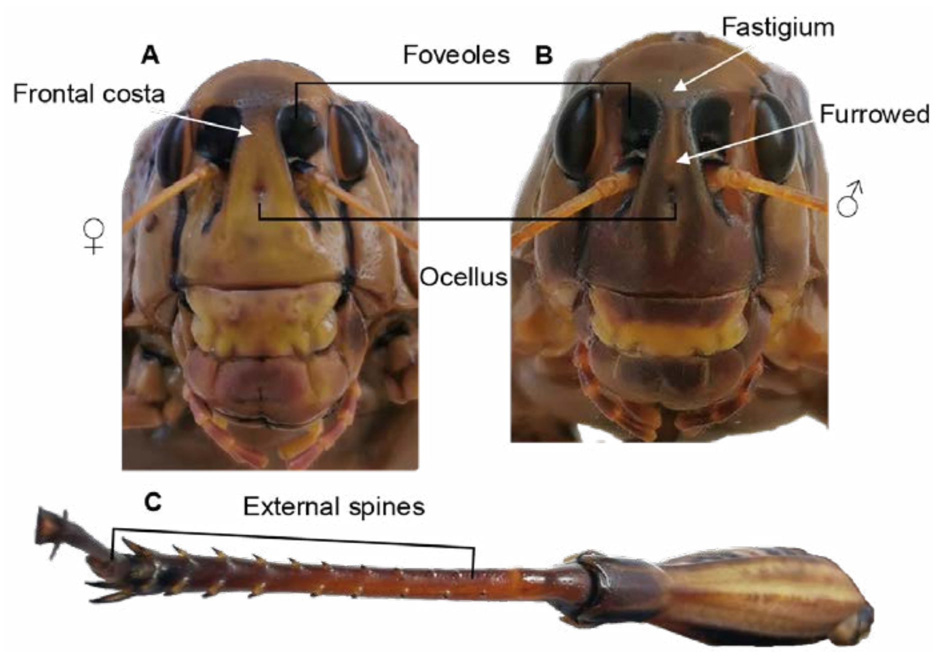

Figure 35. A-C: *Brachystola mexicana*. A, and B. Head of moderate size, wider in the inferior part than the superior, deep foveoles of dark color, the fastigium slightly furrowed, continually rounded with the prominent frontal costa; the costa expands uniformly above the ocellus, C. Posterior tibia with 10 small spines arranged irregularly on the exterior line.

***Stenopelmatus* sp.**

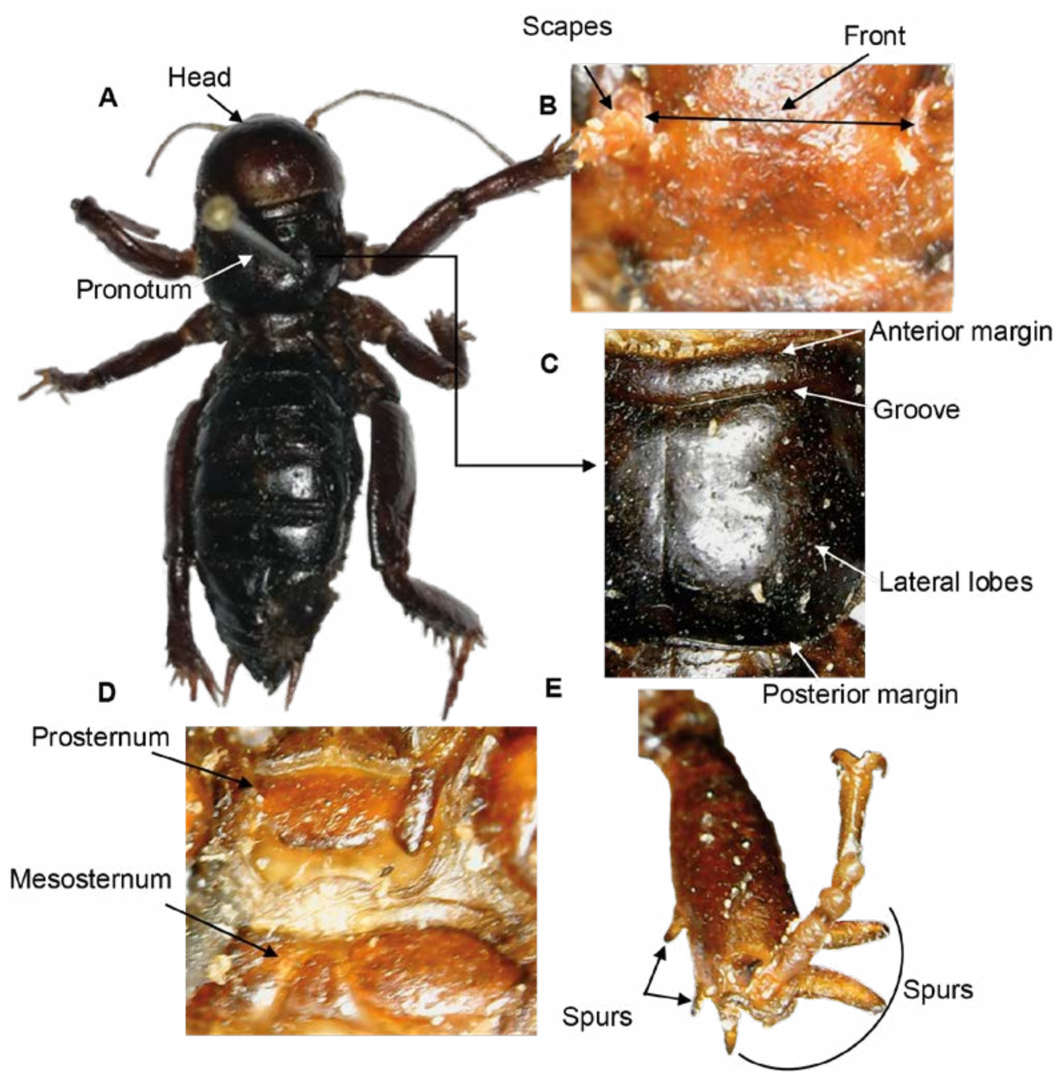

Figure 36. A-E. *Stenopelmatus* sp. Female (♀): A. Spherical head, B. Wide and flat front. The antenna cavities and the scapes are clearly smaller than the space between these cavities. Quite separate antennae, C. Narrow posterior pronotum and slightly bent upwards, except in the anterior margin. Short lateral lobes, slightly inclined, D. Prosternum approximately square, with bent margins, which end in a small blunt nodule on the posterior part, E. The anterior tibia distally wide with three pointy spurs on the interior of the apex and two shorter spurs in the inferior part.

Derived from the results of molecular biology studies carried out in the Laboratory of Integral Phytosanitary Diagnosis of Colegio de Postgraduados Campus Montecillo, in Texcoco, Estado de México, the following species were determined: *Ducetia japonica*, *Schistocerca nitens* and *Ceuthophilus pallidipes*.

The families Acrididae, Tettigoniidae and Pyrgomorphidae represented the highest number of genera determined taxonomically, with 41.40%, 23.32% and 21.73%, respectively. These results agree with those by Pocco *et al*. (2010), who mention these families as the most abundant in grasslands. For their part, Cornejo *et al*. (2006) point out that Tettigoniidae, Acrididae and Gryllidae represent the largest number of species in Mexico, perhaps because there is more bibliographic information for their determination.

From the Acrididae family, the genera with greatest dominance were *Schistocerca* and *Achurum* and, according to Fontana *et al*. (2017), they consider the genus *Schistocerca* as important because of the considerable damages it causes in the agricultural sector. For their part, Barrientos-Lozano *et al*. (2013) mention that the order Orthoptera includes pests of great economic and social impact, such as the various species of locust. From the Tettigoniidae family, the most abundant genera were: *Neoconocephalus*, *Pyrgocorypha*, and *Conocephalus*; Barrientos-Lozano *et al*. (2013) refer that these genera are found in humid meadows and are common in Mexico. On the contrary, Barranco and Pascual (1992) report that *Conocephalus* appears exclusively in farmed areas, and not in fallow land. The family Pyrgomorphidae was of great impact and the genus *Sphenarium* was collected, result that agrees with Ramírez-Méndez *et al*. (2019), who mentioned that out of 2806 orthopterans collected in the basin of the Pátzcuaro River, Michoacán, Mexico, the dominating species belonged to two families, Pyrgomorphidae and Acrididae, and the *Sphenarium* genus with 2746 specimens collected. Fontana *et al*. (2017) point out that some species of *Sphenarium* are used as food for humans because of their high density, although their potential as pest in monocrops has also been reported. Sanabria-Urbán *et al*. (2017) mention that *Sphenarium* is culturally and economically important for Mexican people since pre-Hispanic times. Barranco and Pascual (1993) refer that orthopterans are distributed according to the physiognomic type of vegetation, even when the plant species vary in time.

Population density and fluctuation

The highest density of orthopterans was found September, followed by October and November. The highest density of orthopterans was found in Sector I, possibly because in the nopal crop there were no agronomic disturbances. In second place, it was Sector IV, where corn used as forage for cattle was established, and therefore, the application of pesticides was not significant. Then, it was Sector III, with broccoli, bean and squash crops, where frequent disturbances were found, which hypothetically suggests instability of Arthropoda. Finally, the lowest density of orthopterans was found in Sector II, cultivated with avocado, where the agronomic management was *ad hoc* (Table 2) (Figure 37).

Table 2. Density of orthopterans collected by sector and crops during the year 2019.

Month	Collection date	Number of Orthoptera collected by sector				
		Sector I	Sector II	Sector III	Sector IV	Total
August	16-aug-19	28	4	51	25	108
	30-aug-19	45	3	37	38	123
September	13-sep-19	76	19	57	68	220
	27-sep-19	95	16	81	109	301
October	11-oct-19	86	29	98	73	286
	25-oct-19	68	15	65	68	216
November	08-nov-19	70	21	76	80	247
	22-nov-19	78	10	61	77	226
December	06-dec-19	57	1	58	48	164
	20-dec-19	47	5	30	51	133
Total	10	650	123	614	637	2024

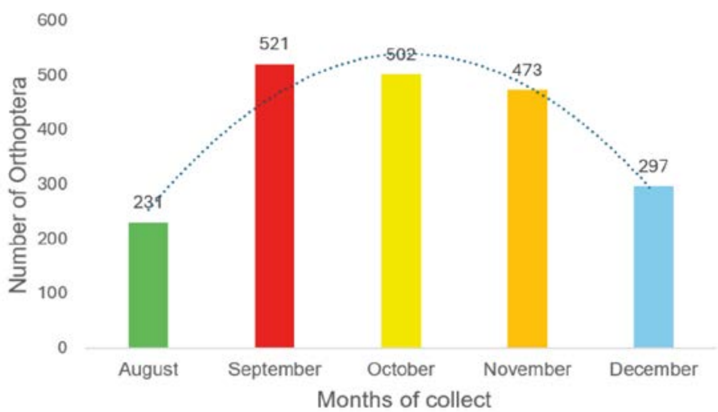

Figure 37. Population fluctuation and density of orthopterans from August to December 2019.

In quantitative terms, the results by genus and species are presented in Table 3, Figure 38. *Schistocerca nitens*, *Sphenarium purpurascens*, *Achurum sumichrasti*, *Neoconocephalus triops*, *Ceuthophilus pallidepes* and *Pyrgocorypha* spp., were the most abundant species, so it can be inferred that the sectors studied are dynamic and have an essential tendency to self-organize even by changing their composition, structure and function throughout time.

It is necessary to highlight that there are prominent differences in behavior between *Acanthorintes tauriformis*, *Conocephalus cinereus*, *Ducetia japónica*, *Neoconocephalus triops*, *Stilpnochlora azteca* and *Pyrgocorypha* spp., compared with *Achurum sumichrasti*, *Arphia conspersa*, *Aidemona azteca*, *Dichromorpha prominula*, *Melanoplus differentialis*, *Rhammatocerus viatorius* and *Schistocerca nitens*; the first have nocturnal habits, while the latter have daytime activity. However, the characteristic that both groups share is homochromy (Massa *et al.*, 2012). In the Analysis of Variance, for sectors and months of collection, whose dependent variable were the Orthopteroids (Table 4), highly significant differences were obtained, and this indicates that at least one sector was different. The coefficient of determination

Table 3. Abundance of genera by date of collection.

Genus	Abundance of Orthoptera genera collected from August to December 2019										
	16-aug-19	**30-aug-19**	**13-sep-19**	**27-sep-19**	**11-oct-19**	**25-oct-19**	**08-nov-19**	**22-nov-19**	**06-dec-19**	**20-dec-19**	**Total**
Acanthorintes tauriformis	2	0	3	6	4	2	3	6	3	1	30
Conocephalus cinereus	6	6	8	7	9	4	10	8	4	2	64
Neoconocephalus triops	**5**	**9**	**15**	**28**	**39**	**24**	**28**	**26**	**14**	**15**	**203**
Ducetia japónica	0	0	2	6	0	0	3	2	0	0	13
Stilpnochlora azteca	0	0	3	12	0	2	4	2	0	2	25
Brachystola mexicana	0	0	1	5	0	1	0	3	0	0	10
Pyrgocorypha spp.	**6**	**8**	**15**	**16**	**24**	**16**	**18**	**18**	**10**	**5**	**136**
Gryllus spp.	1	2	3	7	10	4	9	0	0	2	38
Ceuthophilus pallidipes	**12**	**8**	**10**	**18**	**27**	**17**	**26**	**19**	**13**	**11**	**161**
Achurum sumichrasti	**15**	**19**	**31**	**43**	**40**	**29**	**44**	**35**	**27**	**23**	**306**
Aidemona azteca	0	1	3	6	7	1	2	2	3	0	25
Arphia conspersa	2	0	0	8	2	3	4	5	0	0	24
Dichromorpha prominula	0	0	3	1	4	2	3	2	0	1	16
Melanoplus differentialis	1	2	4	7	10	4	5	7	5	5	50
Rhammatocerus viatorius	2	1	5	7	6	3	7	2	0	0	33
Schistocerca nitens	**30**	**35**	**60**	**63**	**59**	**51**	**38**	**45**	**40**	**32**	**453**
Taeniopoda stali	0	0	3	7	5	0	0	2	0	0	17
Sphenarium purpurascens	**25**	**30**	**51**	**53**	**38**	**52**	**41**	**41**	**45**	**34**	**410**
Stenopelmatus spp.	1	2	0	1	2	1	2	1	0	0	10
Total/Collection date	**108**	**123**	**220**	**301**	**286**	**216**	**247**	**226**	**164**	**133**	**2024**

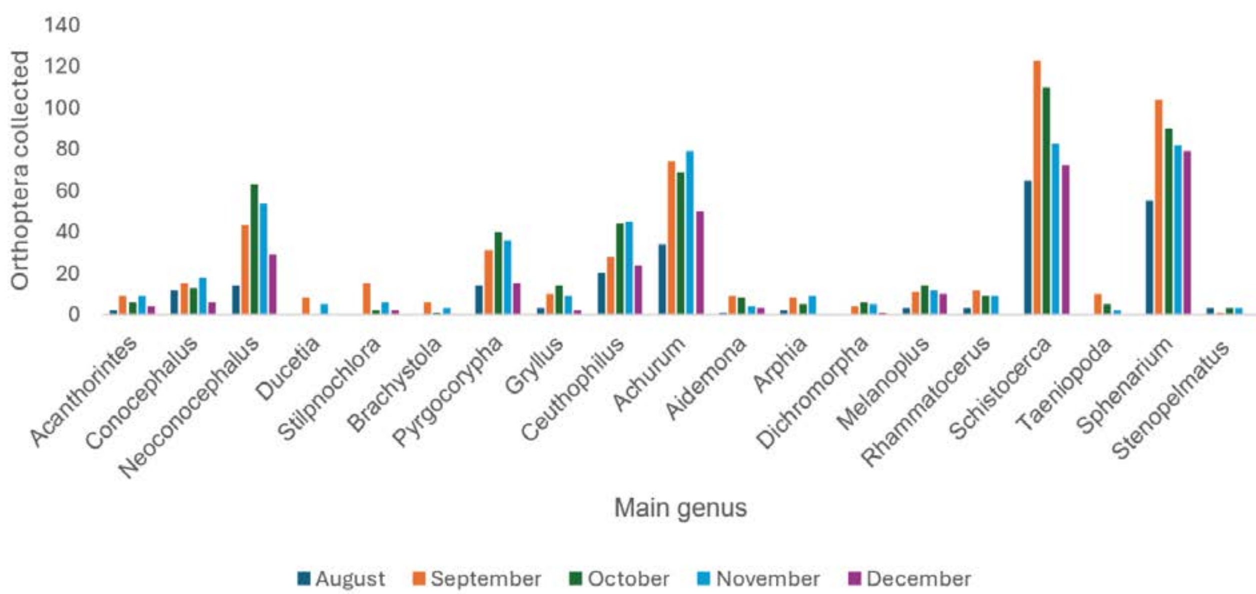

Figure 38. Population fluctuation of orthopterans during the months of August to December 2019.

(R^2) was 94.52% and this explains that the populations of orthopterans were dependent on the crops (sectors) and months of the year. The result from Tukey's means comparison test α=0.05, represents that the sectors farmed with nopal, broccoli, bean, squash and corn are statistically equal. In the sector with avocado the response variable was different.

What has been exposed up to this point can be attributed to the fact that in the sectors farmed with nopal, broccoli, bean, squash, and corn, orthopterans had greater availability of food and spaces to copulate, in contrast with the sector cultivated with avocado. Therefore, this condition generates the opportunity of reflecting on how the inputs are being used in the agroecosystems to satisfy the human needs and the impacts that can happen in the long term. It is a priority to propose the design of agricultural management models based on an approach that is more closely linked to the environment and socially more sensitive, centered not only on production, but also in the ecological stability of the production systems (Machado and Campos, 2008).

Statistically there was significance, and 93.78% of the species of Orthoptera depended on the months. In practice, this result has acceptability, since during the project there was rainfall, and this brought about conditions where orthopterans found food and refuge. The previous result agrees with Mysterud *et al.* (2003) and Hallett *et al.* (2004), who mentioned that during years with rainfall, the production of fresh biomass in plants is high and these factors favor the abundance and diversity of orthopterans. Meanwhile, when the drought period lasts for several years, the productivity of plants is low and, in the case of some grasslands, the accumulation of dry biomass affects negatively the populations of orthopterans because food is less digestible since it has high contents of fibers, and at the same time, it favors the recurrence of fires, which carbonize the eggs of these insects that are found in the soil in a state of diapause (Chambers and Samways 1998; Meyer *et al.*, 2002; Mysterud *et al.*, 2003; Hao and Kang 2004). When the means comparison test (Tukey=0.05) was carried out, whose results was indicated ´***´, *Schistocerca nitens* was the species with greatest significance, followed by *Sphenarium purpurascens* and *Achurum sumichrasti*.

Table 4. Analysis of Variance, for sectors and months of collection, where the dependent variable was the orthopterans.

Analysis of variance for the dependent variable orthoptera				
Source	**DF**	**Sum of squares**	**F Value**	**Pr>F**
Model	7	56607.200	29.62	0.0001
Error	12	3276.00		
Corrected total	19	59883.20		
R-Square		C.V		ORT Mean
0.945294		16.33		101.20
Analysis of variance for the dependent variable orthoptera				
Source	**DF**	**Type I SS**	**F Value**	**Pr>F**
Sector	3	39250.00	47.92	0.0001
Months	4	17357.20	15.89	0.0001

Table 5. Means comparison test of the dependent variable, orthopterans.

Means with the same letter are not significantly different			
Tukey Grouping	**Means**	**N**	**Sector**
A	130.00	5	I Prickly pear
A	127.00	5	III Polycultures
A	122.80	5	IV Corn
B	24.60	5	II Avocado

Table 6. Analysis of Variance, of the months and species, whose dependent variable was density.

Analysis of variance for the dependent variable density				
Source	**DF**	**Sum of squares**	**F Value**	**Pr>F**
Model	22	68413.29	41.88	0.0001
Error	61	4529.93		
Corrected total	83	72943.23		
R-Square		C.V		Den. Mean
0.937898		35.76		24.09
Analysis of variance for the dependent variable density				
Source	**DF**	**Type I SS**	**F Value**	**Pr>F**
Months	4	1405.18	4.73	0.0022
Species	18	67008.11	50.13	0.0001

For the time being, the genus *Schistocerca* can be considered among the most damaging pests in the world. Its different species devastate hundreds of thousands of farmed hectares year after year. The damage is caused by nymphs and adults when they feed on crops, fruit trees, grasses and wild species. In fruit trees, in addition to defoliating, eating fruits and stripping the bark, the swarms cause breaking of branches, when they settle on them (Garza, 2005). For their part, Cigliano *et al.* (2021) describe *Schistocerca nitens* as a solitary and non-migratory species, although under certain climatic conditions it can transform into gregarious and form swarms or invasive upsurges that cause damage to the crops and native flora, since it has a wide range of native geographic distribution, from the United States to Brazil. In contrast, Cano-Santana (1994) considers *S. purpurascens* among the most important Orthoptera herbivores, because of the large size that its populations reach. At the same time, Cano-Santana and Oyama (1992) state that the nymphs hatch at the end of May and beginning of June, while adults appear gradually starting in August and die between December and January. Márquez-Mayaudón (1968), in their observations, evidenced that *S. purpurascens* is very well represented throughout the year, even during the dry season which is the time when there is least availability of fresh food. This means that *S. purpurascens* is identified as a clearly dominating species in the structure of the Orthoptera community (Castellanos-Vargas *et al.*, 2015). Oyama *et al.* (1994) attribute that *S. purpurascens* is responsible for the high levels of floral and leaf damage that several plants experience as a result of their feeding activity. Camacho-Castillo (1999) state that adults prefer to feed in places with fresh vegetation and towards the end of the rainy season, approaching fall, they move to abrupt and closed sites where perennial plant species predominate, on which they feed. Briefly, the results from this study differ from those by Castellanos-Vargas and Cano-Santana (2009), who mention that *S. purpurascens* choose soils with high porosity (30 to 32%) to deposit their eggs, with predominance of sands (30 to 31%), low moisture (0 to 30%), and low compacting (0.44 ± 0.12 kg cm^{2-1}). In addition, they avoid the presence of high percentages of clay (>19.6%), as well as high levels of moisture (>25.5%), organic matter (>15.5%), and compacting ($>0.56 \pm 0.16$ kg cm^{2-1}). The type of soil in the sectors studied is characterized by being clayey.

CONCLUSIONS

The study determined taxonomically 16 species, and the prominent ones were: *Schistocerca nitens*, *Sphenarium purpurascens*, *Achurum sumichrasti*, *Neoconocephalus triops*, *Ceuthophilus pallidipes* and *Pygocorypha* spp. The highest number of orthopterans was collected in the sector cultivated with nopal. The lowest number of orthopterans was collected in the sector cultivated with avocado. The months of August to December were ideal to know the density of orthopterans, since they found the source of food, hosts and spaces to copulate in three sectors.

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