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Additional notes on the genus *Phlugis* (Orthoptera: Tettigoniidae: Meconematinae) with the descriptions of two new arboreal species from Costa Rica

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Abstract

Fourteen new species of the predaceous katydid genus *Phlugis* Stål, 1860 (Meconematinae), collected using pesticide-fogging methods, were recently described from northern Peruvian rainforest canopies. This paper reports the presence of 2 new species of *Phlugis* from rainforest canopies in Costa Rica. Although most of our representation of *Phlugis* species in museums consists primarily of easily collected understory species, the occurrence of a very diverse fauna in rainforest canopies, suggests that many species of this genus are yet to be discovered.

Resumen

Catorce especies nuevas de esperanzas del género predador *Phlugis* StåI, 1860 (Meconematinae) fueron descritas recientemente del canapé de la selva pluvial al noreste de Peru, se colectarón utilizando una nube de pesticida. Este articúlo reporta la presencia de dos especies nuevas de *Phlugis* en los canapés de la selva pluviosa en Costa Rica. Aunque la mayor parte de las especies de *Phlugis* representadas en nuestros museos consiste principalmente de especies colectadas fácilmente. La gran diversidad de la fauna en los canapés de la selva pluviales sugiere que faltan mucho mas especies de este género por ser descubiertas.

Key words

Phlugidini, katydid, Costa Rica, rainforest, arboreal

Introduction

Recently, Nickle (2003) described 17 new species of the predaceous genus *Phlugis* Stål, 1860 (Meconematinae). Fourteen of these species were collected in fogging samples from rainforest canopies. Seven additional species also appeared to be new, but they will be addressed once more specimens are collected to define them. In that study trees were sampled, yielding a total of 24 species, averaging 4.64 species per tree [range 1-11 per tree: 1 species (1 tree), 2 spp. (3 trees), 3 spp. (4 trees), 6, 8, 9, 10, and 11 spp. (each per 1 tree)]. These arboreal species differed significantly from those found at ground level, the latter being clearly related to most other species found from Mexico to Brazil and into the Caribbean Islands and surrounding region.

Males of ground-dwelling species all have simple, cylindrical, apically unmodified cerci, while those of arboreal species are robust and apically distinctly modified. Arboreal species overall also are generally more robust, with larger, more globose eyes than ground-dwelling species.

In a subsequent review of holdings of *Phlugis* specimens at the Academy of Natural Sciences (Philadelphia, PA) [ANSP], U.S. National Museum of Natural History (Washington, DC) [USNM], and University of Michigan Museum of Zoology (Ann Arbor, MI) [UMMZ], I became aware that nearly all of the specimens represented only species found at ground level. These species consisted primarily of *P. abnormis* (Redtenbacher, 1891), *P. chrysopa* (Bolivar, 1888), *P. poecila* Hebard, 1927, *P. simplex* Hebard, 1927, and *P. teres* (De Geer, 1773). Interestingly, the only species of *Phlugis* actually described from a Costa Rican specimen was the species *carribbea* Rehn [as *Alogopteron*]. Rehn (1905) subsequently synonymized his species with *P. virens* (Thunberg, 1815). Thunberg's *virens* was based on an unidentifiable female of unknown origin. Hebard (1927) discussed its species status and concluded that all female specimens reported in the literature as *P. virens* were probably the widespread species *P. chrysopa.* Since it has not been reported formally in the literature, I take this opportunity in placing *P. virens* as a junior synonym of *P. chrysopa.*

Only a few specimens similar to the arboreal species I had described from our canopy collection in Peru, could be found in the above museums, and I suspect that they too are arboreal. Although not reported in this paper, I allude to them because they represent species from other neotropical countries that may prove to be arboreal in niche— once arboreal sampling techniques are used to collect them in sufficient numbers to make reliable judgments regarding their biology.

Interestingly, the only verifiable arboreal *Phlugis* I found in museum collections was a distinct series of specimens from Costa Rica at the Academy of Natural Sciences of Philadelphia. Using pioneering fogging techniques in 1967 to collect canopy-dwelling Orthoptera in Costa Rica, Roberts (1973) obtained a small series of 2 *Phlugis* species. Both species are new to science and are described herein. Comparing them with arboreal species described from Peru, I determined that these species represent an extension of the arboreal fauna of *Phlugis* into North America. Types are deposited in ANSP and Paratypes in ANSP and USNM. The descriptions are based on a series of 9 males, 7 females, and 3 nymphs collected at 2 sites in Costa Rica in 1967 by H.R. and E.H. Roberts, M.S. Harrison, W.W. Moss, and D.A. Nickle.

Collection methods for these species were described in detail by Roberts (1973). The insecticide used in that study was dichlorvos (DDVP) [Vapona®, 2,2-dichlorovinyl 0,0-dimethyl phosphate]. It was applied as a fog to the upper portions of several unidentified trees. The understory beneath the fogging target area was cleared, and plastic sheeting laid out to receive falling insects. The samples of *Phlugis* are based on 9 fogged trees at the Rincón site (yielding

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one of the new species and a ground-dwelling species) and 3 trees at La Selva (yielding only the other new species).

Although 5 ground-dwelling species of *Phlugis* from Costa Rica — *P. abnormis*, *P. chrysopa*, *P. poecila*, *P. simplex*, and *P. teres* — are represented in the collections of the ANSP, USNM, and UMMZ, Roberts' Rincón samples included specimens only of *P. teres*. They probably were collected as accidental intrusive jumpers onto the plastic sheets used to collect the fogged specimens. I was part of that project and was aware that *Phlugis* specimens dropping from treetops were dying or inactive, while other *Phlugis* specimens were very active, jumping on and off the sheets with ease. I am certain some of these were captured along with the canopy samples.

Specimens were measured (in mm) with a device described by Grant (1965), and characters used to evaluate species were essentially those detailed by Emsley *et al*. (1967). Measurements are the same as those defined by Nickle (2003). The male stridulatory file was examined only in *S. robertsi*. All teeth on the stridulatory file on the left tegmen were counted, and the straight-line distance between first and last tooth on the file was recorded as the length of the file. Internal genitalia of males could be seen without the aid of dissections and appeared to be complex in structure. However, no dissections were made at this juncture, because all species of *Phlugis* are easily recognizable without the need to examine internal structures. Internal genitalia should prove to be a useful set of characters when revisionary studies are eventually undertaken; because of the small representation of males in this study, it was considered best to wait to examine these structures.

Phlugis arborealoides Nickle, new species
(Figs 6, 13, 15, 24)

Diagnosis.— Both this species and *P. robertsi* are similar in their size and robust shape, compared with the other smaller, more slender species, found typically at ground level in Mexico and Central America. Males of these 2 species are easily distinguished on the basis of the shapes of tenth tergite and cercus (compare Fig. 6 with 7, and 15 with 16, respectively). Females of these species are nearly identical, but are distinguished by differences in coloration of the basal half of the anal margin of the tegmen (*P. arborealoides* brown, *P. robertsi* green).

Holotype.— ♂. COSTA RICA: Sarapiqui. Rio Puerto Viejo. La Selva. II-26-III- 8-1967. (H.R. & E.H. Roberts, M.S. Harrison, W.W. Moss, D.A. Nickle). Arboreal habitat, insecticide sta. 43. [ANSP]. Allotype. Female. Same data as holotype. [ANSP]. Paratypes. 1 ♂, 4 ♀♀. Same data as holotype. Insecticide stas 41, 43, 44. [ANSP, USNM].

Description.— **Head**: Broad for genus, from above as wide as or wider than long. Eyes prominent, globose, anteroposteriorly ellipsoidal; dorsum of eyes rising well above dorsum of head; in dorsal view, ratio of width of head at compound eyes to width of head behind compound eyes 1.28:1 to 133:1.
Thorax: Pronotum 1.6 to 1.9× longer than wide; metazona of male very weakly inflated, that of female not inflated; metazonal suture located above large, gaping prothoracic spiracle at about posterior third of pronotal disc; anterior margin concave, hind margin convex.
Legs: Genicular lobes of all legs unarmed. **Forelegs**. Femur basally inflated, tapering distally; L/basal W, 1.44 to 1.47; tibia with ventral spines long (inner spines somewhat longer than corresponding outer spines), somewhat evenly spaced, most basal spines arising behind tympanum. **Midlegs**. Femur basally weakly inflated, tapering distally. **Hindlegs.** Femur L/W *ca* 6.0 to 6.9 ♂, 5.4 to 6.0 ♀.
Numbers of spines on legs: Ventral margins – forefemur: inner (anterior) 4; outer (posterior) 3; midfemur: inner (posterior) 0; outer (anterior) 0; hindfemur: inner (posterior) 0; outer (anterior) 0; foretibia: inner (anterior) 5; outer (posterior) 5; midtibia inner (posterior) 0; outer (anterior) 3 to 4; hindtibia: inner (posterior) 0; outer (anterior) 0. Dorsal margins – foretibia: inner (anterior) 0; outer (posterior) 0; midtibia: inner (posterior) 0; outer (anterior) 0; hindtibia: inner (posterior) 27 to 28; outer (anterior) 25 to 26.
Wings: Tegmina and alae well developed; tegmen extending 10.1 to 10.3 mm beyond terminal tergite; alae extending 4.3 to 5.1 mm beyond apex of tegmina in repose. Stridulatory file not examined.
Abdomen: Male. Tenth tergite distally produced, distally recurved between cerci with deep medial groove channelling to narrow, apically pointed tip. Cercus short, cylindrical, recurved along its length, terminally expanded into 2 dorsoventral lobes, dorsal lobe rounded, ventral lobe modified into a sharp, well developed, tooth (Fig. 15). Subgenital plate spatulate basally, narrowing distally with 2 elongated articulating narrow, spatulate lobes; lobes less than half total length of subgenital plate from base to tip of lobes (Fig. 13).
Female. Terminal tergite truncate. Cercus short, cylindrical about half as long as ovipositor. Distal half of ovipositor slender, elongated for genus. Subgenital plate spatulate, apically rounded with a shallow U-shaped emargination.
Color: Uniform light chartreuse green *in vivo*, light green to tan in preserved specimens. Differing from *P. robertsi* in the presence of dark pigmentation along the margin of the basal half of the tegmen.

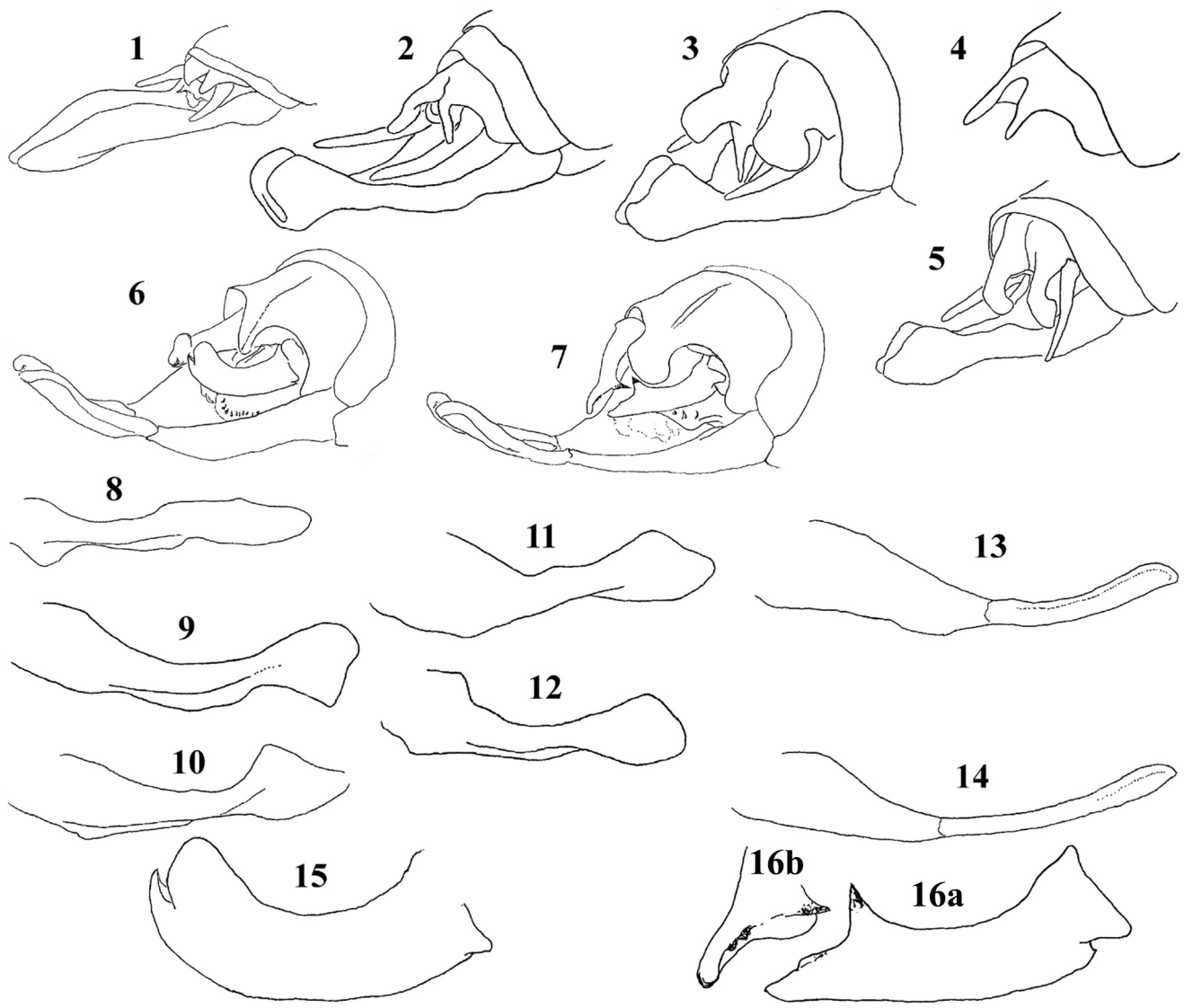
Measurements.— See Table 2.

Etymology.— (Latin), adjective, *arborea* – of trees; *oides* – like, or similar to, referring to similarity of this species to *P. arborea*, the first described species of *Phlugis* to be recognized as having an arboreal niche.

Table 1. Male stridulatory file characteristics of representative *Phlugis* species.

species	no. teeth	length of file (mm)	tooth density
arborealoides	63	0.96	65.62
arborea	64	0.77	85.23
bullatinotum	71	1.19	59.66
celerinicta	62	1.23	50.41
chrysopa (Panama)	37	0.49	75.51
chrysopa (this paper)	65	0.72	90.28
gigantea	82	0.91	90.11
glabra	76	1.02	74.51
robertsi	72	0.99	72.73
scalpra	66	0.67	98.51
simplex	51	0.77	66.23
teres	82	0.62	132.26
wittmani	54	0.57	94.74

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Figs 1-16. Morphological features of Costa Rican *Phlugis* species: 1-5. Distal abdomen, right dorsolateral view: 1. *teres*, 2. *poecila*, 3. *abnormis*, 4. *simplex* (only tenth tergite figured; similar in other respects to 5, *chrysopa*); 5. *chrysopa;* 6- 7. Male abdomen, right dorsolateral view: 6. *arboreoloides*, 7. *robertsi;* 8-14. Male subgenital plate, left lateral view: 8. *teres*, 9. *poecila*, 10. *abnormis*, 11. *chrysopa*, 12. *simplex*, 13. *arborealoides*, 14. *robertsi;* 15-16. Right male cercus: 15. *arborealoides*, lateral; *roberts* 16a, right entire cercus, lateral; 16b, left apex.

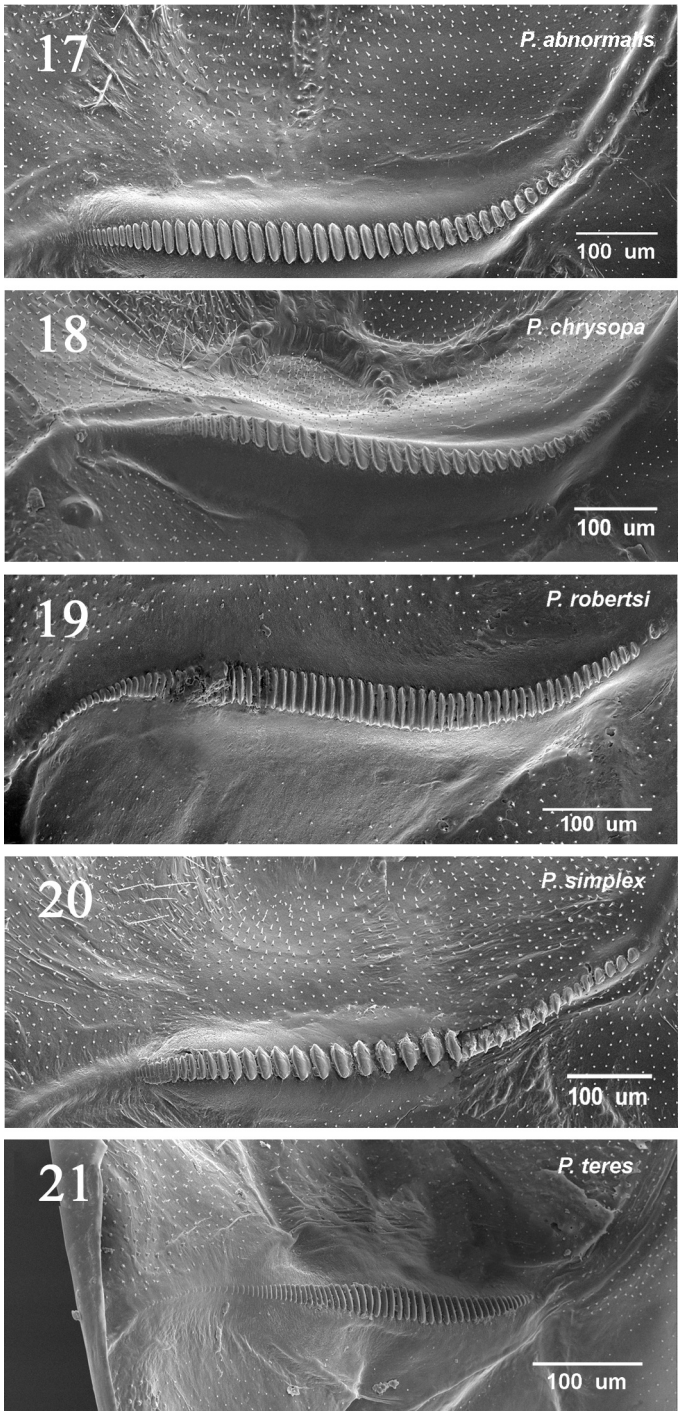
Phlugis robertsi Nickle, new species
(Figs 7, 14, 16a,b, 19, 22, 23)

Diagnosis.— See Diagnosis for *P. arborealoides*.

Holotype.— ♂. COSTA RICA: Osa Peninsula, 3 to 10 mi. s. Rincón II-7-20 1967. (H.R. & E.H. Roberts, M.S. Harrison, W.W. Moss, D.A. Nickle). Arboreal habitat, insecticide sta. 33. [ANSP]. Allotype female. Same data as holotype. [ANSP]. Paratypes. 4 ♂♂, 3 ♀♀. Same data as holotype. insecticide stas. 34, 35, 36. 2 ♂♂, 2 ♀♀. [ANSP]; Rincón, forest between Rincón and airstrip. Field No. 22. 11- 26-1966. 1 ♂, 1 ♀. [ANSP]; 6 mi. s. Rincón , insecticide in forest. Field No. 24. 11-27-1966. 1 ♂ [USNM].

Description.— Differences in measurements are noted, but may not be significant, based on small sample sizes (n=7 specimens of *P. arborealoides*; n=9 of *P. robertsi*). Similar to description of *P. arborealoides*, except as follows: **Abdomen**: Male. Tenth tergite apically produced, somewhat arcuate above bases of cerci, narrowing between them into a broad, paddle-shaped, apically-rounded process (Fig. 7). Cercus robust, cylindrical, tapering distally and terminating in an apical rounded lobe with a shallow, median blade bearing a few small, irregularly spaced teeth and a well developed, sharp, preapical, medially-directed, tooth-like process (Figs 16a, 16b). Subgenital plate basally spatulate, tapering into 2 greatly elongated articulating lobes, formed by a deep medial excision extending at least one half length of subgenital plate; apex of each lobe weakly inflated, with medial margins at inflation attingent; lobes equal to or greater than half total length of subgenital plate (Fig. 14).
Female. Terminal tergite convex, rounded. Cercus long and slender, cylindrical, greater in length than basal inflation of ovipositor. Ovipositor similar to *P. arborealoides*. Subgenital plate spatulate,

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Figs 17-21. Scanning electron micrographs ofstridulatory file on left tegmen of *Phlugis* species: 17. *abnormis*, 18. *chrysopa*, 19. *robertsi*, 20. *simplex*, 21. *teres*.

apically rounded, apically lacking medial emargination.

Color: Uniform light chartreuse green *in viva*, light green to tan in preserved specimens. Differing from *P. arborealoides* in the absence of dark pigmentation along the margin of the basal half of the tegmen.

Measurements.— See Table 2.

Etymology.— A patronym honoring Dr. H. Radclyffe Roberts†, whose pioneering studies on arboreal Orthoptera helped to discover the fauna on which this study is based.

Comparison of Stridulatory Files

Characters associated with male stridulatory apparatus are often useful in species recognition. Although not noe required in the case of known *Phlugis* species, analysis of stridulatory file characters may become necessary as more species are discovered in canopy samples. This study is a follow-up to stridulatory file characters presented for the Peruvian species (Nickle 2003). In that paper the files of the following species [all but *P. chrysopa* (panama) described as new by Nickle] were figured: *bullatinotum*, *celerinicta*, *chrysopa*, *arborea*, *gigantea*, *glabra*, *scalpra*, and *wittmani*. Information regarding stridulatory file characters of all of these species is tabulated herein (Table 1). The stridulatory file of *P. robertsi* (Fig. 19) was the only one of the two new species to be figured as a scanning electron micrograph: this is because only a few males of *P. arborealoides* were available to examine. However, scanning electron micrographs of 4 ground-dwelling species of *Phlugis* are presented for comparison: *abnormis* (Fig. 17), *chrysopa* (Fig. 18), *simplex* (Fig. 20), and *teres* (Fig. 21).

Key to species of *Phlugis* from Costa Rica

1 Inner ventral margin of forefemur with 3 spines, outer ventral margin with 4 spines; male cercus simple, cylindrical, apically unmodified. 2

1' Inner ventral margin of forefemur with 4 spines, outer ventral margin with 3 spines; male cercus heavily sclerotized, apically modified with claw-like structures 6

2 Inner ventral margin of midtibia with 1 to 2 small spines 3

2' Inner ventral margin of midtibia unarmed 4

3 Foretibia with 4 large moveable spurs on each ventral margin, those on inner margin usually apically blunt or rounded; profile of male subgenital plate as in Figs 1,8; ovipositor shorter, 3.4 to 3.8 mm, with distal half compact, more robust . . . . . *teres*

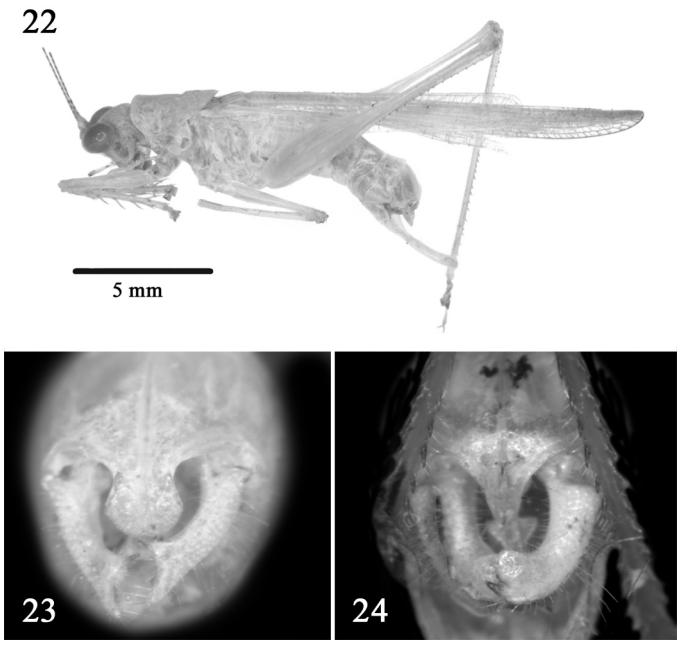
3' Foretibia with 5 large, apically pointed, sharp, moveable spurs on each ventral margin; profile of male subgenital plate as in Figs 2, 9; ovipositor longer, 5.6 to 6.0 mm, with distal half narrower and more gradually upcurved . . . . . *poecila*

4 Apex of male tenth tergite divided into bilobed projection above base of each cercus; each projection consisting of a dorsal broad, rounded, laminate lobe and long, ventrally-directed finger-like lobe, originating from base of medial margin of dorsal lobe and extending nearly to dorsal surface of subgenital plate (Fig. 3); profile of male subgenital plate with distal third distinctly triangulate (Fig. 10) . . . . . *abnormis*

4' Apex of male tenth tergite divided into 2 projections, each consisting of a single finger-like lobe; profile of male subgenital plate differing from above 5

5 Apicolateral lobes of male tenth tergite broad, robust, apically recurved ventrally and distally expanded (Fig. 5); profile of male

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Figs 22-24. New species of *Phlugis:* 22. *robertsi,* habitus; 23-24. tip of male abdomen, posterior view: 23. *robertsi,* 24. *arborealoides.*

subgenital plate similar to that of *P. abnormis,* but triangular portion with more rounded corners (Fig. **11)** . . . . . *chrysopa*

5' Apicolateral lobes of male tenth tergite small, gracile, not apically recurved ventrally (Fig. 4); profile of male subgenital plate with bluntly rounded apex (Fig. 12) . . . . . *simplex*

6 Male tenth tergite apically produced and ventrally more acutely recurved, with a deep medial groove channeling to a narrow, apically truncate to pointed tip (Fig. 6); male cercus robust, apically bilobed, with dorsal lobe rounded and ventral lobe sharply pointed (Fig. 15); male subgenital plate with 2 distally weakly inflated styles equal in length to *ca* one half length of subgenital plate (Fig. 13); basal half of anal margin of tegmen (both sexes) brown . . . *arborealoides*

6' Male tenth tergite apically produced and narrowing into a recurved, apically-rounded paddle-shaped lobe (Fig. 7); male cercus also robust, but apically modified into a median preapical sharp-toothed process with a blade-like margin aligned toward the rounded cercal apex (Figs 16a, b); male subgenital plate with 2 distally weakly inflated styles greater in length than one half length of subgenital plate (Fig. 14); basal half of anal margin of tegmen (both sexes) green . . . . . *robertsi*

Table 2. Measurements of new *Phlugis* species from Costa Rica.

Measurements means, range, in mm.	species	
	Phlugis arborealoides [3 males, 3 femles]	*Phlugis robertsi* [3 males, 3 femles]
total length		
male	22.5, 22.2-22.7	22.8, 20.4-22.0
female	23.3, 22.8-23.7	23.7, 20.4-22.0
Length pronotum		
male	3.4, 3.2-3.6	3.5, 3.8-4.0
female	3.4, 3.3-3.5	3.3, 3.8-4.0
width pronotum		
male	2.0, 1.8-2.2	2.0, 2.0-2.4
female	1.9, 1.9-2.2	1.9, 2.0-2.4
length forefemur		
male	3.5, 3.5-3.6	3.7, 3.6-3.9
female	3.5, 3.4-3.7	3.7, 3.6-3.9
width forefemur		
male	0.6, 0.5-0.7	0.6, 3.6-3.9
female	0.6, 0.5-0.7	0.6, 3.6-3.9
length hindfemur		
male	11.4, 11.3-11.6	11.6, 10.6-11.0
female	11.5, 11.1-11.8	11.6, 10.6-11.0
Width hindfemur		
male	1.8, 1.6-1.9	1.8, 1.8-2.1
female	2.0, 1.9-2.0	2.0, 1.8-2.1
length tegmen		
male	13.8, 13.5-14.1	13.3, 10.6-11.1
female	13.9, 13.3-14.5	14.0, 10.6-11.1
width tegmen		
male	1.7, 1.5-1.9	1.7, 1.6-1.7
female	1.8, 1.6-1.9	2.0, 1.9-2.1
eye length		
male	1.6, 1.5-1.6	1.6, 1.5-1.6
female	1.6, 1.5-1.6	1.6, 1.5-1.6
eye width		
male	1.0, 0.9-1.0	1.0, 0.9-1.1
female	1.0, 0.9-1.0	1.0, 0.9-1.1
eye depth		
male	1.2, 1.1-1.2	1.2, 1.1-1.2
female	1.2, 1.1-1.2	1.2, 1.1-1.2
length ovipositor		
female	6.0, 5.6-6.4	6.2, 6.0-6.4

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