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A new North American species of *Bucrates* (Orthoptera: Tettigoniidae: Conocephalinae: Copiphorini)

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Abstract

Bucrates weissmani n.sp. is known from four localities in southern Arizona. It is smaller and more slender than the other four species of *Bucrates*, making it superficially similar to the Central American copiphorine *Caulopsis cuspidata*, but more fundamental features refute the notion that it belongs in *Caulopsis* rather than *Bucrates*. Four other species of *Bucrates* are known. Two of these, *capitatus* (De Geer) and *clausus* (Scudder), occur in sympatry in Central America and tropical South America; *lanista* Rehn is known only from southern Brazil; and *malivolans* (Scudder) is restricted to the southeastern United States. All are easily distinguished morphologically and, for the three for which the songs are known, by their songs. Unlike the two other species of *Bucrates* for which the habitat is known, *B. weissmani* occurs on altitudinal islands at the edge of a desert. The calling song of *B. weissmani* resembles that of numerous species of *Neoconocephalus*, whereas the songs of *B. malivolans* and *B. capitatus*, resemble each other more than either song resembles that of *B. weissmani*.

Key words

calling song, *Caulopsis caudata*, *Bucrates weissmani*, *Bucrates capitatus*, *Bucrates malivolans*, phonatomes, Arizona, seasonal life history

Introduction

Coneheaded katydids (Copiphorini) are large enough and loud enough to have been detected, collected, and described wherever they occur in America north of Mexico. This paper describes a species that escaped detection until 1990 when its calling song prompted David Weissman to stop his car at 1679 m elevation on his way down Kitt Peak, Arizona. There he collected two males and a female. Independently, in 2001, Jeffrey Cole, was attracted to an unfamiliar song and collected a male at 1359 m near Madera Canyon, Arizona. In 2001, Weissman suggested that I describe his recently discovered species of conehead from Arizona. I agreed and a few months later established a species page on SINA (2001-date) under the name "*Bucrates* n. sp. A." Thus when Cole consulted SINA for help in identifying the unfamiliar conehead he had collected, he contacted me about his new locality for "*Bucrates* sp. A" and soon sent the specimen to me for inclusion in this paper. In 2013, both Weissman and Cole returned to southern Arizona, where Weissman added a third locality for the new species, collected eight more specimens, and noted the altitudinal and ecological distributions of the species. Cole recorded and collected a male at what becomes the fourth altitudinal island the species is known to occupy.

Methods

Access to supporting materials (SM).—To improve access to the original data and the analyses that were undertaken for this paper, four tables were composed and assigned to SM. These may be accessed through hyperlinks in BioOne's "Full Text" and PDF digital versions.

Collecting sites of specimens examined.—D.B. Weissman and Jeff Cole provided specimens of the new species from the five sites listed below. Unless within brackets, [.], the data are from labels on the specimens.

Site #1. D.B. & B.I. Weissman (DBW stop90-52), 2 ♂♂, 1♀, Arizona, Pima County, Kitt Peak, el. 1370-2130m, 17Jun1990. [In 2013, DBW wrote that with a better GPS, the elevation range had been 1097 to 1913m, corresponding to mile posts 2 to 10.5, and that mp 8.7, el. 1737m and 31.9506N 111.6253W, would be a good type locality.]

Site #2. Jeff Cole, 1♂M, Arizona, Pima County, Proctor Rd, 2 mi W of Madera Canyon Rd, 31.741N, 110.887W, 1359m, 4-5Aug2001.

Site #3. D.B. & D.W. Weissman (DBW stop13-17), 2♂♂, Arizona, Cochise County, Ramsey Canyon Preserve, 31.4476N 110.3068W, el. 1679m, 1Jun2013.

Site #4. D.B. & D.W. Weissman (DBW stop13-36), 1♂, 1♀, Arizona, Pima County, Kitt Peak, 31.9506N 111.6253W, el. 1737m, 7Jun2013.

Site #5. J.A. Cole & J.F. Limón, 1♂, Arizona, Cochise County, Cochise Stronghold, FR4809, [Dragoon Mountains,] 31.93949N, 109.96156W, el. 1451 m, 13Jul2013.

Calling song recording and analysis.—In a paper on the calling songs and forewing movements of a genus of conocephalines, Morris & Walker (1976) defined *phonatome* as "all the sound produced during one cycle of [fore]wing movement." That term will be used here because it is appropriate to the songs described.

As detailed in SMTable4, Weissman made five tape recordings of four *B. weissmani* males. The four most recent recordings were made of caged specimens at room temperatures of 24 to 28°C, using a Sennheiser ME40 microphone and a Uher 4000 Report IC recorder at a tape speed of 19 cm/s. They were later digitized at a sampling rate of 44,100 per s with a bit depth of 16. Cool Edit 2000 was used to determine phonatome rate (ph/s) from a brief sample taken from the approximate middle of each third of each of the four recordings. When the values were not identical, the median value was accepted. Peak frequency was determined in a similar fashion but with an extensive sample taken from each one third. Weissman's four 19.9 cm/s recordings are archived in Cornell's Macaulay

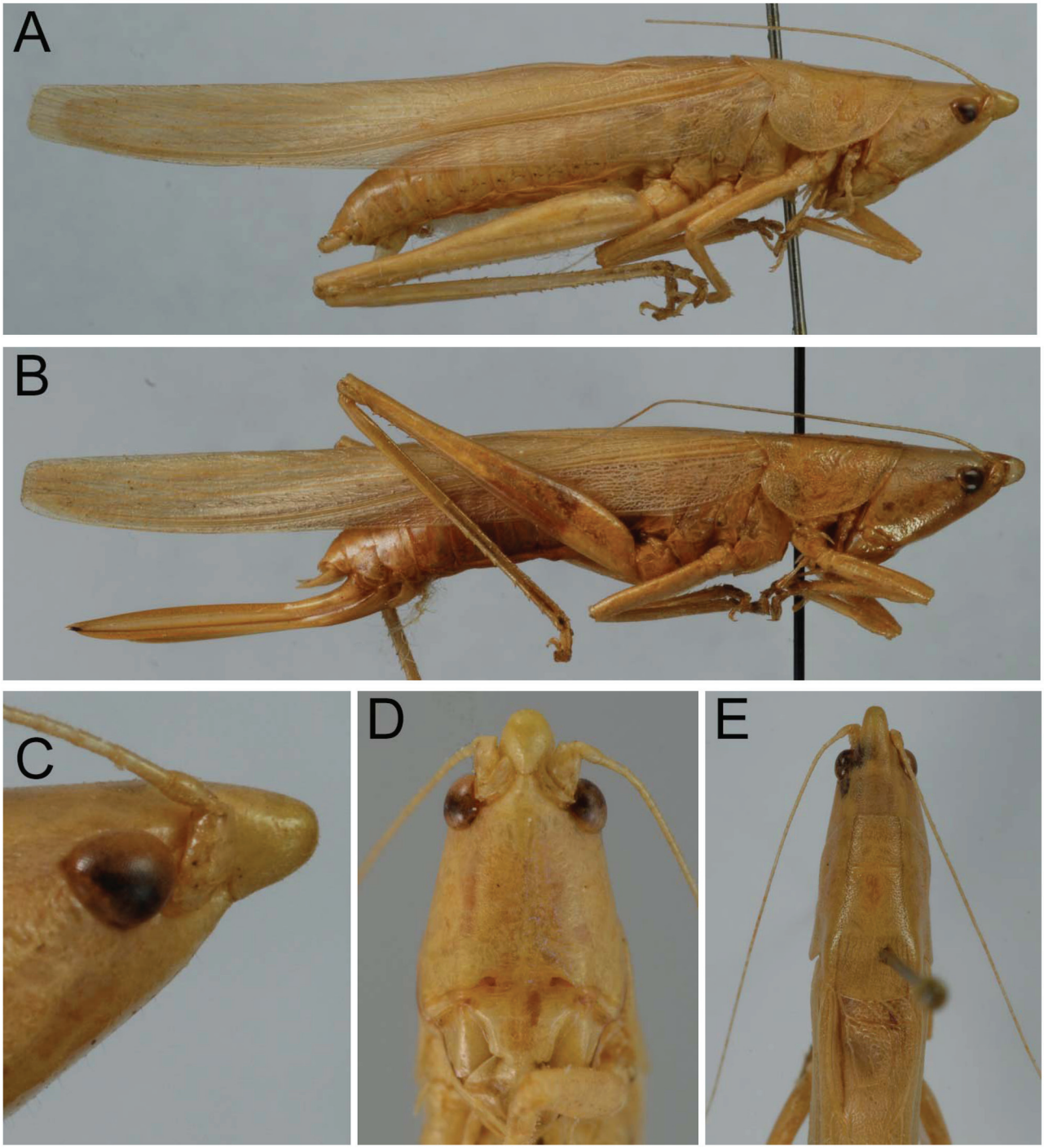

Fig. 1. *Bucrates weissmani* n.sp. A. Male (holotype). B. Female (allotype). C. Male cone. D. Male face. E. Male anterior dorsum. (Photographs by Lyell Buss, University of Florida.)

Library of Natural Sounds (SMTable4). Cole made one recording of *B. weissmani* calling song, in the field, with a Sony digital PCM-D50 recorder with built-in microphones sensitive to 40kHz, set to sample at 96 kHz and a bit depth of 16. His recording is posted at http://entnemdept.ifas.ufl.edu/walker/Buzz/180a.htm.

Results

Bucrates weissmani n. sp.
Weissman's Conehead

Holotype.— Male: Site #1 (see Methods). See Fig. 1A, C-E (in the online version of this article, the figures can be viewed at 400% without loss of resolution. They are also online at http://www.entnemdept.ufl.edu/walker/buzz/180a.htm). Terminalia as in Fig. 2. Lengths (mm): body (including tegmina) 40, tegmina 30, pro-

notum 7.3, hind femur 15. Brown color form. California Academy of Science, Type No. 18493.

Females: Sites #1 (allotype) and #4. See Fig. 1B. Lengths: body 41, 42; tegmina 31, 32; pronotum 6.3, 6.4; hind femur 15, 15; ovipositor 14, 14. Brown and green color forms.

SMTable1 has the measurements and other data for all *B. weissmani* specimens examined.

Discussion

Generic status.—In 21 of the 22 previously known species of North American copiphorines (SINA 2014), the fastigium is separated from the frons by a sizable gap, but in *Bucrates malivolans*, and other members of its genus, there is no such gap (http://entnemdept.ufl.edu/walker/buzz/s160k.htm). Instead the ventral surface of the fastigium is continuous with the frons (Fig. 1C, D). Thus if one assumes that *weissmani* belongs to a North American genus, *Bucrates* is the best choice. However, the four species already in the genus *Bucrates* are larger (Table 1) and, in each species, the fastigium is short compared with that of *weissmani* (Fig. 1E), making it prudent to consider copiphorine genera beyond the four Nearctic ones before settling on *Bucrates*. The list of candidate genera was expanded by the inclusion of other New World genera. Old World genera were excluded because Tettigoniidae have not been revised on a worldwide basis since the late nineteenth and early twentieth centuries (Nickle & Naskrecki 1997). This has led to species being assigned to genus on the basis of their geographic location. For example, species of coneheads that would be assigned to *Neoconocephalus* if native to the New World, would be assigned to *Ruspolia* if native to the Old World, and to *Euconocephalus* if native to the Indo-Australian region (Naskrecki 2000). Based on the keys, illustrations, and text of Nickle (1992) and Naskrecki (2000), *B. weissmani* is indeed a *Bucrates*. Key differences between *B. weissmani* and *Caulopsis* are indicated in SMTable2. SMTable3 gives the ranges of key measurements for all species of *Bucrates*.

Relation of weissmani *to other species of* Bucrates.—Of the five species of *Bucrates*, only *capitatus* and *clausus* are sympatric. Naskrecki (2000) has described and illustrated the differences between these two, and the geographical ranges of the other three species are separated by 1200 km or more from the range of any other *Bucrates* species. Specifically, *malivolans* is separated from *weissmani* by *ca* 1200km (east Texas to south Arizona); *weissmani* is separated from *clausus* by *ca* 1500 km (south Arizona to Jalisco, Mexico); and *lanista*, from *clausus* and *capitatus*, by *ca* 3700 km (Porto Alegre, Brasil, to Venezuela). Table 1, which is provided instead of a key to species, compares *Bucrates* species and reveals that males, when known, can be identified by their terminalia and that females can be identified by combinations of morphological features.

Calling songs.—The song of *B. weissmani* is a buzzy, high pitched, continuous whine produced by *ca* 185 wing-stroke cycles per s at 25°C. SMTable4 lists the six known recordings and their physical characteristics. As indicated in Methods and in the SM table, digital files of these recordings are accessible online. Compared with the songs of other Nearctic coneheads, the song of *B. weissmani* most resembles the songs of *Neoconocephalus velox* and *N. palustris*, which have songs of similar quality and continuity with rates at 25°C of ca. 196 and 202 ph/s (SINA 2014 at http://entnemdept.ifas.ufl.edu/walker/Buzz/198a.htm and http://entnemdept.ifas.ufl.edu/walker/Buzz/195a.htm).

Table 1. Comparison of *Bucrates* species. Morphological data for *capitatus* and *clausus* are from Naskrecki (2000).

Species	Width of fastigium of vertex[a]/width of scapus[b]	Male cerci	Male styli	Tegminal lengths of macropterous females (mm)	Length of ovipositor/ length of hind femur	Geographical distribution	Habitat
weissmani	~1.5 × as wide as scapus	two well-developed subapical spines (Fig. 2)	cylindrical (Fig. 2)	31-32	0.93 (ovip.< femur)	southern Arizona, USA	perennial bunch grasses at altitudinal islands at eastern edge of Sonoran desert
malivolans	~1.5 × as wide as scapus	one well-developed subapical spine[c]	flattened dorso-ventrally	45-50	1.59-1.64 (ovip.>>femur)	eastern Texas to Florida; north along coast to New Jersey	freshwater marshes; cattails, sawgrass [also see Hebard 1939]
clausus	twice as wide as scapus	two apical spines	cylindrical	47-51	0.92-1.01 (ovip~=femur)	Jalisco, Mexico to Bogata, Colombia	not known
capitatus	4 × as wide as scapus	two subapical spines	flattened dorso-ventrally	46-50	1.20-1.29 (ovip>femur)	Guatemala to Venezuela and Bahia, Brazil	clearings in tropical forest (Belwood & Morris 1987)
lanista	(type at ANSP)	male not known	male not known	54-55	1.12 (ovip>femur)	Porto Alegra, Brazil (30°S lat.)	not known (Rehn 1918)

[a]In *weissmani*, the width of the fastigium of the vertex is difficult to determine because its base, which would be the widest place along its length, has no definitive beginning. In *malivolans*, its widest point is along its length, which makes it easier to measure with precision.
[b]In both *weissmani* and *malivolans* the irregular shape of the scapus makes it difficult to define and measure its width. This column would have been omitted except for the quotient of the two widths recommended use in distinguishing both males and females of *clausus* and *capitatus*.
[c]A small outer subapical spine lies on the large, sclerotized base of the inner spine (see photo at http://entnemdept.ifas.ufl.edu/walker/Buzz/181a.htm).

In contrast to *B. weissmani*, *B. malivolans* produces a coarse, raspy buzz that is repeated individually or at a nearly regular rate of about 2 per second for short to medium sequences. Each buzz consists of 5 to 8 phonatomes with the intensity and duration of the successive phonatomes slightly increasing. At 25°C the phonatomes within each buzz are produced at a rate of *ca* 51ph/s (based on audiospectrographic analyses of 47 recorded songs as documented at http://entnemdept.ifas.ufl.edu/walker/Buzz/181a.htm). The 6 s of song whose waveform is illustrated at that site is a sequence of 13 closely similar buzzes; the first five of these have 7 phonatomes each and the last eight have 8 phonatomes each. The last two buzzes are expanded at http://entnemdept.ifas.ufl.edu/walker/Buzz/181ss3.htm.

The only other species of *Bucrates* for which a calling song has been reported is *B. capitatus*. For that species Belwood & Morris (1987, Fig. 1A) show a 1.6 s audiospectrogram that includes 15 phonatomes made at a temperature within the range of 25-27°C. These closely resemble audiospectrograms of phonatomes of *B. malivolans* but are produced at slower rates. The first nine of the *capitatus* phonotomes are evenly spaced during the first 0.8 s of the sample and the last six are nearly evenly spaced during the final 0.8 s—*i.e.*, the phonatomes seem to have been produced at discrete rates of *ca* 11.25 ph/s and 7.50 ph/s. This makes an average rate of 9.375 ph/s for the 1.6 s shown. Should this average continue, the number of phonatomes in 1 minute would be 563, but Belwood & Morris place the number of phonatomes per minute at 450. Thus, the 1.6 s sample they display is more densely populated with phonatomes than average. Should the two phonatome rates be the only two produced and the proportions of the two rates be the same as those in their illustration, some 12 s of silence would need to be inserted to reduce the count from 563 to 450 phonatomes. In *B. malivolans*, indeterminate periods of silence are often inserted between bouts of regularly spaced phonatome sequences. The songs of both *malivolans* and *capitatus* have modest phonatome rates produced with interruptions, whereas *weissmani* calling songs are long continued and have a much higher phonatome rate.

Geography.—*Bucrates weissmani* occurs in a part of Arizona that is on the eastern edge of the Sonoran Desert and has a number of small mountain ranges that rise above the predominantly treeless plains of 914 to 1219m [=3,000 to 4,000 ft. on the 1:250K Nogales USGS topographic map from which these elevations were read]. The range of elevations at which *weissmani* males were heard calling on Kitt Peak was 1079 to 1913 m. The elevations of the three other localities for the species (1359, 1451 and 1679 m) were within this range. Because, in the future, suitable habitats for *weissmani* may migrate upward, here are the maximum elevations within the four small mountain ranges known to harbor *weissmani*. Kitt Peak (2096 m) is part of the Baboquivari Mtns., whose highest peak is 2356 m. Madera Canyon is about 75 km ESE of Kitt Peak and is in a slope of the Santa Rita Mtns., whose highest peaks are 2617 and 2881 m. Ramsey Canyon Preserve is about 65 km ESE of Madera Canyon and is in a slope of the Huachuca Mtns., whose highest peak is 2885 m. The Dragoon Mtns. are about 65 km NNE of Madera Canyon; their highest peak is 2,292m.

Ecology.—The following two paragraphs summarize what is known of the ecology of *B. weissmani*, taken mostly from the collecting notes of D. B. Weissman.

Habitat/behavior.— At Kitt Peak, 7Jun2013, all males and females were on perennial bunch grasses in open, mixed grass-shrub habitat; bunches had some green blades but most blades were brown and dry. At Ramsey Canyon Preserve, 1Jun2013, two males were heard. Both were singing from bunch grasses under open tree cover. All males were captured easily because they continued to sing when approached with head lamps on.

Fig. 2. Terminalia of holotypic male. The cerci are above the subgenital plate and its cylindrical styli. Each cercus has two subapical spines. The outer spine has a minimal basal piece whereas the inner spine has a substantial one (the inner spine of the right cercus is not visible in this image). (Automontage made by Lyell Buss, University of Florida.)

Seasonal life history.—Available evidence suggests that *B. weissmani* is univoltine and has a single period of mating activity each year. Of the 22 other Nearctic species of copiphorines, six occur only at latitudes south of southern Arizona (http://entnemdept.ufl.edu/walker/buzz/katylist.htm#Subfamily Copiphorinae). Of the remaining 16 species, none is bivoltine, although *Neoconocephalus triops* may have that life cycle in southern peninsular Florida and a partial second generation as far north as South Carolina (http://entnemdept.ifas.ufl.edu/walker/Buzz/191dlc.htm).

Of the 16 species of North American copiphorines defined above, 14 (including *Bucrates malivolans*) apparently overwinter in the egg stage. The two exceptions are *N. triops* and *Pyrgocorypha uncinata*, which overwinter as diapausing adults that do not call or mate prior to undergoing diapause (Whitesell & Walker 1978; Fulton 1951). Thus, based on what is known of North American copiphorine life cycles, the egg and the diapausing adult are the two candidates for the overwintering stage of *B. weissmani*. As pointed out by Weissman (pers. comm. 5Feb2014), egg overwintering seems unlikely because low temperatures and occasional severe droughts during late winter and early spring would not be favorable for the

survival of hatchlings and their growth to early-season adulthood. To strengthen this argument Weissman refers to the fact that North American *Gryllus* spp. generally overwinter either in the egg or as mid-to-late nymphal instars (Walker & Masaki 1989) and notes that of the many *Gryllus* spp. he has studied in the Southwest, nearly all overwinter as diapausing nymphs that mature early in the growing season. In view of nymphal diapause being unknown among North American copiphorine species, *B. weissmani* adults that are in reproductive diapause when they mature in the fall seem likely to be the overwintering stage for the species.

Acknowledgements

David B. Weissman (California Academy of Sciences) would have written this paper had he not been too busy with his studies of the genus *Gryllus*. As it was, he not only did most of the field work and song recording described above, he actively helped throughout the writing of this paper. Jeffry Cole (Los Angeles County Museum of Natural History) is responsible for all other field work on the species. David Nickle's (National Museum of Natural History) review significantly improved the manuscript.

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