Calling and courtship songs of the rare, robust ground cricket, *Allonemobius walkeri*

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Abstract

In the original description of *Allonemobius walkeri* Howard & Furth, 1986, the authors describe the species' calling songs in a table that included trill length, length of the interval between trills, pulse rate, and carrier frequency for four individuals. Further investigation of the acoustics of this species reveals that the calling songs are composed of syllables organized into echemes composed of a varying number of syllables, and organized into groups of echemes, of variable length. The echemes are separated by intervals of various lengths. The calling song is pleasing to the ear, with ~27 syllables per second and a carrier frequency of ~7.7 kHz at 25 °C. The characteristics of the echemes and echeme intervals are significantly different when the cricket is singing in sunlight compared to darkness. In sunlight, echemes are shorter, but echeme intervals are longer. There is no effect on calling bout lengths. Courtship songs are quieter than calling songs, with a random delivery of soft and loud chirps in addition to fainter, rhythmic sounds randomly distributed between the chirps. Courtship songs are interspersed with long bouts of calling songs with displays lasting hours.

Keywords

acoustic communication, Nemobiinae, song characteristics

Introduction

Allonemobius walkeri Howard & Furth, 1986 is a rare species of the cricket family Trigonidiidae, subfamily Nemobiinae, found in grassy areas in open sun or at woodland edges next to open, grassy fields in North America (Howard and Furth 1986). They are often found with *Allonemobius allardi* (Alexander and Thomas 1959), but not in all locations. Because of its rarity, *Allonemobius walkeri's* calling songs were briefly described in 1986 (Howard and Furth 1986), but there was no mention of courtship songs.

Under field conditions, singing males may perch in direct sunlight even when apparently hidden under grassy vegetation. This direct sunlight elevates their body temperature well above the ambient conditions in a phenomenon known as sun effects. Under these conditions, it is nearly impossible to know the exact temperature that a singing male cricket is experiencing. These sun effects can be eliminated by recording singing males indoors out of direct sunlight or by using low-E glass that blocks the transmission of a large percentage of the infrared radiation that would warm the crickets.

For field researchers, knowing the songs of singing orthoptera is of great importance to facilitate collection, population estimation, range delineation, and teaching others about these insects. Recently, there has been a significant increase in the use of automated audio recording units to collect field data regarding species richness, population density, and seasonal timing of appearance of singing orthoptera (Forrest 1988, Newson et al. 2017, Riede 2018). A clear description of the songs of different common species can often be gleaned from the literature, and exemplars can be found in sound libraries. However, it is sometimes difficult to find a description or audio example of rare species that would allow researchers to identify confusing audio specimens from field recordings. In this study, I have extensively recorded five individuals of *Allonemobius walkeri* under two lighting conditions (sunlight and darkness), and I have recorded the courtship songs of two males with a female. I describe in detail the characteristics of the calling and courtship songs.

Materials and methods

I collected one male in 2019 and four males and one female in 2020 from a grassy meadow next to a mixed deciduous woodland at a wildlife preserve in Jefferson County, West Virginia, USA. All specimens were maintained in plastic containers that were modified by removing most of the plastic from the sides and lid. The open areas were then covered with no-see-um netting held in place with hot glue. These singing cages are practically transparent to sound. The crickets were fed with iceberg lettuce, Fluker's High-calcium Cricket Diet (Port Allen, LA), and water *ad libitum*. Audio recordings were made in an anechoic room, with dim or no light or in sunlight coming through a south-facing window. The windows were composed of Low-E glass that filtered out much of the infrared radiation, thereby keeping the temperature of the insects more consistent with the ambient temperature of the room. Temperatures were taken with either a Cooper Atkins DFP450W digital pocket thermometer (Middlefield, CT, USA) or a Digi-Sense ZM-94460-78 receiver and ZM-90205-10 transmitter (Vernon Hills, IL, USA). All recordings of calling and courtship songs were made with a Sound Devices 702, Sound Devices MixPre-6 (Reedsburg, WI, USA), or a Zoom F8n digital recorder (Hauppauge, NY, USA) at a sampling rate of 96 kHz at 24-bit depth. The microphone, a Sennheiser MKH 8020 RF condenser (Solrød Stand, Denmark), was placed within 8 cm of the singing males. Audio recordings were processed with Adobe Audition CC 2020 (San Jose, CA, USA) and examined using Raven Pro v 1.6.1 (Cornell Lab of Ornithology). Data analysis was performed in Microsoft Excel (Redmond, WA, USA) and DataGraph software (Chapel Hill, NC, USA).

Courtship songs were recorded by placing a female in a cage with the male, placing the cage in a dimly lit anechoic room, and allowing the insects to interact overnight. Two different males were used for capturing courtship songs. The same female was used for both sessions.

Acoustic terminology follows Baker and Chesmore (2020): a unit of sound produced by one closing stroke of the cricket tegmina is called a syllable; syllables are grouped into short echemes which are organized into calling bouts. Echemes and calling bouts were selected either manually or using a band limited detector in Raven Pro 1.6.1. The detector settings for selecting echemes were minimum frequency = 5.5 kHz, maximum frequency = 9 kHz, minimum duration = 0.60372 s, maximum duration = 600.00363 s, minimum separation = 0.10449 s, minimum occupancy (%) = 18.0, SNR threshold (dB) = 18.0, block size = 9.99619, hop size = 1.99692, and percentile = 10.0. The detector used selects the echemes very accurately. All selections were inspected to make certain that all echemes were selected and that the selection boundaries were accurate. A pause lasting 30 seconds or longer was used to differentiate one calling bout from the next. Comparisons of means were performed on Log10 transformed data due to significant skewness of the raw data with *t*-tests performed in Microsoft Excel 2016 using the data analysis add-on.

Results

The calling songs of *A. walkeri* are composed of calling bouts that average 17.1 ± 14.5 minutes (range from 1.18–121.10 minutes) (n = 5 individual insects, 395 calling bouts). The calling bouts are broken into echemes that average 7.132 s (CI (confidence interval), 3.221–15.792) (range 0.263–594.442 s) (n = 5, 34,039). The intervals between echemes (the echeme intervals), average 0.881 s (CI, 0.375–2.069) (range 0.104–39.59 s) (n = 5, 33,642) (Fig. 1A). Each echeme begins at a low amplitude, crescendos rapidly, and remains at the maximum amplitude for the remainder of the echeme (Fig. 1B). The power ratio of the first few syllables to those of the main portion of the echeme is ~1:10 (11 dB FS).

Calling song characteristics varied significantly when the cricket was singing in bright sunlight versus darkness, with echeme intervals being longer in sunlight and echemes being longer in darkness. However, calling bouts do not differ between sunlight and darkness (Table 1). Temperature readings in the sunlight coming through the windows were within ±1.5 °C of those taken in the shade in the same room.

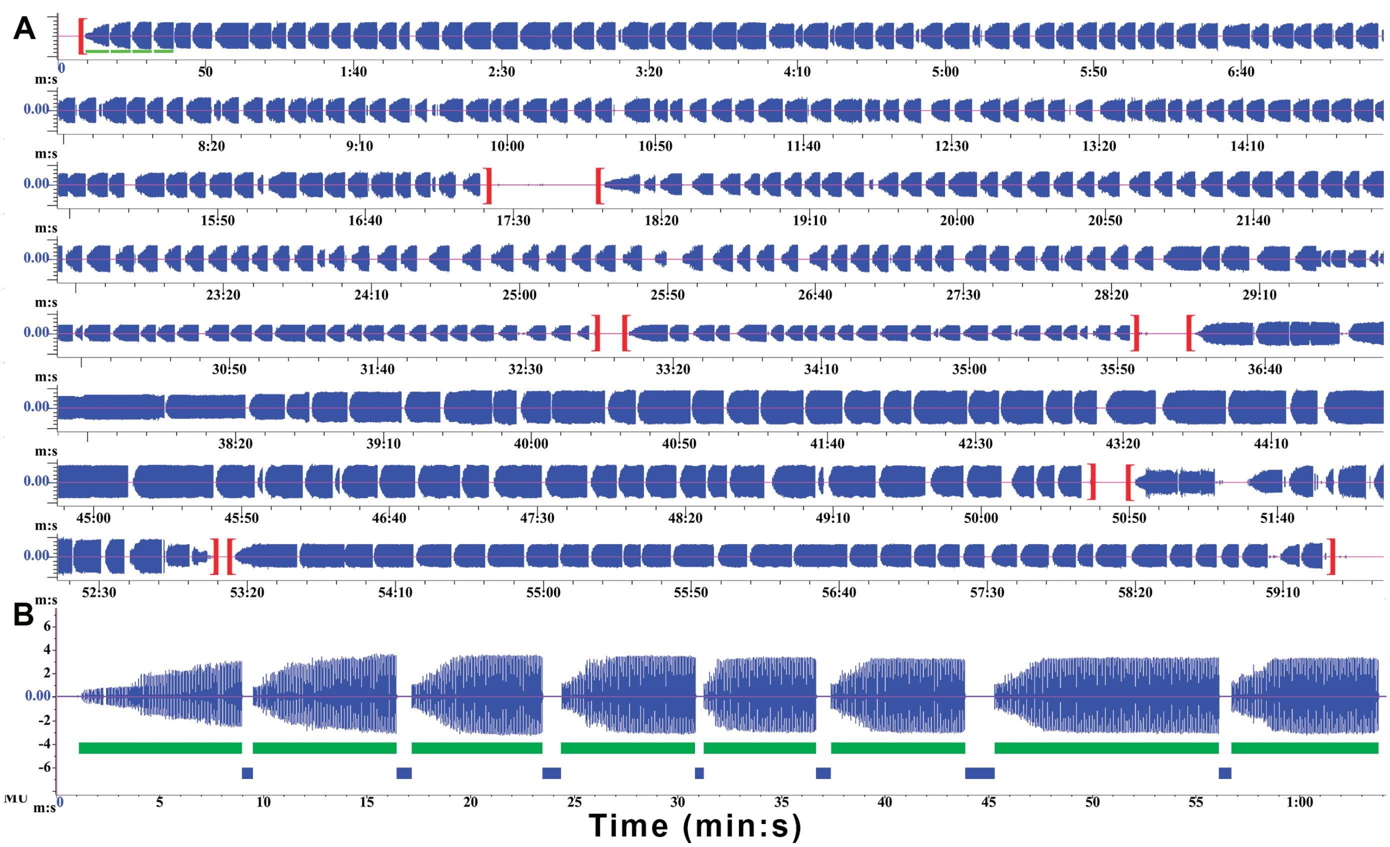

Fig. 1. A. Oscillogram showing the structure of the calling songs of *A. walkeri.* Calling bouts are boxed by red brackets, and echemes are underlined with green bars. The oscillogram shows the varying lengths of the calling bouts, echemes, and echeme intervals. **B.** Time expanded detail of the first minute and five seconds of **A**, showing echemes underlined with green bars and echeme intervals underlined with blue bars. The time scale for both oscillograms is minutes:seconds.

The trilling character of the calling song comes from the individual syllables of the echemes. Syllables are produced on the closing stroke of the male's tegmina, with the opening stroke being mostly silent (Walker and Carlysle 1975) (Fig. 2). The opening stroke does show that the file teeth graze over the scrapper as the tegmina are moved laterad at a varying rate of speed during the opening stroke. The tegmina accelerate from rest to a rapid rate then slow down, pausing briefly before the closing stroke. At 25.0°C, the closing stroke (syllable) is 17.26 ± 1.48 ms, the opening stroke is 20.42 ± 2.21 ms, the carrier frequency is 7.93 ± 0.58 kHz, and the syllables per second are 26.52 ± 0.63 (n = 2, 100). Combining my data with that from Thomas J. Walker's data (SINA. 2020. Singing Insects of North America [https://sina.orthsoc.org/529a.htm]), the trend line for carrier frequency vs syllable per second was calculated to be y = 0.15436× + 3.6269, R^2 = 0.823 (n = 15, 51) (Fig. 3).

Table 1. *Allonemobius walkeri* calling song characteristics in sunlight and darkness; *t*-test analysis showed a statistically significant difference, with echeme interval lengths being longer in sunlight and echeme lengths being longer in darkness. Calling bouts lengths did not differ between the treatments (n includes songs from two individuals recorded in both sunlight and darkness; statistics were performed on Log_{10} transformed data).

Treatment	mean	+CI	-CI	n	p
Echeme interval sunlight (s)	0.9630	0.9906	0.9362	2003	<0.00001
Echeme interval dim/dark (s)	0.5418	0.5611	0.5230	1079	
Echeme duration sunlight (s)	6.4040	6.6032	6.2108	2027	<0.00001
Echeme duration dim/dark (s)	13.1947	14.1172	12.3325	1099	
Calling bout sunlight (min)	12.9122	15.4099	10.8193	85	0.6582
Calling bout dim/dark (min)	12.3509	13.5332	11.2720	310	

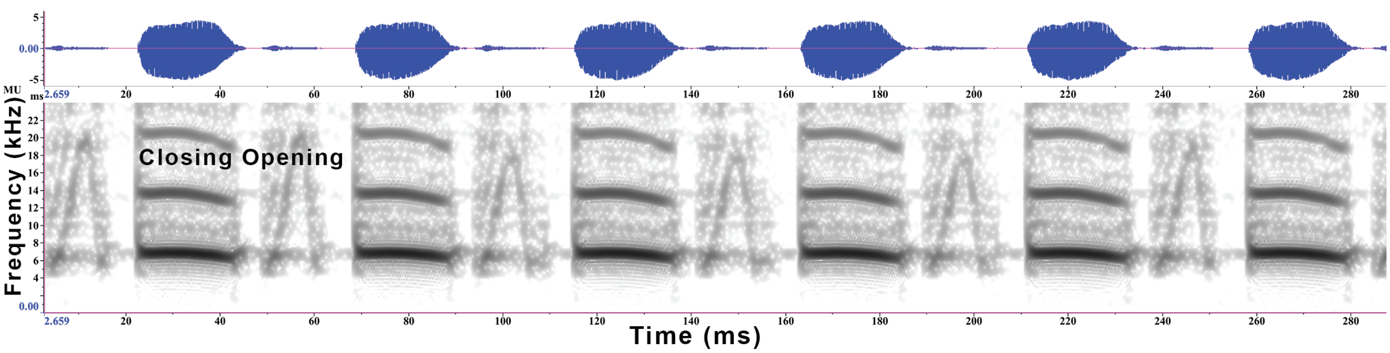

Fig. 2. Oscillogram and audio spectrogram of the calling song of *A. walkeri* showing the closing and opening strokes of the male's tegmina. The closing stroke produces a loud syllable, and the opening stroke is nearly silent but audible when the microphone is close to the singing cricket. Time is in milliseconds.

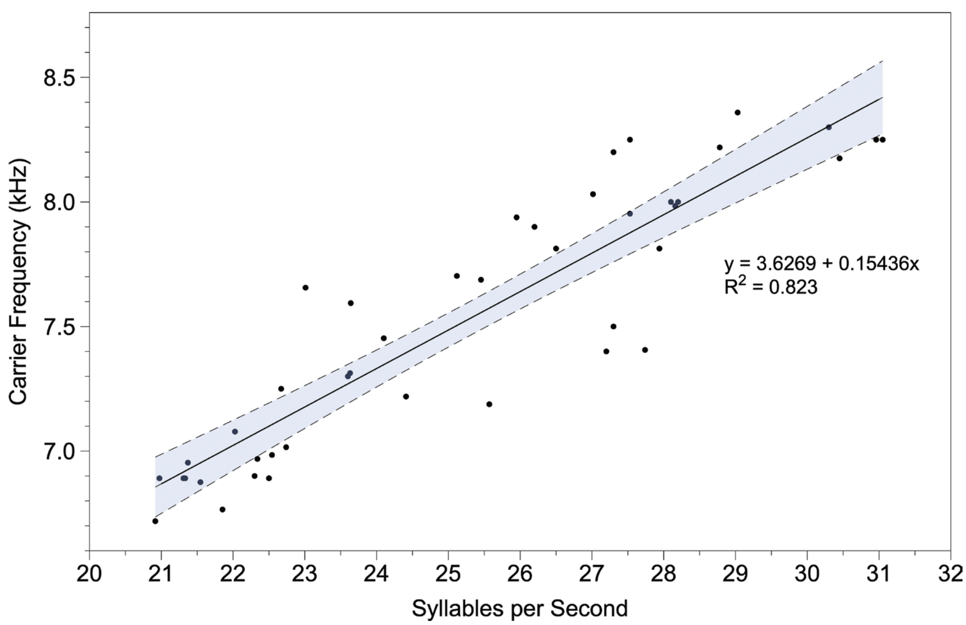

Fig. 3. Graph and regression line with 95% confidence interval of carrier frequency (kHz) versus syllables per second for the calling songs of *Allonemobius walkeri* (n = 15 individual, 51 echemes). Created from combining my data with that of Dr. TJ Walker, SINA 2020.

The courtship song of this species is different from their calling song and is similar to the courtship songs of other *Allonemobius* species, with some similarities to the courtship songs of *Gryllus pennsylvanicus* (Burmeister 1838) and *Gryllus veletis* (Alexander and Bigelow 1960) (Burmeister 1838, Alexander and Bigelow 1960, Alexander 1961). The courtship song of *A. walkeri* is composed of soft, rolling sounds with numerous soft chirps and occasional loud chirps (Alexander and Thomas 1959, Ewing and Hoyle 1965) (Fig. 3). There is no particular pattern to the courtship songs, which can proceed for many minutes within hours-long acoustic sessions (Zuk et al. 2008) and are accompanied by long bouts of calling songs. The shorter, softer chirps of a courtship song average 8.73 ± 3.33 ms at 6.543 ± 0.209 kHz and the longer, louder chirps (which are more like the chirps of calling songs) average 17.48 ± 2.74 ms at 6.660 ± 0.148 kHz (n, 272, at 23.5°C). The syllable rate of the soft and loud chirps varies considerably during delivery. The courtship song's rolling quality appears to be achieved by the male cricket enhancing the sounds made by the tegmina during the opening stroke (the softer, fainter traces in Fig. 4) (Alexander 1961). During an 11.7-hour session, a male sang courtship songs for 2.9 hours interspersed in 6.6 hours of calling songs (Fig. 5). To further demonstrate the difference in the rhythm and character of *A. walkeri's* courtship song in comparison to its calling song, Figure 6 shows both song types at the same time scale.

Discussion

Identification of field recordings of rare cricket species, whether obtained in person or autonomously, can be aided by the existence of reference materials or detailed descriptions of their calling songs (Riede 2018). The only available reference describing the calling songs of *Allonemobius walkeri* is by Howard and Furth in 1986. Having extensively recorded the calling songs of several male *A. walkeri*, I was able to determine the finer details of their songs. I found that the calling songs are composed of echemes of varying lengths that are arranged into calling bouts that also vary in length. Each echeme is separated from the next by an echeme interval of varying length. I also found that there is a significant ef-

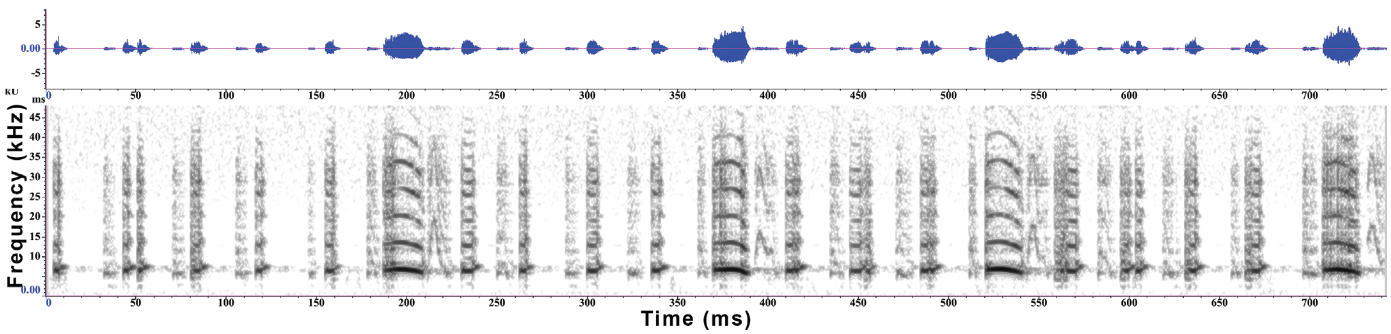

Fig. 4. Detail of courtship song of *A. walkeri.* The spectrogram shows the random nature of the syllables in both length and loudness of the short, softer and long, louder chirps, as well as the fainter, random, opening stroke sounds that create the rolling nature of these songs. Time is in milliseconds.

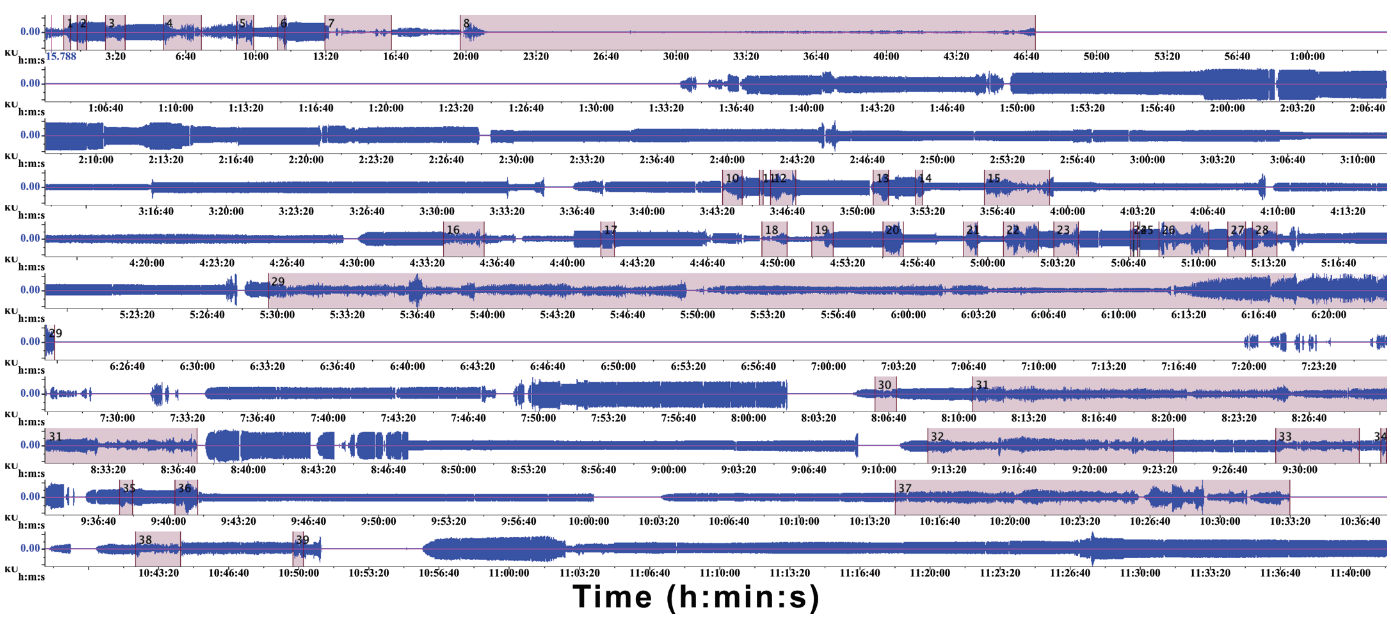

Fig. 5. Oscillogram of the courtship song of *A. walkeri.* The oscillogram shows an entire courtship display with courtship songs (highlighted) interspersed with calling songs and periods of silence. (The amplitude of the songs varies greatly as the cricket moves and changes position relative to the microphone.) Time is hours:minutes:seconds.

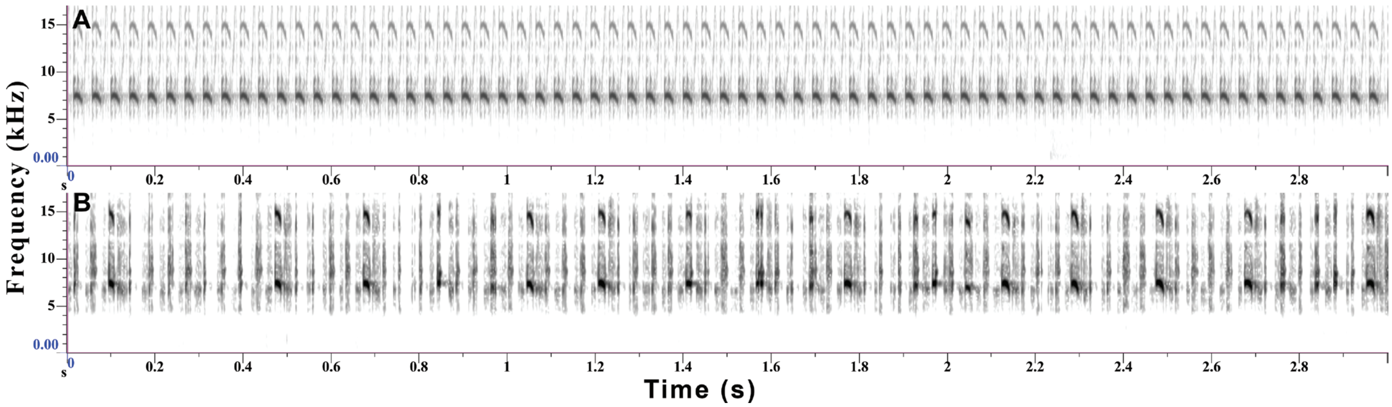

Fig. 6. A. Spectrogram of three seconds of calling song. **B.** Spectrogram of three seconds of courtship song. This comparison shows the distinct difference in the rhythm and character of the two song types of this species.

fect of sunlight on the lengths of the echemes (longer in darkness) and echeme intervals (longer in sunlight) that does not appear to be the result of temperature effects. Further research into the effects of bright light or sunlight (with a minimization of temperature differences) on the singing behavior of ground crickets is needed to determine the underlying reasons for these observed effects on song structure.

I found that the courtship songs of *A. walkeri*, as with the courtship songs of other Nemobiinae, are composed of random brief and long chirps accompanied by rolling, softer sounds. Examination of the audio spectrograms seems to support the conclusion that these softer sounds are the result of the male crickets enhancing the sounds made by the tegmina during the opening stroke. High-speed videography or Doppler-laser vibrometry would be needed to determine exactly how the cricket is creating these sounds.

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All audio recordings associated with this project are archived at the Macaulay Library, Cornell Lab of Ornithology, ML numbers 305704–305815.

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