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Synchronized male cricket calls in choruses of the cricket Anaxipha sp.

Michael Morales

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Michael Morales
University of California, Santa Cruz
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ABSTRACT

In Monteverde, there is a species of cricket within the Genus *Anaxipha* where males sing in loud choruses at night. I wanted to explore the purpose of this behavior by looking at the call and response activity between individual males. In this experiment, I looked at male responses to manipulations of the species male song, which is composed of two elements. I conducted a series of playback experiments on captive crickets. Responses of test subjects were documented while presenting playbacks of manipulated songs. Each playback treatment had a unique response from the crickets being tested. However, overall, it appears that the crickets were either trying to copy the composition the recordings, or keep pace with their speed. Results show that males within this species of cricket are actively listening and responding to each other.

Cantos sincronizados de grillos machos en coros de *Anaxipha* sp.

RESUMEN

En Monteverde, hay una especie de grillo dentro del género *Anaxipha*, donde los machos cantan en coros de alto volumen por las noches. Quise explorar el propósito de este comportamiento estudiando la actividad de cantos y respuestas entre machos. Mediante experimentos, analicé las respuestas de los machos a canciones manipuladas de otros machos de la especie, las cuales normalmente se componen de dos elementos. Los experimentos consistieron en la reproducción de los cantos modificados a grillos cautivos como sujetos de prueba y la grabación de sus respuestas. De los cinco tratamientos diferentes basados en composición del canto o velocidad, todos presentaron una respuesta única generalizada por parte de los sujetos de prueba. Sin embargo, en general, parece que los grillos intentan cantar con la misma composición de las reproducciones de cantos, o seguir el ritmo de su velocidad. Los resultados muestran que los machos dentro de esta especie de grillo están escuchando y respondiendo activamente según los cantos que los rodean.

Orthopterans within the family Gryllidae are known for producing loud calls by rubbing their wings in a process called stridulation (Borror, 1989). While the most common purpose of the call is to attract females, Orthoptera sing for a variety of reasons, including defense against predators or to mark territories (Hanson and Nishida, 2016).

Some species of katydids within the family Tettigoniidae and some crickets in the family Gryllidae have been known to sing in leks when calling (Hartbauer et. All, 2014). Leks are groups of males within a species that work together to create displays to attract females. Lekking behavior and group calling is also seen in mammals, birds, and frogs (Encyclopedia Britannica 2016). Regarding Orthopterans, it is thought that cooperation and competition between males drives this phenomenon. Males compete directly with each other for females. However, they need to cooperate because females tend to prefer males that sing within groups to solo males. (Hanson and Nishida, 2016).

The "beacon effect" makes a group of males more audible/visible through amplification (Buck and Buck, 1966). Also, singing in unison may remove sound clutter from the environment, which would allow males to hear female responses more clearly. When songs are in unison, there is "empty space" for males to hear other calls in the area (Copeland and Moiseff, 2010).

For my study, I chose to experiment with crickets within the genus *Anaxipha.* In Monteverde there is a common species of cricket that starts calling around 5pm every day and continues to sing throughout the night. These crickets are noticeably loud and are some of the most recognizable singers in the night. When these crickets call, they tend to sing together as a unit, rather than separately. To study this behavior, I asked the question, "How do male crickets within this species listen and respond to each other?" I studied this by looking at how individual crickets change their songs with the presence of other male cricket songs. To mimic and control the songs of surrounding males, I used and manipulated live recordings of crickets. I then played back these recordings and manipulations to see how the crickets would respond to the stimulus. I first looked at "if" the subjects were responding, and, later, "how" they were responding.

MATERIALS AND METHODS

In this study, I collected ten male crickets over the course of two weeks from 13 November to 25 November 2017 from the neighborhood and forest around Bajo Del Tigre and the Biological Station. The crickets were stored in clear plastic bags or small cardboard cages with food and moist leaf litter to keep them alive for the duration of the experiment. Each individual male was given a unique name for identification.

I first needed to obtain recordings of crickets for the experiment. Initial recordings for playback treatments were recorded on 14 November 2017. These recordings were played back to the crickets over the course of the experiment in a small classroom at the Monteverde Institute. These recordings were also modified to change song structure and composition for the series of playback treatments. All audio manipulations were done in Ableton Live Lite.

To record crickets, I used a Zoom recorder with a directional microphone pointing to their enclosures. Before recording, I would arrange the crickets in a semi-circle of chairs about 1.5 meters from each other. The purpose of this was to imitate their distributions in nature so that they would feel more comfortable singing in this new environment. I would wait for the crickets to start singing on their own and record based on who sang first or who I needed recordings from. When a cricket started singing, I would move the other crickets out of the room so that they wouldn't interfere with the experiment. I then recorded the cricket alone for one to two minutes to see how the crickets would sing without any outside influences. After that, I would run through a series of playback treatments to see how the cricket would respond. I would play the edited recordings to every cricket for one to five minutes until I could hear a change in the crickets' responses. Each cricket was focused on for one to two minutes when a new response was detected for every recording.

During preliminary observations, I noticed that the species of cricket I was studying had two primary elements in its songs. The more common element, "Element A," averaged at 0.98

seconds in length with 10.32 pulses per call. "Element B" was a shorter, 1-4 pulse call that lasted about 3 seconds (Figure 1). I decided to experiment with these elements to see how the crickets would respond to different patterns by editing the recordings. I made five different edits for the recording to play back to the crickets, which I used as different treatments.

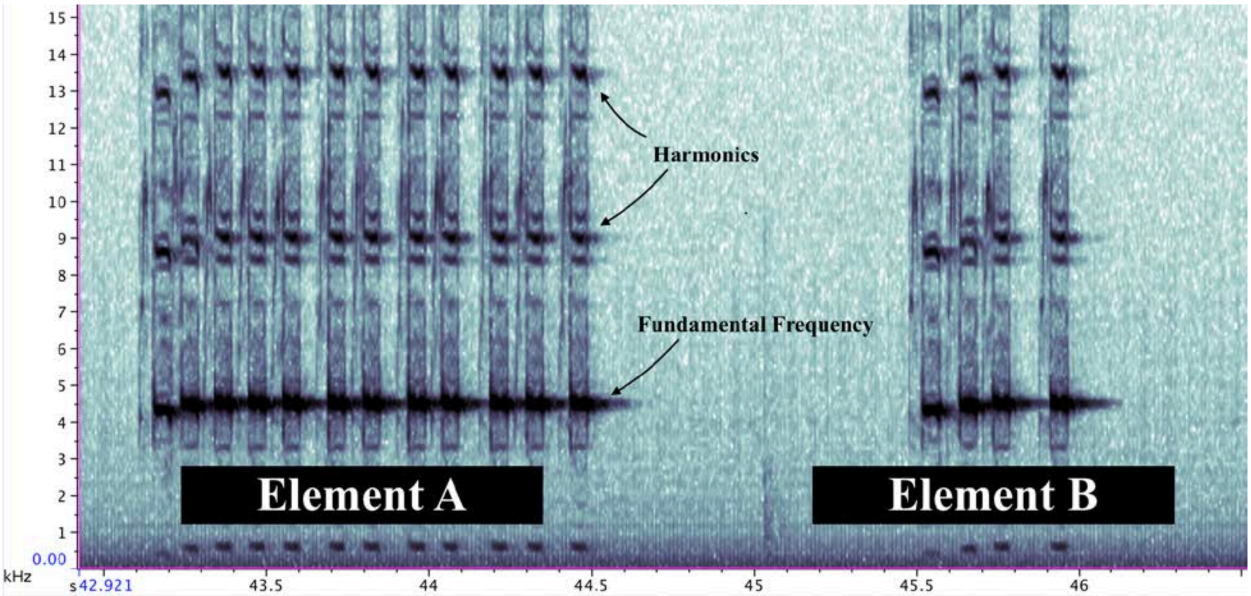

Fig 1. Spectrogram from Raven showing an individual male song of *Anaxipha* sp. This image displays differences in length and composition of song elements A and B.

The first set of treatments dealt with song elements and how song composition could change the test subjects' call patterns. For each test, I aimed the microphone at the test cricket to determine later who was singing in recording analysis. Crickets were easier to identify this way because closer crickets appeared louder in the sound files. For Treatment 1, I only used Element A in the modified recording. I then used a looped recording of a cricket call that alternated between Element A and Element B for Treatment 2. Later in the experiment, for Treatment 3, I modified the recording so that it was only composed of Element B. However, since I released a few of the crickets before this last manipulation, I was only able to get data for six of the nine crickets that sang.

The second set of treatments dealt with temporal patterns in cricket songs. I only used Element A in these treatments to keep the song composition constant. For Treatment 4, I shortened the silent spaces between calls to make the recording sound like the calls were more frequent. This test is labelled as "A Fast," referring to the high frequency of calls in a given amount of time: it is not referring to a manipulation of Element A so that there are more pulses per call. To complement this, I also manipulated the recording to play Element A less frequently. This was Treatment 5 and is labelled as "Slow A."

After recording, files were analyzed in Raven Lite. I looked at the files in 15 or 30 second intervals to analyze the length of calls, element abundance, spacing between calls, number of calls, and number of pulses per call (Figure 2). Intervals were chosen based on consistency of calls within the time recorded, since minor disturbances in the testing environment could silence a cricket for short amounts of time.

RESULTS

Recordings of solo crickets were analyzed first to see how individuals sang without outside influences. I looked at length of calls, timing between calls, number of pulses per call, and number of calls in 30 second intervals. The crickets would develop a pattern and continue to stick with it until disturbed or forcibly stopped. Element A would range from 5 to 14 pulses per call, averaging at 10.32. The length of each call, or "call time" averaged at .98s. The time between calls averaged at 1.69s. (Table 1).

Table 1. Average values with standard deviations for all nine crickets tested. Call time is length of each call from the start of the first pulse to end of last pulse.

	Call Time (s)	# Pulses Per Call	Time Between Calls (s)	Number of Calls in 30 Sec
Average	0.98	10.32	1.69	11.44
STDEV	0.15	1.51	0.19	0.88

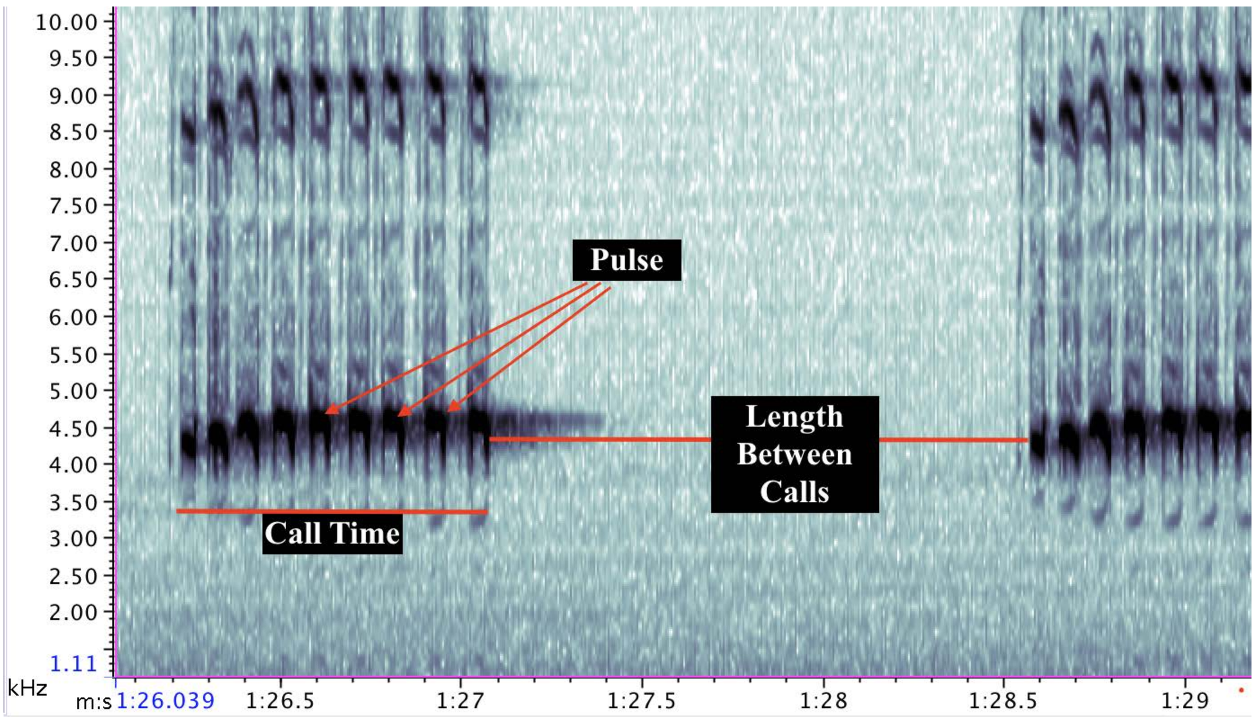

Fig 2. Screenshot of Raven spectrogram showing how recordings were analyzed during data collection. This image only contains Element A.

Of the nine crickets analyzed, all individuals lacked the presence of Element B in their solo songs. Because of this, I looked at the presence of Element B to see if the crickets were changing their calls during the playback experiment. I defined Element B as a call composed of 4 pulses or less. If a cricket used Element B within the 30 second interval I analyzed, I would mark the treatment as a positive for a response to the manipulation. Fig 3. shows the proportion of positive responses for each playback experiment across all crickets tested.

Fig 3. shows that the crickets responded to most of the trials with a change in song composition. Also, Fig 3. shows that the crickets always responded for the AB, B, and A Fast treatments. The treatment with Element A had a significantly lower response rate than the other treatments. Over half of these crickets did not produce Element B in their songs. Also, A Slow had a few trials where the crickets didn't react to the recording.

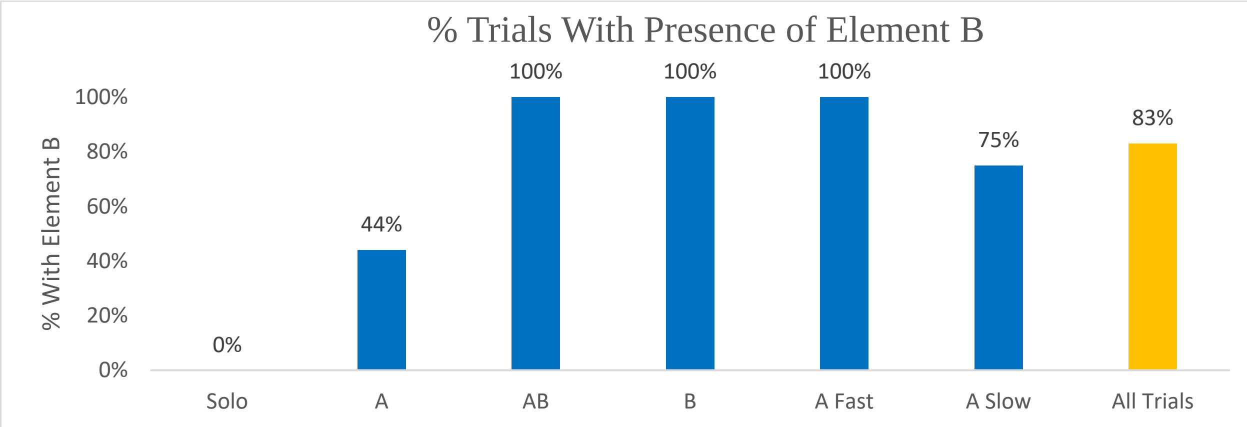

Fig 3. Percentage of the nine cricket responses across each playback treatment. 100% means every cricket used Element B at least once in the 30 seconds of analysis. A, AB, and B refer to elements focused on in the playback experiments. A Fast and A Slow are the temporally manipulated recordings of the experiment. The blue bars represent the 5 treatments. The yellow bar represents all trials. "Solo" is included on this chart to show that Element B was not present in all solo recordings.

After looking at response rate, I analyzed the cricket calls to see how many of Element A and Element B calls were in each treatment. Fig 4. is a graph that compares the average numbers of each element in all treatments, including the solo recordings.

The solo recordings all lacked the presence of Element B as previously stated. Element B was most abundant in Treatment 3 which only played a recording of Element B. This was also the only case where Element B was more abundant than Element A. In Treatment 2: "AB" and Treatment 4: "A Fast", Element B was almost as present as Element A. The crickets often appeared to be alternating between song elements A and B for these treatments. As for Treatment 1: "A" and Treatment 5, "A Slow", Element B was very infrequent and would only appear occasionally.

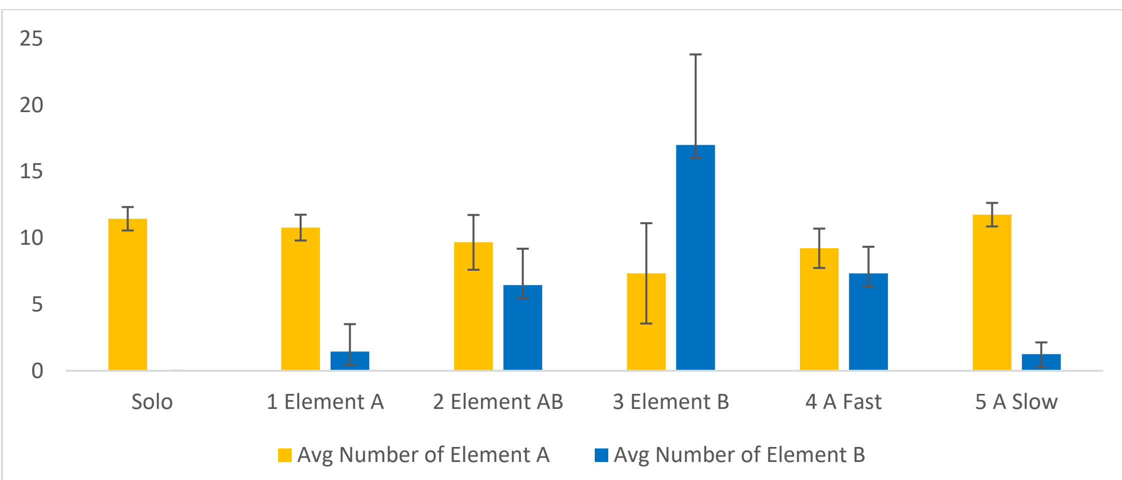

Fig 4. Average numbers of Elements A and B in 30 seconds with standard deviations. Solo data is included to visually compare how crickets sing without other singing males in the area. Numbers on the x-axis 1-5 refer each treatment.

Experiment Results

Each treatment also wielded its own unique responses to what was being played to the crickets. In this paper, due to time limits, I will point out some of the most obvious changes in cricket responses for each trial.

Treatment 1: Element A

In the Element A treatment, crickets responded much less frequently with the presence of Element B. However, the placing of calls is noteworthy. I looked at the proportion of time the crickets spent "leading" by choosing ten calls in each sound file to see if the test subject was calling before the recorded playback. I defined leading as the test subject calling right before the treated recording (Figure 5). Table 2 shows the percentages of calls each cricket spent leading for ten calls during these playback experiments. Results from this analysis show that the crickets spent, on average, more time calling before the recording.

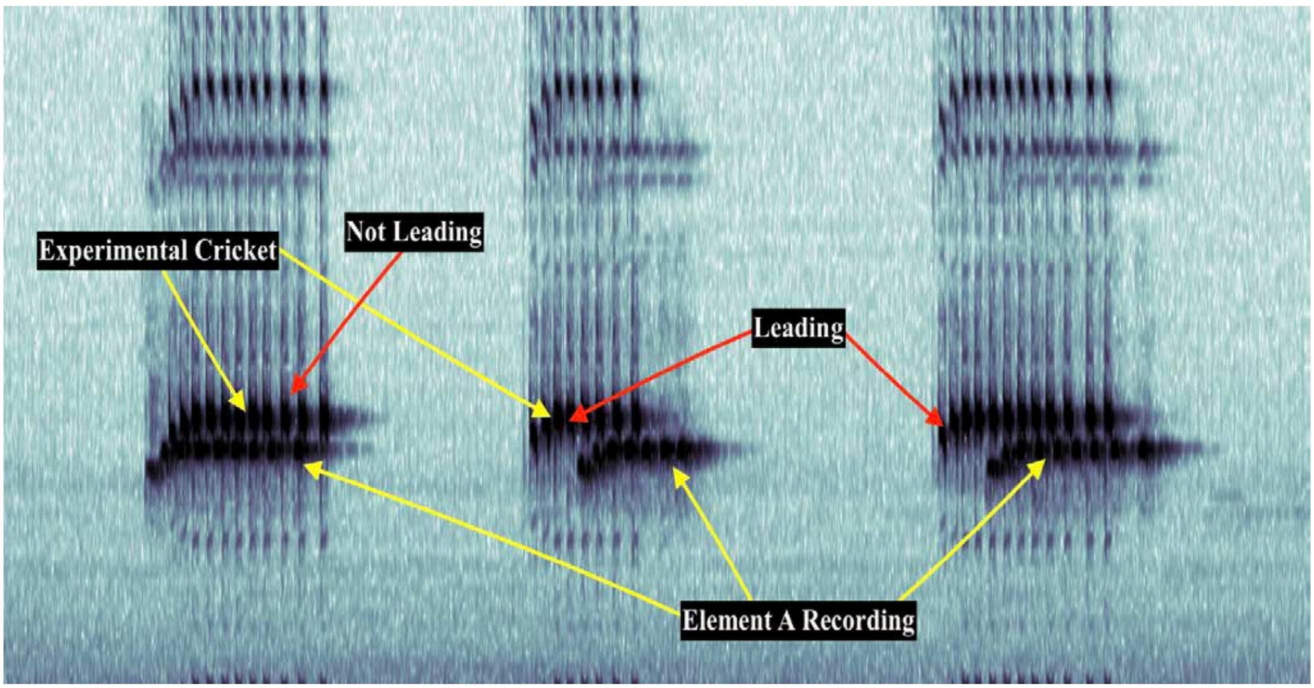

Fig 5. Screenshot of Raven showing analysis of "leading" in Element A treatment. Sound file is from cricket named "Sinatra". The lower frequency lines represent the recording being played to the cricket. Higher frequency lines show Sinatra's response to the recording. Leading is shown in the second two calls. Here, Sinatra is "leading" because it is calling right before the recording.

Table 2. Percentage of calls each cricket spent "leading".

Cricket Name	% Leading in 10 Calls
Popcorn	50%
Jobim	50%
Mugen	100%
Sinatra	80%

Marvin	90%
Droste	70%
Jin	100%
Yancey	80%
Spaven	60%
Average	76%

Treatment 2: Elements A and B

For this part of the experiment, a recording alternating between A and B was played to the crickets. The crickets all responded by including Element B in their calls. All crickets responded with alternating patterns, sometimes skipping B occasionally. However, where the crickets placed their calls was variable. Eight of the nine crickets placed Element B where the recording was placing Element A, and vice versa. (Fig 6 a.) “Popcorn” was the only cricket that placed its elements exactly in synchronicity with the recording. (Fig 6 b.)

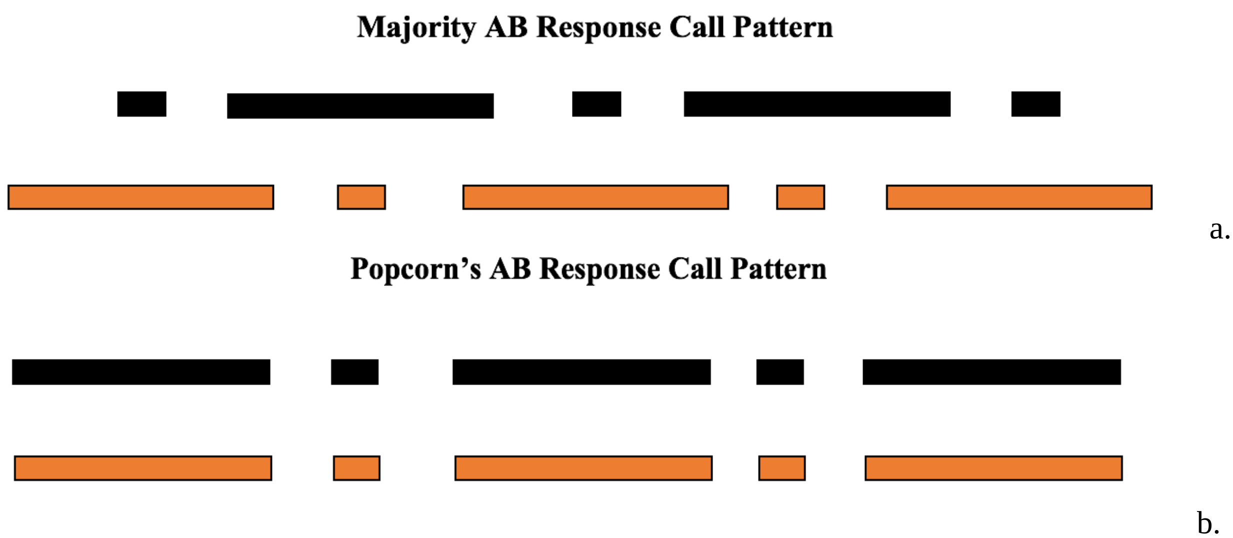

Fig 6. General patterns of element placement in cricket responses. Long dashes represent Element A and short dashes represent Element B. Orange bars represent the recording and black bars represent the cricket’s response.

Treatment 3: Element B

Crickets within this experiment replied with a much quicker pace and used Element B more often. Since the recording was playing Element B every 0.4 seconds, it was surprising to see the crickets respond with similar pacing and brevity. Figure 7 shows one of the cricket’s responses to this playback treatment. Notice the spaces of silence between calls, indicating synchronicity. The image is of both the recording and the cricket, though it can be hard to tell when they are overlapping.

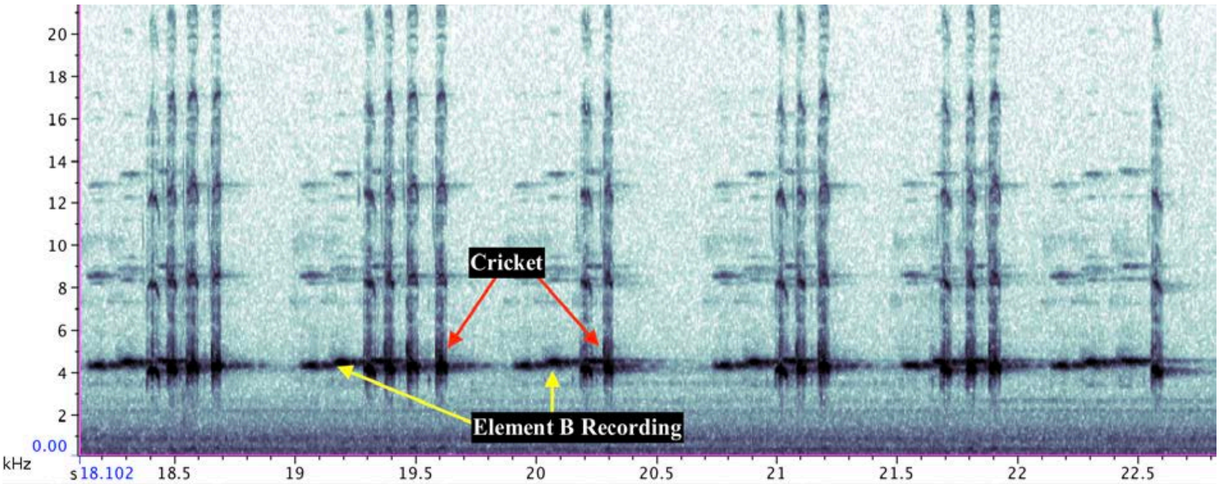

Fig 7. Cricket Response to Element B recording. Sound file is of "Droste".

Figure 7 is one example of how the crickets would respond. Other times, the crickets would use Element A over the course of two Element B's from the recording. The crickets would also stop singing all together for brief periods of time. Most responses contained large amounts of Element B and shorter Element A's. Figure 8 shows how Element A was, on average, shorter for every cricket during these trials.

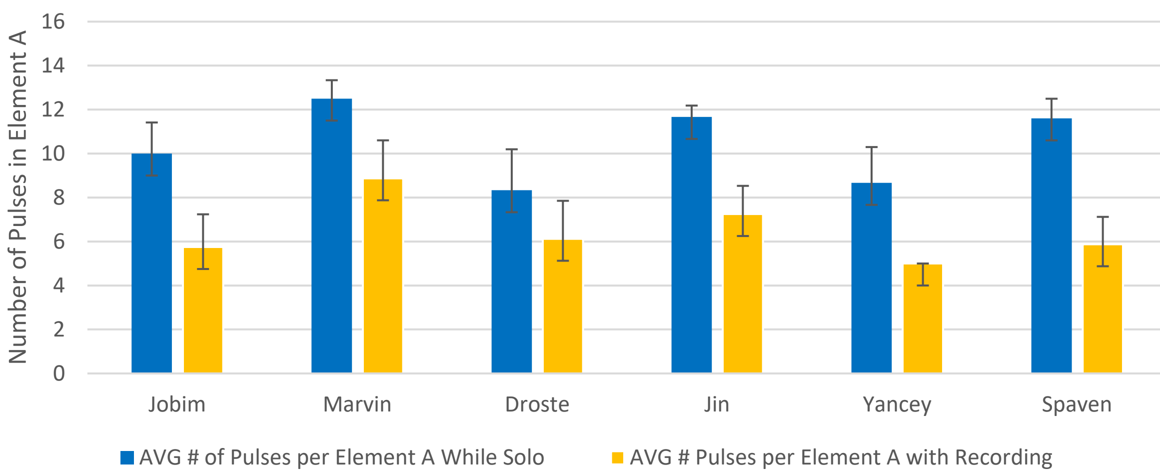

Fig 8. Graph showing differences in average pulse numbers in Element A between sound files of solo crickets and crickets with the Element B recording. Includes standard deviation bars.

Treatment 4, Fast A

The "Fast A" treatment was designed to see if frequency of calls would change the crickets' responses to the recordings. Crickets responded to this treatment in a way that was similar to their responses in the AB manipulation. All trials yielded similar results. The crickets started to alternate between A and B elements, and would sometimes skip B on occasion. Placement of the elements also seemed to be in sync with the recording. The test cricket would place Element B on every other call from the recording, while Element A tended to overlap in unison with the recording (Figure 9).

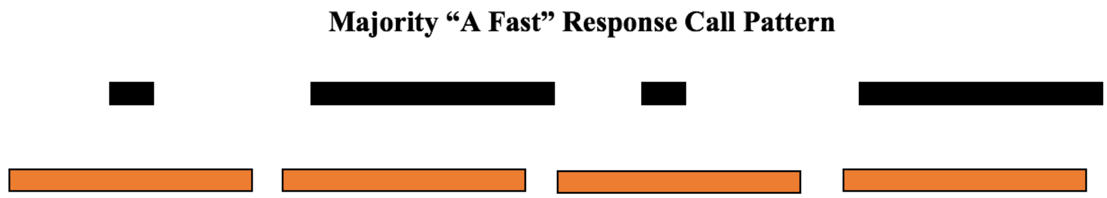

Fig 9. Cricket response to recordings with higher frequencies of Element A. Dashes represent Element A and dots represent Element B. Orange is the recording and black is the cricket's response.

Treatment 5: Slow A

"Slow A" also looked at frequency of calls. The manipulation was designed so that the recording would play Element A every six seconds. The crickets didn't follow an evident pattern for this treatment. They would sing between calls in a fashion similar to when they were solo. However, Element B was present in most of the crickets' responses, indicating some reaction to the playback. The crickets would use Element B very infrequently and seemingly only when the recording was playing. However, sometimes the crickets would also continue singing through recording as if it weren't there. More trials are needed to see if the cricket is sensing itself being "interrupted" by the recording.

DISCUSSION

The fact that most of the crickets responded to almost all the playback experiments shows that this species of cricket is actively listening and responding to its environment. By comparing the responses, it appears that most of the individuals in this species of cricket tries to copy or match the call patterns of neighboring crickets. Also, the Element B part of the cricket songs only appeared when a recording was playing. This could mean it is some sort of communication intended for other males in the area.

Although the crickets in the Element A treatment didn't change their types of calls as often as the other trials, there is still a high possibility that they were listening and responding to the recording. Analyzing who was "leading" provided a little insight into why the males call together. Since the recording was at a constant pace, the crickets had time to get used to the rhythm of calls. They could decide where to place Element A, and most of the time put it right before the recording. This data matches the results in a study on female preference of male katydid calls. Females in that experiment tended to prefer males that would sing a little bit ahead of the chorus. They would even prefer these males over solo males that were separate and off sync (Hartbauer et. al. 2014). The species of crickets I chose to study could have a similar system, and this "lead/follow" data could explain that. However, actual experiments with females choosing males would be a better indicator of this behavior. The leading could also be explained by males finding it easier to pace themselves when they start calling before the recording. More trials are needed to see if that is the case. It would be beneficial to look at leading patterns between two live crickets to see how this system works in the wild.

The AB treatment showed that the alternating pattern was copied by the test crickets. The placing of calls was interesting to look at, however. Placing opposite elements to the recordings seemed to be the most popular response. This could be a way the crickets expend less energy by keeping pace with the rest of the group. In this case, the Element B could be a placeholder to amplify the total sound, without having to make the cricket sing as long. However, the results from the ninth cricket, “Popcorn,” could contradict this thought since it matched the pattern of elements almost perfectly. Perhaps the use of Element B is a way the crickets communicate to keep pace with each other.

The Element B treatment yielded the most changes to song composition. The crickets responded to the recordings with lots of Element B and shortened Element A to keep pace with the quick recording. The shortened Element A responses could indicate the crickets trying to match the recording. Similarly, the high amount of Element B in the responses fits with this thought that these crickets are trying to copy/sing with their neighboring crickets. Also, the entire sound files from this treatment are interesting to look at. Although I only analyzed segments where the crickets were singing for a consistent 15-30 seconds, there were often 10-15 second spaces where the crickets would stop singing all together. The crickets could have been disturbed by a variety of things, however, the consistency of these stops could indicate that this was a direct response to the recording. Perhaps the high frequency of calling required a lot of energy from the crickets. If this is the case, it is interesting to note that the crickets would prefer to expend a lot of energy singing for a short time in sync with their neighbors than a long time out of sync with a pattern like their solo calls. In another experiment, it would be good to test Element B at various frequencies of calling to see how the crickets would respond. Perhaps a slower pacing of Element B would keep the crickets singing for longer periods of time.

The temporally edited treatments also provided some insight for Element B. The Fast A treatment yielded an alternating pattern not unlike the results from the AB treatment. The placement of B in the middle of every other A could be another way the crickets are amplifying the overall sound without having to call as much. Finding B in all the crickets’ responses to this trial means that the crickets don’t need to hear Element B to respond with it.

The Slow A treatment also had a few responses with Element B. However, they were very infrequent, and Element A dominated the responses. The placings of Element B are noteworthy, though. In most of the trials, the crickets responded with Element B only when the recording was playing. This could mean that the cricket sensed the recording was calling and chose to sing a shorter call. If this is the case, the cricket could be choosing to place a shorter call so that it can “hear” who was interrupting it. It also could be that the cricket is placing the short call to disturb the “other cricket’s” rhythm so that the recording isn’t “leading”. This placement of B could also be the cricket sensing an opportunity to use less energy while still producing an amplified sound. More trials are needed with this part of the experiment; perhaps with different frequencies of A to see what speeds are necessary for test crickets to detect a rhythm.

It is still uncertain why this species of cricket chooses to sing in unison. The results from this experiment point to a few possible causes such as energy efficiency, and mate preference. However, more experiments are needed to gain a better understanding of this system. Also, there were several possible causes of error that could have skewed the results. The room used for experiments wasn’t entirely soundproofed, and a few times crickets of the same species were audible from outside. Temperature and light also tend to have effects on some Orthoptera calling patterns (Dolbear 1897). I was unable to keep these factors constant throughout the course of the experiment. Also, many of these recordings were done at different times of the night, creating another possible cause of variation in responses. Other factors like room acoustics, auditory disturbances, and individual variation between crickets could have skewed the results.

Understanding this acoustic cricket system could be a useful tool in learning about animal communication and possibly lekking behaviors, especially within Orthoptera and other insects. Results from this experiment show that these male crickets are listening and responding to each other. In some cases, it appeared that the crickets were even copying the calls of crickets around them. This provides insight into the synchronous calls of the *Anaxipha* sp. cricket. However, there is still a lot of research that needs to be done to fully explain the synchronized singing and purposes of both elements.

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LITERATURE CITED

Buck J, Buck E. 1966 Biology of synchronous flashing of fireflies. Nature 211, 562–564.

Moiseff A, Copeland J. 2010 Firefly synchrony: a behavioral strategy to minimize visual clutter

Hartbauer M, Haitzinger L, Kainz M, Römer H. 2014 Competition and cooperation in a synchronous bushcricket chorus. Royal Society Open Science

Borror D, Triplehorn C, Johnson N. 1989 An Introduction to the Study of Insects. Sixth Edition

Hanson P, Nishida K. 2016 Insects and Other Arthropods of Tropical America

Dolbear, Amos 1897. The Cricket as a Thermometer. *The American Naturalist*. **31**: 970–971.

The Editors of Encyclopædia Britannica. 21 March 2016 "Lek." *Encyclopædia Britannica*, Encyclopædia Britannica, Inc.