Sound Production in Mole Crickets (Orthoptera: Gryllotalpidae: *Scapteriscus*)[1,2,3]

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ABSTRACT

Males of the southern mole cricket, *Scapteriscus acletus* Rehn and Hebard, and the changa, *S. vicinus* Scudder produce calling songs after sunset for 1.0–1.5 h in specially constructed subsurface chambers. Calling songs of 70 *acletus* and 62 *vicinus* were tape recorded in the field at temperatures (soil and air) ranging from 18–32°C. The mean carrier frequency, pulse rate, and intensity (Sound Pressure Level; SPL) of *acletus* calling songs were 2.6 kHz, 55 pulses/sec (p/s), and 69 dB (at 15 cm, Reference SPL; 2×10^{-5} N m^{-2}) and of *vicinus* were 3.2 kHz, 136 p/s, and 65 dB respectively. Regression analysis of the weather factors (viz., soil and air temperatures, relative humidity and rain) on the different parameters of calling songs revealed that the pulse rates of *acletus* and *vicinus* are functions of soil temperature. Males of *acletus* and *vicinus* produce aggressive and courtship songs similar to calling songs with respect to carrier frequency and pulse rate. Sound production by females of *Scapteriscus* species had never been reported, but ♀ *vicinus* made sounds with energy at frequencies varying from 2–6 kHz. Courtship of *vicinus* included producing long and short intermittent trills and tapping the soil with the forelegs.

Mole crickets are important pests in turf and agricultural crops around the world. While studying the behavioral biology of 2 species of mole crickets, *Scapteriscus acletus* Rehn and Hebard, and *S. vicinus* Scudder (Ulagaraj 1975 a–c, Ulagaraj and Walker 1973, 1975), mole cricket sound was suggested as a means of control.[6] Earlier, Ulagaraj and Walker (1973) discovered that large numbers of mole crickets can be attracted to loudspeakers broadcasting natural or synthetic calling songs outdoors. Significantly more mole crickets were attracted to broadcast sound than to UV or fluroescent light traps.[7] Furthermore knowledge on the sound production of different species of mole crickets could be useful in detecting the presence of a particular species in agricultural fields. For instance, the number of singing males in a given area could be surveyed during favorable nights by hearing the calling songs.[8] Therefore, knowledge of the acoustical behavior of mole crickets is important for future investigations.

Sound production has been reviewed (Alexander 1967, Bennet-Clark 1971, Nickle and Carlysle 1975, Otte 1974), and excellent books are available on this subject (Busnel 1963, Sales and Pye 1974).

Here I describe sound production of 2 species of mole crickets, *S. acletus* and *S. vicinus*.

METHODS

All observations were made outdoors near Gainesville, FL, during 1972–74. Mole cricket songs were recorded with a Kudelski Nagra III portable tape recorder and Electro-Voice® Model 655C microphone, mounted on a camera tripod and directed downward 15–20 cm above the entrance of the mole cricket burrow. Seventy calling songs of *S. acletus* and 62 calling songs of *S. vicinus* were tape recorded in the field. These recordings were from different males in each instance. The following weather factors were recorded after each tape recording: soil temp, air temp, RH, light intensity, and rain. These weather measurements (except soil temp) were similar to those of Ulagaraj (1975a). The soil temp was measured with a calibrated mercury thermometer as close (>15 cm) to the entrance of the ♂ burrow as possible, and the mercury bulb was inserted 3–5 cm deep in the soil. I examined the features of mole cricket calling songs in 2 ways: the intensity of the calling song was measured in the field, 15 cm above the burrow entrance, using a sound level meter (General Radio Model No. 1551-B, Weighing scale-A., Reference intensity: 2×10^{-5} N m^{-2}). I determined carrier frequency and pulse rate from the tape recordings with a Kay Electric Co.® Sonograph.

To determine the starting time of the calling songs, I recorded the time of the 1st calling songs of *acletus* and *vicinus*. I observed the starting times of *acletus* singing for 17 days and of *vicinus* singing for 25 days. If the 1st calling song was not followed by 2 other calling songs of the same species within 5

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[1] A part of Ph.D. dissertation submitted to the Graduate School, Univ. of Florida, Gainesville, during August 1974. A part of this paper was presented to the 55th annual meeting of the Florida Entomological Society at Tampa and won the 1st prize in a Graduate Students Contest. Paper received for publication Oct. 15, 1974.

[2] Dr. T. J. Walker pointed out to me that little is known about mole crickets, and his knowledge on insect biology, especially bio-acoustics stimulated me to do research on mole crickets. I thank him for his help throughout this research and for critcizing this manuscript. Appreciation is expressed to Dr. W. G. Eden and Dr. R. I. Sailer for their interest in mole cricket research. I thank Drs. J. E. Lloyd and D. H. Habeck for their encouragement, and Drs. D. K. McE. Kevan and V. R. Vickery (McGill Univ.) for criticisms on the manuscript. Finally I thank Miss N. Brown and Mrs. Ulagaraj for the typescript.

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[6] Ulagaraj, S. M. 1974. Mole crickets: Ecology, behavior and acoustical communication (Orthoptera: Gryllotalpidae: *Scapteriscus*). Ph.D. Dissertation, Univ. of Florida, 72 pp. (Xerox, University Microfilms, Ann Arbor, Mich.). He discussed 3 drawbacks in using mole cricket sound as control.

[7] For instance, during 7 days of trapping the number of *scapteriscus acletus* ($\bar{x}\pm$SD$=52\pm17$, Range 29–71) trapped nightly inside a single sound trap at broadcast sound (2.7 kHz, 55 pulses/sec and 100 dB at 15 cm) was 17 times larger than the number of *acletus* ($\bar{x}\pm$SD$=3\pm2$, Range=0–25) captured nightly in a single UV light trap.

[8] As an exception, the short-winged mole cricket, *Scapteriscus abbreviatus* Scudder that occurs in southern Florida, does not produce calling songs. However, the adult males produce courtship sounds.

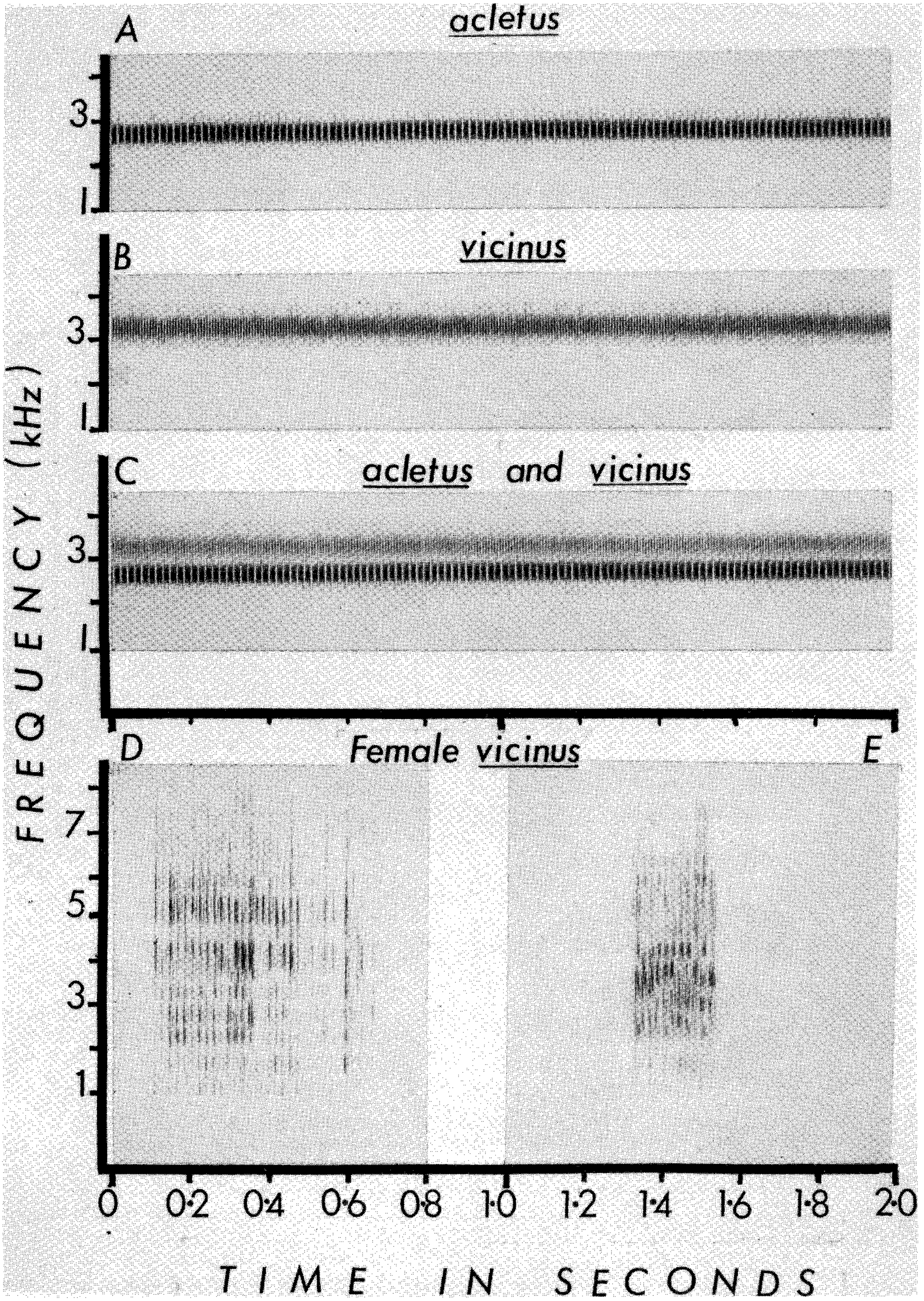

FIG. 1.—Audiospectrograms of ♂ and ♀ songs of *Scapteriscus* species—(A) calling song of *S. acletus* at 25°C soil temp; (B) calling song of *S. vicinus* at 25° soil temp; (C) calling song of *S. acletus* and *S. vicinus* at 25° soil temp; (D, E) ♀ sounds of *S. vicinus* at 26°C air temp.

min, I discarded the previously noted (starting) time.

Castings of borrows of singing males were made with mixture of 60 g of Carter's household cement and 100 ml of acetone. I observed the courtship through the bottom of a transparent plastic box with 3 cm of moist soil. Courship occurred in the burrows constructed in the soil. These burrows were visible through the bottom of the plastic box. A male and marked (virgin) female were confined in each box. During observations, the position of the virgin female with reference to the male could be identified by the marking on the female. I noted the behavior of *vicinus* once, for 2 h, and of *acletus* 3 times, each of 15 min duration.

To learn if soil moisture influences the production of ♂ calling songs, 4 plots (70 m^2) were marked in an unirrigated tobacco field on 21 May 1973. I irrigated 2 of these plots with overhead sprinklers for ½ h during that night, and left the other 2 plots unirrigated. There was no rain during the period of the experiment. After 24 h, I counted the number of singing adults in all 4 plots.

The effect of weather factors on the different parameters of ♂ calling songs in *acletus* and *vicinus* was examined by using the method of least squares for fitting a multiple regression model (Draper and Smith 1966) based on a straight line equation $y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3$ where y = estimated or predicted value of a parameter of calling song (viz., intensity, carrier frequency or pulse rate), b_0 = constant, b_1, b_2, b_3 = the estimate or measure of the strength on the effect of x_1, x_2, x_3 on the response of y; x_1, x_2, x_3 = the independent variable (i.e., weather factors: soil temp, air temp, and RH).

All the tape recordings of *acletus* and *vicinus* are deposited in the Tape Library of the University of Florida Entomology Department.

RESULTS

(1) *Method of Sound Production.*—Sound production in crickets is by tegminal stridulation (Alexander 1967, Walker and Carlysle 1975). It is difficult to make observations of singing mole crickets because they are in the soil, but it appears that the method of sound production by *S. acletus* and *S. vicinus* is similar to that of other crickets. On 1 occasion I observed a ♂ *vicinus* producing the calling songs in a plastic box without any soil. The rapidly moving wings were raised about 15–20° above the thorax. The left wing was over the right wing (unlike the position reported for other crickets).

(2) *Male Calling Songs.*—(a) Features of Male Calling Songs.—The ♂ calling songs of mole crickets can be identified by the nature of their trills, (Fig. 1). For instance, *acletus* and *vicinus* have bell-like trills. In *acletus,* the trills are often uninterrupted for a minute or more, whereas in *vicinus* brief pauses (usually less than a second) occur several times each minute. The males of *acletus* and *vicinus* produce their calling songs nearly continuously for 1.0–1.5 h in the absence of other members of the same species.

Three parameters of ♂ calling songs of *acletus* and *vicinus* are presented in Table 1. The distribution of carrier frequencies of the calling songs of *acletus* and *vicinus* is shown in Fig. 2B. The modal frequencies of *acletus* and *vicinus* were 2.7 kHz and 3.2 kHz respectively (Fig. 2B). The pulse rates of *acletus* and *vicinus* are dramatically different in their calling songs (Fig. 2A and 1A-C).

(b) Habitat and Time of Singing.—The calling songs were heard near the borders of ponds and lakes, on the sides of streams, road sides, fields and lawns. The songs of *vicinus* were heard mostly in lawns, pastures, and annually tilled fields. With some exceptions,[9] *acletus* and *vicinus* begin their calling after sunset. For instance, *acletus* sang 27 min (n = 17 days, SD = 8, and Range 11–45 min) after sunset, whereas *vicinus*[9] started its singing 15 min (n = 25 days, SD = 7, and Range 17–31 min) after sunset. In most cases, the light intensity was less than 65 lx when calling songs started. During and after rain, I herad the calling songs of *acletus* and *vicinus* at all times of night.

(c) Special Burrows for Sound Production.—Like the European (*Gryllotalpa gryllotalpa*) and French (*G. vineae*) mole crickets, *S. acletus* and *S. vicinus* produce their calling songs in burrows specially constructed for singing. I have examined more than 15 of the subsurface burrows of *acletus* and *vicinus.* The 2 species have similar singing burrows. Each has a bulb (1 × b × h: 2.5×1.0×2.0 cm singing chamber) 3–5 cm below the soil. This bulb has 3 openings; a narrow passage opening at the ground surface and 2 side tunnels connecting to other burrows.

[9] On March 31, and June 6, 1973, *vicinus* sang 17 and 2 min before sunset.

Table 1.—Characters of ♂ calling songs in *Scapteriscus* species.

Parameter of calling song	*S. acletus*					*S. vicinus*				
	n	$\bar{X}$	±	SD	Range	n	$\bar{X}$	±	SD	Range
Intensity (db)[a]	52	68.5	±	12.8	42–106	40	65.4	±	6.00	53–74
Carrier frequency (kHz)	70	2.62	±	0.14	2.4–3.0	62	3.20	±	0.38	2.8–3.6
Pulse rate (pulses/sec)	70	54.7	±	4.6	40–60	62	135.9	±	23.20	105–168

[a] Sound Pressure Level (SPL); Reference SPL=2×10^{-5} N m^{-2}; Measured 15 cm from the entrance of the male burrow.
n=total number of calling songs examined for the parameter at 18–32°C. Each calling song was from a different individual.

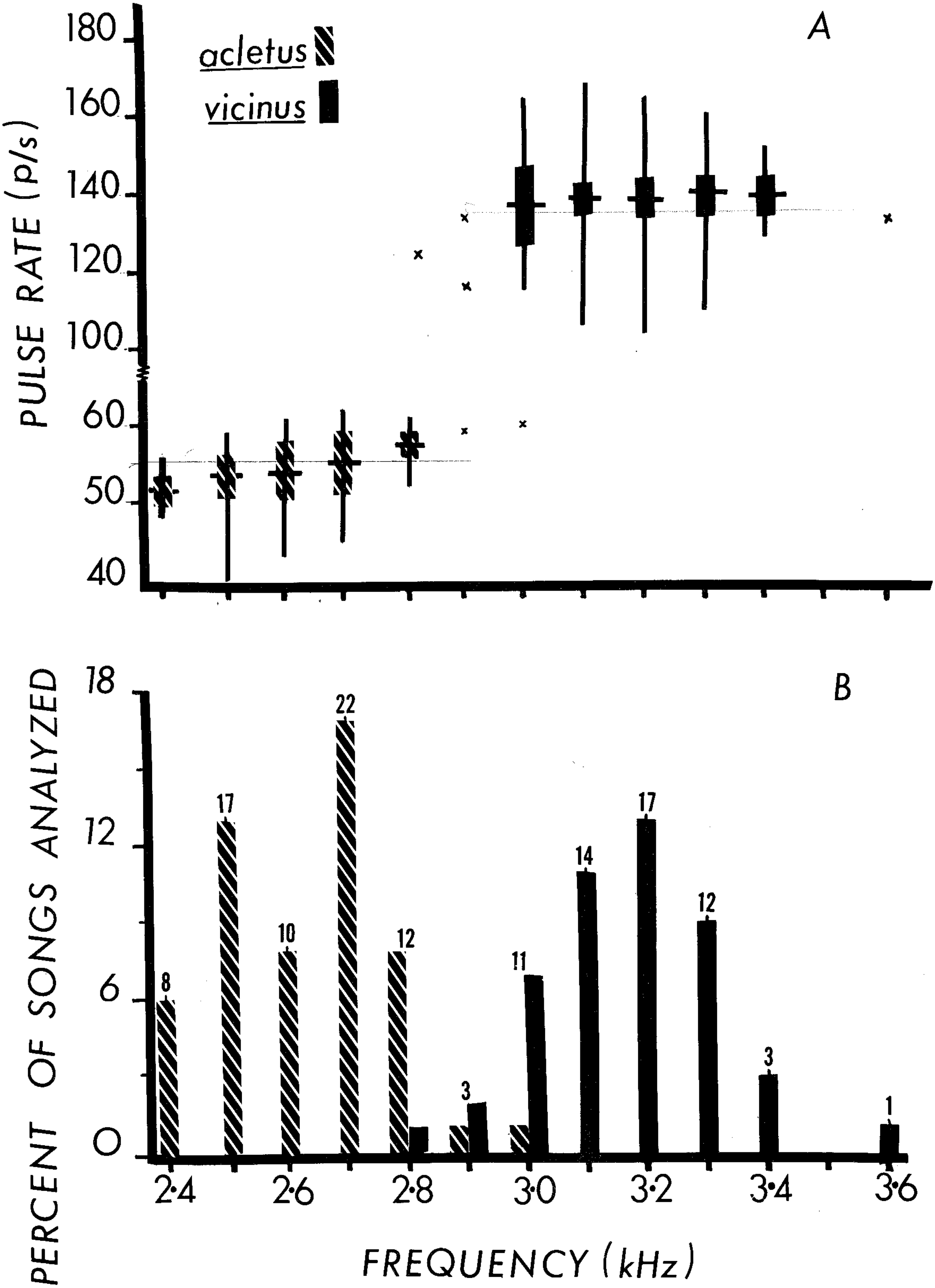

FIG. 2.—(A) The relation of pulse rate to carrier frequency in *S. acletus* and *S. vicinus* ♂ calling songs, p/s= pulses/sec. The vertical line is the range in pulse rate, the broader portion of the line is 2 SE on either side of the mean. (B) The carrier frequency of *S. acletus* and *S. vicinus* songs. The number above the bars indicate the actual number of songs having that particular frequency. The height is the number of songs expressed as a percent of the total songs of that species examined for carrier frequency. Each song was recorded from a different male.

The narrow passage (1 cm diam) that leads to the surface opening (entrance) from the bulb was 5–7 cm long and has an angle of 30–45° to the ground level.

(d) Acoustical Behavior.—Before singing, males of *acletus* and *vicinus* open an entrance to their burrows. They smooth the entrance, the narrow passage, and singing bulb with their tibial dactyls. After working on the narrow passage to the entrance, they back into the burrow, turn around and start singing, with the abdomen towards the entrance. Males start their songs with short trills of 2–3 seconds. Sometimes they stop singing, turn around and return to smoothing the narrow passage to the entrance. Of 10 caged *acletus* that were observed outdoors, 4 closed the entrance after singing and 3 of these opened entrances in new positions on the following evening.

(e) Effect of Weather on the Production of Calling Songs.—I never heard the calling songs of *acletus* and *vicinus* below 18°C (air and soil) in the field or the laboratory. In addition to soil temp, soil moisture influenced the production of calling songs of *acletus* and *vicinus*. In the irrigation experiment on May 21, 1973, 2 *acletus* and 15 *vicinus* were singing in the 2 irrigated plots and none in the unirrigated.

Regression analysis of the effect of weather factors on the different parameters of ♂ calling songs revealed no correlation between temperatures (soil and air) or RH and intensity or carrier frequencies of the calling songs of either *acletus* or *vicinus* ($P = 0.05$). Similarly, I found no significant correlation between pulse rate and air temp (at 1.5 m) or RH ($P = 0.05$). But pulse raes of *acletus* and *vicinus* are functions of soil temp (Fig. 3).

(f) Functions of Male Calling Songs.—Generally crickets and katydids, the calling songs of males attract the sexually responsive females (Alexander 1967). The calling songs of *acletus* and *vicinus* attract the flying females. On 3 occasions I observed flying females of *acletus* and *vicinus* landing and entering burrows of calling conspecific males. Ulagaraj (1975a) gave evidence for additional role of calling songs in *acletus* and *vicinus*—flying adults use the calling songs as a sign of habitat suitable for colonization.

(3) *Aggressive Song*.—In addition to the calling songs, males of *acletus* and *vicinus* produce 2 other kinds of songs—aggressive songs and courtship songs (Fig. 4). The aggressive song is produced in the presence of another male. When a male confronts another male, short trills are produced intermittently. Twice I observed aggressive singing of *vicinus* in a

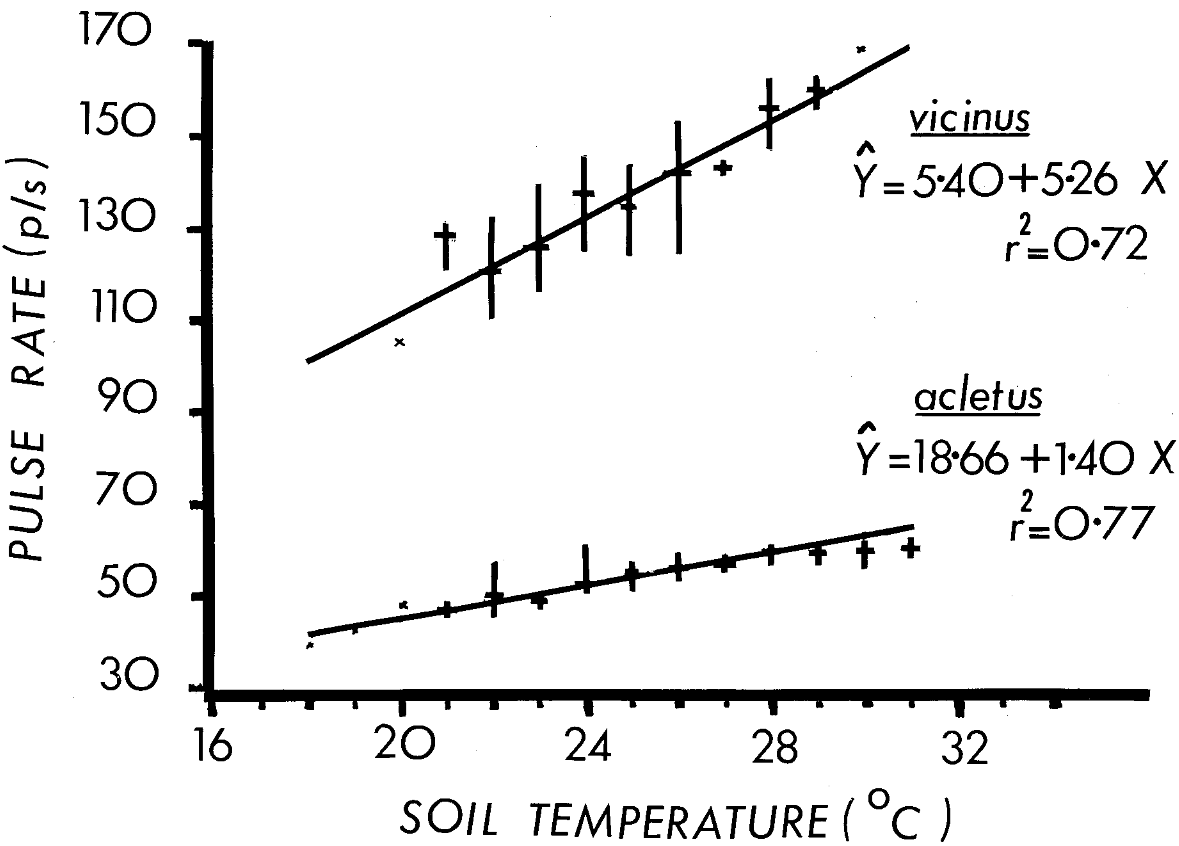

FIG. 3.—The effect of soil temp on the pulse rate of 70 *S. acletus* calling songs and 62 *S. vicinus* calling songs. The regression lines are calculated on all individual values. The vertical lines show the range on each side of mean, p/s=pulse/sec. Each calling song was recorded from a different individual.

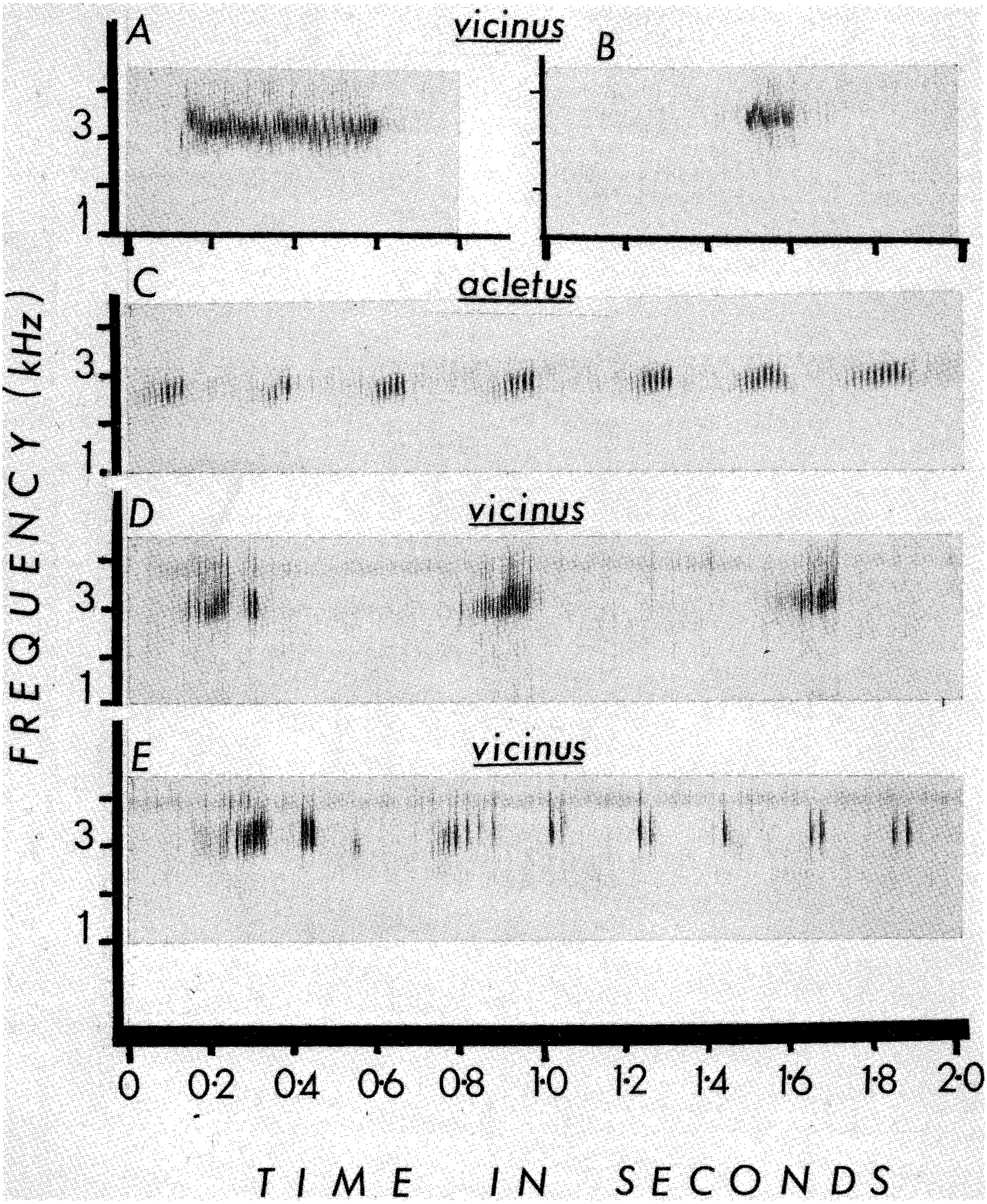

FIG. 4.—Audiospectrograms of aggressive and courtship songs of *Scapteriscus* species. The soil temp is given for each song. *S. vicinus* male produced long (A) or short (B) trills in the presence of another (*vicinus* or *acletus*) male (24°C). (C) Courtship sounds of ♂ *S. acletus* (27°C). (D, E) Courtship sounds of ♂ *S. vicinus* (25°C).

plastic box. The wings were raised 15–20° above the thorax (as in calling) and contrary to my observation of the calling song, the right wing was above the left wing. After the short trills, the males pushed each other with their tibial dactyls. I could detect no differences in the aggressive songs of a captive *vicinus* in the presence of a single ♂ *acletus* or a single ♂ *vicinus* (Fig. 4A, B).

(4) *Courtship Songs.*—Males of *acletus* and *vicinus* make characteristic courtship songs in the presence of conspecific females. A single male in the presence of a single female produces a courtship song intermittently from 15 min to 3 days. I heard courtship songs of *acletus* in the field at all times of day (Fig. 4C). The courtship songs of *acletus* and *vicinus* are rhythmic sequences of short trills, produced intermittently. The carrier frequencies and pulse rates of these songs are similar to calling. The courtship song of *vicinus* has 2 phases, a beginning phase of a long sequence of trills (Fig. 4D), followed by a sequence of short trills (Fig. 4E), and tapping of the soil with forelegs on the soil.

On 3 occasions outdoors, I observed a calling male stop its continuous (calling) song and produce courtship songs 5–30 sec after a female entered its singing burrow. In the laboratory, the males of *acletus* and *vicinus* produce their courtship song tail-to-tail with the female (in a linear burrow). In the case of confined *vicinus,* the males turn around prior to tapping the soil with the fore tibia. Rate of tapping varied from 7–13 taps/second. Mating in *scapteriscus* species has never been reported and I did not observe it.

(5) *Female Sound Production.*—In addition to the ♂ songs (calling, aggressive, and courting), I noticed females of *vicinus* producing short bursts of sound (Fig. 1D, E), audible to a distance of 2 m. On 8 March 1974, I collected 20 ♀ of *vicinus* while broadcasting sound (Ulagaraj 1975a) and kept them in a plastic box, with 6 cm of soil covered with 2 moist paper towels. During the same night, I heard dull short bursts of sounds from the plastic box. I saw 2 ♀ *vicinus* facing each other on the surface of the paper towel. One of the females raised its wings. During the lateral reciprocation of the wings (same as in calling males), the female produced a dull sound. The ♀ sound has substantial energy at frequencies varying from 2–6 kKz and its pulse rates varied from 54–57 pulses/sec (p/s) compared to 135 p/s (at 25°C) in ♂ calling. The pulses are in groups of short duration as in courtship.

DISCUSSION

The calling songs of *S. acletus* and *S. vicinus* differ distinctively in their carrier frequencies and pulse rates (Fig. 1–3, Table 1). Such distinctive features have been used in detecting new species of mole crickets in the field. For instance, Bennet-Clark (1970a) described a new species of French mole cricket, *G. vineae,* and reported that its calling song differed from that of the European mole cricket, *G. gryllotalpa.* The calling songs of *G. gryllotalpa* was "a quiet dull jarring rumble," with a carrier frequency of 1.5 kHz, while the song of *G. vineae* was "a loud piercing ringing, like an electric bell" with a carrier frequency of 3.5 kHz. Similarly, Nevo and Blondheim (1972) reported that 2 chromosomal forms of *"G. gryllotalpa"* from Israel have distinctive calling songs, one with long trills and the other with chirps.

The distinctive parameters of *acletus* and *vicinus* calling songs were also important in species-specific phototaxis.[10] For instance, Ulagaraj and Walker (1975) discovered that the flying *acletus* could be attracted in greatest numbers, when they broadcast, at unnaturally high intensities, carrier frequencies and pulse rates like those of natural song. Furthermore, the calling songs of *acletus* and *vicinus* were used by the flying adults for habitat selection. Recently (1975a), Ulagaraj gave experimental evidence to show that flying adults use sexual signaling of males of their species as an indication of a habitat suitable for colonization. Earlier, Ulagaraj and Walker (1973) had suggested that those individuals flying toward the sound as a habitat-indicating signal and those flying toward it as a male-indicating signal should end their flight differently. They therefore predicted that those mole crickets landing within the sound trap would include a significantly smaller proportion of males than those landing outside the trap. When the sex ratio of *acletus* that had landed inside and outside the sound trap was compared for 23 days (n = 4314), Ulagaraj (1975a) found that the percentage of males trapped outside the sound trap was always higher than the percentage of males trapped inside the sound trap.

Unlike the French and European mole crickets, *acletus* and *vicinus* have single entrances for their subsurface burrows. Bennet-Clark (1970a, b) discovered that the singing males of both *G. gryllotalpa* and *G. vineae* had horn-shaped burrows with 2 entrances, furthermore he reported the shape of these burrows enhanced the sound propagation. Similar to what has been observed for *acletus* and *vicinus,* Ghosh (1912) has observed the acoustical behavior of big brown cricket, *Brachytrupes portentosus* Lichtenstein[11] in India during August and September. He reported that "the (male) cricket comes up from its underground burrow, sits just at the opening with the head turned towards the hole and the body away from it and then pours forth its song." The tegmina were raised up from the body, forming an angle of about 60°.

Since mole crickets, unlike katydids and most other crickets (Walker 1975), sing from the soil, the effect of soil temp on calling songs can be understood (Fig. 3). But, the effect of weather factors on a few parameters of male calling songs is not fully understood. For instance, in 5 species of crickets (representing 3 genera and 3 subfamilies), the carrier frequency was a (regression) function of air temp at least at low and moderate temp (10–25°C) (Walker 1962). But in *acletus,* there is no significant correla-

[10] Very recently (Cade, W. 1975. Science 190: 1312), Dr. T. J. Walker and Mr. J. Mangold have discovered that a tachnid fly, *Euphasiopteryx ochracea* is attracted to the tape-recorded songs of *S. acletus* and they were also able to raise the adult flies from artificially infested *S. acletus* and *Gryllus rubens* males in Florida. Such acoustically orienting parasites and also crickets, other than mole crickets (Ulagaraj and Walker 1973), use the ♂ calling songs of mole crickets.

[11] These crickets (Gryllidae: Orthoptera) were used as human food at Burma. They were sold as *"Payit-Kyaw"* (literally, fried cricket) in markets. Chopard (1968) lists *Brachytrypes achatinus* Stoll as a synonym of *Brachytrupes portentosus* L.

tion (P = 0.05) between pulse rate and frequency (Fig. 2A).[12] Besides weather, genetic factors affect the ♂ calling songs in crickets (Walker, 1962).

Sound production among ♀ crickets is an unusual phenomenon (Nickle and Carlysle 1975). In *vicinus* females, the carrier frequencies were as high as 6 kHz as compared to a maximum of 3.6 kHz in ♂ calling songs. Similar ♀ sounds have been observed on different species of mole crickets (Petrunkewitsch and von Giuaita 1901, Baumgartner 1905, 1910, Tindale 1928, Zhantiev and Korsunovskaya 1973), but none of these authors (except Zhantiev and Korsunovskaya) has commented upon their biological significance. Zhantiev and Korsunovskaya (1973) have stated that the function of ♀ sounds was "territorial and threatening". These ♀ sounds (including those of *vicinus*) are probably in the nature of aggressive behavior.

[12] Even though there is no significant correlation between pulse rate and frequency (Fig. 2A), the mean pulse rate at the lowest frequency (2.4 kHz) is significantly lower than the mean pulse rate at 2.8 kHz.

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