Mole Crickets: Ecology, Behavior, and Dispersal Flight (Orthoptera: Gryllotalpidae: *Scapteriscus*)[1,2,3]

S. M. ULAGARAJ[6]

Department of Entomology and Nematology, University of Florida, Gainesville 32611

ABSTRACT

The southern mole cricket, *Scapteriscus acletus* Rehn and Hebard, and the changa, *S. vicinus* Scudder, are pests of turf and agricultural crops in the southeastern United States. Both species fly during spring and fall in Gainesville, Fla. The numbers of flying *acletus* and *vicinus* were monitored each night during those seasons (1972–73). Monitoring was done by (1) attracting the flying adults of these 2 species to loudspeakers broadcasting tape recordings of natural and synthetic mole cricket calling songs and (2) collecting flying adults to UV and fluorescent lights. About 28 times more mole crickets were collected during the spring flight than during the fall flight. Spring collections were 55% *acletus* ($n = 5675$) and fall collections were 16% *acletus* ($n = 199$). During 1972 and 1973, females comprised 83% of those collected of both *acletus* ($n = 9161$) and *vicinus* ($n = 7521$). The percent of females that had mated increased as flight season progressed. The flight started soon after sunset and continued for an hour. Of 1844 adult *acletus* marked and released 35 were recaptured on subsequent nights, proving that at least 2% of adults fly more than once. Three adults were recaptured twice. Recaptures were made up to 6.5 wk and at distances as great as 0.7 km. *S. acletus* flight speed was estimated at 7–11 km/h. Flights of *acletus* and *vicinus* did not occur below 18°C (air and soil) temperature.

Mole crickets are subterranean insects and are important pests attacking a variety of crops, lawns, and pastures. Chopard (1968) listed 5 genera and 47 species in the family Gryllotalpidae. Although research on the control of mole crickets has been carried on for the last 7 decades, mole cricket problems have continued. The lack of real progress may be due to the lack of basic information on mole cricket biology—especially behavior and ecology. Chopard (1968) has surveyed the literature on mole crickets. Barrett (1902) reported that *Scapteriscus vicinus* Scudder in Puerto Rico was observed in flight from 7 to 10 PM, in addition to twilight hours. Beck and Skinner (1967) collected *S. acletus* Rehn and Hebard and *vicinus* at light traps in Tifton, Ga., from 1 April to 31 Oct. 1966. They trapped 99 *acletus* and 70 *vicinus* and 2 *Neocurtilla hexadactyla* Perty. During the first half of the trapping period their collections were 92% *vicinus* and in the last half they were 85% *acletus*. Hayslip (1943) found that *acletus* and *vicinus* flight occurred shortly after dark and lasted about an hour. He stated that *acletus* and *vicinus* flew in spring and fall and that *acletus* was predominant in fall. Migratory flight in insects (Dingle 1972) and thermoregulation of insects (Heinrich 1974) have been recently reviewed. This paper reports on the ecology, behavior, and dispersal flights of 2 species of mole crickets: the southern mole cricket, *S. acletus*, and the changa, *S. vicinus*.

Materials and Methods

The experiments were conducted on a lighted golf course (State Highway No. 26, 16 km west of Gainesville, Fla.) in 1972 and on an unlighted field (Green Acre Farm, University of Florida, State Highway No. 241, 19 km northwest of Gainesville) in 1973 and 1974. The observations on mole cricket flight were made daily, except on rainy or cold days (air <18°C) from 10 April to 31 July 1972, and from 22 Feb. to 31 July 1973. I went to the field from 1 Nov. 1972 to 1 Feb. 1973 on those nights when the air temperature exceeded 20°C. The following weather factors were recorded at sunset time: soil temperature, air temperature, light intensity, and rain. Soil temperature was taken 3–5 cm deep at 4–6 places in the field. The air temperature was recorded 1.5 m above the ground. A light meter (Photovolt Corp. Model No. 200) with the sensor aimed directly upward measured the light intensity. Each evening the presence or absence of rain was recorded by means of a specially constructed mercury light trap.[4] The presence of 3 ml of water in the collection jar of the mercury light trap indicated that there was rain during the preceding 24 h of observation.

I monitored the flying mole crickets in 2 ways. The first method was to collect adults at lights. The sampling techniques used were: (a) to pick up nightly after 10 PM all mole crickets that had flown to street lights at 6 locations in and around Gainesville; (b) to trap the flying adults in 2 kinds of light traps (viz., 2 UV light traps and the mercury light trap.[4]) The light traps were kept at the Green Acre Farm, and the trapped mole crickets were collected weekly. The 2nd method was to record each night

[1] Received for publication 12 Sept. 1974.
[2] Florida Agric. Exp. Stn. Journal Series No. 5564.
[3] A part of Ph.D. Dissertation submitted to the Grad. School, Univ. Florida on 24 Aug. 1974.
[6] Present address: Entomology Dept., Purdue Univ., W. Lafayette, IN 47907.

[4] A light trap was made by fixing a (1000 W) mercury vapour light on top of a 3-m diam steel container. The mole crickets that flew to the mercury light were trapped in the steel container and collected in a 2.5-liter jar screwed to a jar ring soldered to the bottom of the steel container.

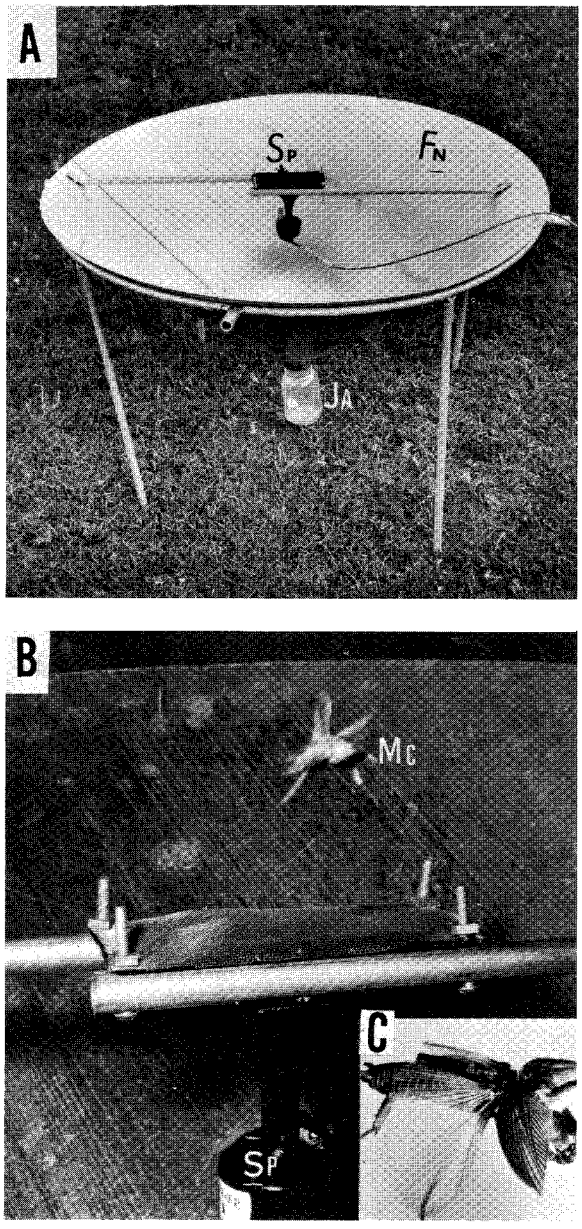


FIG. 1.—Large numbers of mole crickets were attracted to outdoor loudspeakers broadcasting male calling songs. (A) Sound trap used to trap the flying mole crickets. It consisted of a 1.2-m diam funnel (Fn) with a speaker (Sp), and a jar (Ja); (B) attraction of flying mole cricket (Mc) to the broadcasting outdoor loudspeaker (Sp) covered with aluminum wire screen; (C) tethered *acletus* flying in the laboratory.

all the mole crickets that flew to loudspeakers (Fig. 1B) broadcasting tape recordings of natural and synthetic mole cricket calling songs. The equipment (Fig. 1A) used to attract and collect mole crickets flying to the sound was like that described by Ulagaraj and Walker (1973). Adults collected under the lights and at broadcast sound were identified (i.e., as *acletus* or *vicinus;* Blatchley 1920),[5] sexed, and counted. Sexing was done on the basis of the black spot on the dorsal side of the male forewing—females lack this spot.

To determine whether the flying females were mated or not, I examined 75 *acletus* and 89 *vicinus* for sperm in spermathecae. On more than 5 occasions separated by a week or more, I sampled 10–25 ♀ that flew into the sound trap. These females were immediately placed in containers apart from males. The spermatheca was dissected out, squashed with a drop of water under a cover slip, and examined (450× magnification) for sperm.

The starting time of mole cricket flight and the variation in the number of flying adults during a night were studied by broadcasting. The calling songs of *acletus* and *vicinus* were broadcast immediately after sunset. As soon as 3 or more adults had flown into the sound trap, I considered the flight to have begun. To observe the fluctuations of the flying population during an evening, I removed adults from the sound trap at 5-min intervals.

An attempt was made to study the wing-beat frequencies of flying mole crickets and temperature of thoracic muscles in the flying adults. A flight mill similar to that of Chambers and O'Connel (1969) was used to study the wing-beat frequencies of mole crickets. Seven female *vicinus* collected 30 April 1973 were tested on the flight mill 1 May 1973. In timing the duration of the flights, I disregarded pauses of 15 s or less. Wing-beat frequency was measured with a stroboscopic light (Strobatac, General Radio Model No. 631-B). The thoracic temperature of flying insects was measured within 30 s after they had stopped flying. I pierced the metasternum of the adult with a needle containing a thermocouple and measured the temperature with Bailey Instrument Co. Model BAT-4 indicator. At the golf course, measurements of thoracic temperature of female *acletus* were made within 60 s of their landing.

Marking, releasing, and recapturing the *acletus* was carried out from May to July 1974 at the Green Acre Farm to find out whether individuals flew more than once and the distance flown. Flying adults ($n \geqslant 3000$) were obtained at broadcasting loudspeakers. I used different colors of acrylic paint to mark different portions of the pronotum to indicate the date, distance, and direction of release. A total of 1844 *acletus* (24% males) were marked and released. Capturing, marking, and releasing of adults were carried out on the same night. The adults (in groups of 5) were placed in paper cups (10 cm × 5 cm height) during the interval between capture and release to prevent cannibalism or injury. On a given night the adults were released at a single distance from a center point, but in various directions. Re-

[5] *Scapteriscus acletus* and *S. vicinus* can be distinguished by means of tibial dactyls of the front legs. Dactyls of *acletus* are separated by a distance at least equal to ½ their basal width. Dactyls of *vicinus* are almost (or quite) touching at the base. See also Hayslip (1943).

capturing was at the center point by broadcasting synthetic songs of *acletus*. Adults that landed inside the sound trap were examined for marks with a portable UV light (Ultra Violet Products Inc. Model UVL-22). The marks were clearly distinguishable by their brilliant fluorescence. The recaptured (i.e., previously marked) adults were marked distinctively and released on the same night from the same distance and direction that they had been previously released.

The air speed of flying *acletus* ($n = 10$) was observed at the golf course on 3 June 1973. The method of observation was similar to that of Arbogast (1965).[6]

I tested a hypothesis that mole crickets fly through or above forests. The experiments were conducted in 2 situations using the broadcasting techniques. In the first one, an area (100×200 m) covered with pines and oak trees (>20 m high) was selected between 2 open fields. On 22 April 1973 I placed a sound trap at the midpoint of the woods and also in the open field and broadcast *vicinus* songs for 14 min. In the other situation (14 May 1973), *acletus* and *vicinus* songs were broadcast on the roof of a 3-story building surrounded by lawns and woods.

Results

Geographical and Ecological Distribution of Mole Crickets

Mole crickets occur around the world approximately between latitudes 55° N and 50° S. The genus *Scapteriscus* occurs in the New World, India, and Bangladesh (Chopard 1969). *S. acletus* and *vicinus* are found in the southeastern United States (Fig. 2). *S. acletus* is a native species and *vicinus* is probably introduced. *S. vicinus* is known to occur in Cuba, Puerto Rico, Trinidad, and humid sandy areas of the northern part of South America. It appears that *vicinus* was introduced into the United States from the West Indies (Worsham and Reed 1912) ca. 1889. Barrett (1902) reported the common belief of Puerto Rican agriculturists that *vicinus* arrived in guano from South America ca. 1850. He believed that *vicinus* was present earlier than 1850 in Puerto Rico. Wolcott (1941) failed to find a natural enemy for *vicinus* in Puerto Rico but found a wasp, *Larra americana* Saussure, in Belem, Brazil, and colonized it in Puerto Rico. It appears to me that *vicinus* is native to northern South America.

S. acletus and *vicinus* are nocturnal and can be found in wet to moist sandy areas where natural vegetation has been considerably disturbed. They are not known from wooded areas. The common habitats of *acletus* and *vicinus* are lawns, golf courses, borders of highways, pastures and annually tilled fields (viz., gardens, nurseries, and crop lands). *S. acletus,* but not *vicinus,* occurs near the edges of lakes, ponds, and streams.

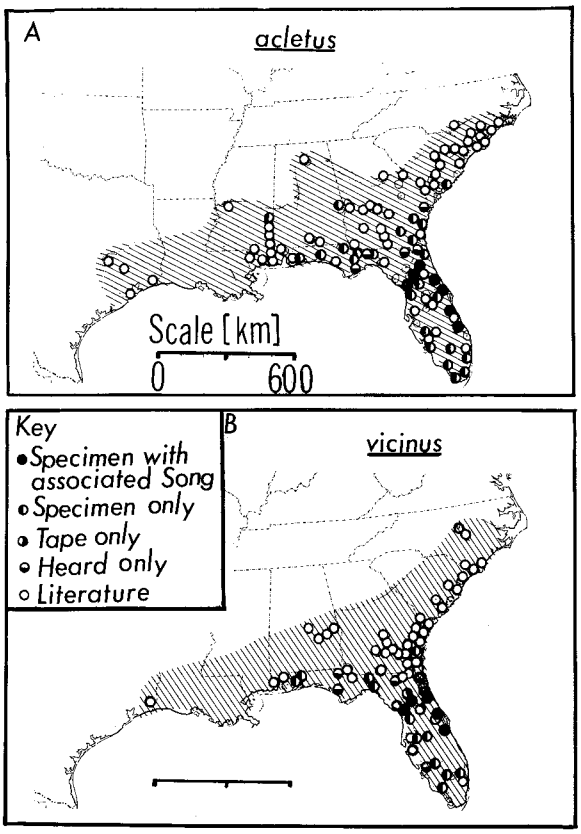


FIG. 2.—Distribution maps of *Scapteriscus acletus* (A) and *S. vicinus* (B) in the U. S. The predicted distribution is shaded and the points show county records. Song and specimen records are from Dr. T. J. Walker, Univ. Fla. Data from the Economic Insect Survey, USDA, ARS, Plant Protection Div., Beltsville, Md., are included as literature records.

Flight Season

In Gainesville, Fla., there are 2 flights of *acletus* and *vicinus:* a major spring flight and minor fall flight. A total of 5675 adults (55% *acletus*) were captured during spring 1972, whereas 199 adults (16% *acletus*) were collected in fall 1972. With a few exceptions, the flight activities of *acletus* and *vicinus* are largely seasonally separated (Fig. 3C). During 1973 *acletus* flew from May to July, and *vicinus* flew from March to May. In 11 instances during 1972 and 1973 *acletus* and *vicinus* flew in large numbers ($n \geqslant 20$) on the same night (Fig. 3A, B, C). I have noticed a few adults of both species flying other months. For instance, I have collected *acletus* ($n \leqslant 9$ per night) adults in March and April when *vicinus* flew predominantly. Similarly, *vicinus* ($n \leqslant 5$ per night) adults were found in July when *acletus* was predominant. Fall flights occurred on 4, 7, 11, and 12 Nov.; 5, 6, 7, and 9 Dec.; and 2 Jan. 1973. I collected 32 *acletus* and 167 *vicinus* in these 9 days. Of those collected in November ($n = 54$),

[6] Arbogast, R. T. 1965. Biology and migratory behavior of *Agraulis vanillae* (L.) (Lepidoptera, Nymphalidae). Ph.D. Dissertation, Univ. Florida. 96 pp.

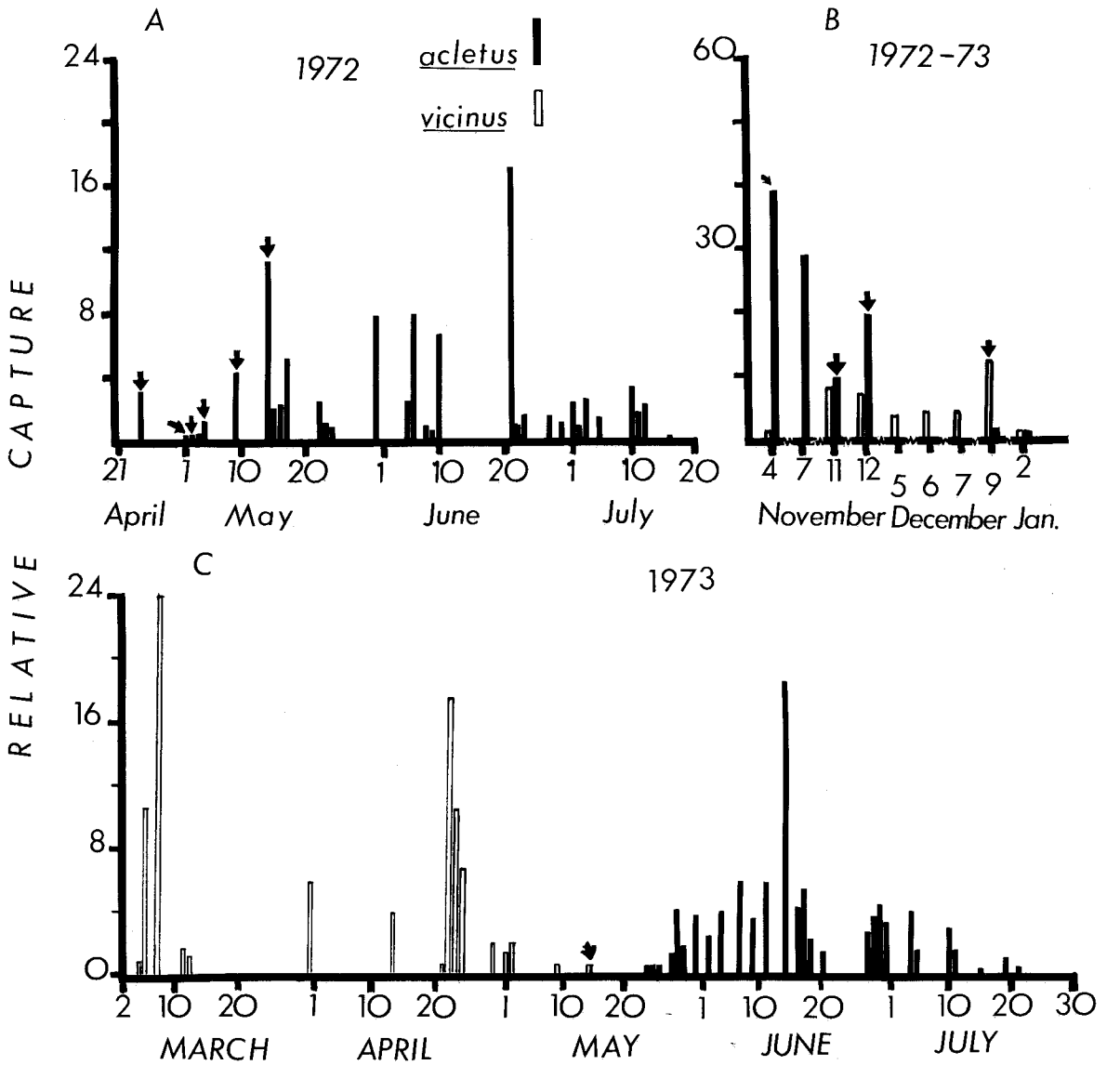


FIG. 3.—The flight activities of *acletus* and *vicinus* monitored by broadcasting technique during spring flight 1972 (A), and spring flight 1973 (C). The relative capture is the number of *acletus* or *vicinus* captured on a particular date as a percent of the total capture of that species during the season. During fall flight 1972–73 (B), *vicinus* was predominant (99%) during Dec. and Jan. The nights on which both *acletus* and *vicinus* flew are shown by arrows.

56% were *acletus*. Of those captured in December and January (n = 145), 99% were *vicinus* (Fig. 3B).

Sex Ratio of the Flying Adults

During my observations (except 31 May 1973), the number of flying females was consistently more than the number of males. I collected 9161 *acletus* and 7521 *vicinus* adults during 1972 and 1973. Of these, 83% were females in both species. Sex ratios of *acletus* and *vicinus* from 2 sampling techniques are given in Fig. 4. Sex ratios of *acletus* collected at light and sound are not significantly different from each other (P = 0.05), while the sex ratio of *vicinus* collected under light was significantly different from the sex ratio of (*vicinus*) adults trapped by sound (P = 0.05). The percent of females that had sperm in the spermathecae was found to increase as the mole cricket flight season progressed (Fig. 5).

Flight Starting Time and Duration

Flight activities started immediately after sunset (Table 1) and continued for an hour (Fig. 6). Adults of *acletus* and *vicinus* emerged from the ground. I observed *vicinus* adults on the surface of the soil soon after sunset. Most of the *acletus* ob-

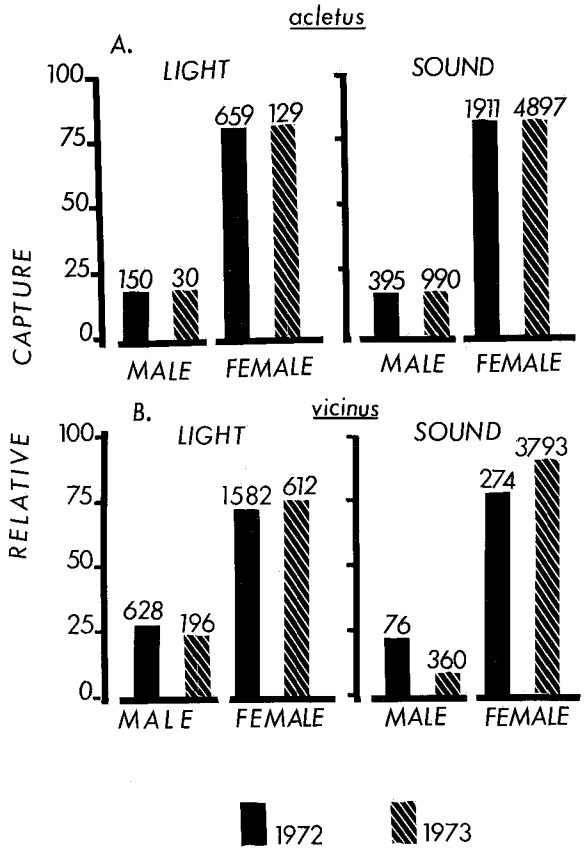


FIG. 4.—Sex ratio in *Acletus* (A) and *vicinus* (B) collected under fluorescent light (LIGHT) and at the broadcasting loudspeakers (SOUND). The numbers above the bars are the actual numbers collected. The relative capture is the number of a particular sex by a particular method during a year expressed as a percent of the total capture of that method and year.

Table 1.—Starting time of flight in *Scapteriscus acletus* and *vicinus*.

Species	Days observed	Flight starting time: Minutes after sunset $\bar{X}$	SD	Range
acletus	21	35[a]	9	28–44
vicinus	28	22[a]	7	18–31

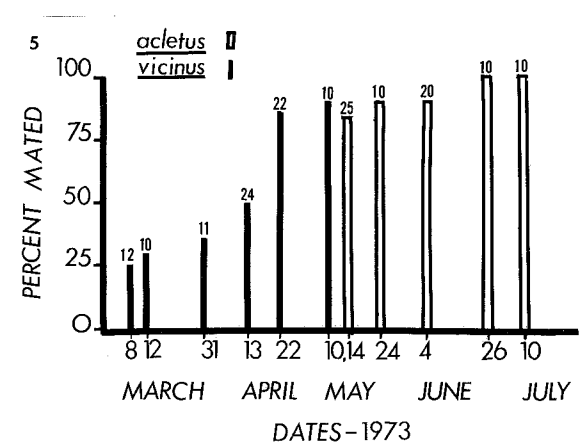
[a] Means are significantly different ($P = 0.05$).

served did not come out of the ground until it became dark (light intensity <20 lux). A few came to the surface soon after sunset.

Flight Behavior

Some of the *acletus* and *vicinus* on the soil raised their tegmina and moved them rapidly. The movements were similar to those observed during noise production (wings moved laterally), but silent (Ulagaraj 1974). In *acletus*, the wings were moving fast while the hind and front legs were kept close to the body. The mesothoracic legs were kept wide apart. In adidtion to the movement of the tegmina, the body was also vibrating. Probably mole crickets raise their body temperature before takeoff.

Takeoff was not closely observed in *acletus*, but in *vicinus* the head and front portions of the body were raised, keeping the front legs close to the head, and the body was pushed into the air by the hind legs. Sometimes *vicinus* made small leaps ranging from 15–30 cm for several times before it took off. In some cases, I saw *acletus* and *vicinus* making short flights of 0.5–2.0 m.



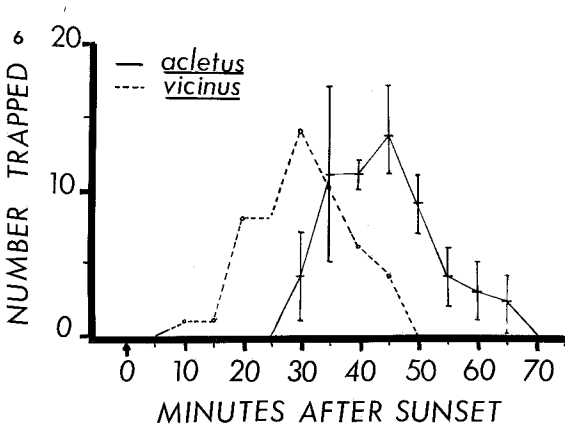


FIG. 5.—The proportion of females in *acletus* and *vicinus* that were mated at various times during the flight season. The numbers above the bars indicate the total number of females examined for sperm in the spermathecae on that date.

FIG. 6.—Fluctuation in the population of flying *acletus* and *vicinus* during a night determined by broadcasting techniques. The number trapped is the number of mole crickets collected in the sound trap during a 5-min period. Arrow shows the sunset time. Vertical bar is 2 SE on either side of the mean. Assay for *acletus* population was made on 29, 31 May, 2 and 7 June 1973, and assay of *vicinus* was made on 20 April 1974.

Table 2.—Wing-beat frequency of female *S. vicinus* (n = 7) at 23.5°C air temperature and 50% RH.

Statistic	Duration of flight (min)	Wing-beat[a] frequency	Thoracic temp after flight (°C)
Mean	17	806	29
SD	14	69	2
Range	3–45	670–890	27–32

[a] Per minute.

Landing of both species were observed in the presence or absence of broadcast. I could not detect any differences in the landing behavior of *acletus* and *vicinus*. Landing occurred in several patterns at the Golf Course in the absence of broadcast. Some adults landed on the ground smoothly like aircraft; some abruptly crashed to earth. I observed that after landing, mole crickets did 1 of 3 things—some (3 ♀) entered a male's burrow, most of the rest dug into the soil, and some flew again.

Physiology of Flight

Mean wing-beat frequency of tethered female *vicinus* was 806 per minute at 23.5°C (air) and 50% relative humidity. One female flew 45 min on the flight mill (Table 2). There is no correlation between the duration of flight and the thoracic temperature of the tethered females. The mean thoracic temperature, recorded from the flying *acletus* outdoors, was 4°C above the ambient (air) temperature (SD = 0.97, range = 2.0–5.3°C) (Table 3).

Dispersal Flights of Mole Crickets

In the dispersal studies, 2% of marked *acletus* were recaptured (i.e., were proved to fly more than one night) (Fig. 7A). Three adults flew more than 2 nights (Fig. 7C). The maximum duration between the release of a marked adult and recapture of the same individual was 6 wk, proving that some adults fly again during a period of 6 wk. Some individuals flew ca. 1 km (Fig. 7B). The air speed of *acletus* varied from 7.2 to 18 km/h ($\bar{X} \pm$ SD = 11.8± 1.1) on a clear night with no wind.

The results of experiments designed to see whether mole crickets could fly through and above woods were positive. I collected 133 *vicinus* in the sound trap in the middle of the woods and 154 *vicinus* in the trap in the open field. On one occasion I was hit by flying adults while walking through the woods during broadcasting. I collected 33 *acletus* and 42 *vicinus* on top of the 3-story building. This suggests that at least some adults fly over barrier 20 m high.

Effect of Weather on Flight

Weather conditions affect mole cricket flight. I have never seen *acletus* or *vicinus* fly below 18°C (soil and air). For instance, *vicinus* flight did not occur from 14–30 Mar. 1973 and from 1–12 April 1973 due to cold (soil temperature <20°C) and a few rainy days. At the lighted golf course, I never saw flying mole crickets during a few cold nights. On many occasions I observed large numbers of flying mole crickets after the rain, especially after a long dry period. The percent of males flying after the rain was higher than those on days not preceded by rain (Table 4). Furthermore, during 1973, major flight (i.e., <4% relative capture in Fig. 3C) of *acletus* occurred on those days that were preceded by rains.

Table 3.—Thoracic temperatures of female *S. acletus* recorded soon after the adults landed at the lighted Golf Course.

Date of observation (1972)	n	RH (%)	Temp (°C)		Thoracic temp (°C)		
			Air	Soil	$\bar{X}$	SD	Range
21 May	5	65	24.0	25	29.3	0.27	26.0–29.5
4 June	2	66	25.0	25	28.0	1.40	27.0–29.0
4 June	2	66	24.5	25	28.5	2.12	27.0–30.0
24 June	4	78	26.0	—	29.5	0.58	29.0–30.0
1 July	2	83	28.0	27	30.0	—	—

Table 4.—Percent of *S. acletus* males trapped inside the sound trap at broadcast sound (2.7 kHz; 55 pulses per second[p/s]; and 100 dB at 15 cm).

Days observed[a]		Trapped inside sound trap at 2.7 kHz and 55 p/s					
		No. trapped			% ♂ trapped		
Type of day	n	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range
After rain	7	52	17	29–71	27	17	12–64
No rain for 48 h	11	49	21	23–85	5	2	4– 9

[a] Observation was made within 2 h after sunset.

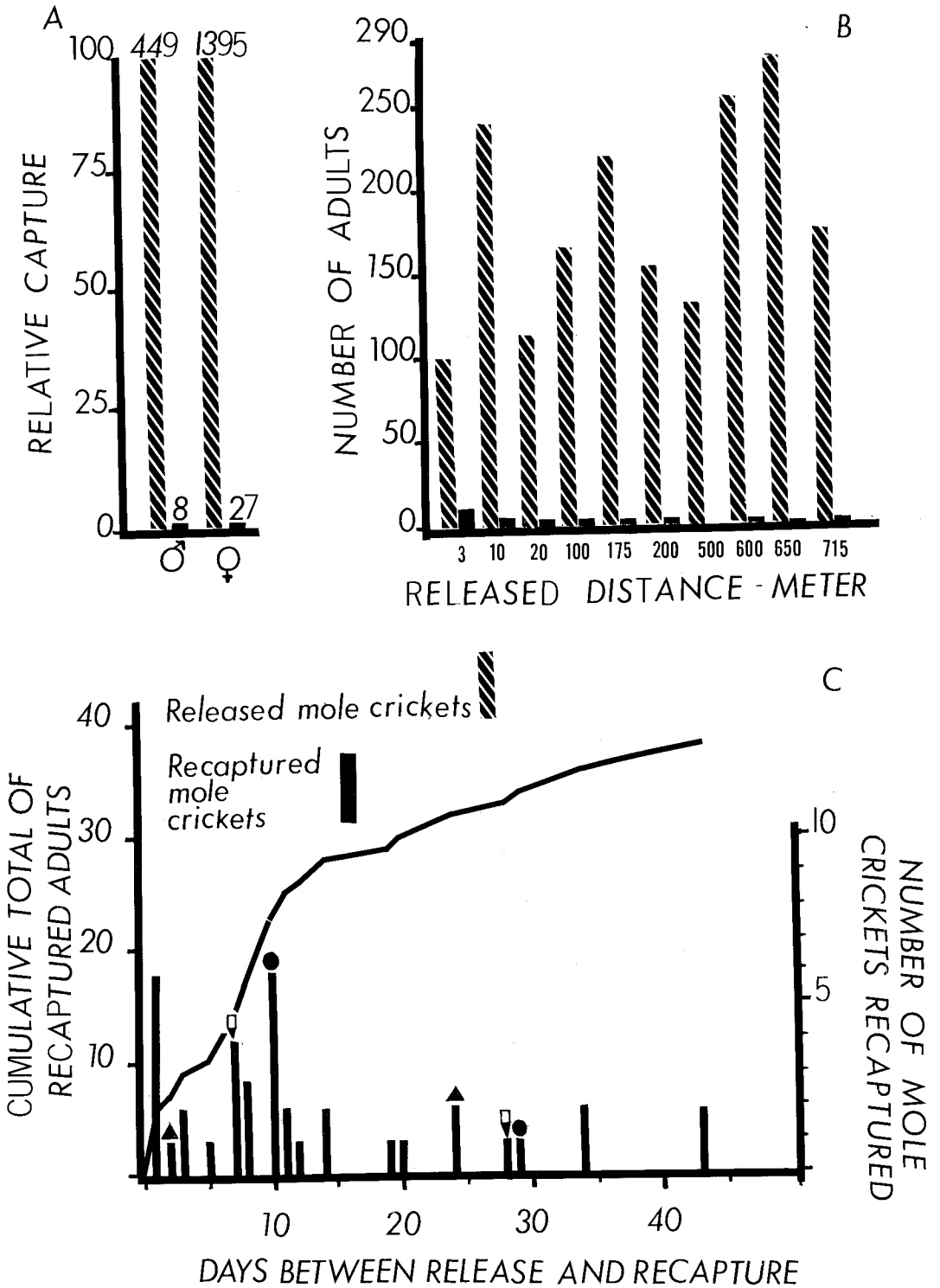


FIG. 7.—Marking, releasing, and recapturing of *acletus were* carried out during May to July 1973. (A) A total of 1844 marked adults were released in the field and 35 adults (i.e., 2%) were recaptured. (B) Some adults flew more than 700 m. (C) At least 2% of the adults flew more than 1 night and 3 flew more than 2 nights. Symbols (e.g., Triangle) of the same type represented a single individual that was captured thrice. The zero day is the date of marking and releasing in the field. The relative capture is the total number of those numbers of that sex released. The number above the bar is the actual number of males and females used.

Table 5.—Sex ratios of *S. acletus* trapped inside the sound trap and collected outside the sound trap.

Days observed	Trapped inside the sound trap				Collected outside the sound trap			
	No. trapped		% ♂		No. trapped		% ♂	
	n	Range	*n*	Range	*n*	Range	*n*	Range
6[a]	694[b]	15–188	10	6–18	769[b]	23–193	13	4–46
15	898[c]	11–112	16	0–65	1560[c]	11–257	24	9–44

[a] Data cited by Ulagaraj and Walker (1973).
[b] The difference among the sex ratios that were trapped inside and collected outside is not significant ($P = 0.05$).
[c] The difference among the sex ratios that were trapped inside and collected outside is significant ($P = 0.05$).

Discussion

Mole crickets occupy temporary habitats, and therefore flight is adaptive to individuals. The factors (such as deficiency of food, crowding of individuals with incipient cannibalism, and physical disruption of habitat) causing the mole crickets to fly are unknown.

The presence of the crucial ontogenetic stage (e.g., recently molted adults) might influence the mole cricket flight. It appears that there were 2 peaks of flight for *vicinus* during 1973 (Fig. 3C). The 1st peak (5 Mar. 1973) was probably due to the overwintering adults that started flying afer the warm weather. The 2nd peak (22 April 1973) might be due to the new adults that developed from overwintering nymphs (for details on seasonal life cycles of *acletus* and *vicinus,* see Ulagaraj 1974).[7] In Puerto Rico, *vicinus* flew from October to December (Van Zwaluwenburg 1918), but the major flight in Gainesville occurred during March to May 1973. I was not able to monitor *vicinus* flight every night during 1972.

It is not known what cues are used by mole crickets to start their flight in the evening. Light intensity might play a role. I have never seen mole crickets fly at a light intensity of more than 65 lux. I found the flight of *acletus* occurring after the flight of *vicinus* (Table 1; Fig. 6). Similarly, singing of *acletus* started after that of *vicinus* (Ulagaraj 1975). Lloyd (1966, 1969) and Farnworth (1973)[8] observed that fireflies, *Photinus* species, flew at a specific time during the night.

Physiological studies on energy expenditure and source of fuel used for flight are some the areas that would help to elucidate mole cricket flight.

Earlier, Ulagaraj and Walker (1973) interpreted the flights of mole crickets as dispersive flights. Furthermore they speculated that flying adults might use the sexual signaling of males of their species as an indication of a habitat suitable for colonization. They suggested that those 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 landing within the sound trap would include a significantly smaller proportion of males than those landing outside the trap.

The sex ratio of *acletus* that had landed inside and outside the sound trap was compared for 21 days (Table 5). Except on 2 days, the percentage of males collected outside the sound trap was higher than the percentage of males trapped inside the sound trap. I also compared the sex ratio of *acletus* landing inside and outside the sound trap each 10-min interval on 31 May and 2 June 1973 ($n = 393$) and found that the percentage of males landing outside the trap was always higher than the percentage of males inside the sound trap. These experiments support the hypothesis that male mole crickets use calling songs as a sign of suitable habitat.

Large numbers of mole crickets were observed to fly after rainy days. It seems that the subsurface burrow system of these adults might have been destroyed by the rain. Moreover the adults which fly after the rain could easily construct a new burrow system in the moist soil.

Dispersal studies suggest that treated fields could be reinfested several times in the same season. Furthermore, the flight range of mole crickets probably exceeds 15 km during favorable weather conditions. It seems that the adults may disperse from one field (e.g., a pasture) to another. It is probable that newly arrived (mated) females lay eggs in a field and fly again.

Acknowledgment

I thank Dr. T. J. Walker for advice, constant encouragement, and constructive criticisms. Photographs (Fig. 1B, C) were taken by Dr. T. J. Walker. I thank Mr. D. A. Nickle for help and Dr. J. Sharp for the supply of flight mill parts. Appreciation is expressed to Drs. W. H. Whitcomb and R. C. Wilkinson for encouragement and to the staff of the West End Golf Course, Gainesville, for the facilities. I thank Miss D. Harris for typing the manuscript.

[7] Ulagaraj, S. M. 1974. Mole crickets: ecology, behavior, and acoustical communication (Orthoptera: Gryllotalpidae: *Scapteriscus*). Ph.D. Dissertation, Univ. Florida. 72 pp.
[8] Farnworth, E. G. 1973. Flashing behavior, ecology and systematics of Jamaican lampyrid fireflies. Ph.D. Dissertation. Univ. Florida. 277 pp.

REFERENCES CITED

Barrett, O. W. 1902. The changa, or mole cricket in Puerto Rico. Puerto Rico Agric. Exp. Stn. Bull. 2: 1–19.

Beck, E. W., and J. L. Skinner. 1967. Screening of insecticide against the changa and Southern mole-cricket attacking seedling millet. J. Econ. Entomol. 60: 1517–9.

Blatchley, W. S. 1920. Family VIII. Gryllidae, The crickets, Subfamily I. Gryllotalpinae. Pages 642–54 *in* Orthoptera of northeastern America with special reference to the faunas of Indiana and Florida. Nature Publ. Co., Indianapolis.

Chambers, D. L., and T. B. O'Connel. 1969. A flight mill for studies with the Mexican fruitfly. Ann. Entomol. Soc. Am. 62: 917–20.

Chopard, L. 1968. Orthopterum catalogus. Utegeverij. Dr. W. Junk. N.V., Gravenhage 12: 443–59.

1969. The fauna of India and adjacent countries. Orthoptera, Grylloidea. Vol. 2. Govt. of India, Delhi. 421 pp.

Dingle, H. 1972. Migratory strategies of insects. Science (Wash., D.C.) 175: 1327–95.

Hayslip, N. C. 1943. Notes on biological studies of mole crickets at Plant City, Florida. Fla. Entomol. 26: 33–46.

Heinrich, B. 1974. Thermogegulation in endothermic insects. Science (Wash., D.C.) 185: 747–56.

Lloyd, J. E. 1966. Studies on the flash communication system of *Photinus* fireflies. Univ. Mich., Misc. Publ. Mus. Zool. 130: 1–193.

1969. Signals and systematics of Jamaican fireflies: notes on behavior and on undescribed species. Entomol. News 80: 169–76.

Ulagaraj, S. M. 1975. Sound production in mole crickets (Orthoptera: Gryllotalpidae: *Scapteriscus*). Ann. Entomol. Soc. Am. 68: in press.

Ulagaraj, S. M., and T. J. Walker. 1973. Phonotaxis of crickets in flight: attraction of male and female crickets to male calling songs. Science (Wash., D.C.) 182: 1278–9.

Van Zwaluwenburg, R. G. 1918. The changa or West Indian mole cricket. Puerto Rico Agric. Exp. Stn. Bull. 23: 1–28.

Wolcott, G. N. 1941. The establishment in Puerto Rico of *Larra americana* Saussure. J. Econ. Entomol. 34: 53–6.

Worsham, E. L., and W. V. Reed. 1912. The mole cricket. Georgia Exp. Stn. Bull. 105: 251–63.

Reprinted from the
ENVIRONMENTAL ENTOMOLOGY