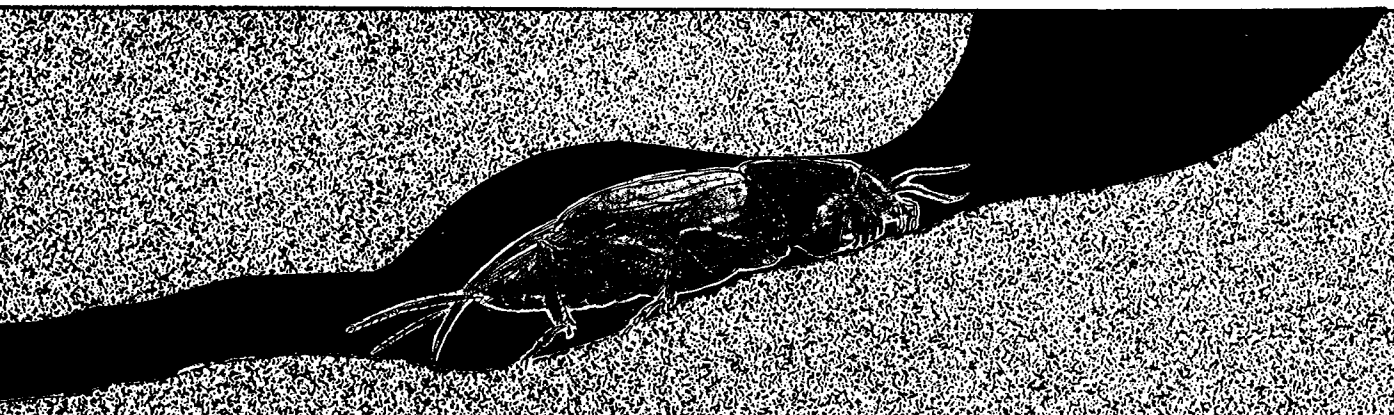


Status, Distribution and Life History of the Prairie Mole Cricket, *Gryllotalpa major* Saussure

by 1987
Dennis E. Figg and Paul D. Calvert

ABSTRACT

The prairie mole cricket, Gryllotalpa major Saussure, is a subterranean Orthopteran specially adapted to the southwest region of the tallgrass prairie. Records of historic occurrence originate from Kansas, Oklahoma, Missouri, Arkansas, Illinois and Mississippi. Present distribution, determined by a survey conducted in 1986 and 1987, is significantly smaller than the historic range. Changes in the landscape, primarily the result of settlement and conversion of the prairie into agricultural land, have eliminated most of the tallgrass prairie. Current populations persist on small prairie remnants. Some of these prairies are being managed by public agencies and private conservation organizations. The lack of appropriate management on some prairies and detrimental land use on others are threatening remaining populations. The prairie mole cricket should be considered for "threatened" status by the U.S. Fish and Wildlife Service and protected in its current range.

STATUS, DISTRIBUTION AND LIFE HISTORY OF THE PRAIRIE MOLE CRICKET, *Gryllotalpa major* Saussure

by

Dennis E. Figg and Paul D. Calvert

Natural History Section

Missouri Department of Conservation

Jefferson City, Missouri

December, 1987

Support for this project was provided cooperatively by the U.S. Fish and Wildlife Service and the Missouri Department of Conservation under Contract No. 14-16-0003-86-929.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Tallgrass prairie was a dominant natural community of the central United States at the time of European settlement, occupying about three percent of the North American continent (Küchler 1964). With settlement of the region the prairie was converted to agricultural crop land, fenced for livestock management and the natural influences that maintained the grasslands, primarily the control of prairie wildfire, were nearly eliminated. As the grasslands dwindled so did much of the characteristic fauna and flora.

The present study was conducted to increase our knowledge of a little known grassland invertebrate, the prairie mole cricket, Gryllotalpa major Saussure (Figure 1). Prior to this work the only information about the species was the original taxonomic description and information taken from the labels of museum specimens. There was no information in the literature about the distribution, behavior, life history or population biology of the prairie mole cricket.

The primary goals of this project were to collect individuals, characterize their habitat and survey suitable habitat rangewide to determine the present distribution. Because little was known about the life history of this mole cricket we initiated concurrent efforts to collect life history information and to develop an understanding of the biology of the species. Much of what we now know about the prairie mole cricket is based on our observations combined with knowledge of other species of mole crickets.

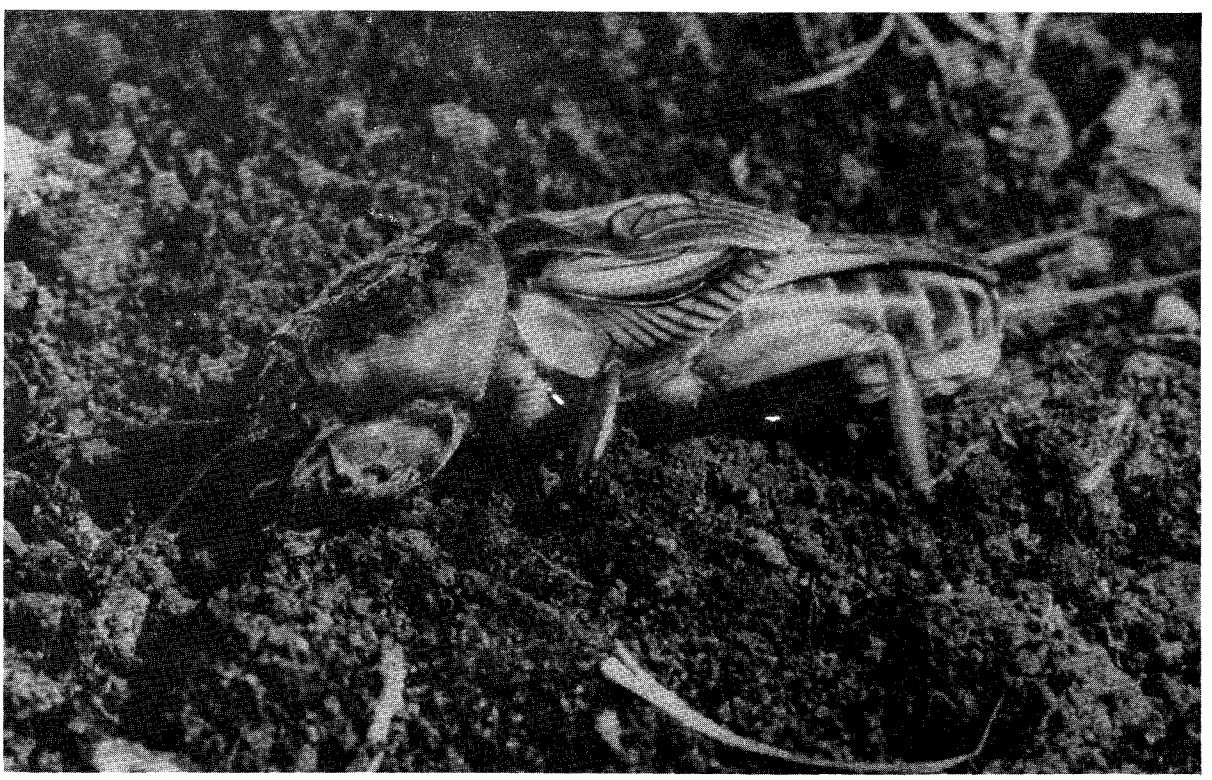


Figure 1. Prairie mole cricket, Gryllotalpa major Saussure.

METHODS AND MATERIALS

PRELIMINARY STUDIES

Preliminary field work was conducted in May and June, 1986. We attempted to:

1) collect specimens from suitable habitat
2) describe the type of habitat where prairie mole crickets occurred
3) determine successful methods for collecting and surveying prairie mole crickets.

Twenty-eight sampling locations were selected in Missouri, reflecting a range of habitat types. Natural communities that retained a high degree of presettlement character, particularly those in the vicinity of relatively recent mole cricket records, were given high priority. These sites represented eight natural communities: dry (loess) prairie, dry-mesic prairie (with substrates of chert and sandstone/shale), mesic prairie, wet-mesic prairie, hardpan prairie, wet prairie and marsh.

We searched for prairie mole crickets using standard collecting techniques: net sweeping of 10-meter transects, black-lighting with a Universal light trap and a portable light trap suspended over white cloth, and pitfall traps distributed throughout suitable habitat. None of these standard insect collecting methods were successful and all were abandoned. Net sweeping for prairie mole crickets is useless. The height and vigor of prairie vegetation precludes netting soil-surface or below-ground arthropods. Neither of the black-light traps attracted mole crickets. Light traps in other light spectra may prove more useful as some of the label information for preserved specimens says "city lights". No specimens were obtained from pitfall traps, although long pitfall traps constructed of three-inch PVC pipe would sample greater surface area than the small buckets used in this study.

During the 1986 field season the most successful method for locating prairie mole cricket populations was to listen for calling males during the courtship period. Potential habitat is approached at least one hour prior to sunset. Just after sunset, at approximately 50 minutes preceding darkness, males begin to call from a tunnel and resonance chamber in the prairie soil. Calling terminates abruptly at darkness, thus sampling potential habitat by this method is restricted to this brief period of time.

SPECIMEN REVIEW

A list of G. major specimens in major entomology collections was available prior to this study (Dr. Tom Walker, University of Florida-Gainesville, pers. comm.). Specimens from Kansas, Oklahoma, Missouri, Illinois and Mississippi were found in these collections. A more complete review of preserved specimens was conducted.

During the fall of 1986 curators of entomology and natural history collections in the central United States were contacted and provided taxonomic information to separate G. major from other mole crickets, particularly a close relative distributed across most of the eastern United States, the northern mole cricket, Neocurtilla hexadactyla (Perty). Curators were asked to review all mole crickets in their collections and provide label data from G. major specimens. Curators from states adjacent to those of known prairie mole cricket occurrence were also contacted: Arkansas, Indiana, Iowa, Kentucky, Louisiana, Nebraska, Ohio, Tennessee and Texas.

SURVEY

In 1987, field surveys to locate extant prairie mole cricket occurrences were expanded from Missouri to the other states of the historic range: Arkansas, Illinois, Kansas, Mississippi and Oklahoma. Texas and Iowa were also added to the survey. Texas was added because prairie mole crickets once occurred in most of the Oklahoma border counties, the two states being separated only by the Red River. The survey extended northward into Iowa because of uncertainty as to how far north the Illinois specimen was obtained.

In mid-March, 1987, each cooperator from the eight-state region received a packet of materials: introductory letter, prairie mole cricket fact sheet, description of the species with a diagram of diagnostic characters, reporting forms with instructions, a slide or picture of the prairie mole cricket and a continuous loop tape of the male call. The selection of survey locations was left to the discretion of the cooperator.

All cooperators were instructed to visit survey locations between April 15 and May 15, 1987, during the evening hours of twilight to listen for calling males. Since adult males call only during a brief period every evening, cooperators were only required to visit potential habitat and listen for males, using the tape recording for verification. If the call was heard, the survey location was considered complete. Cooperators were asked to characterize the population as good (seems to be in all available habitat), very few, or one individual. Cooperators who located large populations were encouraged to obtain voucher specimens. If no calls were heard, the cooperator returned to the site on another night, if possible, to check again under different conditions. All efforts, whether positive or negative, were recorded on the report form and returned. Cooperators visited as many sites as their schedule allowed.

LIFE HISTORY OBSERVATIONS

All of the cooperators were asked to gather life history information as it became available at their respective sampling locations. In 1987, a special effort was made to collect life history information from prairies in southern Pettis County, Missouri, particularly Paint Brush Prairie. Hand-collected individuals were obtained for voucher specimens, taxidermic purposes, laboratory studies and gut tract analysis. Individuals collected for laboratory observation were taken to the University of Florida-Gainesville by Dr. Tom Walker. Individuals collected for gut tract analysis were dissected and the crop and entire digestive tract removed. The contents were identified by the authors with the aid of a dissecting scope.

During preliminary studies two prairie mole cricket burrows were excavated to detect the presence of males, females, eggs, or nymphs. No individuals or activity were observed. During 1987 attempts were made to better understand the structure of the prairie mole cricket burrow systems. We approached five calling male territories in late April and marked the entrance with a flag. The following morning we carefully excavated the burrow system, measured the opening, the dimensions of the burrows and chambers, and the length of the entire system. The burrows were mapped on graph paper. In May we repeated this exercise at Grandfather Prairie. At this time, plaster casts were obtained from seven mole cricket burrows. In every instance the presence of males or females was recorded as well as the characteristics of the burrow system.

Seasonal activity of prairie mole crickets was monitored at Paint Brush Prairie during the spring of 1987. Beginning in March the prairie was visited nightly to detect the first calling males. Although calling males are easily detected, the level of activity is difficult to quantify. We noted the first occurrence of activity, periods of increasing frequency, perceived peaks of activity and the end of activity.

Pest species of mole crickets can be attracted in large numbers by broadcasting synthetic male calling songs during the flight period (Methany et al. 1983). Dr. Tom Walker, provided a sound synthesizing unit using a prairie mole cricket recording we obtained in 1986. Sound synthesizing units are mechanical devices that amplify synthetic cricket calls and successfully attract adults (Walker 1982). The unit was played at Grandfather Prairie on May 15, 1987, and again at Niawathe Prairie on May 16, 1987, in an attempt to attract mole crickets. The unit was turned on prior to the calling period and continued to play beyond the normal period of prairie mole cricket calling. A white sheet surrounding the unit was monitored for landing crickets continually during the test period.

POPULATION SAMPLING

During 1987 we attempted to measure the number and distribution of calling males on an 80-acre portion of Paint Brush Prairie. Before we could begin sampling we had to establish the degree of site tenacity for calling males. Early observations suggested that, once established, calling males would stay at the same location throughout the courtship period. Many of the small aggregations observed in 1986 were relocated at the same location on succeeding nights. This seemed reasonable since construction of the acoustical burrow must require a lot of energy.

In 1987, one of the earliest calling males was captured and released 0.25 mile from the captive site. It was placed at the edge of the prairie where it could be easily monitored. The male burrowed into the soil in the immediate vicinity of release, established a burrow system and called from this location for the next three weeks.

We also attempted to flag the location of all calling males within a three-acre portion of the prairie. Every evening during the calling period the burrow entrance of each calling male was approached and a colored flag was placed at the entrance. Blue flags were used during the first week. All entrances were marked within two nights. The following week entrances were marked with red flags, and marked by yellow flags the third week. Observations were made in the interim to insure that all individuals were located. The location of each of the flagged territories was measured from the corners of the sample plot and mapped to reveal movement of mole crickets during the test period.

Population sampling efforts were initiated concurrently, also at Paint Brush Prairie. Although strip transect censusing was first developed for use with birds (Emlen 1971) it can be used with calling mole crickets. Two people walked four transects ten meters wide, counting the number of calling crickets between them. Each transect was 0.25 mile long and sampled one acre of habitat. A second attempt was made with six people, each separated by ten-meters for a distance of 0.25 mile. In this attempt, two transects were walked, sampling five acres of habitat each time.

RESULTS AND DISCUSSION

HISTORIC OCCURRENCE

Seventy-three specimens of G. major were reported from various entomology and natural history collections (Appendix I). All specimens originated from the region of presumed occurrence: Arkansas, Illinois, Kansas, Missouri, Mississippi and Oklahoma. No specimens have been collected from the other states that were searched: Iowa, Indiana, Kentucky, Louisiana, Nebraska, Ohio, Tennessee and Texas.

The historic range of the prairie mole cricket (Figure 2) was determined by the occurrence of previously collected specimens. The range is primarily the southwest portion of the tallgrass prairie, an area of approximately 270,000 km^2 that encompasses east and central Kansas, most of Oklahoma, southwest Missouri and northwest Arkansas.

There are a few scattered records from outside this core of occurrence. Only one specimen (the type specimen) was collected from Illinois. Its label information contained only the word "Illinois", so date of collection and collecting location are unknown. One Missouri Bootheel record is documented from sand prairie of the Mississippi River floodplain. The Illinois specimen may have been collected in similar habitat just across the river. Additional records of occurrence are known from Mississippi. Although Mississippi was not known as a prairie state, a small amount of prairie did exist there historically. There is not sufficient information to determine how widely the prairie mole cricket occurred in these disjunct portions of the range.

PRESENT DISTRIBUTION

During 1986 and 1987, 160 locations in eight states were surveyed for prairie mole crickets (Figure 3, Appendix II). Cooperators had few problems with the survey beyond the initial selection of sites to survey. Rainy cool weather complicated some efforts. Instructions about the calling period, described as the period preceding sunset instead of the period following sunset, caused some confusion. Cooperators were notified of the discrepancy and most of them had already compensated for the adjustment.

Prairie mole crickets were located at 63 of the survey locations (Table 1). The majority of occurrences were from Missouri and Arkansas. There were two occurrences in Kansas and one in Oklahoma. No prairie mole crickets were reported from Illinois, Mississippi, Iowa, or Texas.

Results of the survey show that populations of the prairie mole cricket still occur within the core of the presettlement range (Figure 4) but most appear to be restricted to the eastern edge; a broad band of prairie fragments that extends from Sedalia, Missouri, to the north and south into Arkansas as far as Charleston. Present distribution cannot be described as a "range" of occurrence because of the fragmented nature of present prairie habitat. No occurrences were found in Illinois or Mississippi. With reported lack of prairie habitat the prairie mole cricket is probably extirpated from both of these states as well as from the Missouri Bootheel.

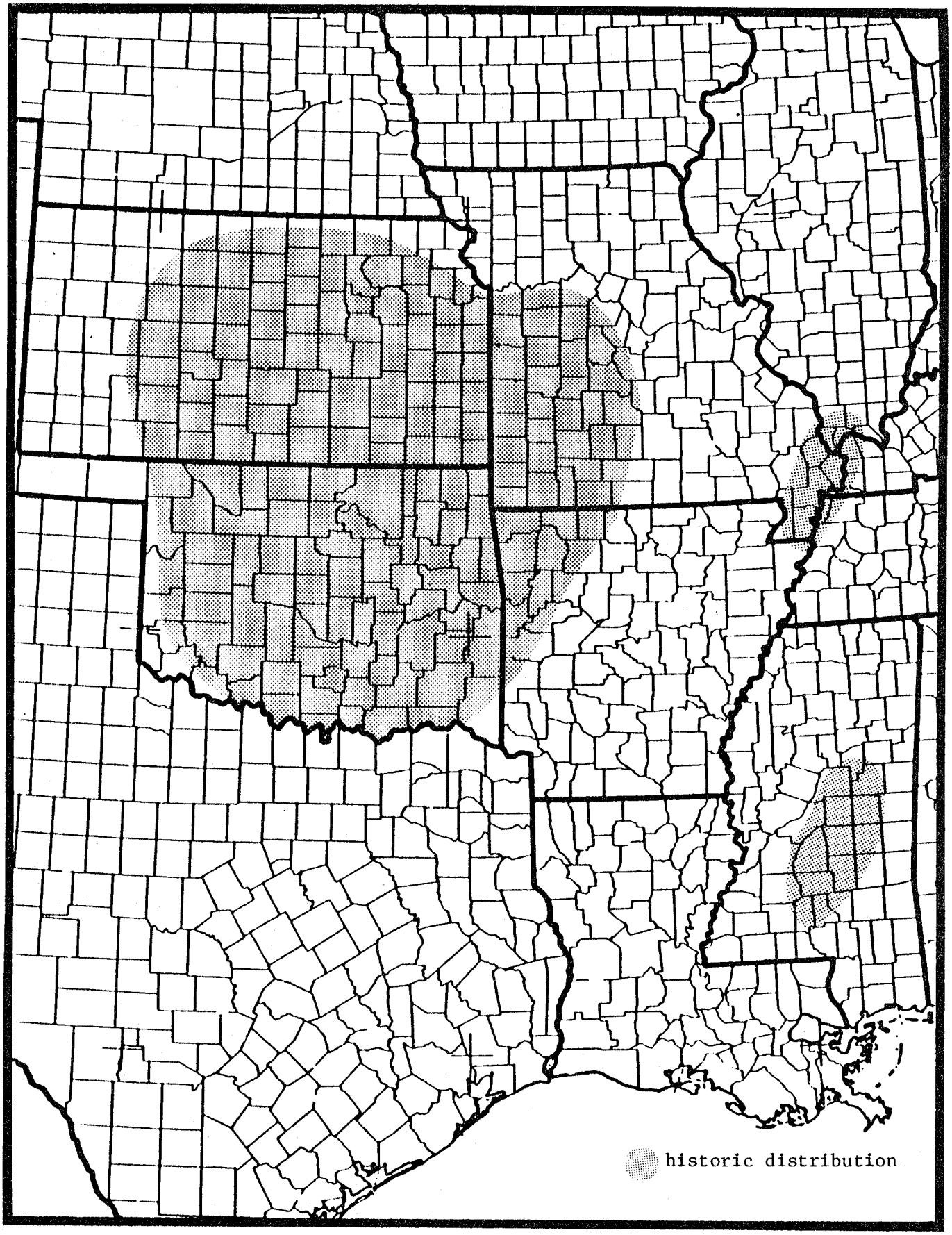


Figure 2. Historic distribution of the prairie mole cricket, based on specimen collection data.

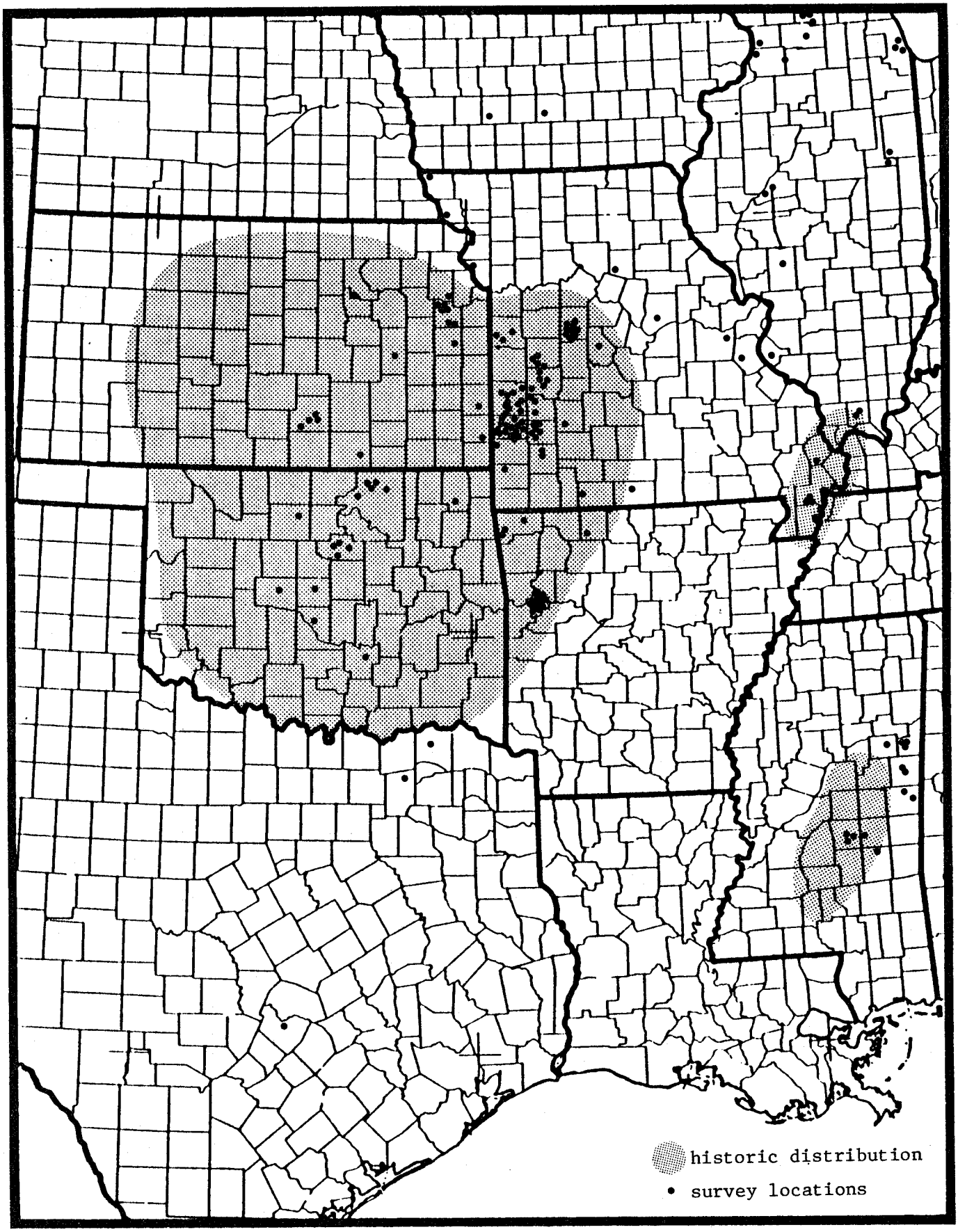


Figure 3. Locations surveyed for prairie mole crickets in 1986 and 1987.

Table 1. Sites where prairie mole crickets were located during the 1986-87 survey.

COUNTY	SITENAME	LOCATION	SIZE(acres)
ARKANSAS			
Benton	Rice Prairie	T18NR33W Sec 33	38
Benton	Stump Prairie	T18NR33W Sec 27	20
Franklin	Burt Prairie	T08NR28W Sec 31	40
Franklin	Cherokee Prairie	T08NR29W Sec 23,25,26,35	640
Franklin	Craft Prairie	T08NR29W Sec 14	40
Franklin	Mainard Prairie	T08NR28W Sec 7	80
Franklin	Meek-Flanagan-C. McFerron-K. McFerron Prairie	T08NR28W Sec 29,30	390
Franklin	H. Flanagan-R. Hudson-Sullivan-Barton-Johnson-M. Hudson-W. Flanagan-Prairie	T08NR28W Sec 17,19,20	360
Franklin	No Site Name Prairie	T08NR29W Sec 27	55
Franklin	Pendergrass Pile Prairie	T08NR28W Sec 13,23	35
Franklin	Vest-Flanagan-Acouch	T08NR28W Sec 14,15	105
Franklin	Vesta Prairie	T08NR29W Sec 13	150
KANSAS			
Bourbon	Hollister Wildlife Area	T26SR23E Sec 25	>320
Crawford	20th Street Prairie	T30SR24E Sec 13	>40
MISSOURI			
Barton	Catlin Prairie	T33NR31W Sec 1,12	160(+180)
Barton	Cook Meadow Prairie	T31NR29W Sec 21	160
Barton	Dorris Creek Prairie	T31NR30W Sec 33	160(+160)
Barton	Golden Prairie	T30NR29W Sec 8	300
Barton	Hunkah Prairie	T32NR33W Sec 27	160
Barton	Lamar Airport	T32NR31W Sec 26	20
Barton	Pawhuska Prairie	T32NR29W Sec 7	77
Barton	Prairie State Park	T32NR33W Sec 15,16,17 20,21,22	>1400
Barton	Private Prairie 1 (Pettis Knob Prairie)	T31NR29W Sec 33	30
Barton	Private Prairie 2 (Schriener Prairie)	T31NR31W Sec 2	160
Barton	Private Prairie 2 (Dorris Creek North Pr.)	T31NR30W Sec 34	10
Barton	Private Prairie 3 (Hannon Prairie East)	T33NR32W Sec 3	170
Barton	Private Prairie 4 (Prairie View School Pr.)	T33NR31W Sec 2	100

Table 1. (continued)

Barton	Private Prairie 5 (Prairie View South Pr.)	T33NR31W Sec 12	20
Barton	Private Prairie 6 (Irwin Prairie)	T33NR31W Sec 12	10
Barton	Tzi-Sho Prairie	T33NR33W Sec 23	240
Cedar	Mo-Ko Prairie	T36NR28W Sec 14,15	420
Cedar	Monegaw Prairie	T36NR28W Sec 25,36	270
Cedar	Sky Prairie	T34NR28W Sec 13	200
Dade	Burns Meadow	T31NR28W Sec 28	160
Dade	Hunt Prairie	T30NR28W Sec 6	160
Dade	Indigo Prairie	T30NR28W Sec 4	40
Dade	Native Prairie 1 (Horse Creek Prairie)	T30NR28W Sec 1	160
Dade	Niawathe Prairie	T32NR28W Sec 14	320
Dade	Penn-Sylvania Prairie	T32NR28W Sec 22	160
Henry	Hillebrand Tract Prairie	T40NR27W Sec 30	5
Henry	Hoppe Tract Prairie	T40NR26W Sec 35	20
Henry	Ragland-Dunning-Wittig Tract Prairie (McKenna Pr.)	T40NR27W Sec 36	160
Jasper	Wah-Sha-She Prairie	T30NR34W Sec 31,32	160(+400)
Lawrence	Private Prairie 1 (Stahl Prairie)	T28NR27W Sec 2	40
Newton	Diamond Grove Prairie	T27NR32W Sec 36	570
Pettis	Drovers Prairie	T43NR22W Sec 1	80(+40)
Pettis	Grandfather Prairie	T44NR21W Sec 32,29	80(+60)
Pettis	Friendly Prairie	T44NR22W Sec 25	40
Pettis	Highway 52 Prairie	T44NR21W Sec 6	35
Pettis	Paint Brush Prairie	T44NR21W Sec 29,32	240
Pettis	Unnamed Prairie 1 (Paint Brush Pr. North)	T44NR21W Sec 29	25
Pettis	Unnamed Prairie 2 (Hwy U Prairie)	T44NR21W Sec 27	15
Pettis	Unnamed Prairie 3 (Paint Brush Pr. South)	T44NR21W Sec 32,33	80
St. Clair	Chapman Tract Prairie	T37NR25W Sec 11	<5
St. Clair	Conrad-Neuenschwander Tract (Valley Center Pr.)	T39NR26W Sec 3	160
St. Clair	Osceola IDP Tract Pr.	T38NR25W Sec 21	5
St. Clair	Taberville Prairie	T38NR28W Sec 14,15,22, 23,26	1680
St. Clair	Wah-Kon-Tah Prairie	T36NR28W Sec 2,3,10,11	720
Vernon	Gay Feather Prairie	T34NR30W Sec 1	116
Vernon	Little Osage Prairie	T35NR31W Sec 34	80
Vernon	Nevada City Prairie	T35NR31W Sec 10	<5
Vernon	Osage Prairie	T34NR31W Sec 3,4	1467
Vernon	Portia Lawn & Pasture	T36NR29W Sec 11	<5
OKLAHOMA			
Cleveland	Colonial Estates Park	T09NR02W Sec 33	6-20

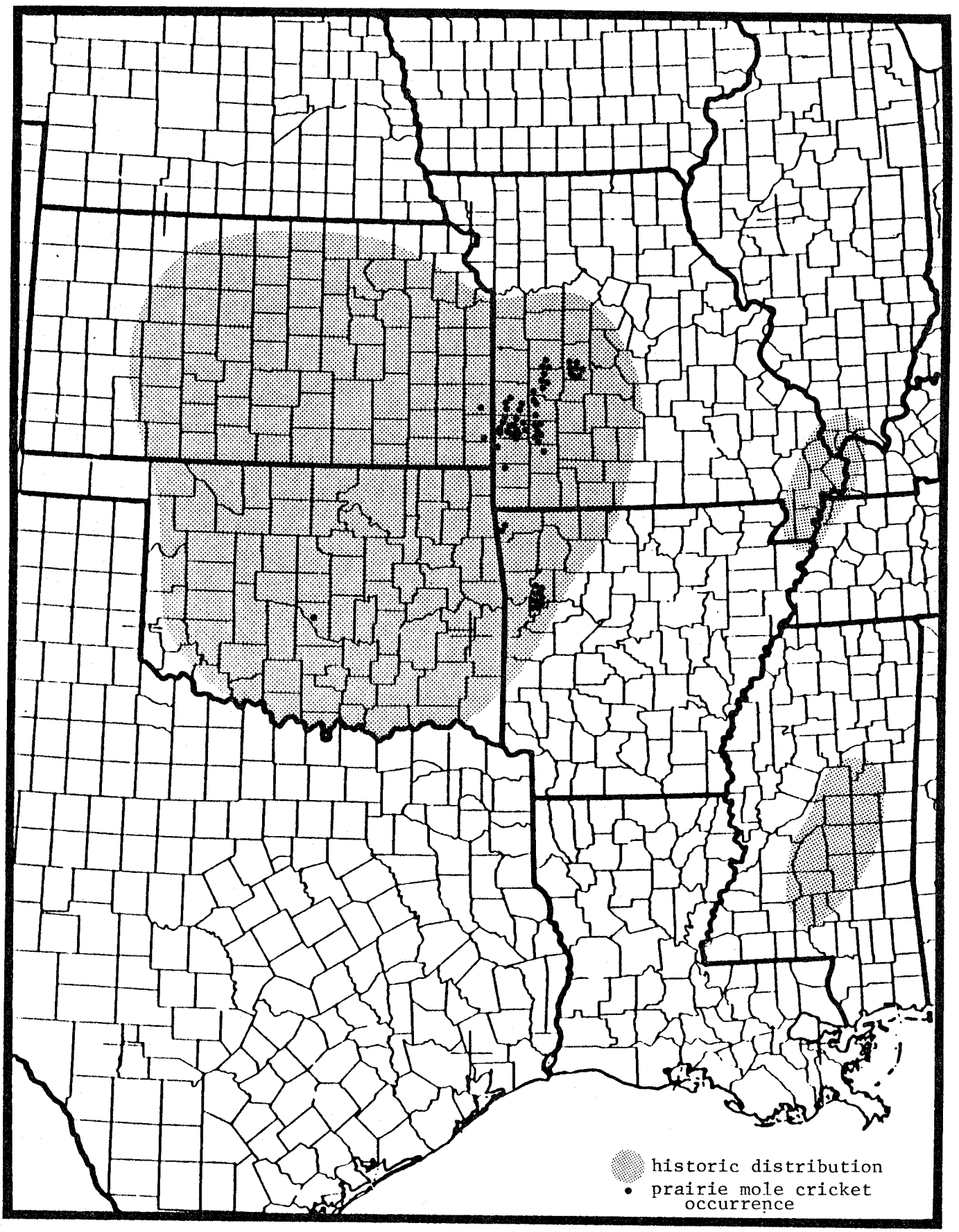


Figure 4. Sites where prairie mole crickets were located during the 1986-87 survey.

Mole crickets are unique members of the Orthoptera, characterized by forelegs that are highly modified for digging. All belong to the family Gryllotalpidae. There are two species of mole crickets native to the eastern United States: the prairie mole cricket, Gryllotalpa major Saussure, and the northern mole cricket, Neocurtilla hexadactyla (Perty). Five species of exotic mole crickets have unintentionally been introduced into the United States: Gryllotalpa africana Palisot de Beauvois, G. gryllotalpa L., Scapteriscus abbreviatus Scudder, S. acletus Rehn and Hebard, and S. vicinus Scudder (Nickle and Castner 1984).

The native mole crickets are of no economic importance and as a result are poorly studied. Many of the introduced species, however, are pests of turf and pastures in the southern United States and considerable effort has been made to understand their life history and population biology. Because sampling methods have yet to be correlated with actual population numbers the latter is still not understood.

Life History

Adult prairie mole crickets are among the largest insects in North America, measuring 6 cm (2.5 inches) from tip of the antennae to the ends of the cerci. Individuals may weigh as much as 2.6 grams (Walker pers. comm.). The prairie mole cricket is long-lived in comparison to most insects, probably maturing in two years (perhaps three). Observations on the various stages of development are nearly impossible in the natural setting and require a combination of laboratory rearing and field observations.

Eggs are presumedly laid during June and July. Females observed in the laboratory were kept with males for at least two days and then the males removed. One female was found dead on the surface of the soil on June 25. No eggs were found in the burrow system. The other female was alive on July 16 and appeared gravid, but was later discovered dead. Again no eggs or nymphs were found. In N. hexadactyla, the female deposits 30 to 70 light gray eggs which the female guards until hatching (Hayslip 1943). The number of eggs laid and their treatment by female prairie mole crickets is probably very similar to that of N. hexadactyla.

Prairie mole cricket nymphs are miniature versions of the adults except they lack wings. There are probably 6-7 juvenile stages separated by molts (Walker pers. comm.). There are a few specimens of immatures in museum collections but none were observed in this study. Nothing is known of their biology or development or how they relate to the prairie habitat.

Adult mole crickets become active at the soil surface twice during the year (Figure 5). While prairie mole crickets were not observed to be active in the fall in this study, previously collected specimens (Appendix I) demonstrate that some individuals are active during October. In many mole crickets, small fall flights precede longer spring flights of adults of a single generation (Walker 1984). Prairie mole crickets come to the soil surface in the spring for courtship and reproduction. Males and females are identical externally except for the modified forewings that the males use to attract sexually responsive females (Alexander 1975).

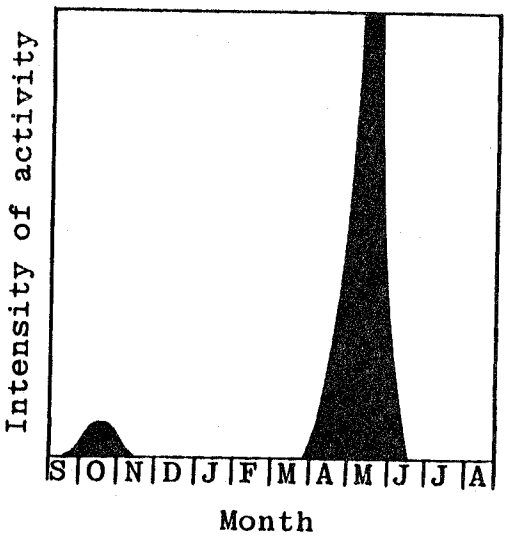


Figure 5. Seasonality and relative intensity of adult prairie mole cricket activity.

Male Calling and Female Flights

How early in the spring prairie mole crickets become active at or near the soil surface is unknown, but numerous specimens in the collection record date as early as mid-April. One 1928 specimen from Tulsa, Oklahoma, was collected on March 28. In Missouri, the first calling males are observed in April and calling activity continued through May. In 1987, the first male at Paint Brush Prairie began calling on April 7. This was followed by several evenings of inactivity. More than one male was heard on April 12, and the number of calling males continued to increase until it appeared to reach a maximum by April 29. Calling activity remained high for the first two weeks of May, then declined until it ended on May 28 (Figure 6).

Prairie mole crickets do not sing at the soil surface but do so in specially designed chambers inside the entrance of their burrow. Although previous researchers were aware that mole crickets called from underground burrows, Bennet-Clark (1970) was the first to demonstrate that these burrows are designed to increase the efficiency of sound production.

Prairie mole cricket burrow systems observed in this study were all similar in dimensions and general structure. The generalized prairie mole cricket burrow system is Y-shaped and lies roughly parallel to the soil surface (Figure 7). The burrows are shallow and have about 1.0 cm of soil between the tunnel roof and the soil surface. The size of the tunnels consistently measured about 2.0 cm in width and height, closely approximating the dimensions of the insect. Two entrances were observed in all but one of the tunnels we inspected. The entrances are much larger than the insect, being greatly expanded into the shape of a funnel - the horn. The surface opening of the horn was circular and measured about 2.5 cm. The horn was about 6.0 cm long. At its furthest end it constricts, and then opens into an oval chamber - the bulb. The bulb measures about 3.5 cm long by 2.5 cm wide and 3.0 cm high. Presumedly the male sits in the bulb with the abdomen directed outward into the horn while it calls. Beyond this bulb the tunnel constricts into a continuous surface tunnel. The two branches join, and beyond this point the single tunnel angles downward into the soil and ends. The depth of the ending tunnel ranged from 5.0 cm to over 25.0 cm below the soil surface. There is no evidence of the burrow on the soil surface. They are difficult to locate, frequently being obscured by prairie vegetation.

The arrangement of the prairie mole cricket burrow system is very similar to other mole crickets. The burrow of Gryllotalpa vineae is designed similarly, although the opening of the horn at the soil surface is divided into two channels (Bennet-Clark 1970). We observed this only when plant

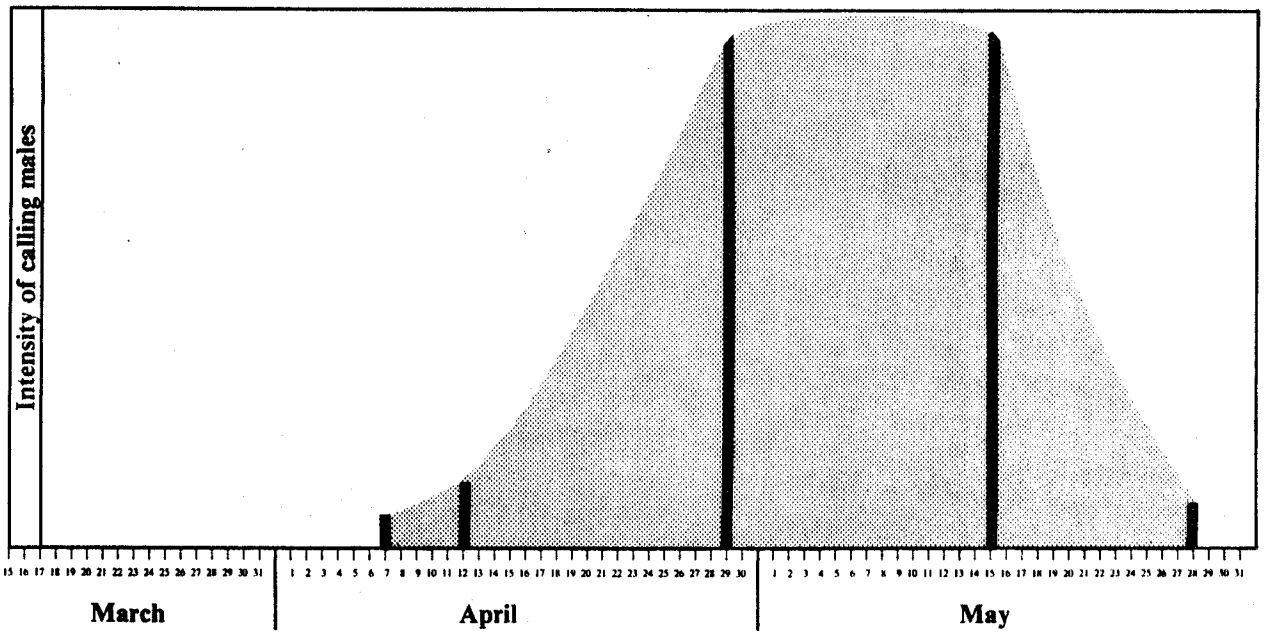
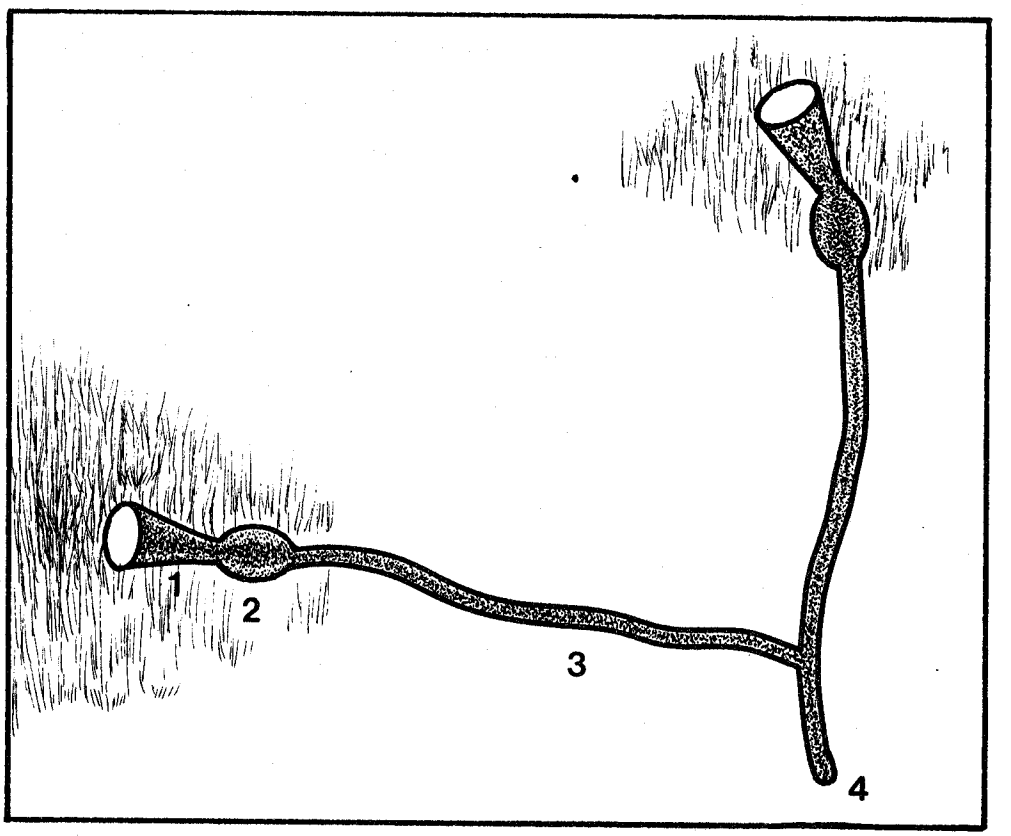


Figure 6. Seasonality and relative intensity of calling activity by male prairie mole crickets at Paint Brush Prairie during 1987.

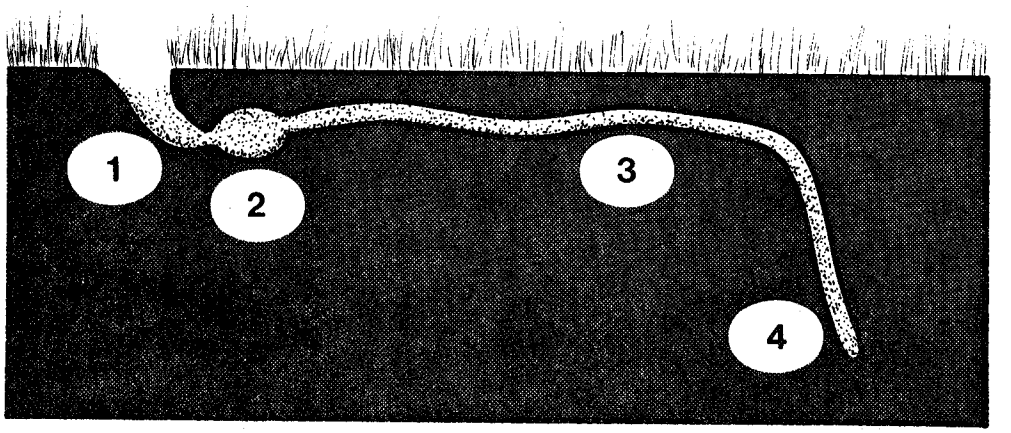
material appeared to divide the opening into two channels. This was observed twice and may have been accidental. S. acletus and S. vicinus construct similar burrows and plug the entrance of the tunnel with soil when not in use (Nickerson et al. 1979). We never observed plugs in prairie mole cricket burrows. The function of prairie mole cricket burrows is assumed to be the same as other mole crickets - to increase acoustical output. The first mole cricket calling at Paint Brush Prairie in 1987 could be heard over 0.25 mile away, attesting to the increased efficiency of these structures.

The calling period is about 50 minutes, beginning 5 to 10 minutes following sunset and ending rather abruptly at darkness. Under cold, wet, or windy conditions male crickets did not call, but when conditions are optimal, the occurrence of calling during these 50 minutes is predictable. Once initiated, calling continues until darkness. S. vicinus and S. acletus also produce continuous trills and rarely stop during the calling period (Forrest 1983).

Females engage in flights during the same period that males call. Although few females were observed during this study, one female was captured as she landed near the artificial calling device. Another was observed flying but was not captured. Flight is exceptionally hazardous and energy consuming for mole crickets which are relatively heavy insects and are built for tunneling. Safety and energy concerns are optimally met in early evening when darkness handicaps visually hunting predators and the



VERTICAL VIEW



HORIZONTAL VIEW

2 cm

Figure 7. Generalized prairie mole cricket burrow showing the (1) horn, (2) bulb, (3) surface tunnel and (4) deep tunnel.

temperature differential that mole crickets must overcome in preflight warmups has barely begun its nightly increase (Walker 1983). This specialized period of activity has been observed for other mole crickets. Both S. vicinus and S. acletus fly and call for little more than an hour, beginning shortly after sunset (Forrest 1983). These crickets usually remain in flight 5 to 20 minutes, but some may fly more than 40 minutes, and may travel as far as 8 km^2 (5 miles).

Environmental factors that limit male activity also affect female flights during early spring. Temperature significantly limits insect activity. Mole crickets must warm up their thoracic muscles to temperatures above 25°C before takeoff is possible and they do not (or cannot) fly when air temperatures are below 17°C (Forrest 1983). S. vicinus flights in Gainesville, Florida, do not occur at temperatures less than 18°C. Their flight period may range from February to May when, early in the season, temperatures often approach or fall below this mark soon after sunset (Ulagaraj 1975).

Soil characteristics also affect spring activity, particularly that of males. Soil moisture contributes to the success of the acoustics of the calling chamber. As soils dry out the chamber eventually reaches the point where it functions so poorly that it is nonfunctional. Fluctuations in the calling activity of males were observed to change through time, some nights with greater intensity than others. The reason for this is not known, but soil moisture is a possible explanation. Forrest (1983) reported that as days passed without precipitation soils dried out and calling intensities gradually decreased over successive nights.

The limiting factors of temperature and soil moisture vary each spring from year to year. Droughty springs probably shorten the calling period. Late season cool temperatures limit the flights of the females. Mature prairie mole crickets of any one generation are affected by environmental factors they cannot control. The period of courtship activity varies within the range, from site to site, and from year to year.

Courtship Aggregations

Many cooperators noted that the locations of calling males are not evenly distributed in prairie habitat, but appear to be aggregated. In instances where the number of calling males was quite low it was obvious that all calling males were closely associated. Tzi-Sho Prairie in Barton County, Missouri, is a good example. In 1986 only four calling males occurred on less than one-half acre of a 160-acre prairie. The following year only two males were found on the prairie at exactly the same location. Large populations are more difficult to assess because the volume of many calling males leads the observer to believe that the crickets are calling from "everywhere", but on closer examination they too show a high degree of aggregation.

The distribution of calling males was observed at Paint Brush Prairie by flagging all of the burrow entrances on an 80-acre portion of the prairie (Figure 8). We flagged the locations of all of the calling males except for eight on the eastern-most edge. The total number of calling males was 46. Thirty-one males (67%) were aggregated in an area of three acres. Two-thirds of the calling male population used only 3.8% of the available habitat. The remaining males were not evenly distributed and were not considered members of the aggregation. There may be some relationship to the aggregation, or benefit to these scattered males, that is not apparent to us.

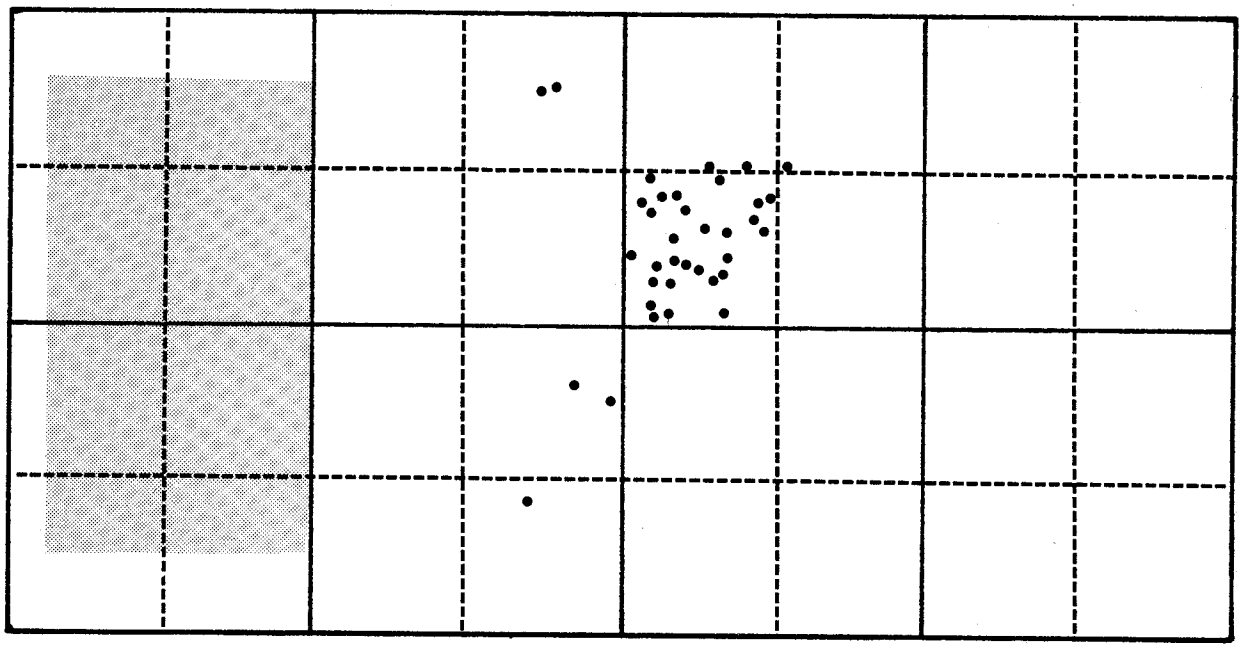


Figure 8. Distribution of calling males on an 80-acre portion of Paint Brush Prairie in 1987 (the shaded area represents eight calling males that were counted, but exact location not flagged).

Aggregation of males can come about for a number of reasons. The aggregation may represent a cohort of males that grew up in the immediate area. They may even have originated from the same female. Scattered males in the surrounding habitat might then represent less successful growth by other "families". Another possibility is that aggregation is associated with the best soils for construction of the acoustical burrows. The scattered males are those that could not compete for the best soils and were forced to locate in small pockets of acceptable soils. No soil pattern seems to substantiate this premise. In fact, in this example the aggregation occurs on a ridge of noticeably shallow soil. At other sites, male aggregations were seen in richer, deeper soils.

Clearly a good portion of males are aggregated during the courtship period. This may be a reproductive strategy. Since female flights and male calling is synchronized, females have the opportunity to choose among males. Scapteriscus females have been shown to select males which call the loudest (Forrest 1980), and "high-intensity" males attract up to ten times as many females as males calling at lower intensities. If females are restricting their mating to groups of competing males (because of the advantage of selecting among many males), males should aggregate (Alexander 1975).

Walker (1983) introduced the term **spree** to describe a concurrent display by most or all sexually active males in a population. A spree is different from a lek in that it does not require spatial aggregation of males. Walker concludes that brief nightly choruses of S. acletus and S. vicinus are

sprees, giving females an increased opportunity to compare males. Prairie mole cricket males call within a restrictive period of time each night (a spree). In addition, a large portion of the males are aggregated in specific locations on the prairie. These aggregations may well represent leks.

Habitat

The prairie mole cricket is a species of the southwest tallgrass prairie. While this geographically defines the region of occurrence, it does not describe the habitat. The prairie grasslands varied tremendously. Some areas were dry and excessively drained; others were characterized by saturated soils. These extremes affected the occurrence of flora and fauna. Interspersed with the prairie were dry rocky glades, woody ravines, fens, savannas and forests. Where the prairie mole cricket survived and thrived on the presettlement landscape, and what habitat factors limited the species, are unknown.

The locations surveyed during 1986 and 1987 represent nine different natural communities (Table 2) when classified according to The Terrestrial Natural Communities of Missouri (Nelson 1985). Natural communities that presently support prairie mole crickets are mostly dry-mesic prairies. Some of these prairies have portions that are more mesic. Prairie mole crickets were also found on hardpan prairies. Prairies represented in the survey are generally classified as mid-grass prairie dominated by little bluestem (Schizacharium (Andropogon) scoparius) or tallgrass prairie dominated by big bluestem (S. gerardii). Other characteristic grasses include Indian grass (Sorghastrum nutans), prairie dropseed (Sporobolus heterolepis) and side-oats grama (Bouteloua curtipendula). Forbs are also important components, varying according to the region, the site, the prairie type and past management history.

Naturally occurring habitats that do not support prairie mole crickets include: wet prairies, marshes, dolomite glades and dry loess hill prairies. Natural communities with saturated soils, or frequently saturated soils, are not preferred by the prairie mole cricket but are commonly associated with N. hexadactyla. No crickets were found on any of the dry loess hill prairies that were surveyed in Missouri or Illinois.

Non-native habitats associated with existing populations did not support prairie mole cricket populations. These include agricultural crop fields, old fields, fescue pastures, and forests.

On several occasions one male cricket was located in what appeared to be unsuitable habitat. This was always across the road or across a wooded ravine from an existing population that did occur in suitable habitat. A notable exception to this is one small group of males found in a fescue-bluegrass field (Appendix II, Portia lawn and pasture). Clearly, these individuals are not in native vegetation but they do occur in an area of Missouri where numerous fragments of prairie still exist. They probably represent a group of males that dispersed to the area, perhaps attracted by soil type and soil moisture. It is extremely unlikely that this group can establish a self-sustaining population at this location. Errant dispersal in today's fragmented habitat is a threat to existing populations.

Soils play a significant role in vegetation and as a result can be a determinant for the animal community. A soil-inhabiting arthropod is more likely to be constrained by soil type and composition than would most

Table 2. Natural communities sampled for prairie mole cricket occurrence with selected sites listed for each habitat type.

Natural Community	Examples
dry (loess) prairie	Fults Hill Prairie, Monroe Co., IL McCormack Loess Hill Prairie, Holt Co., MO Star School Hill Prairie, Atchison, Co., MO
dry-mesic chert prairie	Friendly Prairie, Pettis Co., MO Hite Prairie, Morgan Co., MO Paint Brush Prairie, Pettis Co., MO Sky Prairie, Cedar Co., MO Wah-Koh-Tah Prairie, St. Clair Co., MO
dry-mesic limestone/ dolomite prairie	Konza Prairie, Riley/Geary Co., KS
dry-mesic sandstone/ shale prairie	Hunkah Prairie, Barton Co., MO Niawathe Prairie, Dade Co., MO Tzi-Sho Prairie, Barton Co., MO
dry to dry-mesic sand prairie	Ayers Sand Prairie, Carroll Co., IL Sand Prairie, Scrub Oak Preserve, Mason Co., IL Thomas Fulton Sand Prairie, Whiteside Co., IL
hardpan prairie	Tucker Prairie, Callaway Co., MO Wah-Sha-She Prairie, Jasper Co., MO
wet prairie	Locust Creek Prairie, Linn Co., MO Marmaton River Bottoms, Vernon Co., MO
wet prairie/marsh	Horton Bottoms, Vernon Co., MO Little Bean Marsh, Platte Co., MO
limestone/dolomite glade	Caney Mountain Picnic Area, Ozark Co., MO Valley View Glades, Jefferson Co., MO

aboveground species. Silt, sand and clay soils would all respond differently to digging and burrow maintenance. The topography of the southwest prairie region is level to gently rolling, predominantly underlain by shale, sandstone and limestone. Soils formed in shale residuum are deep, clay-pan soils. Those formed from sandstone and limestone are more loamy. These soils tend to be poorly to moderately drained, depending in part on the degree of slope. Soils can be very shallow on the ridges (Allgood 1979).

Most of the extant prairie mole cricket populations occur on silt loams and sandy silt loams that are moderately well drained (Table 3). Silt loams characterize nearly the entire region of prairie mole cricket distribution. Derived from shales and sandstones, they tend to be acid and low to medium in natural fertility. Seasonal droughtiness and wetness and a moderate to high susceptibility to erosion are major influences (Toney 1987).

Many of the prairies that persist today have very shallow soils. It is not unusual for areas of bedrock to be found at the surface. Some of the prairies that appear to support good prairie mole cricket populations have thin soils with chert rubble just below the surface. Historically, these areas were less likely to be plowed for crop land and were often used for grazing and hay production. Several extant populations do occur on deeper soils that are less influenced by substrate.

Minor or subtle changes in soil type may affect the activity of the prairie mole cricket but few observations were noted. Some cooperators reported that mole crickets were excluded from wet soil stream terraces and seepy areas on the prairie. This also appears true for sites in Missouri. Apparent preference for well-drained soils may relate more to the requirements of male calling than anything affecting growth and development of the species.

Where prairie mole crickets now occur is an imperfect record of habitat preference, but when combined with life history information, does describe the range of habitat in which mole crickets live. Dry-mesic prairie with thin soils may not really represent optimal habitat for prairie mole crickets, but merely habitat that is presently available and acceptable. Prairie mole crickets probably occurred widely in tallgrass prairie of varying soil depth and soil moisture, being excluded only from the extremes.

Food Habits

Seven adult males and one adult female were collected for gut tract analysis. Only a small number of individuals were examined because of the difficulty of obtaining individuals and concerns about the effect of removal on the population.

The crops of all male specimens were empty, suggesting the males were not feeding during the period of capture. The crop of the female, however, contained unidentifiable plant materials that were believed to be masticated roots. Other researchers have reported finding empty crops in study specimens (Fowler et al. 1985, Methany 1981) but the reason for this is poorly understood. Perhaps *G. major* males are simply non-feeding during the reproductive period, spending all their energy on courtship preparation. Females, however, continue to feed because of their developing eggs.

Both plant and animal parts were recorded from the remainder of the digestive tract of both sexes. None of the plant materials were identifiable. We found no grass blades, leaf fragments or portions of above

Table 3. Primary soil types represented at selected prairie mole cricket locations in Missouri and Arkansas.

SITENAME	SOILS	SOIL DESCRIPTION
Cherokee Prairie Franklin Co., AR	----------	Soils are derived from shale residuum.
Diamond Grove Prairie Newton Co., MO	Creldon silt loam Gerald silt loam Keeno cherty silt loam Hoberg silt loam Tonti silt loam Wayben/Cedar Gap	Soils vary from a silt loam to cherty limestone residuum.
Dorris Creek Prairie Barton Co., MO	Barden silt loam Parsons silt loam Barco fine sandy loam Barden-Parson-alluvial	Soils vary from a fine to a silt loam formed from sandstone and shale residuum. Bedrock varies from 12 to over 50 inches below the surface.
Friendly Prairie Pettis Co., MO	Eldon cherty silt loam Parsons silt loam	Cherty silt loam to a silt loam formed from shale and cherty limestone residuum. Bedrock is over 50 inches below the surface.
Osage Prairie Vernon Co., MO	Radley, Parsons, Barden Liberal, Coweta, Barco Liberal silt loam Barco fine sandy loam Barden silt loam Barco loam Hepler-Radley Complex Verdigris silt loam Cleora fine sandy loam Parson silt loam	Soils vary from a fine sandy loam to a silt loam formed from sandstone residuum. Bedrock varies from near ground level to over 50 inches below the surface.
Sky Prairie Cedar Co., MO	----------	Soils vary from a stoney fine sandy loam to a loam formed from sandstone residuum. Bedrock varies from 0 to 50 inches below the surface.
Stump Prairie Benton Co., AR	Jay silt loam	Moderately well drained silt loam.

Taberville Prairie St. Clair, Co., MO	Deepwater silt loam Quarles silt loam	Soils vary from a fine sandy loam to a silt loam. Bedrock of sandstone and shale is found from 0 to 50 inches below the surface.
Wah-Sha-She Prairie Jasper Co., MO	Cherokee silt loam Parson silt loam	Soils are deep silt loam formed from shale residuum overlain by a thin mantle of loess. Poorly drained soils due to a clay pan.

ground vegetation, suggesting that all feeding takes place underground. White pulpy root material made up the bulk of the gut contents, at least 95% in volume. Scattered variously with the root material were many insect-animal fragments. Identifiable parts included beetle antennae, palpi, and elytra fragments, spider leg fragments and various bits of insect cuticle. We also observed sand and soil particles.

The prairie mole cricket apparently has a diet similar to other Gryllotalpidae. S. vicinus feeds largely on plant material (Walker and Ngo Dong 1982) as do S. didactylus and S. imitatus (Nickle and Castner 1984). The diet of N. hexadactyla includes both animal and plant materials in approximately equal proportions (Fowler et al. 1985). How prairie mole cricket diet varies from nymph to adult, or between sexes is unknown.

CURRENT POPULATIONS

There is little understanding of the population biology of prairie mole crickets. Most of the volunteers participating in the survey were intent upon locating as many occurrences as time allowed. Obtaining information on the number of individuals at these locations was secondary and could only be characterized in a general sense.

Early in the study we believed that most of the populations were quite large. Some populations appeared to be very healthy (i.e. Niawathe Prairie, Paint Brush Prairie) while others were so small that the number of calling males was easily determined by simple counts. Survey efforts in 1986, with no population information collected, were misleading as to the number of calling males in a population. When an observer stands in the center of a group of calling males, the noise is so loud and constant that it appears that the calling males are everywhere.

In 1987 the cooperators generally categorized the population of calling males when populations were located (Table 4). 15.6% of the sites had only one calling male, 20.3% were characterized as very few and 64.1% of the sample locations had good populations. These responses are subjective since factors like weather, relationship to neighboring habitat, and length of time at the sample site were not taken into consideration. In general, we believe that even the best populations do not represent large numbers of males in all available habitat.

The most curious category of occurrences are the sites where only one calling male was heard, a number that hardly represents a "population". Several of these occurrences are from small prairie tracts very near suitable habitat that supports a better population of mole crickets. At least one occurrence does represent the actual number of calling males. Only one calling male was located on the first night of survey at the Norman, Oklahoma, site. On subsequent visits the one male, at the same location, was all that was ever located.

Some prairie mole cricket populations were characterized by very few individuals despite the availability of significant prairie habitat. Osage Prairie in Vernon County, Missouri, is a good example. During 1986 we located a small group of calling males on a small portion of the prairie. About the same number occurred in the same location in 1987, despite the fact that the area encompasses over 1400 acres. Past management may explain the low population in this example. This prairie was heavily grazed in the past. Grazing does not explain the low populations at locations such as Diamond Grove Prairie in Newton County, Missouri.

Table 4. General population character of prairie mole cricket occurrences.

COUNTY	SITENAME	ONE	VERY FEW	GOOD
ARKANSAS				
Benton	Rice Prairie			X
Benton	Stump Prairie			X
Franklin	Burt Prairie			X
Franklin	Cherokee Prairie			X
Franklin	Craft Prairie			X
Franklin	Mainard Prairie			X
Franklin	Meek-Flanagan-C. McFerron-K. McFerron Prairie			X
Franklin	H. Flanagan-R. Hudson-Sullivan-Barton-Johnson-M. Hudson-W. Flanagan-Prairie			X
Franklin	No Site Name Prairie	X		
Franklin	Pendergrass Pile Prairie			X
Franklin	Vest-Flanagan-Acouch	X		
Franklin	Vesta Prairie			X
KANSAS				
Bourbon	Hollister Wildlife Area	X		
Crawford	20th Street Prairie			X
MISSOURI				
Barton	Catlin Prairie		X	
Barton	Cook Meadow Prairie		X	
Barton	Dorris Creek Prairie			X
Barton	Golden Prairie			X
Barton	Hunkah Prairie		X	
Barton	Lamar Airport		X	
Barton	Pawhuska Prairie		X	
Barton	Prairie State Park			X
Barton	Private Prairie 1 (Pettis Knob Prairie)			X
Barton	Private Prairie 2 (Schriener Prairie)		X	
Barton	Private Prairie 2 (Dorris Creek North Pr.)			X
Barton	Private Prairie 3 (Hannon Prairie East)			X
Barton	Private Prairie 4 (Prairie View School Pr.)			X

Table 4. (continued)

Barton	Private Prairie 5 (Prairie View South Pr.)		X	
Barton	Private Prairie 6 (Irwin Prairie)			X
Barton	Tzi-Sho Prairie		X	
Cedar	Mo-Ko Prairie		X	
Cedar	Monegaw Prairie			X
Cedar	Sky Prairie			X
Dade	Burns Meadow	X		
Dade	Hunt Prairie			X
Dade	Indigo Prairie			X
Dade	Native Prairie 1 (Horse Creek Prairie)			X
Dade	Niawathe Prairie			X
Dade	Penn-Sylvania Prairie			X
Henry	Hillebrand Tract Prairie	X		
Henry	Hoppe Tract Prairie			X
Henry	Ragland-Dunning-Wittig Tract Prairie (McKenna Pr.)			X
Jasper	Wah-Sha-She Prairie			X
Lawrence	Private Prairie 1 (Stahl Prairie)			X
Newton	Diamond Grove Prairie		X	
Pettis	Drovers Prairie			X
Pettis	Grandfather Prairie			X
Pettis	Friendly Prairie			X
Pettis	Highway 52 Prairie			X
Pettis	Paint Brush Prairie			X
Pettis	Unnamed Prairie 1 (Paint Brush Pr. North)			X
Pettis	Unnamed Prairie 2 (Hwy U Prairie)	X		
Pettis	Unnamed Prairie 3 (Paint Brush Pr. South)			X
St. Clair	Chapman Tract Prairie	X		
St. Clair	Conrad-Neuenschwander Tract (Valley Center Pr.)			X
St. Clair	Osceola IDP Tract Pr.	X		
St. Clair	Taberville Prairie			X
St. Clair	Wah-Kon-Tah Prairie			X
Vernon	Gay Feather Prairie			X
Vernon	Little Osage Prairie		X	
Vernon	Nevada City Prairie	X		
Vernon	Osage Prairie		X	
Vernon	Portia Lawn & Pasture		X	
OKLAHOMA				
Cleveland	Colonial Estates Park	X		

This 570 acre prairie is surrounded by additional private prairies. The population in 1986 was fewer than 10 males, and the number detected in 1987 was even smaller. Past management does not account for this low population since this site has been a hay meadow for decades; management that should not adversely affect this species.

The largest populations occur in areas where a significant number of good quality prairie remnants occur in close proximity to one another. This was first noticed in Pettis County, Missouri, when the association of the prairie fragments was mapped. Associations of prairie remnants that have numerous occurrences in good habitat include: Paint Brush Prairie complex, Catlin Prairie complex, Niawathe Prairie complex and Cherokee Prairie complex.

Attempts to relate the number of individuals to the size of the habitat were futile. Most of the small sites sampled were not really isolated from other prairie fragments and could be influenced by them over time. The lack of prairie mole crickets in what otherwise appears to be suitable habitat may demonstrate the effect of loss of populations through habitat fragmentation. Sites like Hite Prairie in Morgan county, Missouri, Mt. Vernon Prairie in Lawrence County, Missouri, and West Dolan Prairie in Cass County, Missouri, are good prairies well within the known range of the species. They are small remnants (60, 40, and 10 acres respectively) with no prairie mole crickets. Lack of prairie mole crickets, however, may be attributable to other factors such as past management. Of course there is no data to prove they definitely occurred there in the past.

Paint Brush Prairie Population

We investigated the site tenacity of calling males at Paint Brush Prairie during the 1987 courtship period. We initially established three one-acre sample plots in the main calling aggregation, but due to the short period of flagging time each night only one of the sample plots was used in this test. Twelve mole cricket burrows were marked with flags during the first week. During the second week again twelve burrows were located. Two of them were new locations and two of the ones used the previous week had been abandoned. In the third week, no new burrows were located and flagging was not continued because the courtship period ended.

Ten mole crickets (83%) called from the same location for the duration of the study. Two of the tunnels were abandoned and two were added. The abandoned tunnels represent males that either died naturally, were taken by predators, or relocated to another part of the prairie. We do not know if the two new burrows were relocated males from within the study site or recruits from outside the aggregation.

These observations demonstrate that once established, male prairie mole crickets can be expected to remain at the site of the acoustical burrow for the duration of the courtship period. This was even noted for males not associated with the calling aggregation, since other individuals were flagged variously across the prairie and they too called reliably from the same location night after night. The pest mole crickets S. acletus and S. vicinus also call from nonrandomly distributed (clumped) aggregations. Unlike the prairie mole cricket they seldom call from the same chamber on consecutive nights and excavate new burrows regularly, although the distance the burrow is moved is generally small (Kleyla and Dodson 1978).

During this courtship period, we walked transects and counted the

number of calling males encountered. At first nonrandom transects were walked, but because of the highly aggregated nature of the calling males nearly all of the transects produced no crickets. We repeated the exercise, but this time tried to choose areas that would encounter at least one mole cricket. Four-ten meter transects provide the following results: 2,2,4,0. Four acres were sampled (5% of the habitat). Based on this sample, the population of calling males is two per acre, or 160 males on the entire tract. Two-50 meter transects provided the following results: 1,3. Ten acres of habitat were sampled (12.5% of the habitat). Based on this sample the population of calling males is 0.4 crickets per acre, or 32 calling males on the 80-acre tract.

We were convinced that transect censusing may not accurately sample the mole cricket population because of the highly aggregated nature of the calling males. Transects were predetermined, not random. To test the accuracy of the sampling procedures we attempted to flag the location of all of the calling males. Only mole cricket burrows in the eastern portion of the prairie were not flagged because of time. They were counted, however, and there were eight individuals. The actual population of calling males on this 80-acre tract was 46.

In aggregated populations, strip transect censusing is of limited value. In the case of prairie mole cricket populations it may be easier and more accurate to mark burrows and obtain an actual count of the population.

The actual number of calling males at Paint Brush Prairie is low relative to the availability of prairie habitat. The ratio of females to males is unknown. However, the absence of females in the air during the evening calling period, and the fact that only two females were attracted to the sound trap suggests that females probably do not outnumber males. If these numbers represent the density of prairie mole crickets in good prairie habitat, then certainly populations are low.

The prairie mole cricket has disappeared or declined significantly from its former range. The only information regarding historic distribution and population is taken from specimen collections. Labels of pre-survey specimens date as far back as the 1870s. Some of the earliest dates include 1874 and 1875, from Riley County, Kansas and 1876, from Jasper County, Missouri. The Illinois specimen is undated, but the date of collection necessarily precedes 1874, the date of the original published description. Specimen collection continued into the nineteen hundreds but declined significantly following the 1930s.

In the last 50 years very few specimens were deposited into entomology collections. Specimens from the periphery of the range, Illinois and Mississippi, were not collected at all. The trend is significant because the decline of specimens occurred rangewide, even in localities with extensive research programs and intensive insect collecting effort.

Fortunately eight specimens were collected by an amateur insect collector in Nevada, Missouri, in 1959 and 1960. These records were the stimulus for attempting to relocate the species in southwest Missouri. This survey did find prairie mole cricket populations still occurring in southwest Missouri, Kansas, Oklahoma and northwest Arkansas.

The tallgrass prairie region that provided habitat for the prairie mole cricket once encompassed approximately 270,000 km^2. Prairie habitat is now reduced to small remnants, sometimes isolated from one another by miles of non-prairie habitat. Today, less than 0.5 % of Missouri's presettlement prairie remains (Wilcove 1987). The largest remnant of the tallgrass prairie that escaped the plow is represented by the Flint Hills, a region of approximately 10,000 km^2 that extends from northeastern Kansas into northeastern Oklahoma (Knapp and Seastedt 1986). Loss of prairie, and the fragmented nature of remaining prairie grasslands, are the most significant factors contributing to the decline of the prairie mole cricket.

Individual populations located in this study seem small in relation to the amount of prairie habitat available. Small isolated populations are subject to a number of factors that make them highly vulnerable to extinction: vulnerability to natural catastrophes, demographic stochasticity, genetic deterioration and social dysfunction (Wilcove 1987). The largest prairie mole cricket populations appear to be associated with aggregations of prairie fragments. These closely related prairie remnants probably reinforce the population by distributing mole crickets among the range of habitat and management influences. Each of the subpopulations are vulnerable. If fragmentation continues and these subpopulations are lost, the population becomes threatened.

It appears that extant populations have a relatively small number of reproductive males. Since prairie mole crickets spree (or perhaps lek) as part of their reproductive strategy there is a minimum number of calling males needed for successfully reproduction. Low populations may remain low, or are eventually lost, because the threshold number of males is too small to efficiently attract females.

Additional factors in the mole cricket's own life history may be contributing to further decline. Males and females that disperse

outward expect to encounter tallgrass prairie habitat just as their ancestors did for centuries. Present populations may fail to recognize the limits of their habitat (Walker 1980) resulting in dispersal into unsuitable surroundings. Whereas local flights have no effect on population density, migratory flights have the potential of depleting or flooding a local population or of stabilizing a population through density-dependent emigration (Stinner et al. 1983). Normal dispersal may be stabilizing the population in groups of prairie remnants. This same dispersal mechanism can prove disastrous on a small isolated prairie. Migration from the habitat may explain low populations or lack of occurrence in what otherwise appears to be suitable habitat.

Prairie mole crickets are conspicuously absent from the Flint Hills, despite this being the largest tallgrass prairie remnant remaining today. The collection record clearly demonstrates that the mole cricket did occur there historically. Prairie mole crickets do not tolerate grazing even though large grazers, buffalo and elk, were certainly one of the historic influences on the tallgrass prairie. Their activity probably caused localized extirpations of the prairie mole cricket, but grazing activity in any one area was short-lived and they moved on. These areas were subsequently reinvaded by the prairie mole cricket. The Flint Hills has been rangeland for cattle for many decades. During some periods of history the area was severely overgrazed, leading to soil erosion and compaction on a large scale. Over the long-term prairie mole crickets have been extirpated from this region, and there is little chance for recolonization. Reinvasion of the prairie can occur only if the grazing ends and if a mole cricket population occurs nearby for colonization.

The prairie mole cricket exists at present in small isolated fragments of tallgrass prairie, a habitat that has been all but lost to settlement and agriculture. Extant populations are vulnerable because of continued loss of habitat, land use that is detrimental to the species, and features in their own life history that make them less likely to persist in fragmented habitat. While populations have been located through recent survey, and others surely exist within the core of the historic range, the species is threatened and a federal protection status is needed.

RECOMMENDATIONS

The prairie mole cricket has been extirpated from most of its former range. Present populations are small and fragmented. The following recommendations may ensure continued existence of the species:

1. The prairie mole cricket should be considered for federal listing by the U.S. Fish and Wildlife Service. A status of federally threatened is appropriate due to continued loss of habitat and detrimental land use in much of the remaining habitat. The prairie mole cricket has not declined to the point that it is facing immediate peril, or endangerment. This is largely because many extant populations occur on land being managed as public prairie. The prairie mole cricket and other prairie animals and plants are being managed for at these sites (even if indirectly). Protection should be implemented in each of the states of the present range: Arkansas, Kansas, Missouri and Oklahoma. If mole crickets are discovered in Illinois or Mississippi these populations would also warrant state listing.

2. Hay meadow prairies with no history of grazing are the most likely sites for locating current populations of prairie mole crickets. Surveys should continue in suitable habitat throughout the former range to identify remaining populations. This is particularly important in the parts of the range where extensive rangeland occurs, since future changes in land use (removal of grazing) would provide the best chance for recovery of the species.

3. Research on management of the species should be conducted and management practices that can be inferred to be acceptable should be emphasized at prairies currently supporting the species. Prairie grasslands should be managed to reduced woody encroachment and prevent the introduction of exotic species. Fire and haying are management tools that appear to have no adverse effect on prairie mole cricket populations. When grazing is used as a management tool it should be done lightly and on a rotational basis in small units (in relation to the total size of the tract). When possible, one or more of the units should be left out of the grazing rotation completely.

4. More information about the life history of the species is needed. The length of time to maturity, nymphal life history, use of habitat throughout the life and population biology will be needed to plan for recovery of the species. An annual monitoring program should be initiated at several extant populations to improve knowledge of population fluctuations.

ACKNOWLEDGMENTS

We are indebted to a great many people who contributed to the success of this project. Most of the survey was done by volunteers, too numerous to mention, who were willing to assist the survey with little more than a thank you. Of particular mention is Tom Toney whose dedication and love for a place called a prairie kept us motivated. Tom Walker has been a continuous source of information and encouragement, steering our efforts with suggestions, gnawing questions and endless interest. We received tremendous support from the Natural History staff of the Missouri Department of Conservation. Diana Munsterman organized and produced the manuscript and Donna Pasley assisted with artwork and figures. Much appreciation goes to Jim Engel and the U.S. Fish and Wildlife Service for funding the survey.

Our deepest gratitude goes to those unnamed people who noticed the passing of the tallgrass prairie and through their efforts managed to set aside examples for future generations. These places are, after all, the last stronghold for the prairie mole cricket . . . . . and other creatures we have yet to notice.

REFERENCES

Alexander, R.D. 1975. Natural selection and specialized chorusing behavior in acoustical insects. IN D. Pimentel, ed., Insects, Science and Society. Academic Press, New York.

Allgood, F.P. 1979. Missouri General Soil Map and Soil Association Descriptions. USDA Soil Conservation Service, Columbia, MO. 74pp.

Bennet-Clark, H.C. 1970. The mechanism and efficiency of sound production in mole crickets. J. Exp. Biology 52:619-652.

Borrer, D.J., D.M. DeLong, and C.A. Triplehorn. 1976. An Introduction to the Study of Insects. Fourth Edition. Press. 852pp.

Emlen, J.T. 1971. Population counts of birds derived from transect counts. Auk 88:323-341.

Forrest, T.G. 1980. Phonotaxis in mole crickets: its reproductive significance. Fla. Entomol. 63(1):45-53.

Forrest, T.G. 1983. Calling songs and mate choice in mole crickets. Pages 185-204 IN D.T. Gwynne and G.K. Morris, eds. Orthopteran mating systems: sexual competition in a diverse group of insects. Westview Press, Boulder, Co.

Fowler, H.G., M.T. Vieira de Camargo, and L. Crestana. 1985. Feeding habits of Brazilian mole crickets (Orthoptera:Gryllotalpidae: Scapteriscus spp. and Neocurtilla sp.). J. Econ. Entomol. 78(5):1076-1078.

Hayslip, N.C. 1943. Notes on biological studies of mole crickets at Plant City, Florida. Fla. Entomol. 26(3):33-46.

Klelyla, P.C. and G. Dodson. 1978. Calling behavior and spatial distribution of two species of mole crickets in the field. Ann. Entomol. Soc. Am. 71:602-604.

Knapp, A.K. and T.R. Seastedt. 1986. Detritus Accumulation Limits Productivity of Tallgrass Prairie. BioScience 36(10):662-668.

Metheny, E.L. Jr. 1981. Contrasting feeding habits of pest mole cricket species. J. Econ. Entomol. 74:444-445.

Metheny, E.L. Jr., R.L. Kepner, and K.M. Portier. 1983. Landing distribution and density of two sound-attracted mole crickets (Orthoptera: Gryllotalpidae:Scapteriscus). Ann. Entomol. Soc. Am. 76(2):278-281.

Nelson, P.W. 1985. The Terrestrial Natural Communities of Missouri. Missouri Department of Natural Resources. 197pp.

Nickerson, J.C., D.E. Snyder, and C.C. Oliver. 1979. Acoustical burrows constructed by mole crickets. Ann. Entomol. Soc. Am. 72(3):438-440.

Nickle, D.A. and J.L. Castner. 1984. Introduced species of mole crickets in the United States, Puerto Rico, and the Virgin Islands (Orthoptera: Gryllotalpidae). Ann. Entomol. Soc. Am. 77(4):450-465.

Stinner, R.E., C.S. Barfield, J.L. Stimac, and L. Dohse. 1983. Dispersal and movement of insect pests. Ann. Rev. Entomol. 28:319-335.

Toney, T. 1987. Draft Prairie Plan. Missouri Department of Conservation. Unpublished document. 201pp.

Ulagaraj, S.M. 1975. Mole crickets: ecology, behavior, and dispersal flight (Orthoptera:Gryllotalpidae: Scapteriscus). Environ. Entomol. 4(2):265-273.

Walker, T.J. 1982. Sound traps for sampling mole cricket flights (Orthoptera: Gryllotalpidae: Scapteriscus). Fla. Entomol. 65(1):105-110.

Walker, T.J. 1983. Diel patterns of calling in nocturnal orthoptera. Pages 45-72, IN D.T. Gwynne and G.K. Morris, eds. Orthopteran mating systems: sexual competition in a diverse group of insects. Westview Press, Boulder, Co.

Walker, T.J. 1984. Mole Crickets in Florida. Agricultural Experiment Station Bulletin 846, December 1984. 54pp.

Walker, T. J. and G.N. Gritz. 1983. Migratory and local flights in mole crickets, Scapteriscus spp. (Gryllotalpidae). Environ. Entomol. 12(3):953-958.

Walker, T.J. and Ngo Dong. 1982. Mole crickets and pasture grasses: damage by Scapteriscus vicinus but not by S. acletus (Orthoptera: Gryllotalpidae). Fla. Entomol. 65:300-306.

Walker, W.F. 1980. Sperm utilization strategies in non-social insects. Am. Natur. 115:780-799.

Wilcove, D.S. 1987. From fragmentation to extinction. Natural Areas Journal 7(1):23-29.

APPENDIX I. Existing (pre-survey) specimen records of Gryllotalpa major.

DATE	COUNTY	SITENAME	NOTES
ARKANSAS			
07/09/1968	Washington	Fayetteville	---
ILLINOIS			
---	---	---	Type specimen, only information with the specimen was "Illinois"
KANSAS			
---	Labette		Hebard 1932
---	Riley	Manhattan	Hebard 1932
---	Riley	---	Hebard 1934
---	Rooks	---	Hebard 1934
---	Labette	---	Type specimen G. ponderosa, long-winged female. Coll: Brunor
05/05/1874	Riley	Popenoe	Coll: G.A. Dean
04/11/1875	Riley	Popenoe	---
06/01/1921	Rooks	Stockton	Long-winged female
1929	Riley	---	In prairie soil
04/29/1929	Riley	Manhattan	Long-winged male
04/29/1929	Riley	Manhattan	Long-winged male
04/11/1931	Riley	---	---
04/04/1932	Labette	Altamout	Coll: D.E. Slingerland
05/03/1933	Riley	Manhattan	Long-winged female
05/13/1957	Douglas	Lawrence	Coll: G.W. Byers
05/10/1962	Douglas	Lawrence	Coll: G.W. Byers
MISSISSIPPI			
---	Winston	Louisville	Hebard 1932
04/18/1889	Winston	Louisville	Male
04/13/1931	Simpson	Braxton	Long-winged female
MISSOURI			
---	Jasper	Carthage	Hebard 1932
---	Wright	Mtn. Grove	Juvenile V
---	Greene	Springfield	---
---	Greene	Springfield	Long-winged male
---	Wright	Mtn. Grove	Juvenile

APPENDIX I. (continued)

05/01/1876	Jasper	Carthage	---
05/05/1890	Barton	Milford	---
05/02/1904	Wright	Mtn. Grove	Long-winged male
05/02/1904	Wright	Mtn. Grove	---
04/26/1949	Lawrence	Pierce City	
05/18/1958	Vernon	---	---
05/18/1958	Vernon	---	Male
05/18/1958	Vernon	---	---
04/28/1959	Vernon	Nevada	Coll: J.W. McReynolds
04/29/1959	Vernon	Nevada	Lights. Coll: J.W. McReynolds
10/20/1960	Vernon	Nevada	Coll: J.W. McReynolds
10/20/1960	Vernon	Nevada	Coll: J.W. McReynolds
05/03/1962	Cooper	Boonville	On driveway. Coll: D.A. Kloud
04/21/1963	Vernon	Nevada	In area. Coll: D&J McReynolds
05/15/1971	New Madrid	Portageville	On sidewalk of motel Coll: Keaster

OKLAHOMA

---	Payne	Stillwater	Hebard 1932
---	Payne	Stillwater	Hubbell & Ortenburger 1927
---	Tulsa	Turley	Long-winged male
04/?	Hughes	Wetumka	Male
06/03/?	Lincoln	Stroud	Long-winged male
04/16/1895	Lincoln	Carney	Hubbel & Ortenburger 1927
04/16/1895	Lincoln	Carney	Male
1896	Payne	Stillwater	---
05/04/1900	Payne	Stillwater	Long-winged male
04/15/1916	Johnston	Tishomingo	Hubbel & Ortenburger 1927
04/15/1916	Johnston	Tishomingo	Long-winged male
04/1920	Okmulgee	Okmulgee	Male
1923	Tulsa/Osage	Tulsa	Hubbel & Ortenburger 1927
04/1925	Okfuskee -	Okemah	Long-winged male
04/1925	Okmulgee	Okmulgee	Hubbel & Ortenburger 1927
05/1925	Washita -	Foss	---
05/27/1925	McClain -	---	Coll: Scholl
06/08/1926	Mayes -	Pryor	Long-winged male
03/28/1928	Tulsa/Osage	Tulsa	Long-winged female
04/23/1929	Cleveland -	Norman	Long-winged female
04/05/1930	Cleveland	Norman	Long-winged female
04/31/1931	Cleveland	---	---
04/24/1933	Oklahoma -	---	Long-winged female
05/21/1936	Tulsa/Osage	Tulsa	Male
05/03/1939	Cotton -	Devol	Long-winged female
04/25/1957	Payne	---	---
05/16/1963	Pottawatomie-	---	---
04/04/1978	Payne	Stillwater	Coll: C. McCloy
05/22/1983	Payne	Stillwater	Coll: L. Waters
04/22/1985	Payne	Stillwater	---

APPENDIX II. Locations surveyed for Gryllotalpa major during 1986 and 1987.

COUNTY	SITENAME	DATE	COOPERATOR
ARKANSAS			
Benton	Rice Prairie	4/27-28/87	Ellen Nevel
Benton	Searles Prairie	4/25/87	Ellen Nevel
Benton	Stump Prairie	4/27-28/87	Ellen Nevel
Boone	Baker Prairie	5/14/87	Ellen Nevel Martha Milburn
Franklin	Burt Prairie	4/23/87	Ken Smith
Franklin	Cherokee Prairie	4/22/87	Ken Smith
Franklin	Craft Prairie	5/9/87	Chris Carlton
Franklin	Mainard Prairie	5/9/87	Chris Carlton
Franklin	Meek-Flanagan-C. McFerron-K. McFerron Prairie	4/23/87	Ken Smith
Franklin	Moore Prairie	4/22/87	Ken Smith
Franklin	H. Flanagan-R. Hudson-Sullivan-Barton-Johnson-M. Hudson-W. Flanagan-Prairie	4/23/87	Ken Smith
Franklin	No Site Name Prairie	4/22/87	Ken Smith
Franklin	Pendergrass Pile Prairie	5/9/87	Chris Carlton
Franklin	Stubblefield Prairie	5/9/87	Chris Carlton
Franklin	Vest-Flanagan-Acouch	5/9/87	Chris Carlton
Franklin	Vesta Prairie	5/3/87 5/9/87	Chris Carlton Chris Carlton
ILLINOIS			
Carroll	Ayers Sand Prairie	4/28/87 5/11/87	Randy Nyboer Randy Nyboer
Cook	Miami Woods Prairie	4/26/87	Bob Kruschka
Cook	Shoe Factory Prairie	5/9/87	Bob Kruschka
Cook	Somme Woods Prairie	4/16/87 5/10/87 5/24/87	Bob Kruschka Bob Kruschka Bob Kruschka
Ford	Prospect Cemetery Prairie	4/29/87	Mary K. Solecki John Taft
Iroquois	Loda Cemetery Prairie	4/29/87	Mary K. Solecki John Taft
Johnson	Cave Creek Glade	4/21/87	Max Hutchison
Johnson	Wildcat Bluff Glade	5/6/87	Max Hutchison
Lee	County Line Prairie	5/15/87	Gary Burnett
Macoupin	Denby Prairie	5/14/87	Ed Anderson
Mason	Revis Nature Preserves	5/10/87	Jean Karnes
Mason	Sand Prairie, Scrub Oak Nature Preserve	4/29/87	Jean Karnes Cheryl Jacobs Sue Lauzon Glen Kruse

APPENDIX II. (continued)

Monroe	Fults Hill Prairie	4/25/87	Lynn Hepler
		5/6/87	Lynn Hepler
Ogle	Bicentennial Prairie	4/18/87	Victoria Nuzzo
		5/13/87	Victoria Nuzzo
Whiteside	Thomson Fulton Sand Prairie	4/28/87	Randy Nyboer
		5/11/87	Randy Nyboer
Winnebago	Airport Prairie	4/17/87	Victoria Nuzzo
Winnebago	Harlem Hills Nature Preserve	4/16/87	Victoria Nuzzo
		4/24/87	Victoria Nuzzo
		5/14/87	Victoria Nuzzo
Winnebago	Searl's Prairie	4/28/87	Victoria Nuzzo
		5/5/87	Victoria Nuzzo
		5/12/87	Victoria Nuzzo

IOWA

Adair	Woodside Prairie	5/12/87	Daryl Howell
Warren	Rolling Thunder Prairie	5/6/87	Daryl Howell

KANSAS

Bourbon	Hollister Wildlife Area	5/1/87	Steven Ford
Cowley	Hay Meadow Prairie	4/28/87	Glen Salsbury
Crawford	20th Street Prairie	5/11/87	Steven Ford
Douglas	Baldwin City Lake Prairie	5/15/87	Glen Salsbury
Douglas	Blue Healer Prairie	5/7/87	Paul Liechti
Douglas	Boyd Prairie Preserve	5/9/87	Paul Liechti
Douglas	Elkins Prairie	4/20/87	George Byers
		5/13/87	George Byers
		5/23/87	Paul Liechti
Douglas	Triangle Prairie	5/6/87	Paul Liechti
Douglas	Turnpike Prairie	5/7/87	Paul Liechti
Franklin	Mt. Hope Prairie	5/19/87	Paul Liechti
Jefferson	Rockefeller Prairie	4/28/87	Paul Liechti
Lyon	Ross Natural History Reservation	4/21/87	Tom Eddy John Schrock
		4/26/87	Tom Eddy John Schrock
Riley & Geary	Konza Prairie	4/17/87	Ted Evans Dave Rintoul John Briggs
		5/15/87	Ted Evans Dave Rintoul John Briggs

APPENDIX II. (continued)

Sedgwick	Ninnescah Experimental Tract	4/16/87	Donald Distler
		4/26/87	Donald Distler
		5/2/87	Donald Distler
		5/10/87	Donald Distler
		5/13/87	Donald Distler
Sedgwick	DB-A	4/29/87	Donald Distler
Sedgwick	DB-A	5/6/87	Donald Distler
Sedgwick	DB-B	5/11/87	Donald Distler

MISSISSIPPI

Jasper	Bouteloua Prairie	6/3/87	Ken Gordon
Kemper	K1	5/8/87	Terrance Schiefer
Kemper	K2	5/8/87	Terrance Schiefer
Lowndes	L1	5/7/87	Terrance Schiefer
Lowndes	L2	5/7/87	Terrance Schiefer
Lowndes	L3	5/7/87	Terrance Schiefer
Newton	Highway 80 Prairie	6/3/87	Ken Gordon
Noxubee	N1	5/8/87	Terrance Schiefer
Noxubee	N2	5/8/87	Terrance Schiefer
Oktibbeha	O2	4/15/87	Terrance Schiefer
		4/16/87	Terrance Schiefer
Scott	Durand Oak Prairie	6/3/87	Ken Gordon
Scott	Harrel Prairie	5/31/87	Ken Gordon
		6/7/87	Ken Gordon
Scott	Pinkston Hill Prairie	6/3/87	Ken Gordon

MISSOURI

Atchison	Star School Hill Prairie	5/12/87	Dennis Figg Mike Sweet
Barton	Barton R.R. Prairie	4/21/87	Tom Toney
Barton	Catlin Prairie	4/29/87	Randy Haas
Barton	Cook Meadow Prairie	4/22/87	Tom Toney
Barton	Dorris Creek Prairie	4/28/87	Tom Toney
Barton	Golden Prairie		
Barton	Hunkah Prairie	5/27/86	Dennis Figg Paul Calvert Larry Larson
		4/22/87	Larry Larson
Barton	Lamar Airport	5/10/87	Randy Haas
Barton	Pawhuska Prairie	4/23/87	Gary Robison Mike Shannon
		5/3/87	Randy Haas
Barton	Prairie State Park	5/27/86	Dennis Figg Paul Calvert Larry Larson
		4/24/87	Larry Larson
		5/2/87	Larry Larson

APPENDIX II. (continued)

Barton	Private Prairie 1 (Pettis Knob Prairie)	4/28/87	Tom Toney
Barton	Private Prairie 2 (Schriener Prairie)	5/10/87	Randy Haas
Barton	Private Prairie 2 (Dorris Creek North Pr.)	4/28/87	Tom Toney
Barton	Private Prairie 3 (Hannon Prairie East)	5/11/87	Randy Haas
Barton	Private Prairie 4 (Prairie View School Pr.)	4/29/87	Randy Haas
Barton	Private Prairie 5 (Prairie View South Pr.)	4/29/87	Randy Haas
Barton	Private Prairie 6 (Irwin Prairie)	4/29/87	Randy Haas
Barton	Tzi-Sho Prairie	5/20/86	Paul Calvert
		5/27/86	Dennis Figg
			Paul Calvert
			Larry Larson
		4/22/87	Larry Larson
Callaway	Tucker Prairie	4/30/87	Mike Sweet
			Rich Szlemp
		5/5/87	Mike Sweet
			Rich Szlemp
		5/10/87	Mike Sweet
			Rich Szlemp
Cass	Dorsett Hill Prairie	5/8/87	Joe Werner
Cass	Snowball Hill Prairie	5/9/87	Joe Werner
Cass	West Dolan Prairie	5/19/87	Dennis Figg
Cedar	Mo-Ko Prairie	5/86	Tom Toney
Cedar	Monegaw Prairie	5/86	Tom Toney
Cedar	Sky Prairie	5/86	Tom Toney
Dade	Buenz Meadow	4/28/87	Tom Toney
Dade	Hunt Prairie	4/26/87	Tom Toney
Dade	Indigo Prairie		
Dade	Native Prairie 1 (Horse Creek Prairie)	4/26/87	Tom Toney
Dade	Niawathe Prairie		
Dade	Penn-sylvania Prairie		
Franklin	Shaw Arboretum Experimental Prairie	5/14/87	Bill Davit
Henry	Hillebrand Tract Prairie	5/7/87	Len Gilmore
Henry	Hoppe Tract Prairie	5/7/87	Len Gilmore
Henry	Chapel View Prairie	5/7/87	Len Gilmore
Henry	Ragland-Dunning-Wittig Tract Prairie	5/7/87	Len Gilmore
Holt	McCormack Loess Hill Pr.	5/86	Paul Calvert
Jasper	Wah-Sha-She Prairie	5/20/86	Paul Calvert
		4/28/87	Steven Ford
		5/87	Larry Larson
Jefferson	Valley View Glades	4/25/87	Lynn Hepler
			Teresa Baker
		5/8/87	Lynn Hepler
			Teresa Baker

APPENDIX II. (continued)

Lawrence	Mt. Vernon Prairie	4/23/87	Tom Toney
Lawrence	Private Prairie 1 (Stahl Prairie)	4/24/87	Tom Toney
Linn	Locust Creek Prairie	5/86	Paul Calvert
Morgan	Hite Prairie	4/22/87	Larry Rieken
New Madrid	Portageville Cemetery	4/22/87	Dennis Figg
New Madrid	Portageville Radio Tower	4/22/87	Dennis Figg
New Madrid	Portageville Railroad Prairie	4/22/87	Dennis Figg
Newton	Diamond Grove Prairie	5/16/86	Paul Calvert Greg Gremaud Dennis Figg
		4/15/87	Dennis Figg
Ozark	Caney Mtn. Picnic Area (Mark Twain Nat. Forest)	5/8/87	Eleanor Gaines
Pettis	Drovers Prairie	5/86	Paul Calvert
		5/87	Paul Calvert
Pettis	Grandfather Prairie	4/17/87	Paul Calvert
Pettis	Friendly Prairie	5/86	Paul Calvert
Pettis	Highway 52 Prairie	4/19/87	Paul Calvert
Pettis	Paint Brush Prairie	5/6/86	Paul Calvert
		4/87	Paul Calvert Dennis Figg
		5/87	Paul Calvert Dennis Figg
Pettis	Sedalia R.R. Prairie	5/87	Paul Calvert
Pettis	Unnamed Prairie 1 (Paint Brush Pr. North)	4/30/87	Paul Calvert
Pettis	Unnamed Prairie 2 (Hwy U Prairie)	4/30/87	Paul Calvert
Pettis	Unnamed Prairie 3 (Paint Brush Pr. South)	4/7/87	Paul Calvert
Platte	Little Bean Marsh	5/86	Paul Calvert
Polk	LaPetite Gemme Prairie	4/23/87	Larry Rieken
Scott	Sikeston Old Field	4/23/87	Dennis Figg
St. Clair	Chapman Tract Prairie	5/17/87	Len Gilmore
St. Clair	Conrad-Neuenschwander Tract (Valley Center Pr.)	5/7/87	Len Gilmore
St. Clair	Osceola IDP Tract Pr.	5/10/87	Len Gilmore
		5/16/87	Len Gilmore
St. Clair	Taberville Prairie	5/86	Larry Rieken
St. Clair	Wah-Kon-Tah Prairie	5/86	Larry Rieken
Taney	Dewey Bald	5/7/87	Eleanor Gaines
Vernon	Bushwhacker Prairie	5/11/87	Randy Haas
Vernon	Gay Feather Prairie	5/86	Larry Rieken
Vernon	Horton Bottoms	5/86	Paul Calvert
Vernon	Little Osage Prairie	5/86	Larry Rieken
Vernon	Marmaton River Bottoms	5/86	Paul Calvert Dennis Figg
Vernon	Nevada City Prairie	6/?/86	Rick Thom

APPENDIX II. (continued)

Vernon	Osage Prairie	5/85	Rick Thom Dennis Figg Jerry Overton
		5/86	Rick Thom
		5/87	Rick Thom
Vernon	Portia Lawn & Pasture	4/19/87	Gary Robison
Vernon	Private Prairie 1	4/21/87	Larry Rieken
Vernon	Schell-Osage Prairie Relics	4/22/87	Larry Rieken

OKLAHOMA

Canadian	El Reno Prairie	5/5/87	John Skeen
Cleveland	Colonial Estates Park	4/18	Harley Brown
		4/19	Harley Brown
Craig	White Oak School Prairie	5/13/87	Dennis Figg Paul Calvert
Garfield	Springer Prairie	4/19/87	James McPherson
Oklahoma	Oklahoma City Prairie	5/8	Neil Garrison
Osage	Adams Ranch/vicinity	4/16/87	Dennis Figg
Osage	Bell Ranch/vicinity	4/16/87	Dennis Figg
Osage	Foraker Cemetery Prairie/vicinity	4/16/87	Dennis Figg
Osage	Murffy Ranch	5/5/87	Dennis Geary
Osage	Osage County Prairie	5/5/87	Dennis Geary
Payne	Cross Timbers Research Area	5/14/87	John Skeen Mike Shaw
Payne	Lake Carl Blackwell Prairie	5/10/87	Don Arnold
Payne	Mercury Marine Prairie	5/6/87	Don Arnold
Payne	Unnamed Prairie	4/17/87	James McPherson
Pontotoc	Ross Ranch	4/22/87	Dennis Geary

TEXAS

Hunt	Clymer Prairie	4/16/87	Mike Sweet
Lamar	Tridens Prairie	5/11/87	David Diamond
		5/13/87	Dennis Figg Paul Calvert
Williamson	Westview Prairie	4/15/87	Mike Sweet