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# RESEARCHES CONCERNING TEXAS TETTIGONIIDAE

By

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# TABLE OF CONTENTS

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## INTRODUCTION[1]

The Tettigoniidae play an important role from season to season and year to year in the orthopteran faunal picture as it is staged in Texas.

In northcentral Texas (Isely, 1935, 1937) the campestrian performance on upland hills and prairies, as far as adult players are concerned, opens in mid-May and reaches its climax by mid-June, with five species of the Phaneropterinae and two Decticinae playing the leading parts. A mixed vegetation cover of spring and early summer flowering plants, tall grasses, and frequently low woody shrubs afford protection and food for these May-June tettigonids in their present isolated, optimum, remnant habitats. Rough to rolling topography, thin soils, and overgrazing have made possible the invasion and maintenance of the weedy flowering plants, whose floral parts furnish the necessary host-plant menu for the breeding Phaneropterinae, and a parade ground for the nocturnal activities of the phanerops, as well as the prowling, plundering, predaceous Decticinae.

By midsummer on account of seasonal changes the major tettigonid activities shift from the open upland prairies to timber margins, moist woods, tree tops, grassy sloughs, grassy flats, and lake margins. Species of the midsummer Phaneropterinae, Pseudophyllinae, Copiphorinae, Conocephalinae, and Decticinae, now largely replace the early season Phaneropterinae and Decticinae. In August and September the music of the tettigonid instrumentalists is to be heard mostly though not exclusively in moist environs.

The present paper is concerned primarily with the Tettigoniidae of northcentral Texas. The first part describes field observation of seven of the late spring and early summer species, and experimental studies carried on in the writer's home-garden-laboratory chiefly during the summer of 1937 simultaneously with his acridian researches already published (1938, 1938a). Pictures of cages, insectary, and garden-laboratory are shown and described in Isely, 1938a. Methods of handling experimental specimens (Acrididae) are also given. The second part is a summary of field notes and records of ten years (1931-41) of continuous field checking of the Tettigoniidae of Texas, chiefly in the northcentral section, but also in eastern, western, and southwestern Texas. The field records relate to seasonal succession, habits, local and regional distribution.

I was fortunate in having the assistance in field and laboratory work of my wife, Mary N. Isely, and three technical assistants: Mary Ellen Douglas, Gordon Tucker, and Doyle Cole. I am greatly indebted to Morgan Hebard and H. R. Roberts of the Academy of Natural Sciences of Philadelphia for taxonomic help, to Ruth Maxwell Sanders of the Southwestern Biological Supply Company for the drawings of Figs. 2 and 3; to Dr. Gordon Alexander, Professor of Biology of the University of Colorado, and Dr. Eleanor B. Scott, Professor of English, of Trinity University for reading the manuscript, and to Chester McShan for typing the manuscript.

The Tettigoniidae have received deserved attention from American orthopterists. Breeding and egg laying habits of the eastern katydids have been studied by Riley, Hancock, Fulton, Urquhart, Metcalf and Colby. The life histories of the "Mormon Cricket," Anabrus, and allied crickets have been extensively investigated by Gillette, Cowan, Yothers, and other economic entomologists. Stridulatory activities of the various eastern Tettigoniidae have been reported in detail by Scudder, Blatchley, Morse, Allard, Snodgrass, Rehn, Hebard, and Fulton.[2] Chopard has recently (1938) reviewed the biology of the Tettigoniidae along with other Orthoptera. The southwestern United States Tettigoniidae, however, have been for the most part neglected, as far as critical field observations and experimental studies are concerned.

The Tettigoniidae are orthopterous insects. The species discussed in this paper belong to five subfamilies.

Orthoptera
- Tettigoniidae (Long-horned Grasshoppers)
  - Phaneropterinae (Round-headed Katydids)
  - Pseudophyllinae (True Katydids)
  - Copiphorinae (Cone-headed Grasshoppers)
  - Conocephalinae (Meadow Grasshoppers)
  - Decticinae (The Shield Bearers)

### Species Given Experimental Study

The seven species chosen for experimental researches belong to two sub-families of the Tettigoniidae as follows:

Phaneropterinae: (Round-headed Katydids)
- *Dichopetala emarginata* Brunner
- *Arethaea ambulator* Hebard
- *Arethaea grallator* (Scud.)
- *Amblycorypha p. parvipennis* Stål
- *Amblycorypha huasteca* (Sauss.)

Decticinae: (The Shield Bearers)
- *Pediodectes haldemanii* (Girard)
- *Pediodectes nigromarginatus* (Caudell)

These are typically southwestern in their distribution and all reach population peaks in northcentral Texas. These species are essentially campestrian in their local distribution. Under present cultural conditions in Ellis County their climax habitats are found in upland pastures or weedy flats in bottom

[1] The experimental work which was carried on during the summer of 1937 was part of a series of orthopteran researches which were made possible by a grant from the Penrose Fund of the American Philosophical Society.

[2] The literature indicated by the above list of authors and cited at the close of this paper is doubtless far from complete. It represents, however, the papers which were available. The hinterlander's handicap in research library facilities is in part balanced by the advantages of field access to a diversified flora and fauna.

lands. In Ellis and Dallas counties these upland habitats may be described as Houston clay, shallow phase, soil areas or Trinity clay, alluvial soil, tracts with cover of tall grasses and coarse weeds. These phanerops and decticids have also been taken abundantly in Tarrant, Johnson, and Denton counties in limestone pastures. They were undoubtedly the dominant May-June katydids in favorable environs throughout the blackland prairies of Texas before the days of modern agriculture and are still common to abundant in season in their restricted habitats. The blackland prairies of Texas are mapped in recent publications, *The Flora of Texas* by Cary and Parks (1937, p. 2), and *The Vegetation of Texas* by Tharp (1939). Six of these species were collected in this area by those "Pioneer Naturalists," Jacob Boll and Gustaf W. Belfrage. Both Boll and Belfrage were expert entomologists. Four of the seven species listed above are represented by type specimens collected by them in Dallas and Bosque counties. Boll's intensive collecting territory (1870-1880) included Dallas and adjoining counties. Belfrage worked extensively (1868-82) in Bosque and McLennan and adjoining counties, Geiser (1937) pp. 30 and 302.

Their seasonal and breeding activities based on cage records are in part indicated by data given in Table 1. These data clearly establish the period of

TABLE 1. Seasonal, breeding and egg laying behavior.

| Species | Date earliest adult taken in the field | First date, copulation in cages | First date egg laying in cages | Approximate peak of egg laying | Date last adult taken in the field |
|---|---|---|---|---|---|
| *A. ambulator* | V, 2, '32 | V, 24 | V, 28 | VI, 2 | VI, 27, '37 |
| *A. parvipennis* | V, 13, '33 | V, 30 | VI, 2 | VI, 8 | VI, 26, '36 |
| *P. haldemanii* | V, 27, '33 | VI, 14 | VI, 22 | VI, 25 | VII, 26, '33 |
| *A. grallator* | VI, 3, '32 | VI, 21 | VI, 24 | VI, 28 | VII, 26, '33 |
| *A. huasteca* | VI, 2, '37 | VI, 21 | VI, 24 | VI, 30 | VII, 31, '34 |
| *D. emarginata* | VI, 10, '33 | VI, 22 | VI, 24 | VI, 28 | VII, 19, '34 |
| *P. nigromarginatus* | VI, 21, '37 | VI, 28 | VII, 1 | ? | VII, 12, '34 |
| | | All of the cage records for May-June, 1937. | | | |

adult seasonal activity of the seven species concerned. June is the peak month. While infrequent individuals may be collected late in July, all field records indicate that these species have their seasonal rhythm adjusted so as to meet successfully the exigencies of an occasional severe drouth in the spring and early summer, with its extremes in temperature and aridity and consequent shortage of suitable food and shelter. The diet problem of the flower feeding Phaneropterinae and the carnivorous Pediodectes is quite different; none the less, there appears to be considerable seasonal correlation among these open field Tettigoniidae.

## CAGE STUDIES

Experience gained in handling Acrididae (Isely, 1938a) in cages was employed to advantage in the laboratory studies of the Tettigoniidae. A home laboratory was found to be an ideal set-up for detailed observations of the nocturnal behavior of these katydids. Strong electric flashlights were employed. Hourly observations were recorded for each of the seven species from 6:00 p.m. to 6:00 a.m., as well as frequent daytime observations. The findings concerning each of the seven species will be taken up in the order of their seasonal appearance.

### SEASONAL, BREEDING, AND EGG LAYING BEHAVIOR

#### *Arethaea ambulator*[3] Hebard

Seasonally this is the first tettigonid in northcentral Texas to reach maturity. Juveniles have been taken (1932-39) continuously from early March up to the time of their adult development in early May (Fig. 1).

Since the species is flightless and nocturnal and hides in the vegetation during the day it is likely to be overlooked or classed as rare by the diurnal collector of Orthoptera. However, if its favorite haunts have been discovered, one may uncover many specimens in daytime collecting by working back and forth through the vegetation (Cantrall, 1940). Individuals are occasionally encountered some distances from their climax habitats. These have probably scattered from their breeding centers.

On May 22, 1937, Day's Ranch (Cedar Hill, Dallas Co.) a colony of *A. ambulator* was found among scattered bunches of Andropogon interspersed with Oenothera, Salvia, Penstemon, Thelesperma, Hymenopappus, Gaillardia, and other coarse weeds. Woody plants were represented by Ceanothus (Red Root), Smilax (Green Briar), and low bushes of the Aesculus (Texas Buckeye). The immediate topography was rough. In a short time 21 adults were collected, twelve males and nine females. This was one of the largest colonies encountered in several years of field work and doubtless represents an optimum habitat for the species. These were taken to the laboratory for cage studies.

For two seasons (1935-36) this species had been incidentally studied in cages, but its food preferences were not determined. Early in May, 1937, it was discovered that *A. ambulator* fed eagerly on floral parts of the evening primrose (Oenothera). Beginning May 8, 1937, the food given this long-legged katydid always included flowering shoots of Gaillardia and Oenothera, and with this diet from 20 to 30 adults were kept thriving and under constant observation until the middle of June. A cage 40 x 20 x 30 inches high (Isely 1938b, p. 557), larger than the ones usually employed, was found to be more satisfactory for the activities of *A. ambulator* than the standard cage (18 x 12 x 15 inches) commonly used in these experiments. Soil blocks of Andropogon and Gaillardia were placed in soil pans 8 x 4 x 3 inches and moved to the floor of the large

[3] The full scientific name with author of the species is used when the animal or plant species is first listed, or at the beginning of a new section. In other listings the name of the author is usually omitted.

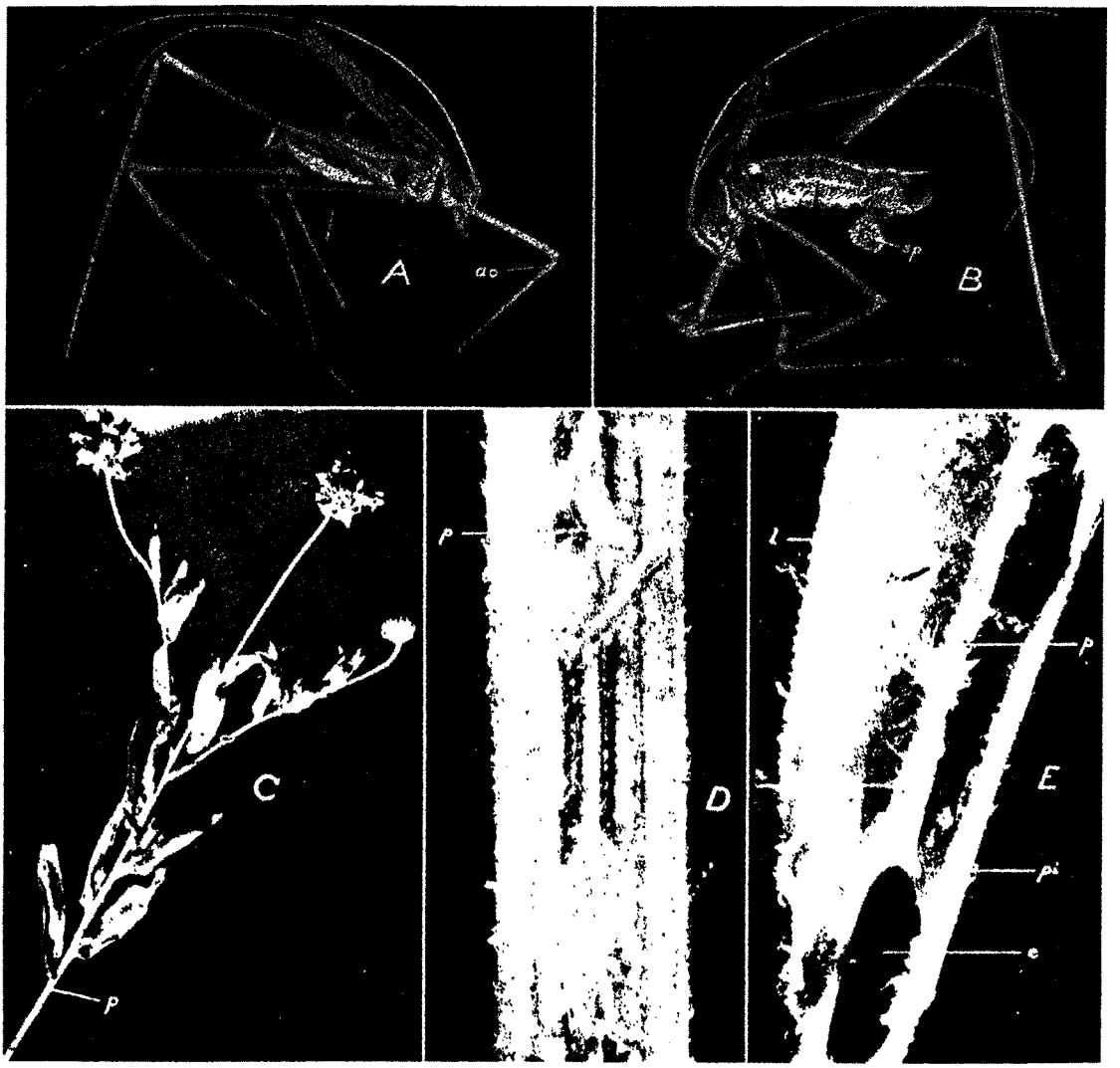


FIG. 1. *Arethaea ambulator* Hebard. A. Male, auditory organ indicated (ao); B. Female, with spermatophore (sp) attached; C. Shoot of *Gaillardia pulchella* Foug.; D. Portion of enlarged Gaillardia stem; E. Split stem of Gaillardia showing eggs in pith *in situ*, l, leaf, pi, pith, e, egg; p, punctures in stems (C, D, E).

experimental cage. Cut shoots of many other plants selected from the flora of climax habitats of *A. ambulator* were put in bottles in water and placed in the cage between the soil pans. This cut vegetation was usually renewed every second day.

*Cage Behavior.* In cages *A. ambulator* spends the day quietly seeking shelter among the bunches of transplanted plants. If the individuals move about, they thread their way deliberately through the vegetation. Unless disturbed, there is little daytime activity. They feed at night and at that time shift about rapidly. *Oenothera serrulata drummondii* T. & G. proved to be their favorite food plant in cages; in fact, if there was an abundance of fresh flowering shoots of this plant other vegetation was not eaten. They eat the petals, the new foliage leaves to limited extent, but especially the nearly mature flower buds. Ray and disk flowers of several Compositae served as second-choice foods. They eat their favorite plant parts quite ravenously when they begin their feeding at dusk. Observations at 8:30 and 10:30 p.m. and 2:30 and 4:00 a.m. show these slender, long-legged katydids actively moving about on top of the cut shoots of plants in bottles, still feeding on flower parts or resting on the sides of the cage.

*Breeding Habits.* In addition to feeding, stridulation, copulation, and egg laying are also chiefly nighttime activities but may extend into the morning hours. Copulation is of such brief duration in the case of *A. ambulator* that unless the observer is alert and close at hand the process is over before the de-

tails can be checked. Records show copulation in progress at 8:10 p.m., May 24; 3:00 a.m., May 25; 7:00 a.m., May 25; 2:30 a.m., May 26; 11:40 p.m., May 29, 6:00 p.m., June 3; 8:00 p.m., June 8. Other females carrying spermatophores indicated occasional nighttime copulation in the cages from May 24 to June 10.

During the courting period the stridulating males moved actively around the females, vigorously opening and closing their strong cerci (Fig. 1, A). If the female permitted, the male slipped back under the abdomen of the female and clasped her with the cerci near the base of her ovipositor. In several cases checked, there was no resistance or movement on the part of the female; more frequently, however, she moved about over the vegetation or retreated to the screens on the side of the cage. If the male succeeded in clasping the receptive female with his cerci, in a few moments a light globule appeared on the surface of the male genital area, increased rapidly in size, and the spermatophore was quickly formed. The female was then released and she moved away, holding the spermatophore (Fig. 1, B) by her vulva (Gillette, 1904). In repeated instances where the time was checked, the duration of copulation averaged about two minutes. In the large cage in one series of observations as many as six males were actively milling over the tops of shoots of Oenothera feeding on the buds, stridulating, and snapping their cerci. At this time only one female was present with the group of six males. As a rule, it was noticed that during the active breeding season the females fed after the males had had their fill of flower parts in the early evening hours. No cases were noted of males seizing other males. One instance was observed in which a male clasped a female carrying a fresh spermatophore. He quickly dropped her and afterwards cleaned the gelatinous material from his cerci with his palps and mandibles.

Stridulatory sounds made by *A. ambulator* were so faint as to be heard only by close attention near the cage. These stridulations are very soft rasps of short duration. In early morning observations at the height of the breeding season, it was noticed that nearly all the males in the cage were making rapid wing movements, indicating stridulation, although sounds were barely audible. Hebard (1935, p. 72) calls attention to the "exceedingly faint stridulation" of the males of *Insara juniperi* Hebard, a katydid allied to *ambulator*.

The egg laying technique of *A. ambulator* was of interest. In the big cage during the breeding season cut shoots of a dozen different prairie plants were kept in the water bottles in the cage as well as transplanted plants in soil boxes. Among these plants the stems of *Gaillardia pulchella* Foug. were almost exclusively selected for oviposition. The egg laying technique is essentially as follows. The female chews into the stem for a minute or two with her mandibles. After a suitable opening is made penetrating to the pith region (Fig. 1, D and E), she bends the abdomen so as to bring the ovipositor well forward

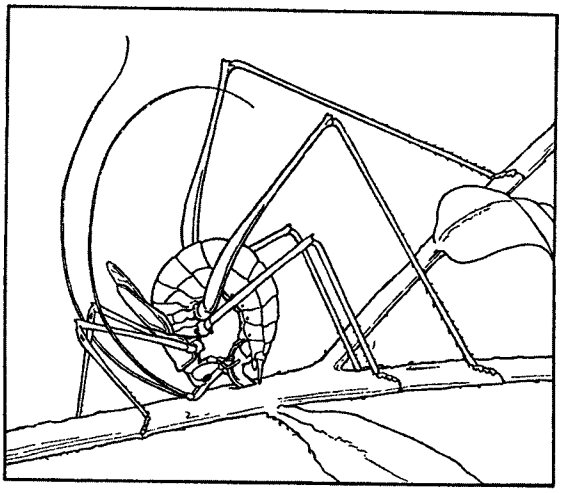

FIG. 2. *Arethaea ambulator* Hebard. Inserting ovipositor in stem of *Gaillardia pulchella* Foug. See Fig. 1, E, which shows eggs in pith of stem.

(Drawn by Ruth Maxwell Sanders)

to the position of the cut surface in the stem. The cerci of the female aid in orienting her body with reference to the stem used for oviposition and help to hold the ovipositor near the middle of the Gaillardia stem. Grasping the point of the well-bent ovipositor with her jaws she gradually works this egg laying guide well into the pith region of the Gaillardia shoot (Fig. 1, D to E). After the ovipositor is well inserted (Fig. 2) abdominal contortions and pulsations indicate that an egg is being deposited. She removes the ovipositor, closes the opening with chewed stem fragments, and moving upward a short distance, makes ready a second orifice (Fig. 1, D) into which the ovipositor may be inserted. With one exception, during the observations of the laying of thirty-eight eggs by several female *ambulators*, the head was toward the top of the stem. Unfortunately the drawing for Fig. 2 shows the head of *ambulator* downward instead of in the typical orientation with the head toward the top of the plant. The most active egg laying period appeared to be from 2:00 to 6:00 a.m. Cage records show one instance of a continuous egg laying performance by a single female over a period of two hours and forty minutes. Sixteen eggs were deposited. This gives an average time interval of nine minutes per egg. The time of egg laying in this instance was from 4:30 to 7:10 a.m. Other timed observations covered as much as twelve minutes in the laying of single eggs. Examination on split stems rarely showed two eggs deposited in one opening. In those observed, the second egg was laid at the side and slightly above the first. There were no cases discovered of the laying of one egg followed by a second egg in a reversed position through the same orifice as reported by Hancock (1904) for the green meadow grasshopper, *Orchelimum vulgare* Harris (*glaberrimum* Brum.).

On June 12, an examination was made of all of the cut shoots and transplanted stems in the *A. ambu-*

*lator* cage. On one stem of Gaillardia five inches in length, thirty-five punctures were found. There was one puncture in a stem of *Engelmannia pinnatifida* T. and G. and a chewed place was found in a stem of *Melilotus alba* Desv. With these exceptions, all of the eggs had been deposited in the stems of Gaillardia. A female that died in the cage on June 14 was dissected and found to be carrying 19 fully mature eggs. Beginning about the middle of June, there came a noticeable lull in the cage activities of *Arethaea ambulator,* although several females were still carrying eggs. Field studies also indicated that populations were definitely on the wane before the middle of June; in fact, the latest field record is "VI, 21, '37."

Adults of *A. ambulator* in cages (1937) fed chiefly on buds and flowers of *Oenothera serrulata drummondii* T. & G. and oviposited in stems of *Gaillardia pulchella* Foug. In field studies, colonies have been found where both plants are absent, clearly indicating that *A. ambulator* is not dependent on these plants for food or for stems in which to lay their eggs. *Oenothera serrulata drummondii* is usually present and some of the largest colonies of *ambulator* which have been annually checked in the vicinity of Waxahachie for the past eight years, are found where both plants are important members of the flora. Recent field studies (1940) of juveniles, second instars, and later nymphs have definitely linked *ambulator* with *Salvia farinacea* Benth (Blue Sage). In cages (spring of 1940) juveniles of *A. ambulator* fed on *Astragalus nuttallianus,* D. C., *Lupinus texensis* Hook and sparingly on *Salvia farinacea. Ambulator* is clearly a discriminating feeder. In further cage studies with juveniles (1940) it was found that a large number of different forbs and grasses were refused when supplied for food as was the case with adults in the (1937) food tests. These field and cage observations were followed (late May, 1940) with further experimental testing of plant stems which might prove acceptable to *ambulator* as a repository for her eggs. At the time only four males and six females of *ambulator* were available for cage studies. These were placed in a large cage along with transplanted bunches of Salvia and several other prairie plants. All of these plants had stems with pith centers. Gaillardia, however, was not used, as the test centered on the possible choice of plant stems for oviposition by *ambulator* in the absence of Gaillardia. Examination of stems was made on June 6, 1940. Twelve typical *ambulator* stem punctures, (Fig. 1, D) were found in stems of Salvia and fourteen punctures in stems of Engelmannia. Split stems showed eggs imbedded in the pith of these stems.

These tests make it evident that Engelmannia and Salvia stems may be used for receiving *ambulator* eggs. In addition it should be noted that both grow from perennial roots. *Salvia farinacea* grows in rather dense clusters and has been observed to serve as the chief shelter plant for early March juveniles of *ambulator* in local upland pastures. It seems obvious that with these qualities Salvia is admirably suited to play an important role in the life activities of *Arethaea ambulator.*

*Amblycorypha parvipennis parvipennis* Stål

This is the second of our katydids to enter as an adult upon the May-June faunal stage. It reaches maturity during the last third of May. June is the month of its major adult activities although in protected localities individuals may live until July. My latest field record, "VI, 26, '33," reports a rather large colony of *parvipennis* among leafy shrubs. Like *Arethaea ambulator, Amblycorypha parvipennis* (Fig. 4, B) is a flightless katydid. While these two species are often taken in the same general habitat, *parvipennis* is more widely distributed locally and less secretive in its daytime behavior than *ambulator,* being frequently encountered in daytime collecting. Cage studies clearly demonstrate, however, that *parvipennis* is mainly nocturnal in its activities.

The following account gives a good idea of a climax habitat of *A. parvipennis* in northcentral Texas. Byrum Farm, six miles north of Waxahachie on highway 34, June 3, 1937, 6:00-8:00 p.m. On this trip there were five collectors. The general plan was to determine daytime and early evening activities of the Tettigoniidae under field conditions. The area for study was a small Trinity clay, (alluvial soil) weedy pasture in a bend of Waxahachie Creek. This tract was formerly cultivated, according to Mr. Byrum, and had quite recently, because of a shift in the highway, been changed to a pasture. Across the creek there is a permanent thirty-acre, rough, upland prairie pasture from which the new pasture was doubtless readily repopulated with insects. The plant cover was made up of various grasses and flowering weeds. Gaillardia, which was just passing, was the dominant cover during May. Gaura, still in its prime and abundant, was of interest as many of the apical shoots were defoliated. Among the immature weeds were numerous bunches of Veronia; other vegetation consisted of Smilax (Green Briar) and rank growths of pecan shoots from old stumps. The fact that fifty specimens of *A. parvipennis* were secured in a short time, should serve to mark this small pasture as a climax habitat of this species. Next in abundance in this weedy pasture habitat was *Pediodectes haldemanii,* whereas occasional specimens of *Arethaea ambulator* and *Arethaea grallator* were also taken, as well as several fifth instars and adults of *Amblycorypha huasteca.* The local abundance of *parvipennis* is further emphasized by the writer's June field record summaries for 1933 and 1934, which show that after dusk, stridulation of *A. parvipennis* is everywhere evident in *favorable* localities.

*Cage Behavior.* Fifteen to thirty adults of *A. parvipennis* were observed continuously in cages from May 20 to the end of June. Like *ambulator, parvipennis* is a flower feeder; foliage leaves of several plant species, however, are also acceptable as food. Flowers, buds, or young leaves of the following plants were eagerly eaten by caged individuals:

Oenothera, Gaura, Pentalostemum, Stillingia, Lactuca, *Lupinus texensis* and *Astragalus nuttallianus;* to a lesser extent the ray flowers of Gaillardia and Thelesperma. Stridulation and mating are complementary katydid activities. *A. parvipennis* was the outstanding instrumentalist in our tettigonid laboratory orchestra. *A. parvipennis* males also synchronize their orchestration; however, as Fulton (1928, p. 446) has shown in his experiments with *Amblycorypha rotundifolia brachyptera* Ball, operated males, i.e., males with tibiae and auditory organs clipped off, played in discord, proving the auditory qualities of the tibial "ears" in *parvipennis.*

*Breeding Habits.* Copulatory behavior of *A. parvipennis* is similar to that of *Phaneroptera furcata furcata* Brunner (Fulton 1930, p. 626) and not unlike that of certain crickets, Nemobius (Fulton 1931, p. 227) or Oecanthus (Hancock, 1905). Mating behavior was repeatedly checked in cages. The stridulating male approached the female with uplifted wings; then he ceased fiddling and backed around toward the female. The female occasionally would move astride, stroking the male on the tergum with her palps as she moved forward until her head was under his wings. If coupling was accomplished, the pair might remain in copulo for a considerable period. If the female left the union with a large glistening spermatophore, it was evident that ensemination would follow. Females carrying spermatophores were common in cages during the entire period of June experimentation.

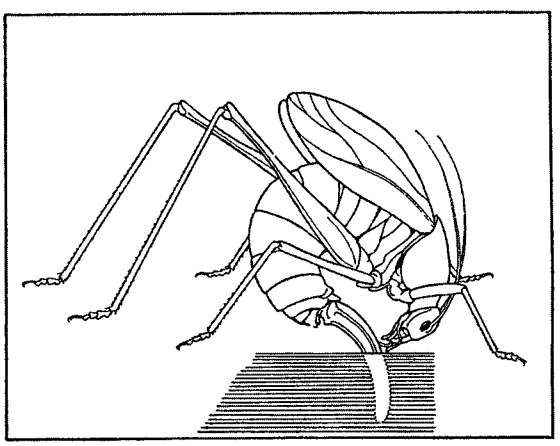

FIG. 3. *Amblycorypha p. parvipennis* Stål. Forcing ovipositor into soil in preparation for oviposition. Note: The egg laying techniques of *Amblycorypha huasteca* (Sauss.) and *Dichopetala emarginata* Brunner are quite similar to those of *A. p. parvipennis.*

(Drawn by Ruth Maxwell Sanders)

*A. p. parvipennis* deposits its eggs in the ground. A female at egg laying time bends so as to form an arch with the body. The mandibles seize the point of the sickle-like ovipositor and assist in directing it into the ground. (Fig. 3). When the evipositor has been fully buried into the ground, she continues to hold it with her jaws. Body pulsations indicate the passage of the eggs into the ground. Egg laying in cages often occurred early in the evening and was, as a rule, a nocturnal activity. Records show egg laying in progress at all hours of the night, 7:45 p.m., 10:30 p.m., 12:30 a.m., etc. Several loose egg masses were secured. On June 8, 1937, an examination of one of the soil pans (Isely 1938a, p. 6) revealed five of these loose clusters of eggs. The count per cluster was as follows: 11, 11, 14, 13, 5 eggs, respectively. The individual eggs are brownish-gray in color, flat and ellipsoidal in form.

### *Pediodectes haldemanii* (Girard)

When *Pediodectes haldemanii* (Fig. 4, E) was taken up for special cage studies in the summer of 1937, it was assumed that this species was chiefly phytophagous and also highly cannibalistic, as are *Anabras simplex* Haldeman (Gillette 1904, Cowan 1929) and *Peranabrus scabricollis* Thomas (Melander and Yothers, 1917). It soon developed, however, that *P. haldemanii* is chiefly carnivorous in its feeding behavior as Fabre reported for the "White-Faced Decticus" (Stawell, 1921). From the twentieth of May to the last of June, 1937, 20 to 30 individuals of this large decticid were in one or two of the regulation cages on the insectary shelves. It was soon found that the foliage of forbs and grasses was little used as food, even under starvation pressure. In cages they would eat to a limited extent the flowers and flower parts of Opuntia, Stillingia, and Melilotus. In further cage studies with *P. haldemanii* juveniles (1940) the fruits of *Astragalus nuttallianus,* D. C., were eaten. Four second instar juveniles were put in a cage on April 6 and supplied with forbs and grasses but no animal food was provided. These four individuals had advanced to the third instar by May 6. It is worthy of note that no cannibalism had occurred even at the time of moulting when some individuals were changing from second to third instars.

*Cage Behavior. P. haldemanii* will eat vegetation sparingly when no animal food is provided in cages. The stems of Sonchus and garden lettuce were eaten. Green weed seeds were also used as food. They appeared neither voracious nor greedy. During the day they spend most of their time on the screen on the back of the cage, especially the upper half. If they move they crawl around more or less de'iberately, moving over their fellows, and these do not seem to object. The count in one of the *P. haldemanii* cages on June 2, 1937 was 16 males and 14 females. In this cage we placed 35 grasshoppers, medium to fairly large in size. Half an hour later only 14 of them were left. A check at 5:30 a.m. the next morning showed 6 grasshoppers remaining. The *P. haldemanii* in feeding snap off a leg of a passing grasshopper or grab the acridian with the fore legs and bite especially into the head region, holding the prey with their fore and middle legs. Very seldom were individuals observed pursuing their prey. They seemed to depend chiefly on cutting off a body part with their large mandibles or grabbing the passing insect with the front legs. The only time *haldemanii*

appeared to be irritated was when another decticid wished to share in the captured food. Under these circumstances they showed a good deal of savage fight. They were frequently satisfied with a leg or an antenna, letting the crippled acridians escape. All of the various Phaneropterinae used in these experiments were also captured as food by caged *haldemanii*.

On June 9, a large number of insects were swept from flowering Melilotus. The numbers were estimated; white-faced flies (Tachina) 50, honeybees (Apis) 25, Pentatomidae 15, and several small butterflies and moths. These were placed in the cage at 4:00 p.m. In a short time it seemed as if every hungry *haldemanii* was feeding on one of these insects. Large grasshoppers (*Xanthippus corallipes pantherinus,* Scud.), and hard-backed beetles (*Calosoma scrutator* Fabr.) were passed up and not eaten. It was also noticed that *P. nigromarginatus* usually remained to the last in the cages of *P. haldemanii*. Several times cannibalism was observed but more often than otherwise, even crippled or moulting individuals of *haldemanii* remained in the cage unmolested.

*P. haldemanii* is an abundant and widely distributed decticid in northcentral Texas. If it were diurnal in its activities instead of primarily nocturnal, it would undoubtedly be much better known. In upland pastures these insects often hide away under coarse weeds. In overgrazed pastures they are sometimes found aggregated in numbers under clusters of the common cactus, Opuntia. One can frequently rout out large numbers of *haldemanii* and *P. nigromarginatus* by cutting heavy growths of Opuntia. Large weeds are often used for roosting, and especially in midsummer the insects show up in considerable numbers among the upper leaves. Here again *haldemanii* is found in company with *P. nigromarginatus*. *P. haldemanii* is taken also in open woods, but in northcentral Texas maximum numbers are found in upland pastures where coarse vegetation serves for shelter and protection. In favorable habitats this species carries over through July but becomes infrequent during August. As Cowan (1929, p. 15) suggests for *Anabrus simplex* (Haldeman) high temperature at the surface of the ground during the day drives the adults up on the weeds. This behavior may be noticed especially in overgrazed pastures where the decticids normally were finding shelter under clusters of cacti. On cool days the insects would not be in evidence, but on excessively hot days (air temperature of 100°F.), large numbers of both *P. haldemanii* and *P. nigromarginatus* would be found high up on the weeds, especially in the near vicinity of the bunches of Opuntia.

*Breeding Habits.* The mating behavior of *P. haldemanii* is similar to that described in some detail by Melander and Yothers (1917) for *Peranabrus scabricollis* Thomas. The stridulating male *haldemanii* backs under the abdomen of the receptive female and if she remains quiet, he may catch hold of her near the base of the ovipositor with his hooked cerci. The actual process of copulation, i.e., until the spermatophore was formed (Fig. 4, E) and the female released, lasted in cage studies from 15 to 20 minutes.

Copulation as well as egg laying was usually a nocturnal activity. My notes for June 22, 1937, read as follows: "At 10:30 p.m. two females trying to oviposit in the middle soil pan. At 12:05 a.m. five females with ovipositors buried in coarse gravel of soil pan attempting to lay. Specimens are nervous and quite active. At 12:45 a.m., without otherwise disturbing egg-laying females, I poured one half cup of water into the soil pan. All the females ceased laying activities and moved to another position in the cage."

In egg laying in cages the female brings the heavy, slightly curved ovipositor (Fig. 4, E) under the body and gradually works it into the ground. In final egg laying position the body of the female is flat on the ground at right angels to the ovipositor. On June 26, 1937, an examination of the soil pans in the *haldemanii* cage was made to determine the number of eggs. Two hundred forty-three elongated cylindrical brownish-gray eggs were secured. These are mass results, as time was not available for individual studies. The depth in the ground of most of the eggs was between an inch and an inch and a half.

The stridulation of *haldemanii* is especially marked during the breeding period. Stridulating may be heard during the nighttime and also up to noon at the height of the breeding season. Miss Douglas, one of my technical assistants, made special study of stridulating activities. Her notes for June 17, 1937, read: "8:10 a.m., I can count 14 males stridulating. At 10:30 a.m., 12 males stridulating. At 5:45 p.m., only one male singing." Hebard (1925, p. 404) describes the song as a "sharp, not loud, dxik—dxik—dxik—, the intervals between the notes brief." Miss Douglas described the chirps as sharp rasps or continuous chirps, at times not unlike certain warning or signal notes of the cardinal.

### *Arethaea grallator* (Scud.) and *Amblycorypha huasteca* (Sauss.)

Since these two species (Fig. 4, A, D) are quite similar in their field and cage behavior and have a like seasonal cycle, they will be discussed in part together. Both are open prairie katydids and as far as field records show are more numerous in individuals and less secretive than any of the other three species of the Phaneropterinae, which were experimentally studied. During a peak season, mid-June, 1933, in favorable habitats these species were so numerous as to fly continuously in numbers before the collectors. This degree of abundance was observed at Bell Branch Country Club (VI, 6, 1933) and McWhorter's Ranch (VI, 10, 1933). They have not reached a similar peak in numbers in any season since 1933. Neither of the species is a strong flyer and individuals are usually easy to collect. As with the other Phaneropterinae, both of these species are flower feeders. Young foliage leaves also make a considerable part of their diet. The plants enumerated

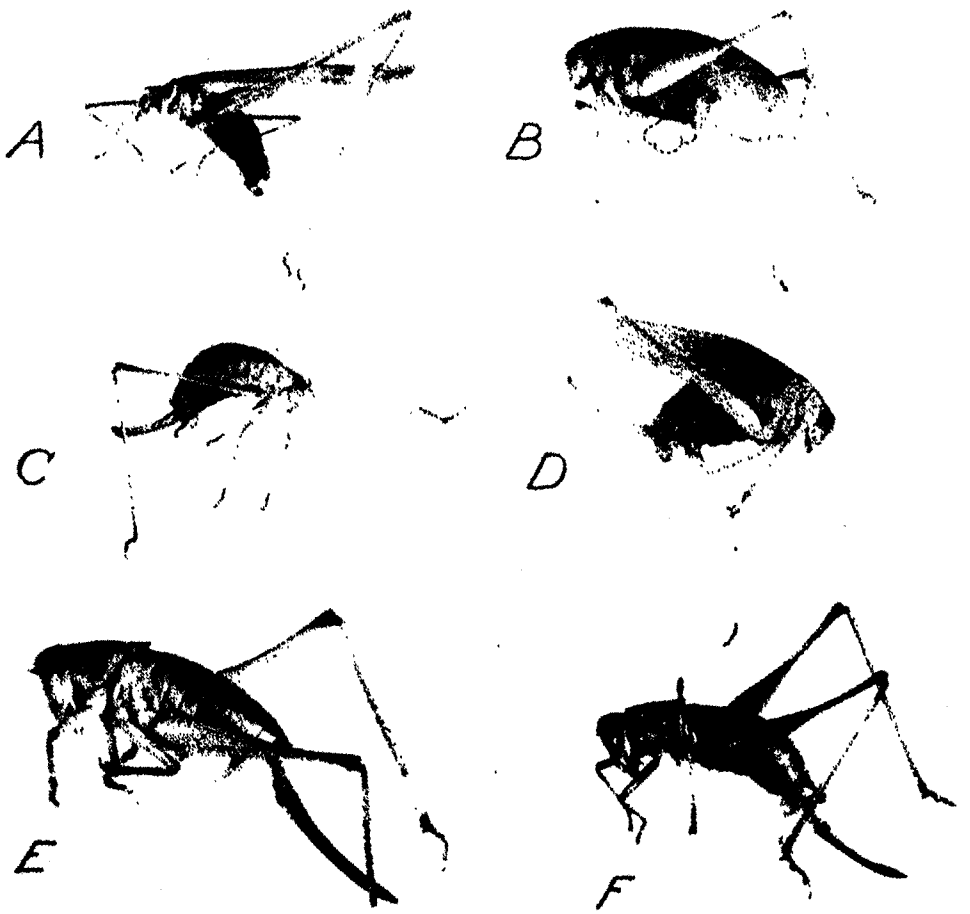


FIG. 4. May-June southwestern Tettigoniidae. A. *Arethaea grallator* (Scud.); B. *Amblycorypha p. parvipennis* Stål; C. *Dichopetala emarginata* Brunner; D. *Amblycorypha huasteca* (Sauss.); E. *Pediodectes haldemanii* (Girard); F. *Pediodectes nigromarginatus* (Caudell). Note: Spermatophores show in A, D, E and F. In B and C the spermatophores had fallen away from the specimens at the time the photograph was made. The sizes of the spermatophores for these two species are indicated by dotted outlines.

for *Amblycorypha parvipennis* proved to be suitable food plants in cages for *Arethaea grallator* and *Amblycorypha huasteca*. No marked differences in their food selection was shown in cage tests. In mating habits and egg laying technique, however, *A. grallator* and *A. huasteca* are very different in their behavior.

*Amblycorypha huasteca* (Sauss.). The breeding, egg laying and stridulating behavior of *huasteca* is similar to that of *A. p. parvipennis*. Twenty to thirty individuals of *A. huasteca*, beginning with fourth and fifth instars and continuing with adults, were observed in cages from late May to the first of July during 1937. As an instrumentalist, *A. huasteca* would probably have to play second fiddle in a *parvipennis-huasteca* orchestra. The call notes of *huasteca* are fainter but fully as insistent at the peak of the breeding season as are those of *parvipennis*.

In egg laying and breeding habits, *huasteca* and *parvipennis* are similar. Time was not available to check *huasteca* as critically as the first three species herein reported; however, 39 eggs of *A. huasteca* were taken from the cage soil pans July 1, 1937. In general form the individual eggs were similar to those of *parvipennis*, and the egg masses were similarly placed in the soil.

*Arethaea grallator*. The cage activity of *grallator* is similar to that of *A. ambulator*. However, in its nocturnal movements, *grallator* does not appear to get about as rapidly as *A. ambulator*, and its egg laying behavior is quite different.

Laboratory records show that on June 24, 1937,

12:30 a.m., a female *grallator* was observed trying to place eggs in the stem of a small Gaillardia. She continued this activity for over thirty minutes. She first appeared to form a shallow cavity near the base of the stem with her mandibles. In this depression an egg was finally deposited and then covered over with bits of chewed stem and mud. A more careful examination the next morning showed several eggs in position, inserted in shallow pits in the side of the stem, one above the other. Again on June 28, at 12:30 a.m., another *grallator* was observed laying eggs. This time dead stems of the grass Hordeum were used to receive the eggs. The general procedure was similar to the one described before. In the morning by daylight the Hordeum stems were examined, and a row of four eggs was found, one above the other. On another stem, there was a row of three eggs plastered over with mud and chewed stem fragments. Altogether, thirty eggs of *A. grallator* were collected, all of them partly inserted in stems near the ground. The method of *A. grallator* in wedging the eggs into small cavities excavated in plant stems and covering them with chewed bits of vegetation and moistened soil appears unique among oviposition methods of American katydids. It may be contrasted with the methods of depositing eggs in stem pith *(A. ambulator),* of placing them between edges of leaves (*Scudderia texensis* Saussure-Pictet, Blatchley 1920, p. 465), (*Scudderia pistillata* Brunner, Urquhart 1938, p. 52), of gluing them to twigs (Microcentrum), or depositing them in soil (Amblycorypha). *A. grallator* buries the end of an egg so as to leave two thirds of the egg exposed. The exposed portion is covered with chewed plant fragments and soft mud.

### *Dichopetala emarginata* Brunner

*Dichopetala emarginata* (Fig. 4, C) is similar to *Arethaea ambulator* in its secretive daytime behavior, both in the field under natural conditions, and in cages. In its local distribution and seasonal cycle it is near to *Arethaea grallator* and *Amblycorypha huasteca,* although apparently less populous and more gregarious in habits. This gregariousness may be related to the fact that *emarginata* is flightless and clumsy in movements. *D. emarginata* is also a flower feeder. In mating habits it is not unlike *ambulator* in that the male seizes the female from beneath, clasping her with his cerci. In the duration of copulation, however, the two species are entirely different. Pairs of *D. emarginata* may remain in copulation for several hours before the spermatophore is formed. Laboratory records show copulation continuing from morning until midafternoon. During this mating activity the female will often move about the vegetation dragging the male after her, posterior end forward and the arched dorsal side down. A faint rasp or buzz best describes the stridulatory sounds of this short-winged species. *D. emarginata* deposits her eggs in the ground and her egg laying technique is similar to that of *A. parvipennis.* The eggs are elongated and cylindrical in form similar to those of *P. haldemanii.*

### *Pediodectes nigromarginatus* (Caudell)

Not until June 21, 1937, were laboratory studies begun with *Pediodectes nigromarginatus* (Fig. 4, F), the last in seasonal succession of the seven Tettigoniidae herein given special study. Twenty-two males and fifteen females were placed in regulation cages to test out food preferences and sexual activities. In field behavior and distribution, *nigromarginatus* closely parallels the habits of *P. haldemanii.* In the field they are often found associated in numbers under large cacti or roosting together high up on the leaves of broad-leaved plants during hot July afternoons. When placed together in cages, these two species of the Decticinae show little or no antagonism. Cage behavior, however, suggests that both are predatory, night-prowling insects.

Though *P. nigromarginatus* is chiefly carnivorous, it fed avidly on flower parts of Melilotus, which were thrown into the cage with insects swept from these flowers. Apparently, since it is considerably smaller in size than *haldemanii* it selects its prey from among the smaller insects. In cages various species of Pentatomidae, juveniles and smaller species of the orthoptera, flower flies, and sow-bugs (Oniscus) were among the animals acceptable as food.

There were instances of cannibalism in the *nigromarginatus* cages, but on the whole, there was no evidence of active cannibalism even when no food had been provided for two or three days and the cages were crowded. Day by day counts of total numbers of specimens in cages showed that the number which fell as prey by cannibalism was small. This appears to be of interest since economic entomologists who have worked extensively with western pest Decticinae (Mormon and Coulee crickets) emphasize the general prevalence of cannibalism in these species. Turner (1915) also calls attention to frequent cannibalism in cage studies of *Cethophilus latens* Scud.

The period for the study of *nigromarginatus* was short. Cage studies, however, show that in the main, the breeding, stridulating, and egg laying habits of *P. nigromarginatus* are similar to those of *P. haldemanii.*

## SIGNIFICANCE OF CAGE STUDIES

### Seasonal Succession and Food Relations

From the writer's viewpoint the food selection results obtained in these cage experiments were of significance. A knowledge of food habits is of importance in explaining seasonal appearance and gives clues to local as well as regional distribution of these southwestern katydids. It was evident in cage studies that all of the five katydids are oligophagous and as adults showed a marked preference for flower parts, and for tender fruit pods. The seasonal passing of the late spring and early summer flowering plants doubtless are important factors in the disappearance of these late spring and early summer

Phaneropterinae. A change in the floral aspect means a shift in faunal picture as far as these prairie katydids are concerned. *Arethaea grallator* and *Amblycorypha huasteca* seem better adapted to hot dry climatic conditions than are *Arethaea ambulator, Amblycorypha parvipennis* and *Dichopetala emarginata*. This may in part explain the later seasonal appearance and survival to mid-July of *grallator* and *huasteca*.

The two Decticinae especially studied do not appear to be as dependent upon seasonal changes as are the flower feeding Phaneropterinae. Their insect food supply found among growths of rank midsummer weeds may be sufficient to carry over these carnivorous insects successfully to the end of July. However, the decticids, from the evidence of their field behavior, doubtless find the July-August temperatures unfavorable to their normal activities. High temperatures of the Texas summer probably account for their rapid decrease in numbers.

### STRIDULATION

Stridulation and its relation to mating habits was a subject of constant checking and study during the progress of these investigations. The argument is frequently advanced, chiefly by armchair critics, that sound production is meaningless in the life of insects. This line of theorizing is not well supported by continuous cage-side observations of the behavior of these tettigonids. There are, to be sure, other urges which impel tettigonid musical sounds, but there is no doubt concerning the close association of stridulation and courting. In every one of the seven species, stridulation was clearly at its height during the active breeding cycle. The typical file rasp mechanism (Allard, 1928, p. 566) of the Tettigoniidae was employed for sound production by each of the species concerned. In several of the species, *Arethaea ambulator, A. grallator, Dichopetala emarginata,* and *Pediodectes nigromarginatus,* the sounds are best described as faint rasps. However, the rapid wing movements, which could be easily observed, were a definite evidence of active stridulation.

Texas open field Tettigoniidae live most of their lives in a habitat which may be described as a tangle of vegetation made up of tall grasses, coarse weeds, and frequently low bushes. In this environment the katydids are active at a level varying from one to three feet above the ground. The decticids are more frequently found at ground level, but especially in hot weather they roost in the leaf axils of tall weeds. Their rasps and low clicks, which represent their stridulatory sounds, undoubtedly contribute to the possibilities of mate finding. This is all the more important on account of their short breeding season. It is fair to assume similar communication by other stridulating Orthoptera. Fulton's (1928) experiments, which were repeated on cage specimens of *Amblycorypha p. parvipennis,* clearly establish the fact of group as well as individual communication by this species in synchronizing their stridulatory music.

### EGGS

Breeding habits among the Orthoptera were reviewed by Turner (1916). Recent studies by Fulton (1931) on the breeding habits of Nemobius and a review of the breeding habits of Ceuthophilus by Hubbell (1936) supply important data. Metcalf and Colby (1930) discuss and figure the egg laying of *Orchelimum vulgare* Harris, as does Urquhart (1938) for *Scudderia pistillata* Brunner. Details of the breeding habits of many species of Orthoptera including the Tettigoniidae are given by Chopard (1938).

The Tettigoniidae kept in cages laid their eggs in the soil or attached them in cavities made in the stems. The methods of oviposition have been briefly outlined for each species. The individual eggs approach two patterns as to form: 1. Four of the katydids have flattened oval eggs. 2. The Decticinae and *Dichopetala emarginata* have oblong cylindrical eggs.

The dimensions of the eggs as recorded in the following table give the average size and suggest the form:

| Species | Length in millimeters | Width in millimeters |
|---|---|---|
| *Amblycorypha p. parvipennis* | 6 | 3 |
| *Amblycorypha huasteca* | 5.8 | 2.5 |
| *Arethaea grallator* | 3.8 | 1.2 |
| *Arethaea ambulator* | 4.2 | 1.4 |
| | | Diameter in millimeters |
| *Pediodectes haldemanii* | 6 | 1.8 |
| *Pediodectes nigromarginatus* | 4.8 | 1.6 |
| *Dichopetala emarginata* | 4.0 | 1.2 |

The eggs of *A. ambulator* are somewhat pointed at one end. It is interesting to note that the rounded end is the one that first enters the pith cavity of the Gaillardia stem. The orientation is shown in Fig. 1, E, in which the lower end of the egg is rounded.

In the other three katydid species which have the flattened, ellipsoidal type, the egg form is quite symmetrical and rounded at each end. The eggs are laid in loose masses, the depth varying from half an inch to an inch in the ground.

In the species which deposit their eggs in the soil there is a definite correlation between depth of eggs in the soil and length of ovipositor.

## FIELD STUDIES

The writer's field studies pertaining to the ecology of the Texas Orthoptera, have been in progress for the past nine years (1931-40). While the Acrididae take first rank among the Orthoptera both in number of species and aggregate populations, the Tettigoniidae are in the forefront as actors in the night shift. Other nocturnal Orthoptera are found among the Gryllidae, Blattidae, Mantidae and Gryllacrididae.

The brief descriptions outlined below of the chief types of vegetational cover in northcentral Texas, which afford tettigonid habitats, will in part picture the environmental conditions under which the long-horned grasshoppers live. The actual tettigonid

micro-habitats are subdivisions in extent and make-up of these larger vegetational complexes which are here grouped under four heads:

1. PRAIRIE. Before the advent of the white man in southwestern North America, the campestrial prairies of northcentral Texas occupied the vast stretches of grassland shown on vegetation maps (Fig. 5) as the blackland and grand prairies. That these floral designations are at the present time chiefly of historical interest in much of this region is evident from the fact that in Ellis County nearly every foot of the former level prairie land is under plow. Grasslands are represented today by small, rough, upland, shallow soil, weedy pastures and occasional strips of grassy flats along railroad rights of way. Among the grasses still present on these flats are the Andropogons, Stipa, and Sporobolus. If the area is restored grassland, Sorghum (Johnson grass) may take a prominent place in the floral complex. The present-day student, therefore, of the Tettigoniidae of northcentral Texas must evolve his ecological factors of distribution mindful of the environmental changes which have occurred.

2. BUSH. Timber margin shrubs, under growth in open woods, and new growth on cutover lands represent shelter plants which provide habitats for the bush katydids. These are low growing shrubs which vary from one to seven feet in height. Prunus (thicket plums), Cornus (rough-leaf dogwood), Adelia (spring herald), and Symphoricarpos (coralberry) are typical examples.

3. SILVAN. These are timber areas with permanent cover of tall trees. Here may be included bottomland tracts and upland woods. Chief among the trees are elms, oaks, pecan, hackberries, and shrubs and vines in the more open areas. These woods afford two definite altitudinal zones. The lower may be characterized as the undergrowth of the shaded open woods and the higher as the arboreal habitats of the tree crowns.

4. SEMI-MARSH. In the east Texas timbers, marsh lands were visited in the vicinity of Elkhart, Marshall (Caddo Lake), and Tyler. In northcentral Texas, where no true marshes were found, the semi-marsh is represented by stream and lake border vegetation, chiefly tall grasses with mixture of willows and other broad-leaved herbaceous plants. Here also should be included low lying tracts adjacent to lakes and streams with a cover of slough grasses. Lake margins in northcentral Texas for the most part border artificial lakes. Country Club Lake at Waxahachie, lake margins of Lake Worth in Tarrant County and White Rock Lake at Dallas have typical lake margin vegetation which provide favorable environments for *O. nigripes* and similar forms. In eastern Texas favorable lake margin and marsh habitats are more generally found than in northcentral.

At least eighty percent of the time which has been given to the tettigonid field studies here reported has centered on areas 1 and 2. Further work in the habitats of areas 3 and 4 should add significant data. Nocturnal work has not been neglected, but here too, additional field studies are desirable.

## HABITS, HABITATS, SEASONAL RANGE, NUMBERS

In the summaries which follow, a species is placed in its primary or climax habitat. If found in sufficient numbers in one of the other three areas named above to justify frequent to occasional[4] population designation, the fact is specified by the number of its secondary habitat in parenthesis following its name as listed in the primary habitat. Among the Tettigoniidae as well as the Acrididae, the index to primary habitats is favorable breeding conditions. These are marked in season by the presence of eggs or juveniles. Occasional or infrequent adults, especially among flying Orthoptera, in a given area are often merely accidental visitants. These infrequent adults may or may not be unable to find favorable egg laying sites. If eggs are deposited, the juveniles may die for lack of minimum diet requirements, or because of other hostile environmental factors.

Recent taxonomic papers of Morgan Hebard have been followed in this paper in listing the order of sub-families, genera, and species. The seasonal range is indicated by naming the months in which the several species have been recorded as an adult in my field studies.

The primary and secondary habitats, population frequency, and usual seasonal range of adult breeding periods are given for all species where sufficient field data were secured. The writer's field records of county distribution are listed for many species. These are followed by brief summaries of field notes pertaining to the habits of the various species not previously treated in the first section of this paper.

PRAIRIE: *Dichopetala emarginata* Brunner (2) was common, mid-June through July and was collected in Dallas, Ellis, and Tarrant counties.

*Arethaea constricta constricta* Brunner (2), occasional to frequent, late June to September and was taken in Dallas, Ellis, Palo Pinto and Tarrant counties.

*Arethaea ambulator* Hebard (2). This little-known Arethaea was common, May to mid-June in Dallas, Denton, Ellis, and Tarrant counties.

*Arethaea grallator* (Scud.) (2) was abundant, June to July in Dallas, Denton, Ellis, Johnson and Tarrant counties, infrequent in Hunt and Lamar counties.

*Amblycorypha huasteca* (Sauss.) (2) even more abundant, June to July than *grallator* and was collected in Dallas, Ellis, Johnson, Parker and Tarrant counties, infrequent in Hunt and Lamar counties.

*Amblycorypha parvipennis parvipennis* (Stål) (2) was common to abundant mid-May to July in Dallas, Denton, Ellis and Tarrant counties.

[4] The frequency of a species is indicated by a method outlined in Isely 1937, pp. 334-5. The terms swarming, abundant, common, frequent, occasional, infrequent, and rare are used in a descending order.

*Neoconocephalus robustus crepitans* (Scud.) (2), common, mid-June through August. *Crepitans* is a campestrian species and in Ellis County is frequently found in remnant grassland flats along railroads. These isolated grassland areas represent the *last stand* habitats of these cone-headed longhorns.

Nocturnal study is necessary for an understanding of the distribution and activities of *crepitans*. The volume of the stridulatory noises of this species is loud enough to attract the attention of the night worker at a distance of two hundred yards. Chiefly by means of these night calls, males are located. If approached cautiously, they may be captured while in full song. Favorable conditions for night study of *N. r. crepitans* are clear moonlight and a stiff breeze. Under these conditions, with the aid of a flashlight, males have been taken in numbers in favorable localities. Occasionally while the collector is stalking a male, he will come upon a female in the near proximity of the male.

*Conocephalus strictus* (Scud.) (2) was frequent, mid-June through October. This species has been taken as late as December. It is a campestrian meadow grasshopper belonging to the prairie fauna. *Strictus*, according to available records and field work, is the most generally distributed of all the Texas Tettigoniidae.

*Pediodectes haldemanii* (Girard) (2) was common, June to July in Dallas, Ellis, Johnson, and Tarrant counties.

*Pediodectes stevensonii* (Thomas) (2) was common, mid-June through August in Dallas, Ellis, Palo Pinto, and Tarrant counties.

*Pediodectes nigromarginatus* (Caudell) (2). This species was common, June to July in Dallas, Ellis, Palo Pinto, and Tarrant counties.

Field evidence suggests that all of the eleven species named above are found throughout the prairie belt. It has been impossible to check the distribution of each species in detail for so large an area. However, wherever field collecting has been done in favorable habitats in northcentral Texas during the peak season of any one of these species, it has been taken in frequent to abundant numbers as indicated above.

BUSH. *Scudderia texensis* Sauss. and Pictet (4). *Texensis* was frequent, July to October. Diurnal field collecting evidence marks *S. texensis* as a timber margin bush katydid. In a stream bend habitat of the Trinity River, near Hutchins, Dallas County, X, 22, 33 it was found to be very abundant and was associated with *S. f. furcata* in tall slough grasses. *Schistocerca americana* Drury was the third orthopterous insect to swell the October population of this river bend, slough grass habitat.

*Scudderia f. furcata* Brunner (4) and (1) was frequent, June through October in Anderson, Dallas, Ellis, Parker, Palo Pinto and Tarrant counties. This species has the widest seasonal range and is the most generally distributed of the northcentral Texas Phaneropterinae. The case cited above, X, 23, 33 is the only time in personal field collecting in northcentral Texas when *S. f. furcata* and *S. texensis* were taken in large numbers. The seasonal spread of *S. f. furcata* may be due to variability in hatching or to two broods in one season.

*Amblycorypha uhleri* (Stål) (1) was a late June to August katydid. It is very local in distribution but in favored habitats may become common. This bush katydid is sometimes associated with last of the season representatives of *parvipennis*.

*Orchelimum silvaticum* McNeill. (4). This species was frequent, August to October, and was collected in Anderson, Dallas and Ellis counties.

SILVAN. *Amblycorypha oblongifolia* (DeGeer) (4) was frequent, June to September. The primary habitat of this species is shaded woods. Twilight collecting has shown that it is common in favorable localities. Egg laying habits were observed by Hancock (1916) and are similar to those of *A. p. parvipennis* as described above in my cage studies.

*Neoconocephalus triops* L. (4) was frequent, August through April. This is an unusual seasonal range. *N. triops* is the only tettigonid to hibernate as an adult. All the other species of northeastern Texas Tettigoniidae pass the winter in the egg stage. *Triops* is unique among North American katydids found north of Mexico in also being recorded (Hebard, 1927) as belonging to the tettigonid fauna of South America.

Field studies of this species were made in the Caddo Lake (Marshall) area, III, 31, 34. At this time frequent individuals were taken in permanent woods; also adults and juveniles, IX, 1, 33 in shaded woods near Elkhart (Anderson County). In Ellis County specimens have been secured in April by nocturnal collecting of singing males. Judging from its stridulatory behavior it breeds in April.

The following observations concerning *triops* should be of interest to students of insect behavior. On the night of April 6, 1935, two singing males were collected with the aid of flashlights in the tall dry grass on a stream margin. These males were making the loud buzzing sound of *N. triops* which may be heard for long distances. The captured specimens were taken to my study and liberated on the study desk for observation, but they soon flew to other parts of the room. The time of turning the specimens from the live jar was 10:00 p.m. At 10:15 p.m. a low subdued droning, buzzing hum was heard to come from one of these *triops* coneheads perched in the window draperies. In spite of two workers checking time, moving about and making close range observations (with the aid of a reading glass, hand lens and spotlight), this *triops* continued his solo without a break for thirteen minutes.

An electric light was held very close to the conehead and a hand lens or reading glass within half an inch of this animated music-box while *triops* was actively stridulating. The antennae were waving vigorously, sometimes in unison. At times the antennae would be rotated as one would swing an arm. The

abdominal pulsations, which were pronounced and rapid, and tegmina movements were closely checked. After several counts, it was determined that the abdominal pulsations averaged one hundred and eight a minute and that the antennae gyrations were made at about the same speed. No rhythmic movements of the tegmina were apparent but rather a nervous jerking of the right or under tegmina. These more or less spasmodic jerks were much slower than the abdominal pulsations and antennae movements, averaging perhaps thirty a minute, and the tegmina movements did not seem to be associated with the low, continuous, buzzing drone. The loud field call was not produced while this cone-head was under observation.

Rehn and Hebard (1914b, 408) describe the field song of *triops* as "a very loud sharp z-z-z-z-z-z-z, indefinitely prolonged" and say further that when *triops* is closely approached, "a constantly recurring impulse gives an audible kr-z-z-z-z, kr-z-z-z-z with no break though a recurring clicking is heard." In the indoor performance of the *triops* here described only the low audible song was heard; doubtless other variations occur.

In the literature at hand, there are no records by other observers who have noted the marked abdominal pulsations which are here described and associated with the low-humming sound of *triops*. However, Allard (Blatchley, 1920, 531) and Fulton (1932, 58) describe stridulatory sounds of *triops* as a "continuously buzzing hum" and as a "loud buzzing sound." These descriptions presumably are based on field observations. However, they tally in part with the sounds made by *triops* which are here reported. In the making of this low drone by the specimen under close observation, I was unable to detect the use of the file-rasp, which is characteristic of the stridulatory technique of the Tettigoniidae and Gryllidae and well described by Allard (1928). Just how this low droning hum of *triops* was produced is not clear. It is apparent however, that the marked abdominal pulsations with the assumed attendant air pressure may produce air currents passing through the trachae, spiracles, wings and tegmina of *triops* which produce the humming, buzzing, droning sounds. These low drones may accompany the harsher stridulatory file-rasp sounds, but when made alone are produced without the aid of the file-rasp mechanism. It is to be hoped that other studies involving morphology and physiology may give further information concerning the technique and mechanism involved which will explain the full repertoire of *triops* and other species of Neoconocephalus.

As a further comment concerning stridulation among the cone-headed grasshoppers, Scudder (1874, 376), as quoted by Blatchley (1920, 376), describes the note of *N. robustus* (Scud.) as heard in New England thus: "The song resembles that of the harvest fly, *Cicada canicularis*. It often lasts for many minutes, and seems at a distance to be quite uniform. On nearer approach one can hear it swelling and decreasing in volume." *N. r. crepitans* (Scud.) is found in northcentral Texas and was briefly discussed above.

When, after thirteen minutes, his musical performance was apparently completed, our *triops* was again moved to the study desk and placed on a sheet of white paper. With two bright lights and a reading glass, continued observations were made, this time of an elaborate and well-executed series of ablutions. First, the antennae were in turn carefully passed between the mandibles, maxillae, palps and other mouth parts; after these, the tarsi, pads, pulvillus, first of the right and left fore legs and then of the middle and hind legs, were treated to the same thorough cleaning. Next followed the careful rubbing of the genae, vertex, and other head and face features with the fore tarsi; after this the tegmina were rubbed with the hind tarsi for their full length. Each hind leg was used in turn to stroke and rub the femur and tibia of the other.

During the entire seventy-five minutes of close scrutiny, this specimen was obviously not giving the slightest heed to the comments and movements of the observers.

*Conocephalus brevipennis* (Scud.), common to abundant on two field days, VIII, 31, 33 and IX, 1, 33 in the vicinity of Elkhart in shaded woods and semi-marsh habitats. As far as the writer's field records show, this species belongs to the Conocephalinae fauna of east Texas.

*Conocephalus saltans* (Scud.). This species occurs in association with *C. brevipennis,* and was found on only one field trip, IX, 1, 33. Most of the specimens of *C. saltans* on this date were late instar juveniles marking this species as belonging to the late summer fauna of shaded woods.

The above shady woods Tettigoniidae belong to the lower zone. Two arboreal species of the silvan group were also found.

*Microcentrum rhombifolium* (Sauss.). Only three specimens of this widely distributed American katydid were collected. All were taken accidentally, apparently attracted by light.

*Pterophylla camellifolia* (Fab.), frequent, late June to August. The "raucous chatterings in the trees" (Allard, 28) of the true katydid has been noted during late June, July, and August in the vicinity of Waxahachie and in east Texas near Ben Wheeler and Palestine. Only a few specimens of this tree-top dweller were collected, although their night calls indicate that they are common in favorable habitats.

All of the bush and silvan species with the exception of *Microcentrum rhombifolium* have been taken in the east Texas timbers. Productive collecting of these species was done during August, 1933, in the vicinities of Elkhart in Anderson County, Ben Wheeler in Van Zandt County, and near Tyler in Smith County.

SEMI-MARSH. *Orchelimum vulgare* Harris. A large colony of this species was studied in the Lake Worth area, Tarrant County, VIII, 10, 33. On that date only a few individuals had reached maturity.

Fifth instar juveniles were abundant. The habitat was well-watered first bottom land with a heavy cover of tall slough grasses.

Metcalf and Colby (1930) give a detailed account of the life history and economic importance of this meadow grasshopper in southern Illinois.

*Orchelimum nigripes* Scud. This is the most generally found lake margin Orchelimum in northeastern Texas. Colonies of this species are found in the tall grasses growing in the water of lake margins or in grasses bordering lakes and streams.

During August and September, every heavily grassed lake margin habitat which has been inspected in Ellis, Dallas, Tarrant, Anderson, and Smith counties has been found to be alive with these active, white-faced, black-horned meadow grasshoppers.

*Orchelimum laticauda* Redt. Only a few specimens of this species have been taken. All were collected in lake margin habitats in Anderson, Dallas, and Tarrant counties during August and September.

*Conocephalus f. fasciatus* (DeGeer), common to abundant, July through October in all favorable habitats in northcentral and east Texas. Adults and late instars have been collected late in December, XII, 21, 33, three males, five females, two juveniles. This widely distributed meadow grasshopper has been found in suitable habitats wherever field work has been done with the exception of the Trans Pecos.

## Regional Distribution in Northeastern Texas

In addition to the twenty-five species discussed above, Rehn and Hebard (1914a, 1914b, 1915) list *Scudderia curvicauda laticauda* Brunner, *Neoconocephalus exiliscanorus* Davis, *Orchelimum buliatum* Rehn and Hebard, *Orchelimum concinnum* (Scud.) as belonging to the tettigonid fauna of northeastern Texas. This would bring the total up to twenty-nine species. Doubtless a few other records will be added to swell the total of tettigonid species found in northeastern Texas. The northcentral Texas area has been critically checked by continuous field studies and the ecologically significant species are fairly well understood. The species which play an important role in the make-up of biotic communities and tettigonid populations are the ones which are numerous in individuals in their optimum habitats. According to the present data twenty species of the Tettigoniidae may be designated as ecologically significant, and these species make up the tettigonid picture of northcentral Texas. May-July is the peak season for katydid-longhorn activity, and only seven species of the Tettigoniidae belong to the August-October orthopteran fauna. The prairie-shrub is the optimum general habitat; only two species of the twenty are limited by lake margin conditions. The boundaries of northeastern Texas (Isely 1937, 320) are shown on the map, Figure 5. In this paper the prairie belts as shown on the map are designated as northcentral Texas and the eastern half is called east Texas.

The eleven prairie species, as far as their Texas distribution is concerned, belong typically to the central Texas area as limited by the blackland and grand prairies. Nine of these prairie species as listed above appear to become infrequent along the eastern margin of the prairie (Fig. 5). Good evidence of this fact was shown in a field trip July 4, 1935. Three collectors worked a three-hundred-acre prairie meadow found eight miles west of Paris (Lamar Co.) on highway 82. Single specimens of *Arethaea gral-*

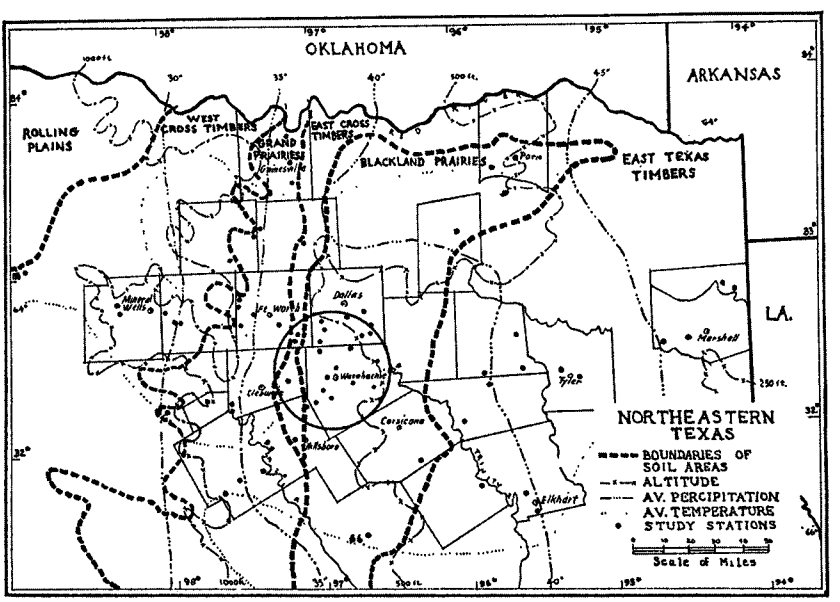


FIG. 5. Map of northeastern Texas showing chief field stations where Orthoptera have been studied. Central area in circle where intensive seasonal and habitat relations have been investigated (1931-40). The vegetation areas of northeastern Texas are outlined and other data explained in the key.

*lator* and *Amblycorypha huasteca* were taken and a dead shell of *A. parvipennis*. Collecting in the vicinity of Greenville and Commerce (Hunt Co.) on May 11, 1940, produced only a few juveniles of *A. grallator*, and *Pediodectes nigromarginatus*. On the other hand, *N. r. crepitans* and *C. strictus* are wide ranging species. While belonging typically to the prairie orthopteran fauna, these two species extend their range beyond the prairies not only in Texas but in other areas east and north.

The fourteen tettigonids listed as bush, silvan, and marsh species belong to the east Texas timber fauna. Species of this group have worked their way into the prairie belt chiefly along the timbered borders of creeks and streams.

If population totals are taken into account, most of the twenty species which were here found in frequent to abundant numbers in northcentral Texas show primary and secondary habitats at the various stations where they have been intensively studied. Apparent exceptions are *Pterophylla camellifolia* Fab., which is restricted to the tree crowns, and *Orchelimum nigripes* Scud., which limits its activities in this area to lake and stream margins.

The year 1933 was clearly a peak year in population for *Amblycorypha huasteca* and *Arethaea grallator*. In no other year of the period of fairly continuous field checking (1932-40) at favorable stations have these species been taken in swarming numbers as in the instances cited in the earlier section of this paper. While never as numerous in individuals in optimum habitats as *Amblycorypha huasteca*, and *Arethaea grallator*, the other prairie species have been fairly stable in their population numbers but show variations from year to year.

The near swarming numbers of *Scudderia texensis* and *Scudderia f. furcata* X, 22, 33, cited in the discussion of these species suggest migratory concentration in a favorable locality near the close of normal seasonal activity. Here too, is another instance of unusual peak populations for the species concerned.

## THE TRANS PECOS TEXAS TETTIGONIIDAE

During the summer of 1939 from mid-June through July and August, a study was made of the Trans Pecos orthopteran fauna in the Big Bend area of Texas, especially in the vicinity of Alpine. This work was undertaken while the writer was teaching in the Sul Ross State Teachers College summer school. Although one to three field trips were made weekly, only a good beginning was made in a personal field check-up of the difficult Trans Pecos orthopteran fauna. The fact that we find in the Trans Pecos a tettigonid fauna wholly different from the one in east Texas is a point of interest. The individuality of the Trans Pecos orthopteran fauna was first suggested to the writer by the well-known orthopterist—Morgan Hebard of the Philadelphia Academy of Science. Due to field work by Mr. Hebard and his associates in this area the orthopteran fauna of the Trans Pecos is fairly well diagnosed. Only part of the scattered literature pertaining to the Tettigoniidae of the Trans Pecos was available to the writer. Brief field records concerning these southwestern Tettigoniidae are given:

PHANEROPTERINAE: *Dichopetala brevihastata* Morse. This species was taken in weedy pastures. One small colony was found in a pasture twelve miles east of Alpine on the Marathon highway VII, 10, 39, eight males and six females were secured. Again at two stations on the highway to the Chisos Mountains, south of Marathon at Ridge Springs and Hackberry Creek. The latter station was a typical Larrea-Prosopis association with interspersed grasses, weeds, and shrubs. *D. brevihastata* adults were frequent at both stations, VII, 1, 39.

*Arethaea gracilipes cerciata* Hebard. One specimen was secured among mountainside grasses, VII, 17, 39, Kokernot Mountain, Alpine.

*Arethaea arachnopyga* Rehn and Hebard. Collected at the same station listed above for *D. brevihastata* VII, 10, 39, eight males and three females.

*Scudderia*. One female, possibly *S. mexicana* (Sauss.) Ranger Canyon, Alpine. VII, 21, 39.

*Amblycorypha insolita* Rehn and Hebard. Three individuals of this species were secured in the Hackberry Creek Larrea-Prosopis habitat where *D. brevihastata* was found, VII, 1, 39.

*Microcentrum rhombifolium* (Sauss.). Only two males of this species were secured. These were taken in the residential part of Alpine.

PSEUDOPHYLLINAE: *Paracyrtophyllus excellus* (Rhen and Hebard). Three specimens, one male and two females, of this fine katydid were sent to the writer for study by L. T. Murray of the Baylor University Museum, Waco, Texas. These were collected by Dr. Murray "in the Basin" Chisos Mountains, VIII, 4, 38.

CONOCEPHALINAE: *Conocephalus strictus* (Scud.). Juveniles of this species were frequently collected at Kokernot Springs among tall grasses. Three adult males and one female were taken VIII, 19, 39, Kokernot Springs, Alpine.

DECTICINAE: *Rehnia cerebrus* Rehn and Hebard. Two individuals of this striking large decticid were taken in tall vegetation. One at Ridge Springs VII, 10, 39, and one at Ranger Canyon, VIII, 21, 39. One of my students, Chester McShan, took three specimens of this species VII, 14, 1940, in Archer County fourteen miles southwest of Wichita Falls, Texas. These were taken among shrubs along the roadside.

*Rehnia victoria* Caudell. One specimen of this species was collected at Ridge Springs, VII, 10, 39. Two specimens of this species were taken near Vernon and Iowa Park, Texas, in late August, 1932, (Isely, 1934).

*Pediodectes stevensonii* (Thomas). Occasional to frequent individuals of this active decticid were taken in coarse mountainside vegetation, first as juveniles and later as adults during August.

*Eremopedes scudderi* Cockerell. One male and one female VII, 14, 39, were taken in coarse mountain-

side vegetation, Kokernot Mountain. Juveniles of this species were taken in desert habitats along the highway to the Chisos Mountains area.

*Other records* discuss distribution of the following species and bring the total number of Trans Pecos Tettigoniidae to sixteen.

*Insara elegans elegans* (Scud.) (Tinkham, 1938, p. 348)

*Arethaea semialata* Rehn and Hebard (Rehn and Hebard, 1914)

*Pediodectes tinkhami* Hebard (Hebard, 1934, p. 36)

*Eremopedes covilleae* Hebard (Hebard, 1934, p. 39)

Four additional species in juvenile stages were collected by the writer which were not determined; these may belong in part to those listed above as other Trans Pecos records.

Only three of the species of northcentral Texas are found in the Trans Pecos. These species are *Conocephalus strictus* (Scud.); *Pediodectes stevensonii* (Thomas); and *Microcentrum rhombifolium* (Saussure). These records suggest that over 80 percent of the Trans Pecos tettigonid fauna is found to be distinctive when compared with the northeastern Texas Tettigoniidae.

In the Trans Pecos, *Conocephalus strictus* is limited in its distribution to small grassy tracts which are found in a few restricted areas adjacent to perpetual springs. *Pediodectes stevensonii* finds shelter in coarse mountainside vegetation. Only two specimens of *Microcentrum rhombifolium* were taken, both in residential Alpine, suggesting the domestic affinities of this species and its possible dissemination through shipments of nursery stock.

In comparing the northcentral Texas fauna with the Trans Pecos fauna it should be noted that the predaceous sub-family Decticinae increases in numbers. Six species, representing three genera, are here reported. The members of this sub-family seem well suited to the desert scrub vegetation of thorn bush, cat claw, cacti, Sotol, Yucca, and Agave. Arethaea is represented by three species, all different from those in northcentral Texas. In contrast, such east Texas genera as Scudderia, Amblycorypha, and Conocephalus have only one species in each genus in the Trans Pecos.

## SUMMARY

1. Cage studies are reported for seven species of southwestern Tettigoniidae which belong to the late spring and summer prairie fauna of northcentral Texas.

2. The behavior of these seven species, including food choices, breeding habits, egg laying technique, and stridulatory activities, are described and analyzed.

3. A new egg laying technique among North American Tettigoniidae is reported for *Arethaea grallator*.

4. Food preference tests show that the five Phaneropterinae are oligophagous in their choice of forbs for food, refusing grasses and as adults showing marked preference for floral parts.

5. The two Decticinae are wholly carnivorous and only incidentally cannibalistic.

6. Stridulation is definitely correlated with sexual activity.

7. A summary of field studies concerning forty-two tettigonid species gives an account of their local distribution, seasonal succession, and populations.

8. Eleven of the species belong to the prairie fauna of northcentral Texas. Nine of these are restricted to the prairie belt, while two wide ranging species, *Conocephalus strictus* and *Neoconocephalus robustus crepitans* are more generally distributed.

9. Eighteen east Texas species, which in part find their way into the prairie belt of northcentral Texas, have followed the wooded tracts which border water courses. These belong to the tettigonid fauna of eastern and southeastern United States. A few of these species range into central North America.

10. Thirteen of the sixteen species reported from the Trans Pecos are different from those found in northeastern Texas or from tettigonids from southeastern or central North America.

11. These investigations point to the Tettigoniidae as promising and amenable material for further researches in the fields of animal behavior, life history studies, and terrestrial ecology.

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