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ORTHOPTERA OF THE PAWNEE SITE, 1971

Robert E. Pfadt

Department of Entomology

University of Wyoming

Laramie, Wyoming

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ABSTRACT

In this monograph of the Orthoptera of the Pawnee Site, Colorado, we plan two major phases or divisions of the work: (i) to summarize all that is published and known about each of the resident species and to write a review of several special topics and (ii) to analyze and summarize the Orthopteran data that have been generated on the Pawnee Site itself. Because much of the latter data are still unavailable and some still are being gathered, we have chosen to start with the literature review and when this is completed to concentrate on the summarization of original Pawnee data.

BIOLOGY OF INDIVIDUAL SPECIES

Acrolophitus hirtipes (Say) crested-keel grasshopper

Gryllus hirtipes Say, 1825, Amer. Entomol. 2:34.

Description

Body length: male 23 - 30 mm, female 35 - 45 mm. General color green. Head, thorax, and legs covered with light-colored hairs. Metazona of pronotum with high, inflated mediolongitudinal crest. Face moderately recessive. Vertex extending greatly beyond and above eyes. Lateral foveolae of vertex obsolete.

Distribution

This species occurs in Alberta, Saskatchewan, Montana, North Dakota, South Dakota, Nebraska, Wyoming, Colorado, New Mexico, Kansas, Oklahoma, and Texas (Fig. 1). Although it remains unreported from Mexico, it probably occurs in the north. This species is replaced by the southern species, *Acrolophitus variegatus* Bruner, in the southwestern grasslands of North America.

Habitat and Host Plants

Acrolophitus hirtipes (Say) occurs in several associations of the Grassland Biome, being most common in the mixed-grass association and the shortgrass association and less common in the bluestem-grama prairie. This is the only species in the Acridinae that is primarily a forb feeder. Criddle (1933*a*,*b*) observed that this grasshopper subsisted almost exclusively upon members of the Boraginaceae. In cage tests he found that it fed upon *Lithospermum*, *Lapula*, *Echium*, and *Myosotis*. The only plant eaten outside of this family was *Phacelia*, a close relative and member of the

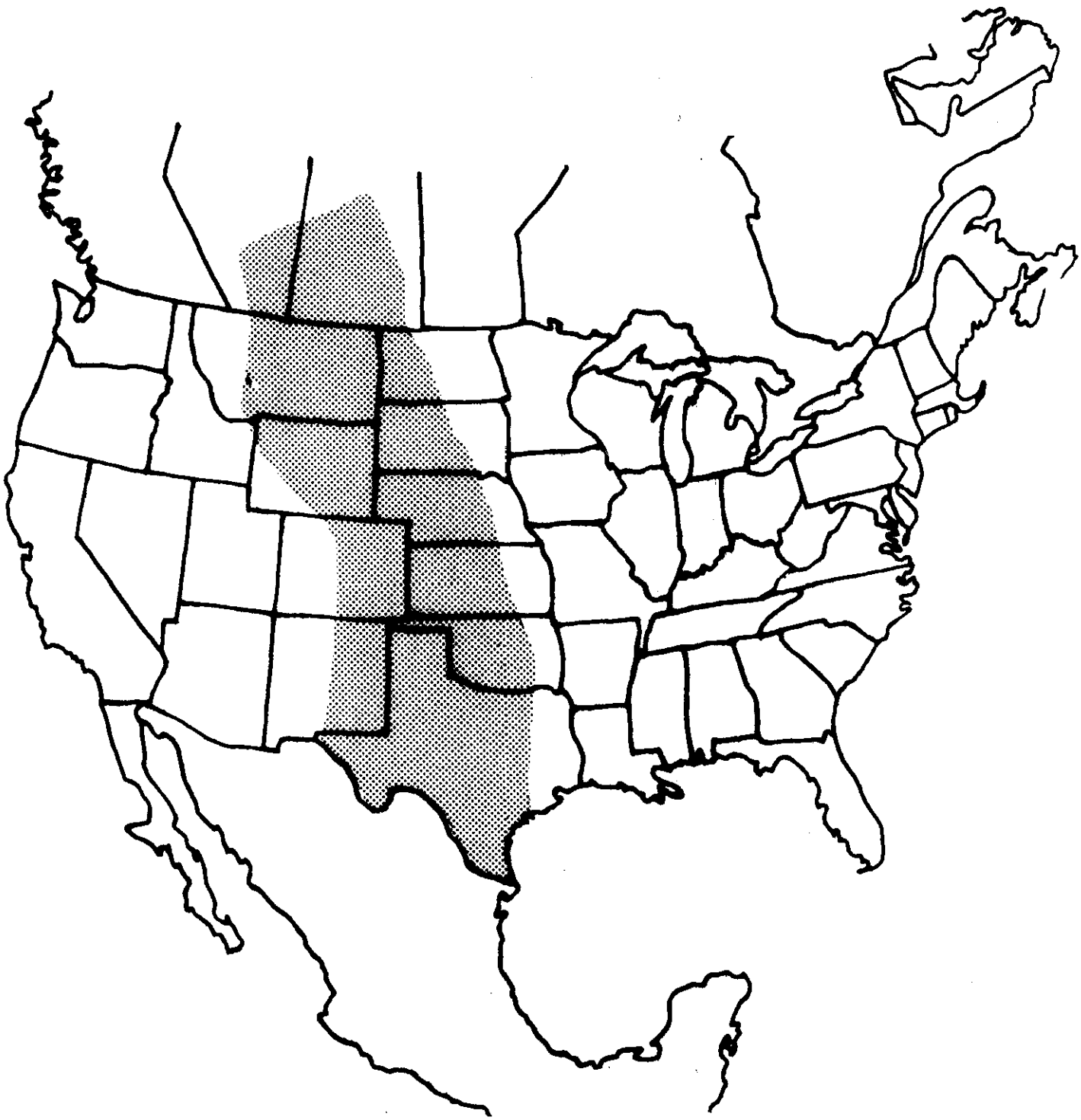

Fig. 1. The known distribution of *Acrolophitus hirtipes* (Say) in North America.

Hydrophyllaceae. He surmised that in Canada *Lithospermum augustifolium* constituted the most important natural food plant. In northeast Texas, Isley (1938) observed this grasshopper feeding on *Evax multicaulis*, and in dissections of two specimens taken at North Platte, Nebraska, Mulkern et al. (1969) found the crops to contain *Lappula redowski*. In Montana, Anderson and Wright (1952) observed one-fifth instar and one adult eating the leaves of *Lappula redowski*. In the Nebraska panhandle, Hagen (1970) states that most of the borages it feeds upon are prostate forms and that, therefore, this grasshopper is more often found in shortgrass ranges. Anderson and Wright (1952) observed only an occasional individual of the species in southeastern Bighorn County, Montana, and of these most were seen on gently sloping, gravelly, southern exposures. In the mixed-grass association of eastern Wyoming we have observed them commonly on gravelly slopes and hill tops. In western Kansas, Brusven (1967) observed individuals of this species most commonly on sparsely vegetated, gravelly ridges, often in small patches of *Cryptantha minima* which he thought served as its food plant and as a place of concealment. In a pasture south of Boulder, Colorado, Alexander and Hilliard (1969) found this species to be associated principally with *Phacelia*.

Life History and Seasonal History

Brusven (1967) has described four of the five nymphal instars of the species. He failed to collect specimens of the first instar which he surmised may occur as early as mid-April; adults appeared from June 1 to 15 in Kansas. In a pasture south of Boulder, Colorado, Alexander and Hilliard (1969) found hatching to occur from late May into June (1958-1960). Adults appeared the first week of July and were present into September.

Onsager and Mulkern (1963) have described the eggs of this species. They are laid in groups of six, arranged in two columns just below the soil surface. No froth has been found in association with the egg mass, and consequently, the eggs are not contained and protected within a pod.

The adults stridulate loudly in the field and can often be located by their sound. Otte (1970) studied this behavior in the laboratory which indicated that pair formation may be achieved by stridulation. He observed males mount females on two occasions. Once, when a female approached and touched a male, he backed up, stridulated, and then approached and mounted the female. In the other case, a male approached a moving female and mounted without stridulating.

Aeropedellus clavatus (Thomas) slant-faced grasshopper

Gomphocerus clavatus Thomas, 1873, Rep. U.S. Geol. Surv. Territories 5:96.

Description

Body length: males 13.5 - 19 mm, females 18 - 23 mm. Coloration usually grayish-brown or green above and yellowish below. Head, pronotum, and tegmina usually much streaked in female. Front of the head distinctly oblique; lateral foveolae visible from above; antennae clavate, this condition being more pronounced in the antennae of the male. Tegmina of female reduced, not extending beyond half of the abdomen; tegmina of male well developed.

Distribution

This species occurs in Minnesota through southern Canada to Yukon and Alaska, and in Iowa, the Dakotas, Nebraska, Colorado, Wyoming, and southward to New Mexico and Arizona where it inhabits the high mountains (Fig. 2).

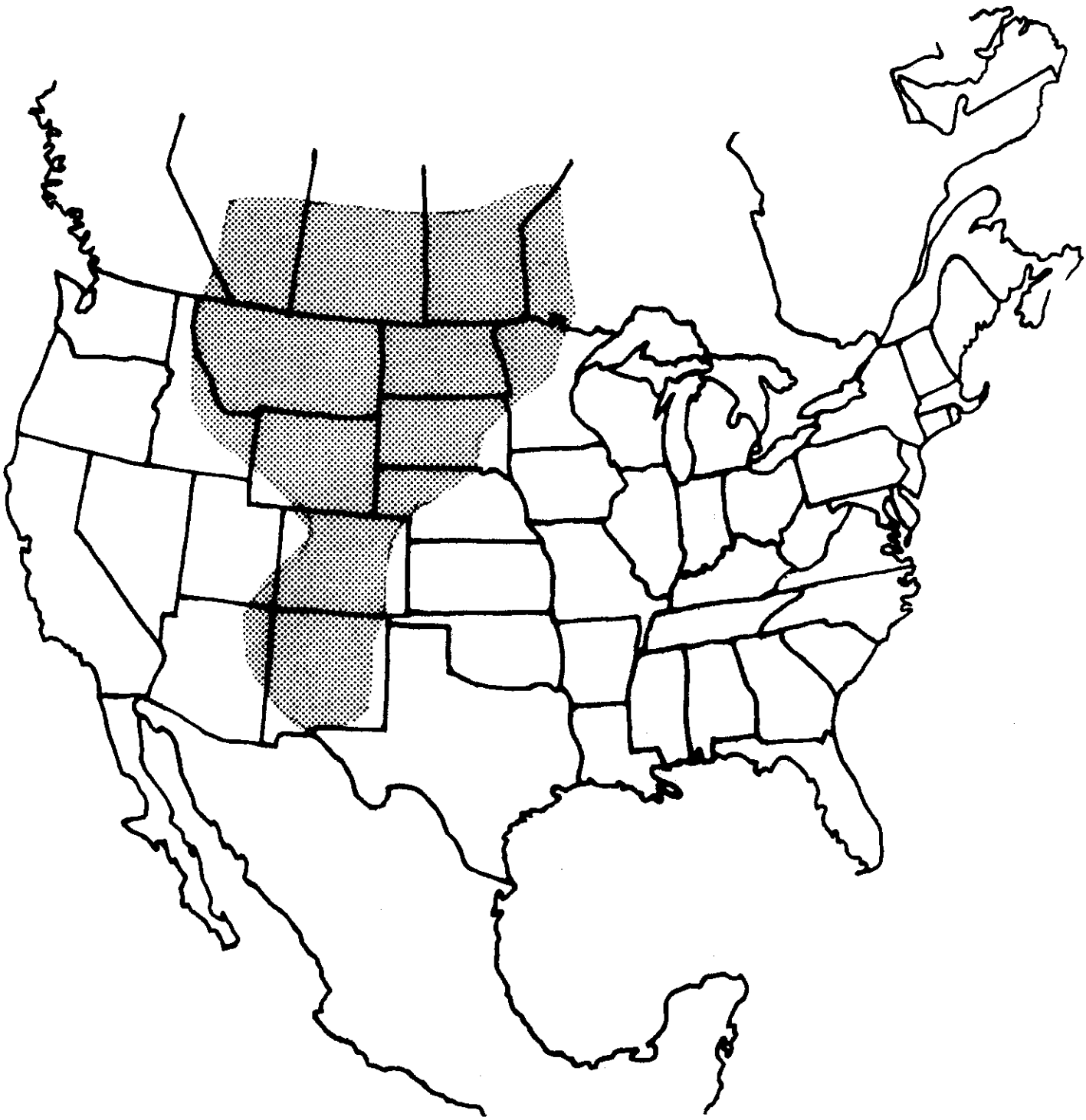

Fig. 2. The known distribution of *Aeropedellus clavatus* (Thomas) in North America.

Habitat and Host Plants

This grasshopper is an alpine and boreal species; it inhabits various types of grassland, e.g., mountain meadows, lush river bottoms, midgrass association, mixed-grass association, and shortgrass association. It becomes an abundant and economic species in certain areas of its distribution. Brooks (1958) writes that in the prairie provinces it is the most widely distributed and abundant of the grassland species, occurring on all dry and somewhat sandy situations south of the forest. On the Hartville, Wyoming, Grasshopper Study Area No. 2 (mixed-grass association), it is one of the dominant species in a dense complex of range grasshoppers.

Alexander and Hilliard (1964, 1969) have studied the life history of this grasshopper from altitudes around Boulder up to altitudes of 13,100 ft on Mount Evans, Colorado, where the species occurs in the alpine tundra.

This grasshopper is principally a grass and sedge feeder, but it does consume small amounts of a limited number of forbs and fungi, pollen, and arthropod parts. Mulkern et al. (1969) recorded the following plant species from the gut of 1220 specimens collected in North Dakota: sedges--*Carex eleocharis* and *Carex pensylvanica*; and grasses--*Andropogon geradi*, A. *scoparius, Bouteloua gracilis, Calamovilfa longifolia, Hordeum jubatum, Koeleria cristata, Panicum leibergii, Panicum virgatum, Poa pratensis, Sporobolus cryptandrus,* and *Stipa comata*. Hansen and Ueckert (1970) recorded the following plant species from the gut of 74 specimens collected in a mountain meadow of Roosevelt National Forest, Larimer County, Colorado: *Carex* sp., *Agropyron* sp., *Danthonia parryi, Festuca idahoensis, Koeleria cristata, Muhlenbergia filiculmis, Phleum pratense, Poa* spp., *Sitanion hystrix,* and *Stipa* spp.

Life History and Seasonal History

Aeropedellus clavatus is one of the earliest of summer grasshoppers. Alexander and Hilliard (1964, 1969) found that hatching began around Boulder, Colorado (5,750 ft), in late April and continued through May; at 6,700 ft hatching began a little later; at 8,500 ft it was from mid-May into the last half of June; and at 12,800 ft hatching began less than 3 weeks later than at 8,500 ft, but the eggs probably had been in diapause through two winters. These authors observed that adults appeared at Chautauqua Mesa by the last week of May and at Chicken Ranch Gulch the first week of June; a few adults were still present in August. At 8,500 ft adults appeared during the third week of June and were most abundant in July and August; at 12,800 ft they appeared by the third week of July and were in maximum numbers the last half of August. Alexander and Hilliard (1969) observed that adults persisted through September at high altitudes even though temperatures often dropped well below freezing.

In their study of the development of this grasshopper Alexander and Hilliard (1964) found that the species has only four nymphal instars, one less than is usually found among grasshoppers. They concluded that this abbreviated development was an adaptation to alpine and boreal conditions. In the first and second instars the developing wings point ventrally; in the third and fourth instars they are turned upward.

Females oviposit in the basal portions and among the roots of sedges and grasses; eggs are laid in clusters of three to six and are enclosed in a dark brown capsule 11 - 12.5 mm long by 5.5 - 6.0 mm in diameter.

Onsager and Mulkern (1963), Tuck and Smith (1939), and Alexander and Hilliard (1964) have described the eggs and pod. The latter authors observed that the eggs from populations at lower elevations hatched after dormancy of one winter, but those from tundra populations passed through at least two winters before hatching.

Ageneotettix deorum (Scudder) sand grasshopper

Chrysochraon deorum Scudder, 1876, Bull. Geol. Geogr. Surv. Territories 2(2):262

Description

Body length: males 14 - 19 mm, females 18 - 25 mm. General coloration dull brown or grayish-brown above and yellow or cream below. Tegmina maculated with subquadrate spots which are usually confined to the median area. Front of head only slightly recessive; lateral foveolae distinct and visible from above; antennae filiform. Organs of flight fully developed in both sexes. Hind tibiae orange; internal spurs of the hind tibiae distinctly unequal.

Distribution

Ageneotettix deorum has a wide distribution in western North America. It occurs from Pacific coastal areas to as far east as Michigan and Indiana and from southern Canada to northern Mexico (Fig. 3).

Habitat and Host Plants

Ageneotettix deorum is widely distributed in the Grassland Biome of North America and in the shrub and grasslands combinations. It builds up to large injurious populations in the shortgrass and mixed-grass associations and is a common species in sandy areas of the tallgrass prairie of the

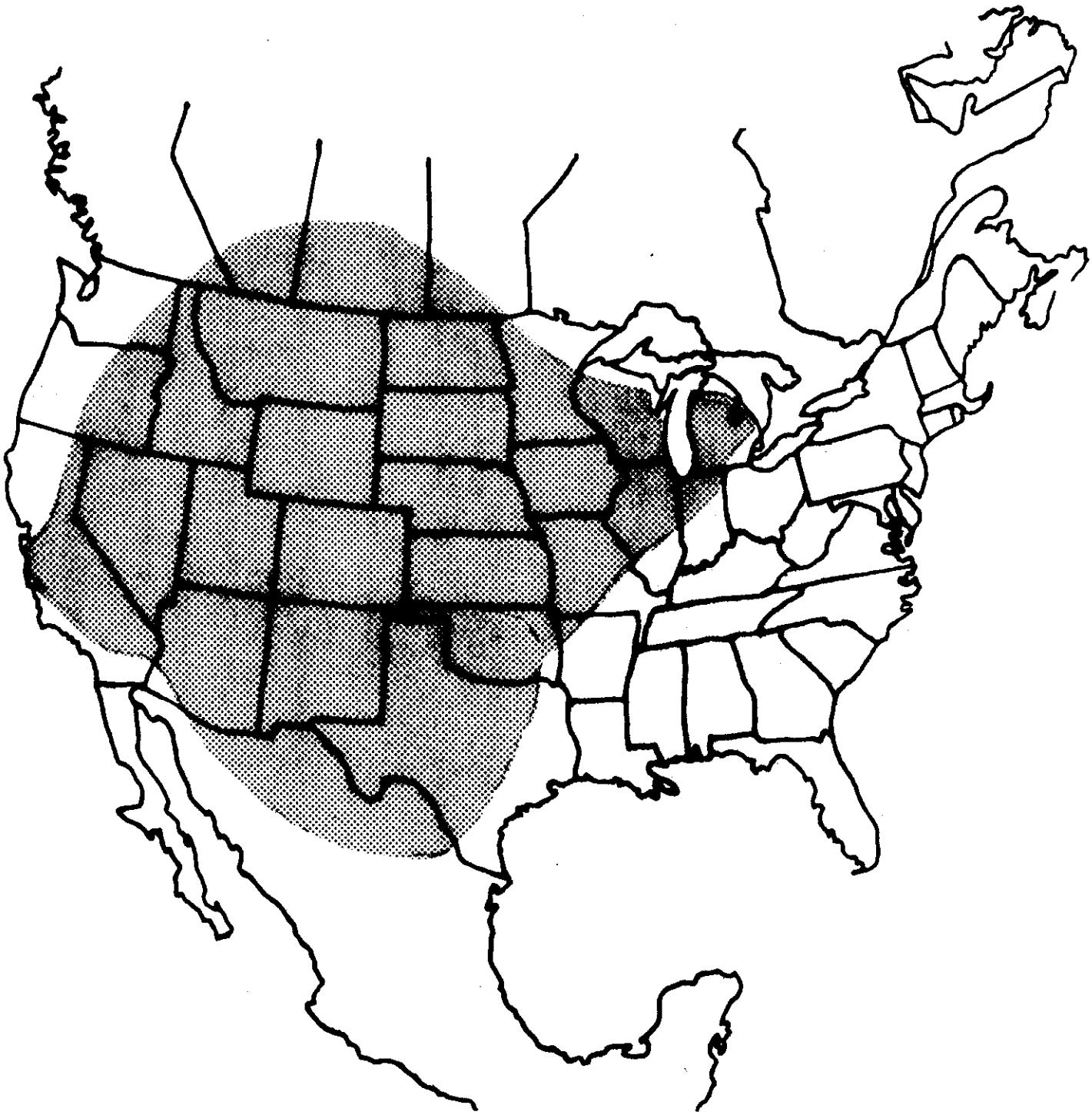

Fig. 3. The known distribution of *Ageneotettix deorum* (Scudder) in North America.

central states. In a study of grasshopper populations near Manhattan, Kansas, Wilbur and Fritz (1940) found that this grasshopper was third in density among the 23 acridid species inhabiting bluestem prairie and the first in density among 20 species infesting a cultivated pasture of orchard bromegrass. Anderson and Wright (1952) state that *Ageneotettix deorum* was one of the most numerous grasshoppers in their study area located near Decker, Montana, in the mixed-grass association. In eastern Nebraska, Whelan (1938) observed that *Ageneotettix deorum* inhabited mostly high prairie grasses. Ball et al. (1942) found it widely distributed though seldom extremely abundant in the shortgrass of Arizona. In North Dakota, Hebard (1936) concluded that the species was common in dry shortgrasses, particularly in sandy areas. Mulkern et al. (1969) found *Ageneotettix deorum* widespread throughout the North Central Great Plains though numbers fluctuated markedly. It was most abundant in the drier, more sparsely vegetated portions or where heavy grazing had reduced the vegetative cover. Hagen (1970) has noted that when rangeland infestations occur in the Nebraska panhandle, which is comprised of shortgrass association and Nebraska sandhills prairie, *Ageneotettix deorum* is the principal species involved. In Colorado, Alexander and Hilliard (1969) recorded *Ageneotettix deorum* as the most abundant member of the subfamily in their plains study stations (pasture south of Boulder, Valmont Butte, Chautauqua Mesa, Chicken Ranch Gulch, and A-1 Weather Station). Its altitude range as a resident in the area extended up to 7,200 ft, but abundance dropped off sharply at the upper stations. Accidentals were found at higher montane elevations, even above the timberline. The eastern most record of distribution of the species is in Michigan where it was unknown until Hubbell (1922) reported a single specimen taken in

Berrien County in 1920. Cantrall (1968) has reported that the species has subsequently spread east and north over a major portion of the lower peninsula where it is found in areas of open, poorly vegetated sandy soils.

Not only do recent records of the species include notes of its unusual abundance in shortgrass and mixed-grass associations, but also records dating from the early 1900's. During August of 1904, Morgan Hebard collected grasshoppers from the shortgrass association in eastern Colorado and made captures of this species at Grand Junction, Antlers, Colorado Springs, Manitou, Garden of the Gods, Roggen, and Akron (Rehn and Hebard, 1906). His largest collection was made at Knob Hill, Colorado Springs, where he captured 73 males and 87 females, and it is likely that this area was the basis for the note of unusual abundance in the following paragraph.

> "This was one of the most plentiful species encountered. It was found in many of the arid localities, but on the prairie it truly swarmed. Each sweep of the net would take a dozen or more specimens in this location, and so great were its numbers that other scarcer specimens, even when seen, would often easily escape in the myriads of this species."

The year 1904 was the end of a serious grasshopper outbreak on the western plains (eastern Colorado, eastern Wyoming, eastern Montana, western Nebraska, and western Kansas) which had begun in 1901 or perhaps even earlier. Bruner (1902, 1905) made extensive surveys covering this outbreak in Nebraska, Colorado, and Wyoming. He noted that *Ageneotettix deorum* occurred throughout the plains region, but was most abundant among the shortgrasses on high ground.

Ageneotettix deorum is a general grass feeder with no clear preference for any particular species. It also feeds on a variety of forbs in trace amounts and has been observed by Anderson and Wright (1952) to feed on dry plant litter found on the ground. Mulkern et al. (1969) have recorded the following plants in the crops of 8,243 specimens collected in the North Central Great Plains: grasses--*Agropyron smithii, Andropogon gerardi, A. scoparius, Bouteloua curtipendula, B. gracilis, B. hirsuta, Bromus japonicus, B. tectorum, Buchloe dactyloides, Calamovilfa longifolia, Koeleria cristata, Panicum capillare, P. leibergii, P. scribnerianum, Poa pratensis, Redfieldia flexuosa, Sporobolus asper, S. cryptandrus,* and *Stipa comata*; sedges--*Carex eleocharis*, *C. filifolia*, and *C. pensylvanica*; and forbs--*Ambrosia psilostachya, Amorpha canescens, Artemisia ludoviciana, Aster ericoides,* and *Astragalus caryocarpus*. These authors also found pollen, fungi, and arthropod parts in the crops. In their detailed field study, Anderson and Wright (1952) observed *A. deorum* to feed more often on western wheatgrass than on other species in the mixed-grass association; after a heavy rain on August 18, 1949, the adults were particularly fond of the new green growth of western wheatgrass and often were seen eating it down to the soil surface. Whether these observations indicate a preference for this species of grass is somewhat in doubt; Anderson (1964) has written that *A. deorum* does not display a preference for any particular grass. These conflicting statements point out the need for careful research on the choice of grasses by *A. deorum*.

Life History and Seasonal History

Among the complex of range grasshoppers in the shortgrass and mixed-grass associations *A. deorum* hatches several days after *Cordillacris occipitalis*

and *Aulocara elliotti*, and together these three make up the dominant early group of species infesting rangeland. In the vicinity of Boulder, Colorado, Alexander and Hilliard (1969) found that hatching occurred at 5,400 ft from the third week of May to mid-June, at 5,750 ft slightly later, and at 6,700 ft from late May or early June to about July 1; adults appeared at 5,400 ft by the last of June, at 5,750 ft by July 7, and at 6,700 ft by mid-July. These authors recorded adults as still present in October. In their study area near Decker, Montana (elevation 3,800 ft), Anderson and Wright (1952) recorded the first hatch in 1949 on April 28 and in 1950 on May 19. They found the first adult in 1950 on July 12. In Arizona, Ball et al. (1942) gave April as the month of hatching and adults as present from June to November. Brusven (1967) has written that in Kansas nymphs appear about May 1 and become adults by late June to mid-July and that it is one of the earliest species in Kansas but one of the slowest to develop.

Brusven (1967) has described and pictured five nymphal instars of this species. The color patterns of nymphs are quite distinctive, making them easy to identify in the field. Onsager and Mulkern (1963) and Tuck and Smith (1940) have described the eggs of this species. Eggs are deposited in groups of four in a pod that is called unique because it is deposited parallel to the soil surface. The eggs are pale yellow or whitish and are 5.3 mm long and 1.6 mm in diameter. No dimension of the pod was given. The eggs are deposited in summer, pass the winter in the ground, and hatch the following spring.

Otte (1970) has described the behavior of courtship, pair formation, and aggression in *A. deorum*. Courting males tipped their hind femora

repeatedly and synchronously from about 45° to nearly vertical and raised and lowered their antennae. Before attempting to mount, the male assumed a particular position with respect to the female. He stood behind one of the female's femora, facing her abdomen and also facing slightly forward. The male's antennae, and often his head, were in contact with the female's abdomen. As he moved into this position he tipped the femora and shook his antennae against the female. Stridulation occurs, but Otte described its meaning only in aggressive behavior.

Amphitornus coloradus (Thomas) slant-faced grasshopper

Stenobothrus coloradus Thomas, 1873, Rep. U.S. Geol. Surv. Territories 5:82.

Description

Body length: males 18 - 20 mm, females 22 - 25 mm. General color yellowish-brown above and yellow below. Usually two conspicuous chocolate-brown stripes extending lengthwise on vertex, one median to each eye, and continuing posteriorly to hind margin of pronotum. Face distinctly recessive. Lateral foveolae and median carina of vertex obsolete. Antennae filiform. Costal area of proximal half of tegmina usually marked with a slight yellow line. Usually outer face of hind femora partially crossed by three dark bands. Hind tibiae blue.

Distribution

Three subspecies of *A. coloradus* are recognized. *A. coloradus saltator* Hebard occurs at high altitudes in Arizona, Nevada, and Utah. *A. coloradus ornatus* McNeill occurs from British Columbia southward to Arizona. *A. coloradus coloradus* (Thomas) occurs from Alberta, Saskatchewan, and Manitoba

south to New Mexico and Texas and east to Illinois. The known distribution of *A. coloradus* is given in Fig. 4.

Habitat and Host Plants

Amphitornus coloradus coloradus is a common and often abundant species in the shortgrass and mixed-grass associations. It occurs discontinuously and in lesser numbers in grasslands to the east. Mulkern et al. (1969) found this species widely distributed in central Nebraska, but in North Dakota they found it restricted to the higher plains and low hills where blue grama and needle and thread were the dominant plants. Brusven (1967) stated that the species occurs mainly over the western half of Kansas, inhabiting the short and midgrass prairies. The easternmost record was in Riley County. Coppock (1962) observed that this species is largely restricted to the western third of Oklahoma and that in some years it is abundant enough on rangeland to cause considerable damage.

Alexander and Hilliard (1969) found *A. coloradus* to be common in Boulder County, Colorado, up to 5,400 ft, scarce at 5,750 ft, and rare as a resident above the latter altitude. They classified it as definitely a plain's species, barely invading the foothills, though occurring as an accidental even above the timberline. Hagen (1970) found *A. coloradus* throughout the Nebraska panhandle and stated that it feeds mostly on rangeland grasses and at times becomes of economic importance. In their study area in the mixed-grass association near Decker, Montana, Anderson and Wright (1952) found nymphs and adults consistently more numerous in areas of needle and thread upon which they fed in preference to the other grasses present.

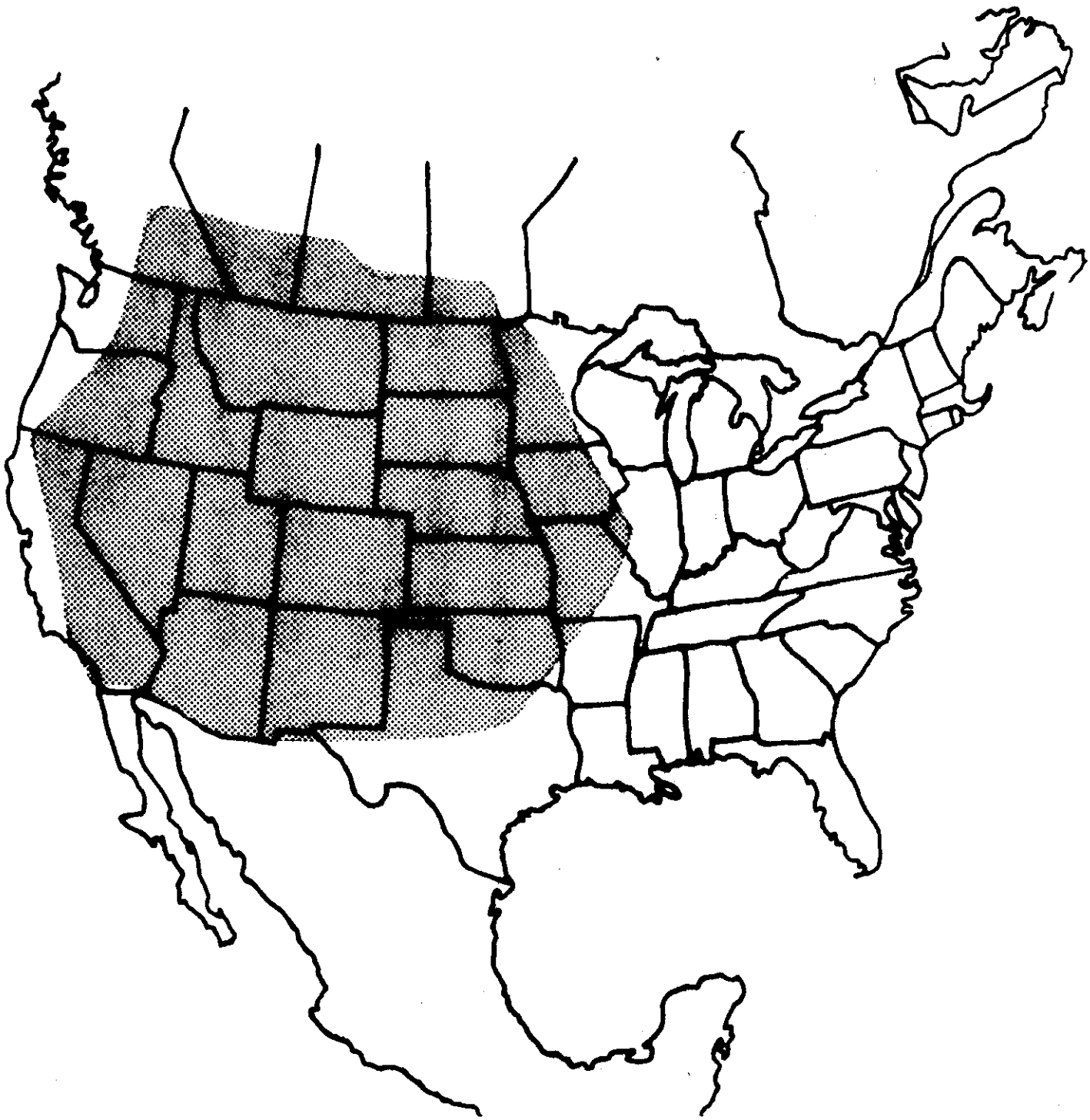

Fig. 4. The known distribution of *Amphitornus coloradus* (Thomas) in North America.

Early records of the 1900's also point out the high densities and economic importance of *A. coloradus*. Bruner (1902) reported it and *Opeia obscura* in unusually large numbers on grassland near McCook, Nebraska, on August 9, 1901. He noted that the two species inhabited higher ground among the shortgrasses "like the *Bouteloua's*. In the same report Bruner summarized that *A. coloradus* is a plain's grasshopper which occurs from middle Nebraska westward to the Rocky Mountains and is found in great numbers in the shorter grasses. Gillette (1904) records *A. coloradus* as a very common species on dry grassy slopes over all the eastern portion of Colorado. He stated that this insect doubtless causes heavy losses on the native pasturelands of Colorado.

From analysis of gut contents of 5,822 grasshoppers collected in Nebraska and North Dakota, Mulkern et al. (1969) concluded that *A. coloradus* preferred blue grama and needle and thread grass. They also recorded this grasshopper as having fed on the following: grasses--*Agropyron smithii, Andropogon gerardi, Andropogon scoparius, Bouteloua curtipendula, Calamovilfa longifolia, Elymus canadensis, Koeleria cristata, Panicum capillare, Panicum virgatum, Poa pratensis,* and *Sporobolus cryptandrus*; and sedges--*Carex eleocharis, Carex filifolia,* and *Carex pensylvanica*. They also found pollen, fungi, arthropod parts, and one undetermined forb in crop contents.

Life History and Seasonal History

The eggs of *A. coloradus* are laid in summer, overwinter, and hatch the following spring. Hatching occurs about the same time as hatching of *Ageneotettix deorum*. In their study area near Decker, Montana (elevation 3,800 ft), Anderson and Wright (1952) recorded a hatching date of May 22, 1950;

they found the first adult on July 8, 1950. Alexander and Hilliard (1969) observed hatching in their Boulder, Colorado, study site (elevation 5,450 ft) from mid-May to mid-June; adults appeared by the end of June and were abundant after mid-July and in August. Brusven (1967) found that in Kansas first instar nymphs appear about May 1 and become adults by mid- to late June.

Brusven (1967) has described and figured five nymphal instars of this species.

A. coloradus oviposits in the crowns of grasses, frequently needle and thread. Onsager and Mulkern (1963) described the pod of this species as unique in its relatively small size and in the nature of the seal. The pod contains an average of four eggs which are whitish and measure 5.4 mm long and 1.2 mm in diameter.

No observations on the stridulation or courtship behavior of this grasshopper have been reported. Anderson and Wright (1952) have observed that adult females remained for long periods without moving upon needle and thread plants, but that adult males constantly moved from plant to plant.

Aulocara elliotti (Thomas) big-headed grasshopper

Stauronotus elliotti Thomas, 1870, Acad. Nat. Sci. (Philadelphia), Proc. 22:82.

Description

Body length: males 16.5 - 21.5 mm, females 20 - 28 mm. General color reddish-brown above, light yellow below. A black patch usually present on each of the lateral lobes of pronotum, and transverse dark bars usually present on hind femora; however, these markings rarely contrast greatly with

the general color as in *Drepanopterna femoratum*. Front of head moderately recessive; lateral foveolae visible from above; antennae filiform and dark apically. Organs of flight fully developed reaching or surpassing the apex of the abdomen. Tegmina showing various degrees of maculation from light to heavy. Hind tibiae blue; internal spurs of hind tibiae moderately unequal. Eighth abdominal sternite of female moderately sinuate.

Distribution

Aulocara elliotti is widely distributed in western North America. It occurs in British Columbia, Alberta, Saskatchewan, and Manitoba southward to California, Arizona, New Mexico, Texas, and Mexico (Fig. 5.).

Habitat and Host Plants

The favored habitat of this grasshopper is in the shortgrass and mixed-grass associations; it also inhabits parts of the tallgrass prairie and shrub and grassland combinations. The species is not as abundant in the tallgrass prairie as it is on the shortgrass and mixed-grass plains. According to the observations of Bruner (1897), it is common in central and western Nebraska, but is rather rare in the eastern part. Whelan (1938) in studying the Orthoptera of a tallgrass prairie tract 9 miles northwest of Lincoln, Nebraska, did not find any *Aulocara elliotti*. In the report of the 1935 grasshopper survey Shotwell (1936) records the capture of 19 specimens in western but none in eastern Nebraska. Between 1937 and 1941 over one and one-half times as many *Aulocara elliotti* were found in the western as in the eastern part of the state (Shotwell and Skoog, 1942). There is a similar distribution of *Aulocara elliotti* in North Dakota. In the 1935 grasshopper survey 95 specimens were captured in western but none in eastern North Dakota, and between 1938 and 1941 almost three times as many

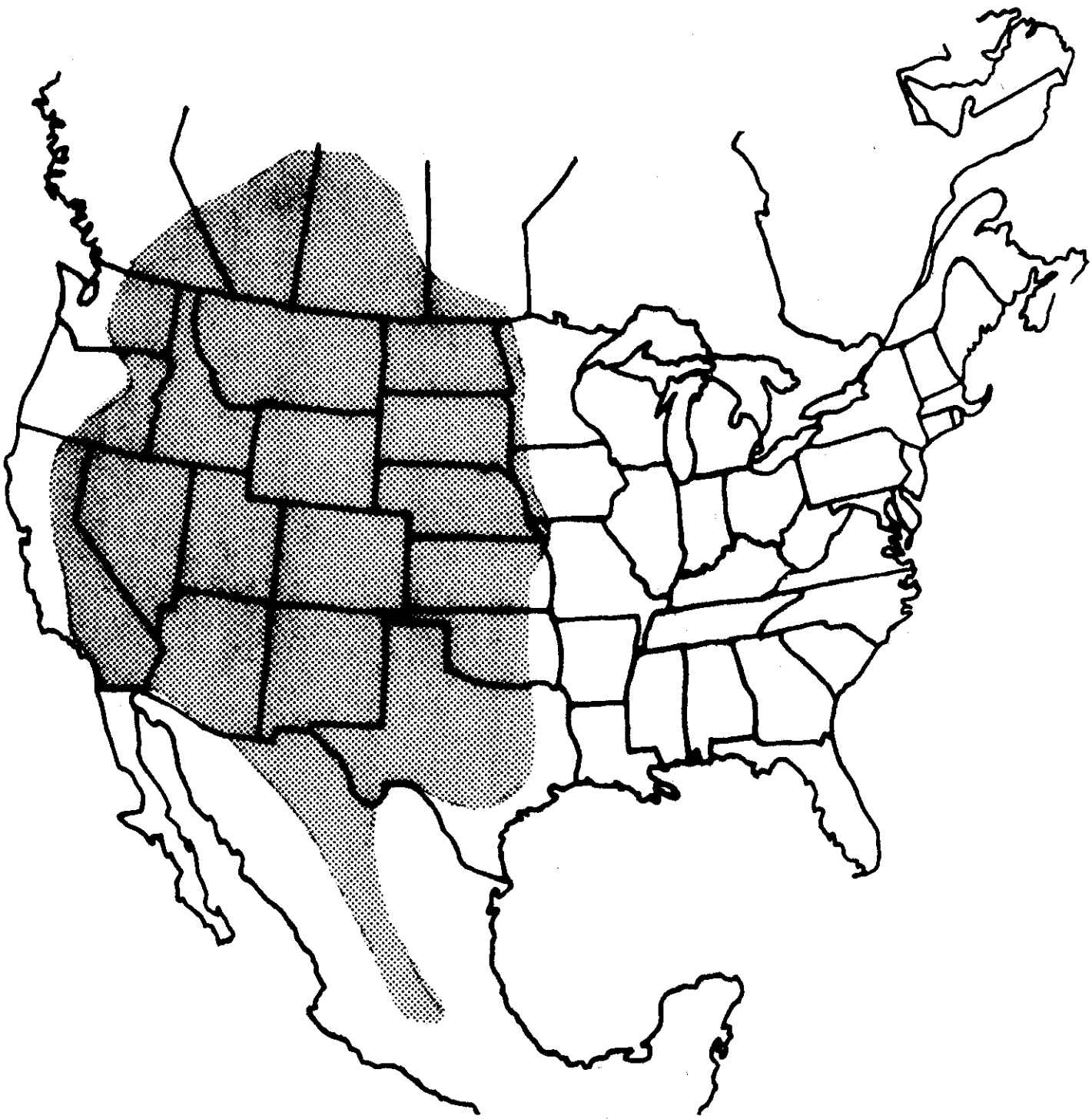

Fig. 5. The known distribution of *Aulocara elliotti* (Thomas) in North America.

Aulocara elliotti were found in the western as in the eastern part of the state. The species is rare in Iowa and in Minnesota having been taken from only three counties in the extreme west in Minnesota and from only two counties in the extreme west in Iowa. *Aulocara elliotti* has been found to be an important species on the range in Kansas (Shotwell, 1938*a*). However, at Manhattan which is in the eastern part of the state and, therefore, in the tallgrass prairie, Wilbur and Fritz (1940) collected only two specimens in a study made from 1933 through 1939. Woodruff (1937) collected no *Aulocara elliotti* during a grasshopper survey of eastern Kansas in 1936.

Based on crop analyses of *Aulocara elliotti* collected in several sites of the mixed-grass association of eastern Wyoming, Marks (1966) concluded that this species is a general grass feeder. He found among a total of 1,166 crops evidence of feeding upon 10 species of grass: *Agropyron smithii, Aristida longiseta, Bouteloua gracilis, Bromus tectorum, Calamovilfa longifolia, Koeleria cristata, Oryzopsis hymenoides, Poa secunda, Schedonnardus paniculatus,* and *Stipa comata.* He also found many crops contained *Carex* spp.

Mulkern et al. (1969) analyzed 37 crops of *Aulocara elliotti* taken in the vicinity of North Platte and Scotts Bluff, Nebraska. The analysis indicated that this grasshopper was a general grass feeder. They found the following plants: grasses--*Agropyron smithii, Bouteloua gracilis, Sporobolus cryptandrus,* and *Stipa comata*; sedges--*Carex filifolia*; and forbs--*Sphaeralcea coccinea.*

Pfadt (1949) observed first and second instar *Aulocara elliotti* feeding on *Poa secunda* and older instars and adults feeding on western wheatgrass in a mixed-grass association 10 miles east of Sheridan, Wyoming. In the mixed-grass association at Decker, Montana, Anderson and Wright (1952) observed all instars and adults feeding on western wheatgrass. From this

observation they concluded that this grass was preferred by *Aulocara elliotti*. Further study is needed to reach a firm conclusion about preferences of this grasshopper for particular grass species.

Because *A. elliotti* is a major pest of the grassland ranges of the West, we shall provide a detailed review of the recorded outbreaks of this species. Populations of outbreak proportions have been reported most frequently from the shortgrass and mixed-grass plains, but high populations have also been recorded in Washington, New Mexico, Arizona, and Utah. The clearest accounts of outbreaks of *Aulocara elliotti* appear in the reports of the State Entomologist of Montana. Cooley (1904) reported heavy range infestations of grasshoppers in eastern Montana during 1901, 1902, and 1903. The three most common grasshoppers in increasing order of abundance were: *Camnula pellucida, Melanoplus sanguinipes,* and *Aulocara elliotti.* So completely were the grasses of the range destroyed in some parts of Montana that ranchers were obliged to sell their stock or to move them to distant ranges. Cooley stated that the trouble began in two localities 150 miles apart, one in Carbon County and the other in Rosebud County. In these localities in the mixed-grass association the insects steadily increased for 3 years until in 1903 the advancing border lines met in the vicinity of Billings. Other areas of the mixed- and shortgrass plains were heavily infested at this time, for Bruner (1902) reported large numbers of grasshoppers in western Nebraska, western Kansas, eastern Wyoming, and eastern Colorado during 1901. One of the prevailing species was *Aulocara elliotti.* Bruner noted grasshoppers to be bad at Casper, Wyoming, but not as bad as farther east in Wyoming and some portions of Nebraska. Bruner (1905) found that the outbreak had ended in 1904. Swenk (1913) reported an outbreak of

range grasshoppers in western Nebraska during 1910 to 1912. *Aulocara elliotti* was one of the species represented in this outbreak.

Grasshopper outbreaks again occurred on the ranges of Montana from 1919 to 1923. Cooley (1919) reported large numbers of *Aulocara elliotti* in three southwestern counties of Montana: Gallatin, Beaverhead, and Madison. At about the same time, that is, in 1921 and 1922, Corkins (1923) reported serious infestations of pasturelands in Colorado. A survey of species infesting the foothills of Larimer County showed that *Melanoplus sanguinipes, Ageneotettix deorum,* and *Aulocara elliotti* were the most abundant species.

From 1934 to 1937 the mixed-grass plains of Montana were once again heavily infested with grasshoppers, and according to Strand (1937), the most important species were *Aulocara elliotti* and *Melanoplus sanguinipes.* During the same years the mixed- and shortgrass plains of Wyoming, Colorado Nebraska, North Dakota, and South Dakota were similarly infested. The important species involved in the outbreak were *Aulocara elliotti, Melanoplus sanguinipes,* and *Ageneotettix deorum* (Shotwell 1934, 1936, 1937 1938*a,b*; Morton 1939).

White and Rock (1945) report that *Aulocara elliotti* is economically the most important species of the grasshoppers affecting the shortgrass plains in Alberta.

All of the above records of heavy infestations are restricted to the mixed- and shortgrass plains, but populations of outbreak proportions outside of this area have been recorded by several observers. Bruner (1885) reported *Aulocara elliotti* numerous at Yakima, Ellensburg, and many other

points in eastern Washington in 1882. In 1885 the same author found much grasshopper damage of grasses in the Northwest and noted that *Aulocara elliotti* was a very common species. Hatch (1938) regards *Aulocara elliotti* as being an injurious pest in Washington. A heavy infestation of the rangeland in Catron and Socorro Counties, New Mexico, in 1892, was reported by Townsend (1893). The principal species was *Aulocara elliotti*. The infestation extended into Apache County, Arizona. At Pratt's ranch in southeast Apache County, Townsend was told that these grasshoppers had destroyed the garden and field crops there the previous year, 1891, and had eaten up the grain fields for 3 consecutive years, 1889 to 1891. Townsend reported that the abundance of grasshoppers on the dates of his observances, June 22 and 23, 1892, indicated destruction of the crop for the fourth consecutive time. Ball et al. (1942) states that *Aulocara elliotti* is one of the most injurious range grasshoppers in Arizona, especially in Graham County and on the Mongollon Plateau. Henderson (1931) has reported that the species is an enemy to agriculture in Utah. He notes that it is numerous and widely distributed in dryland sections of the state and is at times destructive to cereals and alfalfa crops as well as to range grasses. The results of the present review, however, indicate that alfalfa is not fed upon by this grasshopper. Knowlton and Jones (1932) report that *Aulocara elliotti* was especially destructive to wheat in Utah in 1931.

Life History and Seasonal History

Aulocara elliotti deposits its eggs in summer; these overwinter and hatch the following spring. At Decker, Montana, Anderson and Wright (1952)

record the approximate dates of first hatch as May 12, 1949, and May 22, 1950. They observed the first adult July 6, 1950. In Boulder County, Colorado, at altitudes of 5,100 to 5,500 ft, Alexander and Hilliard (1969) noted hatching through June into July and adults in July and August. First instar nymphs appear as early as late April to early May in Kansas and become adults by mid-June (Brusven, 1967). In Arizona hatching begins in late March, and adults are found from May through September (Ball et al., 1942).

Brusven (1967) has described and pictured the five nymphal instars of this species. It is a relatively easy insect to identify in the nymphal stage because of its color patterns.

Females oviposit in bare ground of the grassland habitat. They form a strong pod 14.5 mm long by 4.5 mm in diameter in which are contained an average of eight eggs. Onsager and Mulkern (1963) have described the egg of this species. It is whitish, 5.2 mm long and 1.5 mm in diameter.

Otte (1970) has made observations on the stridulation, aggression, and mating behavior of this species, but has not observed successful pair formation. Ferkovich, Wellso, and Wilson (1967), however, have observed pair formation. If a male was attracted to a receptive female, both the male and female lifted their hind femora, while at the same time the male approached the side or rear of the female and promptly mounted her. If the male was attracted to an unreceptive female, she stridulated aggressively, violently kicked the male off with her hind legs, and moved away.

Anderson and Hastings (1966) have provided notes on the rearing of *Aulocara elliotti* in cages in the greenhouse, and Hastings (1971) has published a laboratory study of the compatibility of males and females from

two populations of this species. Hastings and Pepper (1964) studied variations in physiological vigor of samples of *Aulocara elliotti* from different populations in Montana.

Physiology and Embryology

A regional project on the physiological factors affecting grasshopper populations promoted a number of investigations on the embryology and physiology of the egg of *Aulocara elliotti* in the entomology laboratory at Montana State University, Bozeman. Published papers or theses have been written by Bunde and Pepper (1968); Horvath (1967); Laine (1966); Leopold (1967); Quickenden (1969, 1970); Quickenden and Roemhild (1969); Robinson (1970); Roemhild (1965*a*,*b*, 1967, 1968); Svoboda, Pepper, and Baker (1966); Urban (1970); Van Horn (1966*a*,*b*); and Visscher (1971). These studies were predicated on the hypothesis that grasshopper population fluctuations are regulated by feedback mechanisms operating via the neuroendocrine system.

Cordillacris crenulata (Bruner) sland-faced grasshopper

Ochrilidia crenulata Bruner, 1889, U.S. Nat. Mus., Proc. 12:51.

Description

Body length: males 12 - 15.5 mm, females 17 - 19 mm. Color light grayish-brown above, cream or yellow below. A brown stripe beginning at the hind margin of each eye extends on the side of the head to the hind margin of the lateral lobes of the pronotum. Front of head distinctly recessive; lateral foveolae invisible from above; basal segments of antennae slightly wider than distal segments. Head larger in relation to the pronotum

than in *Cordillacris occipitalis*. Organs of flight fully developed; tegmina usually distinctly two-colored, the costal area light and dovetailing into the dark median area, thus producing a deeply sinuate border.

Distribution

Two subspecies of *Cordillacris crenulata* are recognized. *C. crenulata crenulata* is known from southeastern Alberta and from Montana and western North Dakota southward into Colorado and northern Texas. *C. crenulata prima* occurs in Arizona and New Mexico. The distribution of the species is shown in Fig. 6.

Habitat and Host Plants

The main habitat of this grasshopper is in the shortgrass and mixed-grass associations. It is commonly associated with blue grama grass which is thought to be its preferred host plant. In the mixed-grass association at Decker, Montana, Anderson and Wright (1952) observed that nymphs and adults were most numerous on blue grama which appeared to be the preferred food. On a study plot near Fort Benton, Montana, these authors noted *C. crenulata* doing considerable damage to threadleaf sedge. In western Kansas Brusven (1967) found this species to be closely associated with finer soils, sparsely to heavily vegetated with blue grama and buffalo grass. He concluded that it was not an economically important grasshopper in Kansas. In Arizona Ball et al. (1942) described it as one of the most common grasshoppers in drier areas where soil is thinner and grass more parched. They found it especially common on grama grass range and concluded that it is one of the important grasshoppers in preventing reseeding of grass on the range. In western Oklahoma Coppock (1962) states that it prefers thin soil and scanty cover and is restricted to the shortgrass high plains and black mesa types of vegetation.

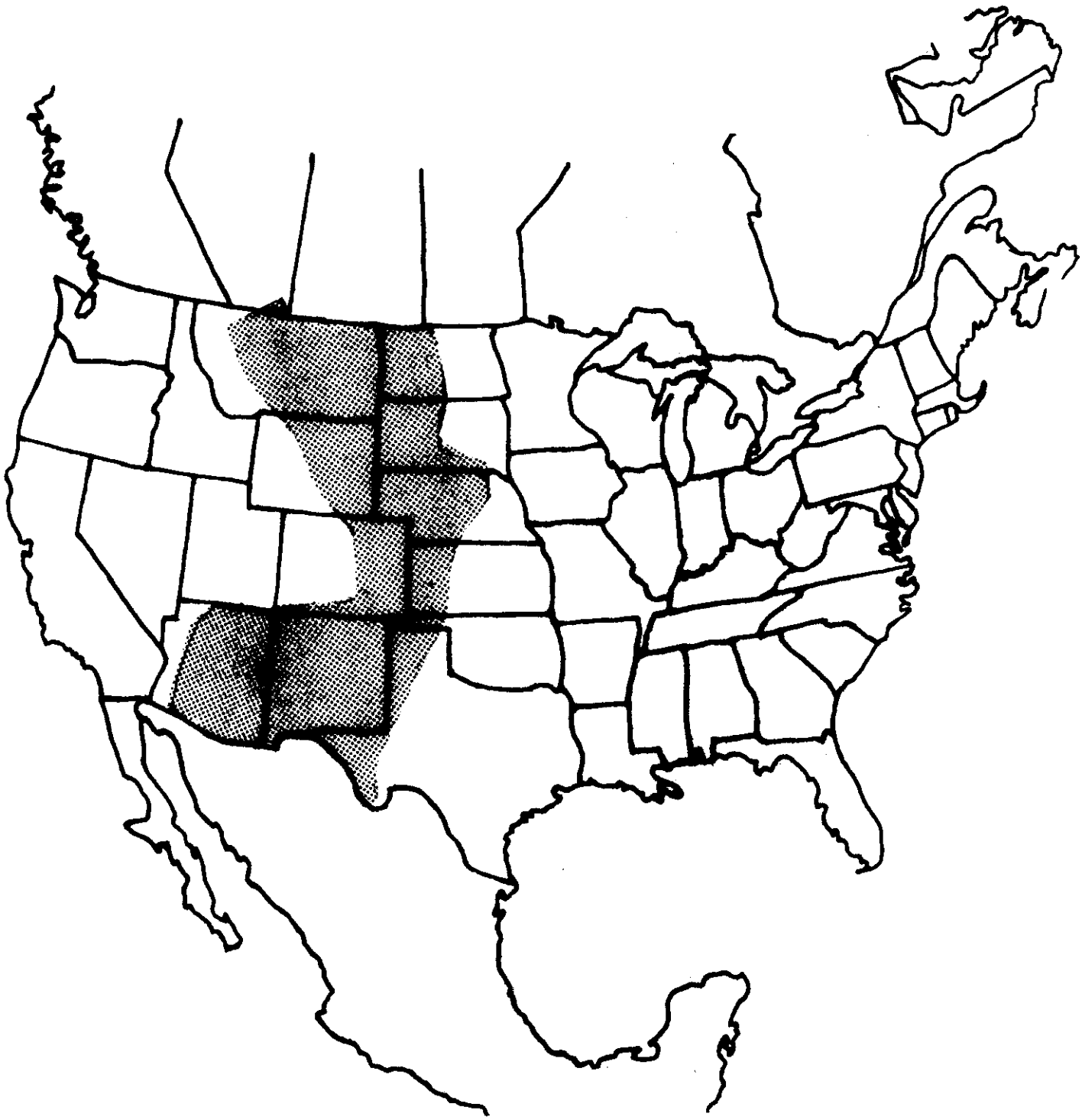

Fig. 6. The known distribution of *Cordillacris crenulata* (Bruner) in North America.

Morgan Hebard found *C. crenulata* quite plentiful on rangeland outside of Colorado Springs in August of 1904 (Rehn and Hebard, 1906). During this trip he collected specimens from the following localities in Colorado: Antlers, Colorado Springs; Knob Hill, Colorado Springs; Austin Bluffs, Colorado Springs; and Garden of the Gods. Gillette (1904) has observed that this species is generally distributed in Colorado on dry, grassy areas east of the Continental Divide to 8,000 ft altitude and is also found over some of the western slope. Otte (1970) has written that at Pueblo, Colorado, in August 1967 he observed many individuals of *C. crenulata* on the ground in an area sparsely covered with "very short grama grass".

No information on the host plants as determined by crop analysis have been published, but such information will become available from the Pawnee Site.

Life History and Seasonal History

In Colorado and Wyoming eggs of this species are laid in late summer and early fall, overwinter and hatch the following year in late spring or early summer. Brusven (1967) stated that in western Kansas first instar nymphs appear about May 1 and become adults in June. This author has described five nymphal instars and has provided a key to separate the nymphs of *Cordillacris crenulata* from *Cordillacris occipitalis*:

1. Lower margin of postocular brown streak discontinuous with lower margin of brown streak on lateral lobe of pronotum; hind tibia usually with distal dark band; dorsum of head with conspicuous narrow longitudinal brown streak . . . . . *C. crenulata.*

2. Lower margin of postocular brown streak continuous with lower margin of brown streak on lateral lobe of pronotum; hind tibia without distal dark band; dorsum of head usually without conspicuous narrow longitudinal brown streak . . . . . *C. occipitalis*.

The eggs and egg pod of this grasshopper have not been described. Otte (1970) has described courtship, pair formation, and aggression behavior in *C. crenulata* which he concluded was similar to that of the behavior of *Cordillacris occipitalis*.

UTILIZATION OF HOST PLANTS AND GROWTH OF GRASSHOPPERS

Insects as a group feed upon a remarkably diverse list of organic substances. Nevertheless the quantitative nutritional requirements of growing insects seem to be relatively uniform (Fraenkel, 1953). Poor growth in insects could be due to a low rate of intake because of the non-availability of a non-nutrient phagostimulant; the addition of nutrient with phagostimulatory activity might lead to increased growth, although the nutrient is neither required nor utilized (Dadd, 1960).

Experimental work with *Melanoplus differentialis* (Hodge, 1933) and *Melanoplus sanguinipes* (Pfadt, 1949; Smith, Handford, and Chefurka, 1952; Barnes, 1955; and Pickford, 1962) has indicated a definite relationship between food and growth. The rate of development, survival of nymphs and adult, size and longevity of adults, fecundity, and size of egg pods of *Melanoplus sanguinipes* were all affected by the food plants. A combination of wheat with a suitable weed such as mustard or dandelion was probably the superior food of all those tested. Reports also show that in the case of individuals or other families a mixed diet of several plants, as opposed to a diet of any single plant, resulted in faster development and greater weight of emerging adults with lower mortality.

Hodge (1933) reported, in the species *Melanoplus differentialis*, that occasional individuals (six males--two on mixed diet, two on rye, two on wheat, and one on barley; seven females--two on mixed, one on barley, one on lettuce, and three on wheat) exhibited an extra instar interpolated between the next to the last and the last and that this response was shown by individuals of either sex on any diet. Smith (1959) also reported the same results with *Melanoplus sanguinipes* fed on oats.

Hodge (1933) in his experiments with *Melanoplus differentialis* utilized 127 grasshoppers for deriving the individual growth curves expressed in weight. He reported that at the time of hatching *Melanoplus differentialis* ranges in fresh (wet) weight from 4.0 - 7.5 mg and averages 5.4 mg. From this initial weight the insects grow rapidly to an average fresh weight of 527.1 mg for the males (average of 31 individuals) and 831.6 mg for the females (average of 18 individuals) immediately after the final molt. The increase in weight per instar is shown in Table 1, expressed in terms of percentage obtained by subtracting the initial weight of each instar from the final weight. This difference divided by the initial weight and multiplied by 100 represents the percentage increase for that instar. Examination of the table shows that in many cases the weight is nearly doubled within an instar; in many more, ecdysis occurs after surprisingly little increase in weight; and in other cases the weight is much more than doubled or occasionally tripled.

A number of papers have been published on the consumption and the utilization of food by grasshoppers and locusts. One of the earliest was written by Parker (1930) who studied the effect of temperature upon the consumption of food by the migratory grasshopper, *Melanoplus sanguinipes* (F.).

Table 1. Average percentage increase in weight per instar (*Melanoplus differentialis*). After Hodge (1933).

Diet	Sex	1st Instar	2nd Instar	3rd Instar	4th Instar	5th Instar	Extra Instar	Last Instar a/	Last Instar b/
Mixed	M	61.7	182.2	149.2	98.6	119.3	76.3	121.3	77.9
Mixed	F	92.2	223.4	124.7	113.5	261.4	--	112.0	79.9
Wheat	M	125.7	122.1	114.7	124.6	121.2	105.9	97.8	82.9
Wheat	F	128.2	194.3	107.1	146.3	137.7	112.8	125.6	87.8
Barley	M	110.6	136.4	40.4	150.6	97.8	130.2	82.8	63.1
Barley	F	82.4	180.5	70.8	86.0	147.7	95.3	125.6	107.0
Rye	M	150.7	100.9	167.9	89.5	93.1	--	100.5	67.1
Rye	F	41.0	305.0	166.3	76.2	295.0	--	--	40.8
Lettuce	M	103.3	122.8	91.3	133.9	155.1	112.7	--	73.1
Lettuce	F	113.3	155.2	88.4	133.8	91.2	133.0	85.5	79.6
Average of	M	116.3	132.8	120.4	119.8	116.2	103.0	106.5	75.4
Average of	F	109.1	207.3	110.2	120.5	158.9	113.2	111.5	84.8
Average of	MF	119.6	162.2	115.7	124.9	135.6	108.9	106.4	78.7

a/ Percentage increase from the beginning of last instar to maximum weight at top of peak of pretransformation weight.

b/ Percentage increase from the beginning of last instar to weight immediately after transformation.

He found that the dry weight of food plant consumed per grasshopper during the nymphal stage was 680 mg at 27°C, 696 mg at 32°C, and 718 mg at 37°C. Temperature had a marked influence on the amount of food eaten per day; but although the nymphal period varied from 25 days at the high temperature to 54 days at the low, there was insignificant variation in total amount of food consumed. During the first 20 days of adult life individuals consumed food plants in following amounts of dry weight: 484 mg at 27°C, 893 mg at 32°C, and 1,159 mg at 37°C. Parker's work was an early effort and did not include details of plant utilization.

In a thorough review of consumption and utilization of food plants by insects Waldbauer (1968) has suggested standard indices for presenting data. These were adapted from the methods used by mammalian nutritionists and will be followed here. Formulas for calculating indices mentioned in this review are the following:

1. Approximate digestibility (A.D.). This coefficient has often been termed "utilization of food" by entomologists. Another point to make is that the difference between the weight of food ingested and the weight of feces actually represents the food which is stored or metabolized less metabolic wastes discharged in the urine or as fecal metabolic products. Hence the designation "approximate" digestibility.

$$A.D. = \frac{\text{wt of food ingested} - \text{wt of feces}}{\text{wt of food ingested}} \times 100$$

2. Efficiency of conversion of ingested food to body substance (E.C.I.).

$$E.C.I. = \frac{\text{wt gained}}{\text{wt food ingested}} \times 100$$

3. Efficiency with which digested food is converted to body substance (E.C.D.).

$$E.C.D. = \frac{\text{wt gained}}{\text{wt of food ingested - wt of feces}} \times 100$$

4. Coefficient of metabolizable energy (C.M.E.).

$$C.M.E. = \frac{\text{gross energy in food eaten - gross energy in feces}}{\text{gross energy in food eaten}}$$

This is the energy available for the production of heat, work, or body substance (Kleiber, 1961).

5. Efficiency of storage of ingested energy [E.S.I.(E)].

$$E.S.I.(E) = \frac{\text{gross energy stored in body}}{\text{gross energy in food eaten}} \times 100$$

6. Efficiency of storage of metabolizable energy [E.S.M.(E)].

$$E.S.M.(E) = \frac{\text{gross energy stored in body}}{\text{gross energy in food eaten - gross energy in feces}} \times 100$$

Smith (1959) studied both consumption and utilization of wheat, western wheatgrass, and oats by the migratory grasshopper. Direct comparisons cannot be made with Parker's work because Smith did not use physiologically defined periods but rather 5-day intervals in his recording of data and calculations. But from the average duration of the nymphal period it is estimated that at 30°C the individual nymphs consumed in dry weight 567 mg of wheat, 612 mg of western wheatgrass, and 373 mg of oats. Oats was less preferred than the other two plants; less was eaten and smaller gains in weight were made by the grasshoppers. The approximate digestibility of the

three plants by the whole nymphal stage of the migratory grasshopper was 34.6% for wheat, 36.3% for western wheatgrass, and 31.9% for oats. The efficiency of conversion of ingested food was 11.6% of oats, 11% of wheat, and 9.5% of western wheatgrass. The efficiency of conversion of digested food was 26.2% of western wheatgrass, 31.7% of wheat, and 36.5% of oats. Smith found that the approximate digestibility of food was greatest in the early instars and fell progressively as the grasshoppers aged.

Davey (1954) found a similar variation in approximate digestibility of grass (*Poa* sp., *Phleum pratense*, and *Agropyron repens*) by desert locust nymphs, *Schistocera gregaria* (Forskål); the nymphs digested 78% of food in the first instar, 52% in the second, 45% in the third, 34% in the fourth, and 35% in the fifth. During the nymphal stage the male of the desert locust consumed 1,663 mg of grass (dry weight) and the female 2,103 mg. The newly fledged male weighed 1,470 mg and the female 1,850 mg. Subtracting the weight (10 mg) of the newly hatched nymph and assuming a 25% dry weight of the locusts, the present writer calculated the efficiency of conversion of ingested food by the males as 25% and by the females as 22%. Davey (1954) also measured the intake of grass and the gain in weight of the locusts during their first 20 days of adult life (before they reached maturity). The males gained an average of 545 mg (133 mg dry wt) and the females 1,275 mg (319 mg dry wt). During the 20-day period males consumed 7.59 g fresh grass (1.237 g dry wt) and the females 14.54 g fresh grass (2.370 g dry wt). Calculation of the efficiency of conversion of ingested food from these data showed that the male converted 11% and the female 13% of the food eaten.

Dadd (1960) determined the approximate digestibility of grass by fifth instar of *S. gregaria* and of *Locusta migratoria* (L.) to average 39% for both species. Chauvin (1946) found that adults of *S. gregaria* digested 33% of endive leaves.

Norris (1961) found adult males of *S. gregaria* digested 23-53% of grass leaves of *Poa, Lolium,* and others. She also found that crowded males ate and excreted more than isolated ones did during the first 10 days of adult life. Five males in a 9-liter cage were sufficient to induce almost the full effect of crowding, and marked effects were shown when only two males were present. After the second or third week, the level of feeding declined. The decline occurred earlier in the early-maturing individuals. Her results indicated an association between a low level of feeding and rapid maturation. The earlier maturation of crowded males must, therefore, either be independent of the level of feeding or be due to their extra consumption being insufficient to compensate for greater metabolic requirements.

Both Nagy (1952) and Smith (1959) showed that degree of digestibility of food by grasshoppers depended on the species of plant. Nagy used the old world grasshopper *Dociostaurus brevicollis* and Smith used the migratory grasshopper of North America. Misra (1962) obtained data on the approximate digestibility of several grasses (*Bromus inermis, Festuca rubra,* and *Poa pratensis*) and the sedge *Carex eleocharis* by the clear-winged grasshopper, *Camnula pellucida* (Scudder), which is a cropland grasshopper and inhabitant of mountain meadows. He found that approximate digestibility was highest among the young grasshoppers and decreased as they aged. First instar nymphs had an average approximate digestibility of 68% and fifth instar 44%. Approximate digestibility also varied depending on the species of food

plant. The A.D. ranged among first instars from 55% (*Poa pratensis*) to 80% (*Carex eleocharis*) and among fifth instars from 36% (*Poa pratensis*) to 55% (*Carex eleocharis*).

In India, Husain, Mathus, and Roonwall (1946) studied the consumption of food plants by the desert locust. This grasshopper consumed 3,133 mg dry wt of green fig leaves during the nymphal stage. Some 64% of this amount was consumed by the last (fifth) nymphal instar. Aproximate digestibility of fig leaves decreased as the grasshoppers aged. Details of these results are summarized in Table 2.

These authors also studied the effect of different temperatures on food consumption. Unlike Parker's (1930) data, their results indicated that the total amount of food eaten during the nymphal stage varied inversely with change in temperature. They found that daily food consumption increased with the temperature up to 33°C, but beyond that no increase occurred. At 37°C consumption was even lower than that at 33°C.

An important consideration in food utilization studies is the presence of food in the gut when grasshoppers are weighed. Husain et al. (1946) determined the duration of fasting before and after the insect molts. Before molting nymphs fast from 12 to 42 hours, while after molting they fast from 3 to 39 hours. The older nymphs fast longer than the younger ones. These authors dissected insects immediately after molting and before any food was taken. They found that the foregut was almost completely free of solid food matter, but the midgut was invariably gorged with food matter. They did not weigh the contents of the midgut nor did they mention the condition in the hindgut.

Table 2. Consumption of green fig leaves by the nymphal instars of *Schistocerca gregaria* (Forsk.).

Instar	Dry Wt of Food Eaten (mg)	Percent of Total Food Eaten	Dry Wt Feces (mg)	Approximate Digestibility
I	70	2	38	49
II	135	4	78	42
III	242	8	167	31
IV	696	22	469	33
V	1990	64	1369	32
Total	3133	100	2121	32

These authors also determined the time taken by the food to traverse the alimentary canal by the use of bismuth subnitrate dusted on cotton leaves and also by feeding blotting paper for a short period and then feeding the usual plant diet. Both methods gave similar results. They found that food took one-half hour to 2 hours to traverse the alimentary canal. For complete evacuation of the food taken at one meal, the required time varied from 2½ hours to 7 hours.

In his review of the consumption and utilization of food by insects Waldbauer (1968) states that Hiratsuka's (1920) study of the silkworm, *Bombyx mori*, remains to this day the most complete study of the intake and expenditure of energy by an insect. A summary of Hiratsuka's results are shown in Table 3.

Table 3. Energy economy of the silkworm, *Bombyx mori*, feeding on mulberry leaves.

Source	Female		Male	
	Energy (kcal)	%	Energy (kcal)	%
Ingested food	15.30	--	13.13	--
Feces and urine	8.76	--	7.72	--
Metabolizable	6.54	100	5.42	100
Heat and work	3.46	53	2.81	52
Eggs (or sperm)	0.82	13	--	--
Silk	1.23	19	1.13	21
Larval exuviae	0.07	1	0.07	1
Pupal exuviae	0.07	1	0.05	1
Dead insect	0.89	14	1.37	25

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APPENDIX I

CHECKLIST OF PAWNEE ORTHOPTERA[1/]

Acrididae - the grasshoppers

Subfamily Acridinae - slant-faced grasshoppers

Acrolophitus hirtipes (Say)

Aeropedellus clavatus (Thomas)

Ageneotettix deorum (Scudder)

Amphitornus coloradus (Thomas)

Aulocara elliotti (Thomas)

Chorthippus curtipennis (Harris)

Cordillacris crenulata (Bruner)

Cordillacris occipitalis (Thomas)

Eritettix simplex tricarinatus (Thomas)

Heliaula rufa (Scudder)

Opeia obscura (Thomas)

Parapomala wyomingensis (Thomas)

Phlibostroma quadrimaculatum (Thomas)

Psoloessa delicatula (Scudder)

Subfamily Oedipodinae - banded-wing grasshoppers

Arphia conspersa (Scudder)

Arphia pseudonietana (Thomas)

Chortophaga viridifasciata (DeGeer)

Dissosteira carolina (L.)

Encoptolophus sordidus costalis (Scudder)

[1/] This list will undoubtedly increase in number as collecting and study continues on the Orthoptera of the Pawnee Site and associated grasslands. Each year since the inception of the project additional species have been added to the list.

APPENDIX I (continued)

Subfamily Oedipodinae - banded-wing grasshoppers (continued)

Hadrotettix trifasciatus (Say)

Mestobregma plattei (Thomas)

Spharagemon collare (Scudder)

Spharagemon equale (Say)

Trachyrhachys aspera Scudder

Trachrhachys kiowa (Thomas)

Trimerotropis campestris McNeill

Tropidolophus formosus (Say)

Xanthippus corallipes (Haldeman)

Subfamily Cyrtacanthacridinae - spur-throated grasshoppers

Aeoloplides turnbulli (Thomas)

Hesperotettix viridis (Thomas)

Melanoplus bivittatus (Say)

Melanoplus complanatipes Scudder

Melanoplus confusus Scudder

Melanoplus femurrubrum (DeGeer)

Melanoplus foedus Scudder

Melanoplus gladstoni Scudder

Melanoplus infantilis Scudder

Melanoplus lakinus (Scudder)

Melanoplus occidentalis (Thomas)

Melanoplus packardii Scudder

Melanoplus sanguinipes (F.)

Phoetaliotes nebrascensis (Thomas)

APPENDIX I (continued)

Gryllacrididae - cave crickets

Ceuthophilus pallidus Thomas

Gryllidae - true crickets

Gryllus sp.

Nemobius fasciatus DeGeer

Oecanthus argentinus (Saussure)

Oecanthus quadripunctatus Beutenmuller

Mantidae - preying mantids

Litaneutria minor (Scudder)

Phasmatidae - walking sticks

Parabacillus coloradus (Scudder)

Tettigoniidae - long-horned grasshoppers

Conocephalus fasciatus (DeGeer)

Conocephalus saltans (Scudder)

Pediodectes stevensonii (Thomas)