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Source: Journal of Orthoptera Research, 21(2) : 227-233

Published By: Orthopterists' Society

URL: <https://doi.org/10.1665/034.021.0207>

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Habitat associations of grasshoppers (Orthoptera: Acrididae) in the heterogeneous cedar glade landscape of the Central Basin of Tennessee

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Abstract

Grasshopper communities were sampled in three associated habitats of the Central Basin of Tennessee: cedar glades, xeric limestone prairies, and cedar hardwood forest. Twenty-five grasshopper species were collected across all three habitats. Eleven species were found in the cedar glades, 12 species were collected in the xeric limestone prairies, and six species were collected from the cedar-hardwood forests. A Principal Component Analysis of the resulting species lists indicated that grasshopper community composition differed significantly between each habitat. Four new state records for Tennessee were documented during this survey. An annotated species list is presented.

Key words

Cedar glade, xeric limestone prairie, cedar hardwood forest, grasshopper, *Melanoplus ingrami*, *Paratylotropidia brunneri*, *Pseudopomola brachyptera*, *Spharagemon saxatile*

Introduction

A list of the grasshoppers (Orthoptera: Acrididae) inhabiting Tennessee was produced by Marcovitch (1920), and literature records for the state have been recently summarized by Hill & Dakin (2011). However, the associations between grasshopper species and particular habitat types or ecoregions are not well known in the state. Documenting the fauna of different habitats is important not only to provide a better understanding of the regional fauna, but also to guide current management and future conservation/restoration projects in these systems. Meyer (1937) conducted the only study of this type with grasshoppers in Tennessee, documenting 11 species of grasshopper inhabiting a cedar glade 21 km (13 miles) southeast of Nashville as part of a broader study that included the Annelida, Mollusca, and Arthropoda of the site. Meyer (1937) characterized the site as open habitats of the glades, red cedar forests, and shrub habitats. However, in her annotated list it appears that grasshoppers were only successfully sampled from the open habitats.

The Central Basin physiographic region of Tennessee is a somewhat elliptical depression situated in the center of the state (Fig. 1). Elevations in the basin are typically 120-215 m below that of the surrounding Low Plateau (Fenneman 1938). Scattered outcroppings of the basin's Ordovician limestone bedrock and shallow soils result in conditions that favor herbaceous vegetation and limit tree growth to isolated individuals or scattered stands of eastern red cedar (*Juniperus virginiana*), and a few other woody species. These open "cedar glades" can be found in several southeastern states, but it is in the Central Basin of Tennessee where they are most prolific, occurring with xeric limestone prairies, eastern red cedar forests, and hardwood forests as part of an edaphically determined mosaic of habitats (Quarterman *et al.* 1993; Baskin & Baskin 1999). These

habitats are considered highly imperiled due to anthropogenic disturbances including fire suppression, recreational driving, and suburban sprawl of the cities of Nashville and Lebanon (Noss 1995; Niemiller *et al.* 2011).

The staff of the Mississippi Entomological Museum have conducted extensive surveys in the cedar glades and associated habitats of the Central Basin of Tennessee to better document the insect fauna of this unique environment. As part of these surveys, the grasshopper fauna of three habitats (cedar glades, xeric limestone prairies, and cedar hardwood forests) of conservation concern were sampled extensively to document the fauna of these endangered habitats.

Methods

Habitats.— Cedar glades (Fig. 2a) are found on shallow Gladeville flaggy silty clay loam situated <1 to 20 cm above the Lebanon or Ridley limestone bedrock. The soil of the cedar glades presents a harsh environment as it is often saturated with precipitation from late autumn to early spring and in contrast is often below wilting point during the summer (Quarterman 1950; Baskin & Baskin 1999). The glades of the Central Basin have long been noted for their floral distinctiveness with four endemic plant species, as well as several more that are considered disjunct from populations in the Ozark Mountains (Gattinger 1901; Harper 1926; Quarterman 1950; Baskin & Baskin 1999; Cofer *et al.* 2008). Floristically, cedar glades are characterized by the presence of the blue green alga, *Nostoc commune*, several foliose lichens, and numerous vascular plants such as cedar glade cress (*Leavenworthia stylosa*), Missouri evening primrose (*Oenothera macrocarpa*), wild petunia (*Ruellia humilis*), Gattinger's prairie clover (*Dalea gattingeri*), Venus' pride (*Houstonia purpurea*), limestone flameflower (*Talinum calcaricum*), widow's cross (*Sedum pulchellum*), Tennessee coneflower (*Echinacea tennesseensis*), white rim scurfpea, (*Pediomelum subacaule*), fluxweed (*Isanthus brachiatus*), prickly pear (*Opuntia cespitosa*), poverty dropseed (*Sporobolus vaginiflorus*), prairie fleabane (*Erigeron strigosus*), and pasture heliotrope (*Heliotropium tenellum*) (Quarterman *et al.* 1993; Baskin & Baskin 1999).

Xeric limestone prairies (Fig. 2b) of the Central Basin occur on slightly deeper (20-30 cm) soils than the cedar glades (Baskin *et al.* 1994). These prairies are often adjacent to cedar glades and in many instances grade floristically into them, as was the case at the three xeric limestone prairie study sites. The prairies, in contrast to the cedar glades, are dominated by the perennial grasses little bluestem (*Schizachyrium scoparium*) and poverty dropseed (*S. vaginiflorus*) (Baskin & Baskin 1977; Delsem 1992; Baskin *et al.* 1994; Lawless *et al.* 2006).

Cedar-hardwood forests (Fig. 2c) often surround the glades and

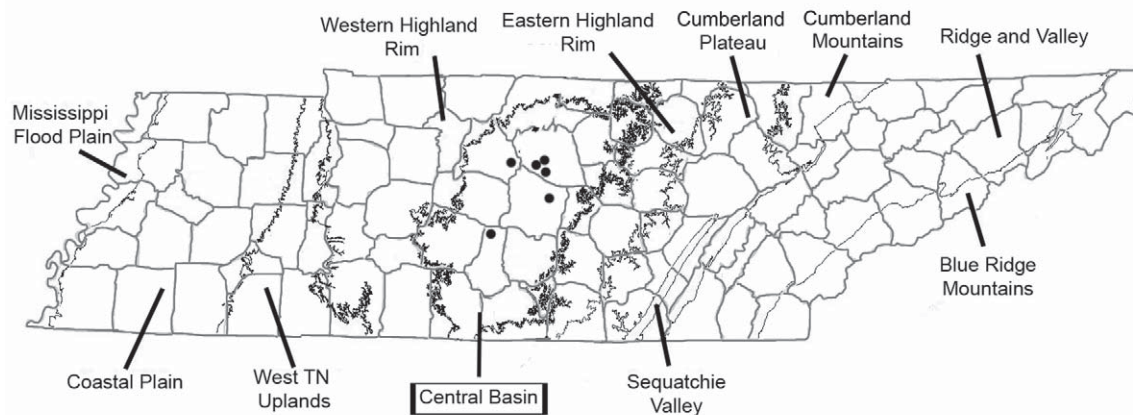


Fig. 1. Physiographic regions of Tennessee, and location of study sites for this survey. (●) denotes approximate location of study sites.

xeric limestone prairies on deeper (>30 cm) or more mesic soils. The overstory of these forests is composed primarily of eastern red cedar, with hackberry (*Celtis laevigata*), winged elm (*Ulmus alata*), blue ash (*Fraxinus quadrangulata*), Ohio buckeye (*Aesculus glabra*), pignut hickory (*Carya glabra*), and several oaks (*Quercus* spp.) making up the remainder (Quarterman 1950). The understory is typically a dense stand of aromatic sumac (*Rhus aromatica*), Carolina buckthorn (*Frangula caroliniana*), cedar glade St. Johnswort (*Hypericum frondosum*) coralberry (*Symphoricarpos orbiculatus*), glade privet (*Forestiera ligustrina*), white crownbeard (*Verbasina virginica*), and/or white flowered leaf cup (*Polymnia candaensis*), while the ground is often carpeted by moss (Quarterman 1950).

Grasshopper sampling.—Grasshoppers were sampled at five state natural areas (Couchville Cedar Glade, Flatrock Cedar Glades and Barrens, John and Hester Lane Cedar Glades, Vesta Cedar Glades, and Wilson School Road Cedar Glade and Forest) and Cedars of Lebanon State Park (Table 1 and Fig. 2). Six cedar glades, three xeric limestone prairies, and four cedar hardwood forests were sampled (Table 1). An effort was made to examine the current fauna of Meyer's study site, as she gave relatively precise locality information for it. Unfortunately, the site is now occupied by a gas station and concrete parking area. Sampling took place during 20-27 July 2009, 28 April - 1 May, 2-5 June, 1-4 August, 7-10 September 2010, and 29-30 April 2011.

Grasshopper specimens were collected with a 30 cm diameter net after a collector on foot flushed them. Additionally, grasshoppers were sampled by thoroughly sweeping the herbaceous vegetation in each habitat type, with the same 30 cm diameter net, and then emptying the contents into a killing jar. Sweeping took place at least 6 meters from the edge of an adjacent habitat. The cedar glade and prairie habitats were relatively small in size (0.16 - 4 ha) and could be sampled effectively in this manner. Specimens were taken back to the Mississippi Entomological Museum (MEM) where they were processed and identified by the author, and deposited as vouchers.

Data analysis.—To compare species composition of the three habitat types, grasshopper presence/absence data were analyzed using a Principal Components Analysis (PCA) with PC-ORD (Version 6; MjM Software Design, Glenden Beach, OR). Only PCA axes with an eigenvalue >1 were considered ecologically meaningful. Scores from significant axes were then analyzed using a one-way ANOVA to test for distinctiveness across assemblages.

Results

Twenty-five species, representing four subfamilies and 14 genera, were collected across all habitats. Eleven species from nine genera were found in the cedar glades, 12 species from ten genera were collected in the xeric limestone prairies, and six species from two genera were collected from the cedar-hardwood forests (Table 2). *Chortophaga viridifasciata* (DeGeer), *Hippiscus ocelote* (Saussure), *Melanoplus scudderi scudderi* (Uhler), and *Syrbula admirabilis* (Uhler) were shared between the cedar glades and xeric prairies and were sampled at all sites of each. However, the forests and the two open habitats had no species in common. The number of species collected in the cedar glades ranged from a low of seven (Cedars of Lebanon State Park and Vesta) to a high of 11 (Wilson School Rd.). Species apparently restricted to cedar glades in these habitats include *Arphia sulphurea* (Fabricius), *Melanoplus ingrami* Hill, *Spharagemon saxatile* Morse and *Trachyrhachys kiowa* (Thomas). The number of species collected in the xeric limestone prairies ranged from a low of six (Couchville) to a high of 10 (Vesta and Flat Rock). Species apparently restricted to the prairies in this ecosystem include *Arphia xanthoptera* (Burmeister), *Hesperotettix viridis pratensis* (Scudder), *Melanoplus femurrubrum* (DeGeer), *Paratyloptropidia brunneri* Scudder, and *Pseudopomola brachyptera* (Scudder). All six species that were collected in the cedar hardwood forests were apparently restricted to them.

The PCA portioned the data (Table 2) into 12 axes, of which only

Table 1. Study site locality data including county, habitat types at each site, and latitude-longitude.

Site	County	Habitat(s)	Lat-Long
Cedars of Lebanon State Park	Wilson	Cedar Glade and Cedar- Hardwood Forest	36°05'31"N 86°19'55"W
Couchville Glade N. A.	Davidson	Cedar Glade and Xeric Limestone Prairie	36°06'04"N 86°31'46"W
Flat Rock Cedar Glade N. A.	Rutherford	Cedar Glade and Xeric Limestone Prairie	35°51'31"N 86°17'44"W
Lane Farm N. A.	Wilson	Cedar Glade and Cedar- Hardwood Forest	36°01'55"N 86°19'55"W
Vesta Cedar Glade N. A.	Wilson	Cedar Glade, Xeric Limestone Prairie and Cedar- Hardwood Forest	36°04'36"N 86°23'45"W
Wilson School Road N. A.	Marshall	Cedar Glade and Cedar- Hardwood Forest	35°39'43"N 86°47'44"W

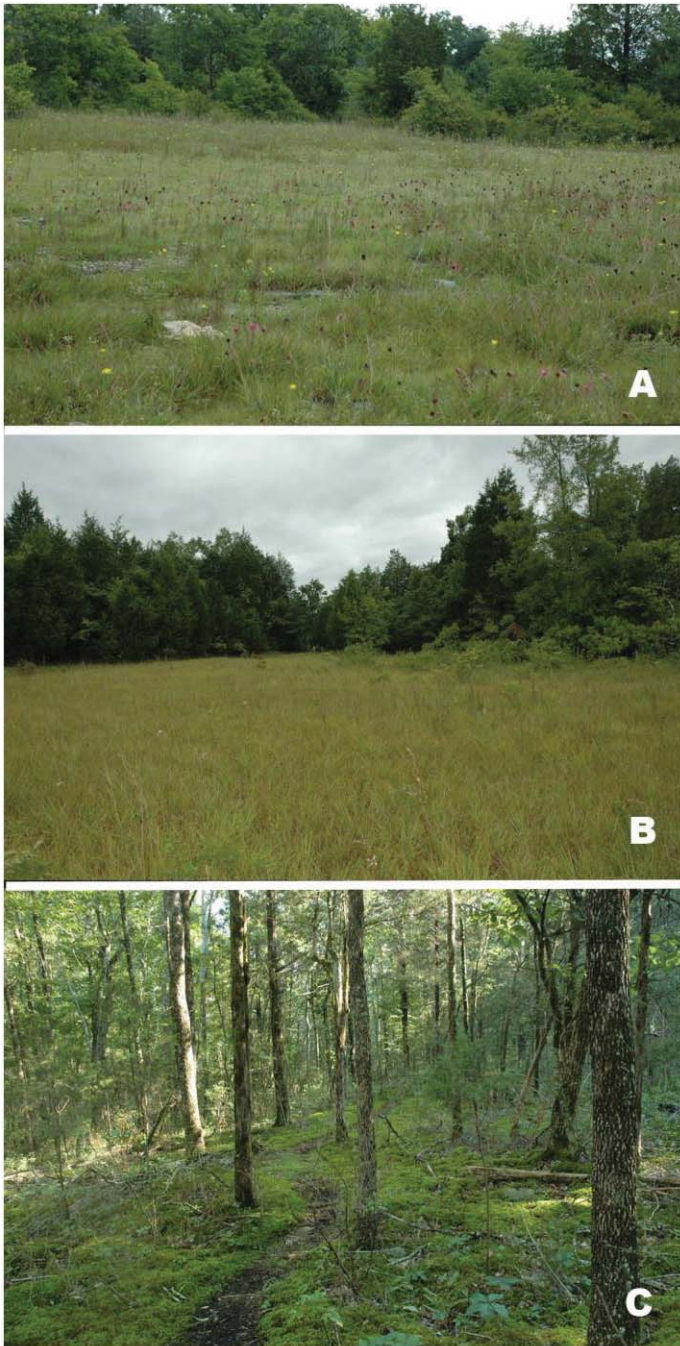


Fig. 2. Habitat view of (A) cedar glade, (B) xeric limestone prairie, and (C) cedar hardwood forest.

two possessed eigen values >1 . These two axes cumulatively explain 70.5 % of the variance in the species composition across the sites. The PCA ordination revealed three distinct grasshopper communities based on species composition of the three habitats sampled (Fig. 3). Axis 1 divides the open sites (glades and xeric limestone prairies) from the forested sites. Axis 2 divides the glades from the xeric limestone prairies. The ANOVA of the axis scores produced by the ordination found these communities to be significantly different ($P < 0.0001$ each).

Discussion

This survey resulted in the documentation of four grasshopper

species for the first time in the state of Tennessee: *Melanoplus punctulatus punctulatus* (Scudder), *Paratylotropidia brunneri*, *Pseudopomola brachyptera*, and *Spharagemon saxatile*. Additionally, the apparent cedar glade endemic, *Melanoplus ingrami*, was discovered and described as a new species (Hill 2010) during the course of this survey (See the species notes section for additional information on each species.)

Three species reported by Meyer (1937) were not detected during this survey. One of these species, *Arphia granulata* (Saussure), was almost certainly misidentified by Meyer, as it is associated with sandy soils along the Coastal Plain (Otte 1984; J. G. Hill, pers. obs.). The other two, *Encoptolophus sordidus* (Burmeister) and *Melanoplus differentialis* (Thomas) represent more plausible records. The large amount of bare ground in the cedar glades would provide suitable habitat for *E. sordidus*, as the species is known to inhabit similar conditions in the Appalachian region of the state (Morse 1904). However, *Chortophaga viridifasciata* was the most commonly collected species in Meyer's study, and it is not uncommon that this species is mistaken for members of the genus *Encoptolophus* (J. G. Hill, pers. obs.). No known vouchers exist from Meyer's study, making this determination questionable. *Melanoplus differentialis* is a common species in disturbed ruderal environments in this region. During this survey, *M. differentialis* was observed inhabiting hay fields and roadsides near the sampling sites, but never in them. Meyer's survey was conducted in an agricultural setting, which may have facilitated the presence of this species.

A direct comparison to Meyer's (1937) data sets is not possible due to differences in sampling procedure, Meyer's broad definition of a glade, and her focus on a single site. The apparent lack of the more conservative glade or prairie species in Meyer's study, coupled with the high abundance of *C. viridifasciata* and the presence of *M. differentialis*, may indicate that Meyer's site experienced higher levels of disturbance than sites used in this survey. It is also possible that Meyer may have missed these species due to sampling limitations as she was focusing on a broader range of organisms.

The cedar glades, xeric limestone prairies, and cedar hardwood forests of this region, support significantly different grasshopper faunas. Moreover, the four species shared between the two open habitats are common species found in many open habitats. Hill (in press) found that the ant fauna of the glade and prairie habitat of the Central Basin also supported distinct assemblages. The uniqueness of the invertebrate communities of each floristically defined habitat of this heterogeneous environment further supports their separate conservation and management. The exact environmental factors that may contribute to the faunal differences between each habitat were not investigated here, but it is likely that innate characteristics of the habitats such as vegetative structure, soil depth, amount of bare rock exposed, and other environmental variables play an important role. The exact relationship between these variables and the grasshopper communities should be examined to further aid in management decisions, particularly where the cedar glade endemic *M. ingrami* is concerned.

Species Notes

The following list is arranged alphabetically by species and is annotated with collection, habitat and site records. Site abbreviations are as follows CVP = Couchville xeric limestone prairie, CVG = Couchville Glade, CLSPF = Cedars of Lebanon State Park cedar hardwood forest, CLSPG = Cedars of Lebanon State Park glade, FRP = Flat Rock xeric limestone prairie, FRG = Flat Rock Glade, LFF = Lane Farm cedar hardwood forest, LFG = Lane Farm glade, WSRF =

Table 2. Grasshoppers recorded from open habitats of cedar glades by Meyer 1937 and those collected in cedar glades, xeric limestone prairies, and cedar-hardwood forests during this survey; *denotes questionable records of Meyer (1937).

Species	Meyer 1937	Present study Glades	Present study Xeric Limestone Prairie	Present study Cedar/Hardwood
<i>Arphia sulphurea</i>	X	X		
<i>Arphia xanthoptera</i>	X		X	
<i>Chortophaga viridifasciata</i>	X	X	X	
<i>Dichromorpha viridis</i>	X	X		
<i>Dissosteria carolina</i>	X	X		
<i>Encoptolophus sordidus*</i>	X			
<i>Hesperotettix viridis pratensis</i>			X	
<i>Hippiscus ocelote</i>	X	X	X	
<i>Melanoplus bivittatus</i>			X	
<i>Melanoplus differentialis</i>	X			
<i>Melanoplus femurrubrum</i>	X		X	
<i>Melanoplus gracilis</i>				X
<i>Melanoplus ingrami</i>		X		
<i>Melanoplus morsei</i>				X
<i>Melanoplus punctulatus</i>				X
<i>Melanoplus rusticus</i>				X
<i>Melanoplus sanguinipes vulturinus</i>	X	X		
<i>Melanoplus scudderii scudderii</i>		X	X	
<i>Melanoplus walshi</i>				X
<i>Orphulella speciosa</i>			X	
<i>Partylotropidia brunneri</i>			X	
<i>Pseudopomola brachyptera</i>			X	
<i>Schistocerca americana</i>			X	
<i>Spharagemon boli</i>	X			X
<i>Spharagemon saxatile</i>		X		
<i>Syrbula admirabilis</i>		X	X	
<i>Trachyrhachys kiowa</i>		X		
Totals	11	11	12	6

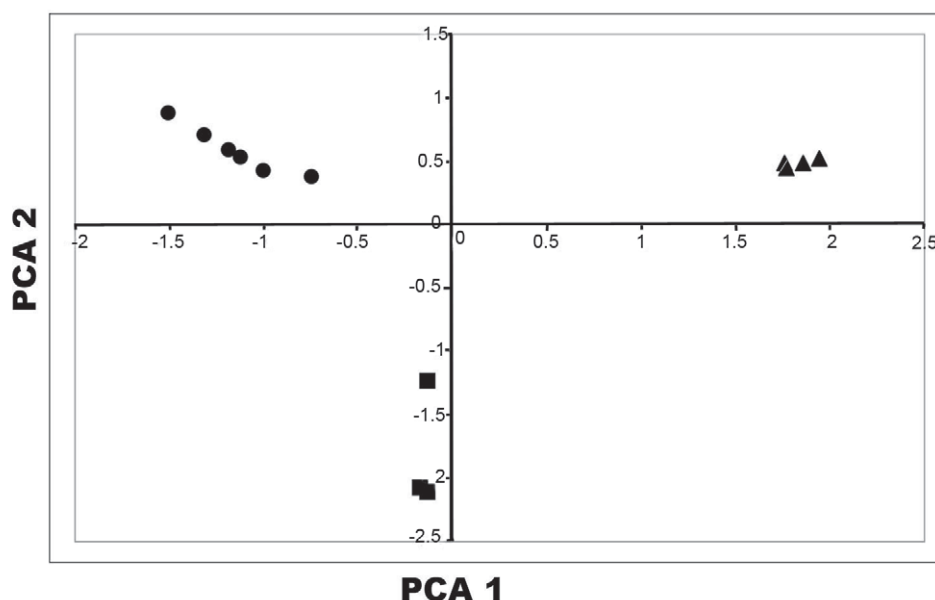


Fig. 3. Plot of the two significant PCA axes. Cedar glades (●), xeric limestone prairies (■), and cedar hardwood forests (▲). PCA axes 1 and 2 explained 43.6 and 26.9 percent of the variation in species composition respectively.

Wilson School Rd. cedar forest, WSRG = Wilson School Rd. glade, VP = Vesta xeric limestone prairie, VF, Vesta cedar hardwood forest, VG = Vesta Glade.

***Arphia sulphurea* Fabricius:** Over-wintering as a nymph allows *A. sulphurea* to be one of the first grasshoppers to reach maturity during spring in the region. Adults can be seen as early as late April and are usually gone by late July. This widespread species was detected in the all glade sites, where they were fairly abundant, but was absent from other habitat types surveyed. CVG, VG, CLSPG, FRG, LFG, and WSRG.

***Arphia xanthoptera* (Burmeister):** This common and widespread fall-maturing species was detected in the xeric limestone prairies and in none of the other habitat types. FRP and VP.

***Chortophaga viridifasciata* (DeGeer):** Like *A. sulphurea*, this species over-winters as a nymph and is one of the first species to reach maturity in the spring. There may be several broods of this widespread species per year in the region. *Chortophaga viridifasciata* was collected in all the glade and xeric limestone prairie sites, with greater abundance in the more disturbed areas of the sites. CVG, CVP, CLSPG, FRG, FRP, LFG, VG, VP, and WSRG.

***Dichromorpha viridis* (Scudder):** This widespread species is more common in disturbed or mesic areas. During this study only a single individual of *D. viridis* was collected; it was found in a wetter area of the glade habitat. WSRG.

***Dissosteira carolina* (Linnaeus):** This common and widespread species inhabited areas of exposed bare rock in the cedar glade habitat. It was never abundant. FRG, WSRG.

***Hesperotettix viridis pratensis* Scudder:** *Hesperotettix viridis* is widely distributed across North America (Helfer 1963, Capinera *et al.* 2004). However, in the eastern United States, this species and its subspecies are localized, often being restricted to naturally open areas (J. G. Hill, unpub. data). Panzer *et al.* (2006) considers *H. v. pratensis* to be a prairie remnant dependent species in Illinoian prairies, and Hill (2007) found it to be restricted to high quality Black Belt prairies in Mississippi. *Hesperotettix viridis pratensis* was detected only in the xeric limestone prairie habitat where it was moderately abundant. It has recently been found in Silurian xeric limestone prairies in southern Tennessee (J.G.H., unpub.). This species should be considered rare in the state, but not as rare as *P. brunneri* or *P. brachyptera*. FRP and VP.

***Hippiscus ocelote* (Saussure):** Like *C. viridifasciata*, this widespread species was collected in all sites of both open habitat types, appearing to be equally abundant in each. CVG, CVP, CLSPG, FRG, FRP, LFG, VG, VP, and WSRG.

***Melanoplus bivittatus* (Say):** This species was detected only in the xeric limestone prairie habitat where it was moderately abundant. FRP and VP.

***Melanoplus femurrubrum* (DeGeer):** This species was detected only in the xeric limestone prairie habitat. It was not abundant as only one individual was seen at each site. CVP and VP.

***Melanoplus gracilis* (Bruner):** This species was detected only in the cedar-hardwood forest where it was the most abundant species during the summer months. *Melanoplus gracilis* could usually be found among stands of *Verbasina virginica* and *Polymnia canadensis*, and was observed consuming the leaves of and nocturnally roosting on *P. canadensis* (Fig. 4C). CLSPF, LFF, VF, and WSRF.

***Melanoplus ingrami* Hill:** This species was described as a new species (Hill 2010) during the course of this survey, and is apparently endemic to the cedar glades of the Central Basin. It was detected at all the cedar glade sampling sites, where it could be found in clumps of low-growing vegetation especially prairie tea (*Croton monanthogymus*) (Fig. 4B). This species is relatively abundant

in these cedar glades, but is apparently restricted to them and should be added to Tennessee's animal watch list. CVG, CLSPG, FRG, LFG, VG, and WSRG.

***Melanoplus morsei* Blatchley:** This species (Fig. 4C) was detected only in the cedar-hardwood forest where it was found commonly among the herbaceous vegetation of the understory. CLSPF and VF.

***Melanoplus punctulatus punctulatus* (Scudder):** This primarily arboreal species was detected only in the cedar-hardwood forest, where one female was found on the trunk of *J. virginiana* and a pair *in copula* were found on the trunk of *F. quadrangulata*. CLSPF and VF.

***Melanoplus rusticus obovatipennis* (Blatchley):** Only one male of this species was detected during this survey. It was found in the herbaceous vegetation of the understory of a cedar hardwood forest. LFF.

***Melanoplus sanguinipes vulturinus* Gurney and Brooks:** Only two individuals of this widespread ruderal species were detected during this survey. Both individuals were found on bare rock in the cedar glade habitat. LFG and WSRG.

***Melanoplus scudderi scudderi* (Uhler):** This late summer/fall maturing species was found in all the sites of both open habitats (cedar glades and xeric limestone prairies). In the xeric limestone prairie, it appears to be associated with areas where forbs are more prominent than in pure grass stands. CVG, CVP, FRG, FRP, VG, VP, CLSPG, LFG, and WSRG.

***Melanoplus walshii* Scudder:** This species was found inhabiting clumps of low growing forbs and shrubs in the understory of the cedar-hardwood forests. It was observed nocturnally roosting on *V. virginica*. VF, and WSRF.

***Orphulella speciosa* (Scudder):** Only one individual of this widespread species was collected during this survey. FRP.

***Paratylotropidia brunneri* Scudder:** The records presented here represent the second collection of this species east of the Mississippi River, and the first from the state of Tennessee. Rehn and Rehn (1943) state that this is definitely a "prairie-land type, crossing the Mississippi as far as known, only in western Illinois". *Paratylotropidia brunneri* was only collected in the xeric limestone prairie area of Vesta Natural Area, where it was uncommon with only 7 individuals seen during this survey. This species should be considered rare in Tennessee. VP.

***Pseudopomala brachyptera* (Scudder):** The records presented here are the first of this species from the state of Tennessee. *Pseudopomala brachyptera* is considered a prairie remnant dependent species in the prairies of Illinois and has also been found to be restricted to high quality Black Belt and Jackson Prairie remnants in Mississippi (Hill 2005, 2007; Panzer *et al.* 2006). This species was detected in the xeric limestone prairie habitat of two natural areas where no more than 4 individuals were ever seen at one visit to a site. *Pseudopomala brachyptera* should be considered rare in Tennessee. CVP and VP.

***Schistocerca americana* (Drury):** Surprisingly, this widespread and highly vagile species was not detected often in these habitats. Overall, only two individuals of this species were observed during this survey. FRP and CVP.

***Spharagemon bolli* Scudder:** Only one individual of this widespread species was observed during this survey. It was found inhabiting a cedar hardwood forest with relatively open understory as is typical for the species. LFF.

***Spharagemon saxatile* Morse:** The records presented here are the first of this species from the state of Tennessee. This species appears to be restricted to extensive areas of exposed rock in the cedar glades where it is perfectly camouflaged against the grayish-white



Fig. 4. Images of several adult grasshopper species found during the survey: A. *Trachyrhachys kiowa* (Thomas) B. *Melanoplus ingrami* Hill, and C. *Melanoplus morsei* Blatchley.

limestone. CVG, FRG, and WSRG.

***Syrbula admirabilis* (Uhler):** This widespread species was detected in all the open habitat sites except one. In the cedar glades it inhabits the more vegetated areas where it is better camouflaged. CVG, CVP, CLSPG, FRG, FRP, LFG, VG, VP, and WSRG.

***Trachyrhachys kiowa* (Thomas):** This species is a denizen of exposed bedrock surfaces in the glades, and appears to be the most abun-

dant species throughout the summer months. Like *S. saxatile*, its color camouflages it when on the exposed limestone bedrock (Fig. 4A). However, unlike the aforementioned species, *T. kiowa* can often be found inhabiting areas of bare-rock as well as sparsely vegetated areas. A minority of individuals had a green stripe along the posterior edge of the pronotum instead of the more common tan or gray. CVG, VG, CLSPG, FRG, LFG, and WSRG.

Acknowledgements

I thank John Barone, Richard Brown, and Joe MacGown for comments on early drafts of the manuscript. Joe MacGown photographed habitats. Roger McCoy and Buddy Ingram kindly provided assistance with fieldwork logistics. Additionally, I am grateful to Carol and Jerry Baskin and the late Hal DeSelm for providing their valuable insights into habitats of the region. This project was partially funded by the W. H. Cross Expedition Endowed Fund. This article is approved for publication as Journal Article No. 12140 of the Mississippi Agriculture and Forestry Experiment Station.

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