PUEBLO CHEMICAL DEPOT GRASSHOPPER MONITORING: 1999 RESULTS

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Executive Summary

In 1999 the U. S. Fish and Wildlife Service contracted the Colorado Natural Heritage Program (CNHP) to set up a long-term invertebrate monitoring program on Pueblo Chemical Depot (PCD) in Pueblo County, Colorado. The monitoring program was established to detect the influence that vegetation type, grazing protocol (grazed vs. ungrazed), and recent changes in grazing protocol have on the structure of invertebrate communities. The three habitat types that we monitored are shortgrass prairie, northern sandhill prairie, and greasewood scrub.

In order to detect differences in species composition six preliminary invertebrate monitoring plots were established in 1999. Two each in shortgrass prairie, northern sandhill prairie, and greasewood scrub. To detect future changes in species composition and density over time 34 permanent grasshopper monitoring plots were established in 2000. These 34 plots are a random subset of the 50 vegetation monitoring plots established in 1998 by Reneee Rondeau Ecologist\Botanist, CNHP. In 1999 all six of the preliminary invertebrate monitoring plots were sampled twice, once during the last week of July and once during the first week of September. In order to understand annual variation in species composition and density we will measure the 34 permanent plots on an annual basis from May to September through the year 2003.

The following report presents the methods and results of the 1999 data.

Study Area and Background Information

General Site History. From at least the early 1900's to 1942 the Depot property was a mixture of privately and state owned parcels with ranching as the primary use. The location of the Depot was selected in 1941 prior to the entry of the United States into World War II and construction began in 1942. The Depot functioned as a storage, maintenance, distribution, and disposal facility for munitions and other military equipment for the U.S. Army for approximately 52 years (1942-1994). Although all the conventional munitions were removed between 1991 and 1994, about 8.5% of the nations chemical weapons stockpile of mustard agent is currently stored at PCD.

Location and Vegetation. The Pueblo Chemical Depot (PCD) is located on rolling prairie in southeastern Colorado, approximately 15 miles east of Pueblo, occupying about 36 square miles. The site is best characterized as a high plains ecosystem composed of a mosaic of vegetation types including shortgrass prairie, northern sandhill prairie, greasewood scrub, wetlands, riparian, and disturbed landscape. The wetland and riparian habitats occupy less than 1% of PCD.

Climate. At the Pueblo Airport (seven miles west of PCD), temperatures vary from a mean daily January minimum of 13.8° F to a mean daily July maximum of 92.4° F. The forty-four year mean annual precipitation has been 12 inches (SD = 3.31), about 45% of which falls during June-August, the period of maximum plant production. Precipitation in 1999 was above average (13.82 in.), (http://www.wrcc.dri.edu).

Livestock Grazing History. PCD has had varied cattle grazing intensities, ranging from areas which have been ungrazed since 1942 within the munitions storage area to year-long heavy grazing in the eastern demolition area. From 1942 to 1998, cattle grazing was permitted on 7,600 of the 23,000 acres at PCD (Steranka 1996 as cited in Rust 1996). According to the USFWS (1987) one cow per 35 acres was allowed, or approx. 220 head total. Although areas within the munitions storage have been ungrazed by domestic livestock since acquisition of the Post in 1942, prior to acquisition, this area was grazed. Areas within the ungrazed portion that were used for munitions storage were mechanically disturbed during construction of the weapons storage facilities in 1942.

In 1995 an ecological study found a difference between plant species canopy cover and relative abundance in the grazed vs. ungrazed areas (Rust 1996). Primarily the canopy cover and abundance of unpalatable grasses, forbs, and shrubs had increased in percent cover and relative abundance. The shrubs included sand sagebrush (*Oligosporus filifolius*), rabbitbrush (*Chrysothamnus nauseosus*), prickly pear cacti (*Opuntia* spp.) and cholla (*Cylindropuntia imbricata*); the grasses and forbs included purple three-awn (*Aristida purpurea*), squirreltail (*Elymus elymoides*), blue grama *(Chondrosum gracile*), horseweed (*Conyza canadensis*), annual sunflower (*Helianthus annuus*), western ragweed *(Ambrosia psilostachya)*, and alyssum (*Alyssum desertorum*). Rust (1996) also reported decreases in canopy cover and abundance of the following plant species in response to year long grazing: spreading fleabane (*Erigeron divergens)*, side-oats grama (*Bouteloua curtipendula*), sandreed grass (*Calamovilfa longifolia*), sand bluestem (*Andropogon hallii*), and switchgrass (*Panicum virgatum)*. Because grasshoppers are the major invertebrate herbivores on western grasslands with functional feeding types that include obligate grass feeders, obligate forb feeders, and mixed grass and forb feeders these changes in the grass and forb community structure on PCD have the potential to influence grasshopper community structure.

In June of 1998 all livestock were removed from PCD. Livestock grazing may be reestablished in the future as a management tool. Along with livestock, prairie dogs also graze the shortgrass prairie of PCD. These native grazers form large towns that have the potential to influence the canopy cover and structure of the shortgrass prairie and in turn grasshopper community structure. In the early months of 1999 there were approximately 2,520 acres of live prairie dog towns at PCD (P. Young, pers. com.). In May of 1999 the first plague positive fleas were collected and by September of 1999 the active acres had dropped to approximately 250 acres (P. Young, pers. com.). To avoid the confounding effects of prairie dog herbivory an attempt was made to avoid placing any of the six preliminary invertebrate sites on active prairie dog towns.

Sampling Objectives

Our primary sampling goal of monitoring grasshopper community structure at PCD is to detect a 20% change at p=0.1 in grasshopper community structure and density over the three years of the project. We are especially interested in the areas where grazing was removed in late spring of 1998 (i.e., ammunition workshop area and eastern demolition area).

Methods

The preliminary project was designed to sample shortgrass prairie, northern sandhill prairie, and greasewood scrub habitat types for differences in grasshopper community structure. This was accomplished by establishing six study plots, one site for each of the 3 vegetation types and 2 grazing uses. Grasshopper community structure was assessed through intensive sweep net collections at every site; sweep samples provide good estimates of relative abundance and species composition (Evans et al. 1983, Evans 1988). Grasshopper collections were made twice: once each in late June and early September. These times were selected to assure census of species with different phenologies: some species overwinter as nymphs and occur as adults in spring and early summer, while other late hatching species occur as adults in late summer and fall.

One transect on each site was used to estimate grasshopper densities, each transect consisted of 20, $0.2m^2$ hoops (Onsager 1977, Onsager and Henry 1977, Onsager 1991). Hoops were placed every 5m along each transect and density counts were made by approaching the hoops and counting every grasshopper that jumps or flies from each hoop. Each hoop was then searched for grasshoppers that did not flee. Qualitative estimates of species composition were conducted each month by intensively sweeping for one hour an area of approximately $50m^2$ surrounding the hoop transect on each site. All collected grasshoppers were frozen for later identification in the laboratory. To minimize bias in estimates of species composition between sites due to interspecific behavior, whenever possible we caught each grasshopper flushed, regardless of ease of capture (Capinera and Sechrist 1982b).

Species composition of grasshoppers was determined by pinning and identifying the samples of adult grasshoppers collected in June and September. Grasshoppers were identified using the keys of Capinera and Sechrist (1982a) and Pfadt (1994). Dr. R. E. Pfadt, University of Wyoming, Wyoming Agricultural Experiment Station confirmed species identifications. Nymphs were omitted from the analysis because of difficulties in identifying the species of some genera. Nymphs comprised 17% of the overall sample (n=350). To compare the influence that habitat type and grazing protocol has on grasshopper community structure we compare common community structure parameters like species richness (number of species, *S*), abundance (number of imagoes, i.e. adult grasshoppers), Shannon-

Wiener's *H'* diversity measure ($H' = \sum_{i=1}^{S} P_i \ln P_i$), Simpson's diversity measure ($D = \frac{1}{\sum_{i=1}^{S} P_i^2}$), and the most commonly used equitability measure ($J = H'/lnS$) between the six preliminary sites. In the formulas above:

S = the number of species or species richness,

P_i = proportion of individuals that each species contributes to the total grasshoppers collected from one site,

Equitability (*J*) is the evenness with which individuals are distributed among the species (i.e. are there 100 individuals representing 10 species with 10 individuals of each species; or are there 100 individuals, representing 10 species with 91 individuals of one species and one each of the other nine species). Equitability takes on values between 0 and 1, where one represents a community where species are evenly distributed and zero represents an uneven composition, and

ln = natural logarithm.

These measures were calculated for each vegetation type and grazing protocol on the six preliminary sites used in 1999.

In addition, differences in grasshopper community structure between sites were summarized through ordination. Ordination provides a useful summary of community data without requiring as many assumptions or as much data as regression or analysis of variance (Ter Braak 1986). Detrended Correspondance Analysis (DCA) was used to relate grasshopper community structure to disturbance category. This method has been used successfully by others in the analysis of grasshopper community structure (Kemp et al. 1990, Quinn et al. 1991, Fielding and Brusven 1993, Baldi and Kisbenedek 1997).

Results

Grasshopper Density Estimates

The sample sizes collected from the hoop transects were inadequate to calculate estimates of grasshopper density and densities are therefore not reported. Most hoops were unoccupied by grasshoppers and most samples in the data set were zero making estimates of density unreliable.

Grasshopper Community Structure

In total 350 grasshoppers representing 40 species (14 Gomphocerinae, 13 Oedipodinae, and 13 Melanoplinae) were collected (Appendix 1). Table one lists the 40 species, their feeding habits and their abundance by site. *Cordillacris occipitalis* and *Opeia obscura* were the two most widely spread and abundant grasshoppers followed by *Paropomala wyomingensis* and *Melanoplus sanguinipes*. Diversity was much lower on the greasewood ungrazed site as measured by the Shannon-Wiener diversity index, but was similar between the remaining five sites (Table 2). Similar differences were found with Simpson's measure of diversity. Measures of equitability (J) for the six sites were also similar to each other.

Between-site differences in community structure were also measured by DCA. The results are displayed in Fig. 1. The primary axis 1 gradient was about 250 SD units (standard deviations of change) and was about 140 SD units for the secondary axis 2 gradient. Sites closer together on the ordination graph have similar compositions of grasshoppers and in general, a distance of 100 SD units indicates a 50% change in grasshopper community composition (Gauch 1985). DCA of abundance data indicated that axis 1 explained 48% of the variation and the first two axes together explained 71% of the variation. On the ordination graph those sites of the same habitat type occur near each other along axis 2, but the grazed sites are separated from the ungrazed sites along axis 1. The magnitude of effect on species composition from grazing was similar in the greasewood and shortgrass habitats, and slightly increased in northern sandhill prairie (Fig. 1). The shortgrass habitats had the greatest percentage of grass-obligate feeders (51%) and the greasewood habitats had the greatest percentage of forb-obligate feeders (27%).

Differences in the presence, absence and abundance of some commonly occurring grasshopper species and the occurrence of uncommon species that primarily occupy disturbed habitats account for the separation on the ordination axes of grazed and ungrazed sites of the same vegetation type.

Discussion

As mentioned in the results a problem was encountered in estimating grasshopper density on the study plots. Hoop sample size was to small. To avoid this problem in future monitoring efforts, the design of hoop transects was altered for the 2000 field season. Two transects per site are now used with hoop areas reduced from 0.2 m^2 to 0.1 m^2 which doubles the hoop number per site. Doubling the hoops at each site should increase the probability that any one hoop is occupied while leaving the total area sampled per site unchanged. Furthermore, replicates per habitat type and grazing protocol were increased to five or six from just one each. This will increase the total number of samples used in estimating the density of the six habitat types and grazing protocols, making these estimates more robust.

Differences in grasshopper community structure by vegetation type and past grazing history were expected. Several studies have related grasshopper community structure to both plant communities and grazing practices (Capinera and Sechrist 1982b, Quinn et al. 1991, Fielding and Brusven 1993, Baldi and Kisbenedek 1997).

That with so few samples the DCA observed strong trends clustering first vegetation types together then separating those vegetation pairs by historical grazing practices suggests a strong influence of both grazing and vegetation on grasshopper community structure at PCD. For example, the majority (67%) of *Trimeritropis* sp. (n=7), which are associated with sparsely vegetated, dry and barren lands (Capinera and Sechrist 1982b) occurred on the grazed shortgrass and grazed greasewood habitats where the vegetation is more disturbed and less abundant. The separation between northern sandhill prairie grazed and ungrazed sites, as evidenced through DCA (Fig. 1), resulted from the absence of two common and abundant species (*Opeia obscura* and *Melanoplus sanguinipes*, see Table 1), and the presence of two uncommon species (*Schistocerca alutacea* and *Spharagemon collare*) on the grazed site (ssg). *Schistocerca alutacea* and *Sp. collare* prefer weedy areas and sparsely vegetated areas respectively, much like that expected on grazed sites (Jepson-Innes and Bock 1989). Neither of these two species was collected from ungrazed sites, supplying further evidence that grazing influences grasshopper community structure. That grasshopper samples from shortgrass areas were dominated by grass-obligate feeders and collections from greasewood areas by forb obligate feeders was expected, but that this was identified in the samples indicates that present sampling methods will adequately assess community structure.

Future monitoring of grasshopper community structure at PCD will continue to assess the differences noted in this report, while also supplying information on how community structure changes on grazed areas after grazing has been eliminated. The ongoing vegetation monitoring effort at PCD and the increase in number of sites being sampled for grasshoppers will supply opportunities for more in-depth analyses of the 2000 through 2003 samples. Analyses examining how differences in vegetation community structure attributable to past grazing practices and examining how future changes in canopy structure associated with the elimination of grazing influence grasshopper community structure over time will be conducted. Additional analyses including the incorporation of vegetation cover and abundance data into DCA, further data exploration using the ordination technique of Multi-response Permutation Procedure (MRPP), parametric procedures including the simple comparative analyses χ^2 and examination of density data will be conducted on future samples. In general, little is known about temporal variation in grasshopper community structure (Fielding and Brusven 1993). The continuation of this research will attempt to fill that gap while identifying how changes in management strategy (i.e. grazing regime) may direct the conservation of invertebrate communities occupying prairie landscapes.

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Literature cited

Baldi, A. and T. Kisbenedek. 1997. Orthopteran assemblages as indicators of grassland naturalness in Hungary. Agriculture, Ecosystem & Environment. 66: 121-129.

Capinera, J.L and T.S. Sechrist. 1982a. Grasshoppers (Acrididae) of Colorado: identification, biology and management. Colorado State University Experiment Station, Fort Collins, Bulletin NO. 584S. 161pp.

Capinera, J.L and T.S. Sechrist. 1982b. Grasshopper (Acrididae) - host plant associations: response of grasshopper populations to cattle grazing intensity. Canadian Zoologist. 114: 1055-1062.

Evans, E.W. 1988. Grasshopper (Insecta: Orthoptera: Acrididae) assemblages of tallgrass prairie: Influences of fire frequency, topography and vegetation. Canadian Journal of Zoology. 66: 1495-1501.

Evans, E.W., R.A. Rogers and D.J. Opfermann. 1983. Sampling grasshopper (Orthoptera: Acrididae) on burned and unburned tallgrass prairie: Night trapping vs. sweeping. Environmental Entomology. 12: 1449-1454.

Fielding, D.J. and M.A. Brusven. 1993. Grasshopper (Orthoptera: Acrididae) community structure and ecological disturbance on southern Idaho rangeland. Environmental Entomology. 22: 71-81.

Gauch, H. G., Jr. 1985. Multivariate analysis in community ecology. Cambridge University Press, New York, New York.

Jepson-Innes, K. and C. E. Bock. 1989. Response of grasshoppers (Orthoptera: Acrididae) to livestock grazing in southeastern Arizona: differences between seasons and subfamilies. Oecologia. 8: 430-431.

Kemp, W.P., S.J. Harvey and K.M. O'Neil. 1990. Patterns of vegetation and grasshopper community composition. Oecologia. 83: 299-308.

Onsager, J.A. 1977. Comparison of five methods for estimating density of rangeland grasshoppers. Journal of Economic Entomology. 70: 187-190.

Onsager, J.A. 1991. Toward an optimum for estimating density of grasshopper (Orthoptera: Acrididae) from a Poisson distribution. Environmental Entomology. 20: 939-944.

Onsager, J.A. and J.E. Henry. 1977 A method for estimating the density of rangeland grasshoppers (Orthoptera: Acrididae) in experimental plots. Acrida. 6:231-237.

Pfadt, R. E. 1994. Field guide to common western grasshoppers. Wyoming Agricultural Experiment Station, Bulletin 912, September 1994. 42pp+

Quinn, M.A., R.L. Kepner, D.D. Walgenbach, R.A. Bohls and P.D. Pooler. 1991. Habitat characteristics and grasshopper community dynamics on mixed-grass rangeland. The Canadian entomologist. 123: 89-103.

Rust International Inc. 1996. Ecological Surveys at Pueblo Chemical Depot, Pueblo, Colorado; Vol. I. Engelwood Co.

Streanka, P. J. Personal communication. 1996 (as cited in Rust 1996).

Ter Braak, C. J. F. 1986. Conical correspondence analysis: a new eigenvecter technique for multivariate direct gradient analysis. Ecology 67: 1167-1179.

Table 1. List of Orthopteran species and their abundances given as number of individuals/habitat.

ORTHOPTERIDEA SPECIES	FEEDING CATEGORY	SITES: SGUG	SGG	SSUG	SSG	GWUG	GWG
Gomphocerinae (Slantfaced)							
Acrolophitis hirtipes	OF						
Ageneotettix deorum	OG						1
Amphitornus coloradus	OG	1	1	4		1	
Aulocara elliotti	OG	2	4	1			1
Aulocara femoratum	OG	2	1				
Cordillacris crenulata	OG	3	1				
Cordillacris occipitalis	OG	1					2
Eritettix simplex	OG	16	1	7	7	1	8
Mermiria bivittata	OG			2		1	
Mermiria picta	?	2	3	1			
Opeia obscura	OG	4	3	2	1		
Paropomala wyomingensis	OG	4	10	14		10	14
Philobostroma quadrimaculatum	OG	1	1	13	1	2	4
Psoloessa delicatula	OG	1	6				2
Oedipodinae (Bandwinged)		3					1
Arphia pseudoneitana	MF						
Derotmema haydeni	MF	1	1	2	1	2	
Hadrotettix trifasciatus	MF	2			2		
Mesobregma plattei	?	1	4			5	
Spharagemon collare	OG	3	6		1		
Trachyrhachys aspera	OG				5		
Trachyrhachys kiowa	OG		4				
Trimerotropis latifasciatus	OG		1				2
Trimerotropis magnifica	?		1				
Trimerotropis melanoptera	?			1			
Trimerotropis pallidipennis	MF		1				
Trimerotropis pistrinaria	MF			1			
Xanthrippus corallipes	OG						1
Melanoplinae (Spurthroated)		1		1	2	1	
Aeoloplides turnbulli	OF						
Dactylotum bicolor	OF		8	3		5	
Hesperotettix viridis	OF	2	1	1	1		
Melanoplus bowditchi	OF	2		2	2		1
Melanoplus confusus	MF		4	13	12		1
Melanoplus femurrubrum	MF	5	5			2	1
Melanoplus foedus	MF	2	4				1
Melanoplus gladstoni	MF		1		1		
Melanoplus occidentalis	MF		2				
Melanoplus packardii	OF	16					4
Melanoplus regalis	?	2	1		1		
Melanoplus sanquinipes	MF				2		1
Schistocerca alutacea	OF	4	8	5	2	1	6

SGUG: shortgrass ungrazed; SGG: shortgrass grazed; SSUG: sandsage ungrazed; SSG: sandsage grazed; GWUG; greasewood ungrazed; GWG: greasewood grazed; OF: obligate forb; OG: obligate grass; MF: mixed feeder.

Table 2. Community structure parameters of orthopteran assemblages at three sites of different vegetation type and grazing protocol (See Table 1 for explanation of sites).

SITE	SGUG	SGG	SSUG	SSG	GWUG	GWG
S	21	24	23	17	10	21
N	74	73	69	47	28	57
H'	2.5701	2.8742	2.4188	2.4007	1.8360	2.5891
Simpson	0.1158	0.0696	0.1183	0.1236	0.2066	0.1111
J	0.8442	0.9094	0.8537	0.8473	0.7974	0.8504

S: number of species; N: number of individuals; *H'*: Shannon-Wiener diversity index; Simpson diversity index; J: equitability.

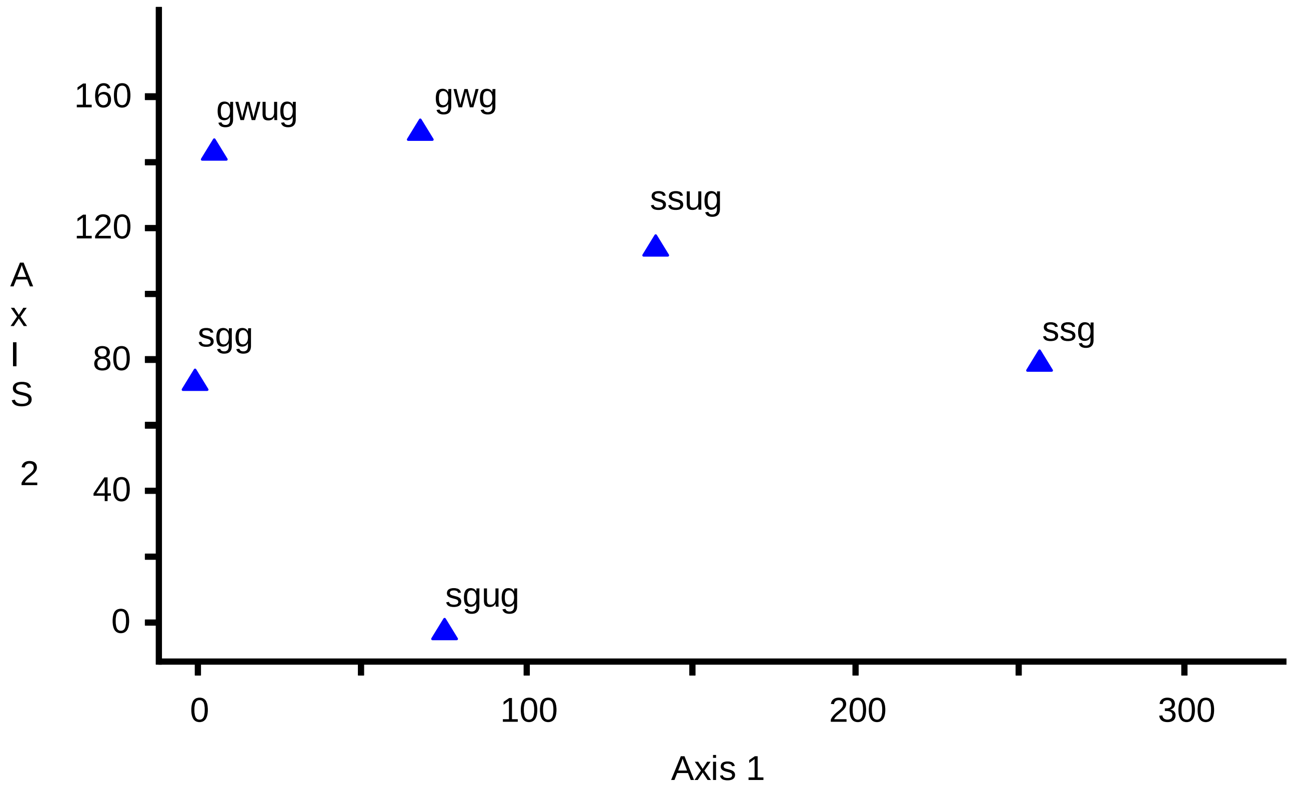

Fig. 1. Ordination of six samples (3 vegetation types and 2 grazing treatments) and abundance data for 40 grasshopper species (see Table 1 for explanation of sites).

Appendix 1

Species	Common Name
Acrolophitus hirtipes	green fool grasshopper
Aeoloplides turnbulli	thistle grasshopper
Ageneotettix deorum	whitewhiskered grasshopper
Amphitornus coloradus	striped slant-faced grasshopper
Arphia pseudoneitana	redwinged grasshopper
Aulocara elliotti	big-headed grasshopper
Aulocara femoratum	white cross grasshopper
Cordillacris crenulata	crenulated grasshopper
Cordillacris occipitalis	spotted wing grashopper
Dactylotum bicolor	pictured grasshopper
Derotmema haydeni	Hayden's grasshopper
Eritettix simplex	velvet-striped grasshopper
Hadrotettix trifasciatus	three-banded grasshopper
Hesperotettix viridis	snakeweed grasshopper
Melanoplus bowditchi	sagebrush gasshopper
Melanoplus confusus	little pasture spur-throated grasshopper
Melanoplus femurrubrum	redlegged grasshopper
Melanoplus foedus	
Melanoplus gladstoni	Gladston grasshopper
Melanoplus occidentalis	flabellate grasshopper
Melanoplus packardii	Packard's grasshopper
Melanoplus regalis	
Melanoplus sanguinipes	lessor migratory grasshopper
Mermiria bivittata	twostriped slantfaced grasshopper
Mermiria picta	
Mesobregma plattei	Platt range grasshopper
Opeia obscura	obscure grasshopper
Paropomala wyomingensis	Wyoming toothpick grasshopper
Philobostroma quadrimaculatum	fourspotted grasshopper
Psoloessa delicatula	brownspotted grasshopper
Schistocerca alutacea	Spotted bird grasshopper
Spharagemon collare	mottled sand grasshopper
Trachyrhachys aspera	finned grasshopper
Trachyrhachys kiowa	Kiowa range grasshopper
Trimerotropis latifasciatus	broad-banded grasshopper
Trimerotropis magnifica	
Trimerotropis melanoptera	black-winged grasshopper
Trimerotropis pallidipennis	pallid-winged grasshopper
Trimerotropis pistrinaria	barren land grasshopper
Xanthrippus corallipes	redshanked grasshopper