The leafhopper species assemblages associated with native and replanted grasslands in southwest Montana
by James Alexander Bess

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Entomology
Montana State University

Abstract:
Leafhopper (Insecta: Homoptera: Cicadellidae) species assemblages were examined and compared between four distinct grassland types in southwestern Montana. Three sample sites (or patches) were chosen within each of the four grassland types (two native and two replanted), for a total of twelve sites. Leafhopper specimens were collected in sweepnet samples from each of the twelve sites in 1988 and 1991. The leafhopper assemblages from the twelve patches were compared using Spearman's correlation analysis to determine which assemblages were most similar. In addition, cluster analyses, using Goodman-Kruskal's Gamma coefficient, were performed to give a pictorial representation of spatial relationships between the assemblages and to compare with the correlation analyses. Analyses were performed on each individual years' data and the combined data. The correlation analysis found the patches with each type to be closely related to one another, although some also correlated closely with patches from other types. Most of these between type associations were between the native grassland sites. Correlations were strongest using the combined data. Cluster analyses produced many spurious associations using the single years' data that were unsubstantiated by patterns observed in the raw data. Cluster analysis of the combined data produced associations similar to those observed, with the correlation analysis and supported by the raw data. A total of 67 leafhopper taxa were identified during this study, 54 of which are new to Montana.

THE LEAFHOPPER SPECIES ASSEMBLAGES ASSOCIATED WITH NATIVE AND REPLANTED GRASSLANDS IN SOUTHWEST MONTANA

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James Alexander Bess

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APPROVAL

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James Alexander Bess

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Date May 15, 1997

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

THE LEAFHOPPER SPECIES ASSEMBLAGES ASSOCIATED WITH NATIVE AND REPLANTED GRASSLANDS IN SOUTHWEST MONTANA

James Alexander Bess, 1997

ABSTRACT

Leafhopper (Insecta: Homoptera: Cicadellidae) species assemblages were examined and compared between four distinct grassland types in southwestern Montana. Three sample sites (or patches) were chosen within each of the four grassland types (two native and two replanted), for a total of twelve sites. Leafhopper specimens were collected in sweepnet samples from each of the twelve sites in 1988 and 1991. The leafhopper assemblages from the twelve patches were compared using Spearman's correlation analysis to determine which assemblages were most similar. In addition, cluster analyses, using Goodman-Kruskal's Gamma coefficient, were performed to give a pictorial representation of spatial relationships between the assemblages and to compare with the correlation analyses. Analyses were performed on each individual years' data and the combined data. The correlation analysis found the patches with each type to be closely related to one another, although some also correlated closely with patches from other types. Most of these between type associations were between the native grassland sites. Correlations were strongest using the combined data. Cluster analyses produced many spurious associations using the single years' data that were unsubstantiated by patterns observed in the raw data. Cluster analysis of the combined data produced associations similar to those observed with the correlation analysis and supported by the raw data. A total of 67 leafhopper taxa were identified during this study, 54 of which are new to Montana.

INTRODUCTION

Kemp et al. (1990) observed that grasshopper (Orthoptera: Acrididae) species in Gallatin County, Montana were distributed non-randomly across grassland sites characterized by different plant assemblages. Despite variation in grasshopper and plant community composition among patches within plant assemblages, certain species of grasshoppers tended to be restricted to xeric, lower elevation sites at the west end of the valley, while others showed an affinity for more mesic, higher elevation sites at the east end. A third group of species was more widely distributed, displaying relatively high abundance across the entire valley. These results were confirmed and expanded by Wachter (1995), who also surveyed the grasshopper communities associated with grasslands in the Bridger and Hyalite Mountain ranges of Gallatin County. Similar evidence for uneven distribution of grasshopper species across habitats has been reported elsewhere in North America (Alexander and Hilliard, 1969; Blatchley, 1920; Cantrall, 1943; Evans, 1988; Fielding and Brusven, 1993, 1995; Joern, 1979, 1982; Mulkern, 1967; Otte, 1981,1984).

Although grasshoppers are often abundant (and sometimes economically important) herbivores in grassland habitats, leafhoppers (Homoptera: Auchenorrhyncha: Cicadellidae) are commonly considered the dominant herbivorous insects in temperate grassland ecosystems, in terms of density of individuals and diversity of species (Cherrill and Rushton, 1993; Waloff, 1973; Waloff and Solomon, 1972). Studies in Europe and North America have shown that leafhopper species also exhibit preferential habitat selection.

In England and Europe, numerous studies have been conducted to determine the effects of variation in environmental parameters on the composition of grassland leafhopper assemblages (Brown, et al., 1992; Morris, 1973, 1981a-b,1990a-b; Novotny, 1994a-b, 1995; Waloff, 1980;

Waloff and Solomon, 1972). These studies can be grouped into four categories: 1) effects of land management practices (i.e. grazing, mowing or fertilizing); 2) effects of soil pH; 3) effects of plant species composition; and 3) effects of habitat successional age.

In studies of grazing effects, Brown et al. (1992) found that the composition of leafhopper assemblages on sheep-grazed calcareous grasslands was strongly affected by plant architecture, as dictated by the particular grazing regime being implemented. Morris (1973) also reported grazing effects on the composition of leafhopper assemblages in British grasslands, particularly with reference to the timing of the grazing event (i.e. spring vs. fall grazing). In addition, ungrazed grasslands contained a greater number of leafhopper individuals and species, when compared with grazed sites. As with Brown et al., Morris believed grassland structure (especially vegetation height) was a driving force in determining the composition of leafhopper assemblages.

Morris (1981a-b, 1983), in studies of the calcareous grasslands of England, observed that cutting of vegetation during the height of the growing season (i.e. July) had a significant deleterious effect on many leafhopper species. Mowing in the spring (May) had a less significant effect of shorter duration, being confined mainly to species that reached the adult stage in early summer. The effects of the July cutting persisted through winter and into spring, especially in species that overwinter as adults. Progressive declines were observed in many species over the course of a three year study (1973-1975), especially on the plots cut in July. Like Brown and associates (1992), Morris observed a greater number of leafhoppers on grasslands that were not intensively managed.

Waloff (1980) and Waloff and Solomon (1972) compared the leafhopper fauna of acidic and calcareous grasslands, noting that some leafhopper species were shared between the two habitats, but in differing proportions. Despite these similarities, there were several leafhopper species reported only from a single grassland type. Morris (1990a-b), in studies of leafhopper colonization in newly sown calcareous grasslands, observed that the leafhopper fauna of these early successional grasslands was dominated by several wide ranging, multivoltine habitat generalists; with very few of the rarer, univoltine species characteristic of more mature, semi-natural grasslands. Morris concluded that habitat structure, habitat age, and proximity to adjacent natural grasslands were as important as plant species composition in the determination of leafhopper assemblages. Brown et al. (1992) also noted that the composition of leafhopper assemblages varied greatly between early successional and older, more stable grassland communities. Much of this variation was attributed to the absence of specific food plants in the early successional habitats. These plants appeared to require old, relatively undisturbed native grasslands for survival, thus limiting the distribution of their associated leafhoppers.

Novotny (1994a-b; 1995), in studies on the grasslands of central Europe, found that the majority of leafhopper species occurring in ruderal, early successional habitats tended to have wider ranges of host plant use than species occurring in older, more stable environments. He also observed that host plant specialization became more prevalent with successional age of the habitat and that many of these specialist species showed poor dispersal capabilities. Leafhoppers that feed on early successional plant species were also found to have greater dispersal capabilities, wider ranges of host plant usage, larger geographic distributions and produced a greater number of generations per year than those feeding on more competitive, stress-tolerant plants.

Although age, management history and structure of grassland plant assemblages has been shown to have a deterministic effect on resident leafhopper assemblages, the distribution of many species appears to be associated with the distribution of their host plants (Brown et al., 1992; Buntin, 1988; Cherrill and Rushton, 1993; Claridge and Wilson, 1978; Gardner and Usher, 1989; Genung and Mead, 1969; Hicks and Whitcomb, 1996; Nagel, 1979; Novotny, 1994a-b, 1995; Prestidge and McNeill, 1983; Teraguchi, 1986; Waloff and Thompson, 1980; Whitcomb et al., 1986, 1987a-b, 1994).

In North America, Whitcomb and associates have conducted numerous studies of the grassland leafhopper fauna's of the Great Plains and Chihuahuan Desert regions (Hicks and Whitcomb, 1996; Whitcomb et al., 1986, 1987a-b; 1994). Their studies have focused on three of the most species-rich grassland genera in North America; Athysanella, Flexamia and Laevicephalus. Their results suggest that the distribution of these leafhoppers is closely associated with the distribution of their host plants, although many do not occur throughout the range of their host. This non-random distribution within the range of their hosts indicates that additional factors are limiting their ability to colonize sites. Therefore, specific grassland types, while they may have plant species in common with other types, often contain unique leafhopper assemblages adapted to a specific set of local environmental parameters.

Because of their role as the dominant insect herbivores in grassland habitats and their apparent sensitivity to variations in their local environment, leafhoppers are good subjects for studying the relationship between insect species distribution and plant community composition. The focus of the current study was to determine if the leafhopper species occurring in Gallatin County, Montana sorted into relatively discrete groupings according to plant assemblage, as was observed in the local grasshopper fauna (Kemp et al., 1990). In addition, I wanted to determine if there were significant differences in leafhopper species composition and relative abundance between native and replanted grasslands within the same plant assemblage. As a final objective, I wanted to update the list of leafhopper species in Montana previously compiled by Fox (1924).

Objectives

The goal of my research was to identify the leafhopper (Homoptera: Cicadellidae) species assemblages associated with four distinct grassland types (following Mueggler and Stewart, 1980) in Gallatin County, Montana. Specific objectives of this project were to:

1. determine if there are distinct leafhopper species assemblages associated with the four plant assemblages (two native, two replanted);
2. determine if the abundance of selected leafhopper species varies with changes in percent cover of known or suspected host plants; and
3. determine which (if any) leafhopper species are restricted in occurrence to native grassland patches.

Hypotheses

My first hypothesis is that discrete assemblages of leafhopper species will be associated with each of the four plant assemblages. The null hypothesis would be that leafhopper species are randomly distributed among the plant assemblages.

My second hypothesis is that the distribution of leafhoppers will be dependent on the distribution of their known or suspected host plants. The null hypothesis is that leafhopper species distribution is unrelated to the distribution of their host plants.

My third hypothesis is that some of the leafhopper species recorded will occur only (or most abundantly) in the native habitat patches within a particular habitat region. The null hypothesis would be that leafhopper species are evenly distributed between native and replanted grasslands within the same habitat region.

MATERIALS AND METHODS

The vegetation data were collected as part of rangeland grasshopper studies being conducted by Dr. William P. Kemp and associates at Montana State University. The leafhopper specimens used in the present study were collected in sweep net samples used in the above-mentioned grasshopper research (Kemp et al., 1990). Throughout this thesis, the terms "patch" and "site" refer to a defined area within which leafhopper and plant data were collected. Each patch contained a distinct plant assemblage previously determined by Kemp et al. (1990).

Selection of Patches

Two primary plant assemblages were selected for this study, the Stipa comata Trin. & Rupr./Bouteloua gracilis (H.B.K.) (**STCO/BOGR**) and Festuca idahoensis Elmer/Agropyron spicatum (Pursh) (**FEID/AGSP**) associations of Mueggler and Stewart (1980). These represent dry and mesic grassland types, respectively, and occur along an elevation and precipitation gradient from 1236 m elevation at Three Forks, (annual precipitation 25-30cm), to 1750 m at the base of the Bridger Mountains (annual precipitation 40-50cm), Gallatin County, Montana (longitudes 111°00'-111°40' east-west, latitudes 46°00'-45°45') (Table 1). Two replanted associations were also studied, the Agropyron cristatum (L.)/Medicago sativa L. (**Agcr/Mesa**) and Bromus inermis Leyss/Medicago sativa L. (**Brin/Mesa**) associations. The replanted **Agcr/Mesa** stands occur within the same elevation and precipitation zone as the native **STCO/BOGR** grasslands and the replanted **Brin/Mesa** stands occur within the same zone as the native **FEID/AGSP** grasslands.

Table 1. Elevation, Precipitation, and Cover Data for the Sample Patches: Gallatin Co., Montana (1991).

Plant Assemblage	Elevation (m)	Mean Annual Precipitation (cm)[1]	% Grass Cover	% Forb Cover	% Bare Ground
STCO/BOGR (all patches)	**1200 - 1400**	**20 - 35**	**54.50 (mean)**	**11.10 (mean)**	**16.20 (mean)**
7A	-	-	50.96	20.41	23.88
10A	-	-	50.21	4.36	10.83
16A	-	-	62.37	8.39	13.75
FEID/AGSP (all patches)	**1400 - 2300**	**35 - 50**	**34.00 (mean)**	**36.90 (mean)**	**6.70 (mean)**
21A	-	-	31.33	30.61	6.78
25A	-	-	35.48	30.63	2.7
26A	-	-	35.17	49.42	10.63
Agcr/Mesa (all patches)	**1200 - 1400**	**20 - 35**	**38.00 (mean)**	**2.90 (mean)**	**28.00 (mean)**
7b	-	-	31.69	1.57	16.25
16b	-	-	50.96	6.33	35.25
17b	-	-	30.41	0.85	34.03
Brin/Mesa (all patches)	**1400 - 2300**	**35 - 50**	**57.00 (mean)**	**8.50 (mean)**	**32.00 (mean)**
21b	-	-	23.53	18.36	25.14
25b	-	-	67.98	1.09	35.25
26b	-	-	79.24	6.02	34.03

[1] Information on precipitation in these Plant Assemblages is taken from Mueggler and Stewart, 1980.

Twelve patches (3 in each of the 4 plant assemblages) were chosen for use in this study. Patch selection was based on a Detrended Correspondence Analysis (DCA) of vegetation characteristics as outlined in Kemp et al. (1990). Three patches within each of the two native plant assemblages, **(STCO/BOGR)** and **(FEID/AGSP)**, were selected because of their close similarities (within assemblage) in plant species composition, precipitation, and elevation (i.e. they had similar coordinates in the DCA). These native plant assemblages were chosen because they occurred at opposite ends of a precipitation and elevation gradient for Gallatin County. Three patches in each of the two replanted plant assemblages, **(Agcr/Mesa)** and **(Brin/Mesa)**, were chosen using the same criteria. For comparisons between native and replanted patches within a habitat zone, patches were always adjacent. In order to minimize edge effect, sampling was restricted to the center of each patch, avoiding the border between adjacent patches. The minimum size of any one patch was 10 hectares and no two distinct native patches shared a common border.

Sampling Techniques

Vegetation Sampling

The vegetation within each of the four plant assemblages was sampled during July and August of 1991 to coincide with peak standing cover of plants (Kemp et al., 1990). Forty 0.10 m^2 (20 x 50 cm) quadrats were sampled along a randomly selected transect at each of the twelve patches. Within each quadrat, percent canopy cover of each plant species, litter, moss/lichen, and bare ground were estimated in 5% increments following the methods described by Daubenmire

(1959). Subsequent analyses were based on mean cover-estimates of plant species over all quadrats in a patch, as was done in previous studies (Kemp et al., 1990).

Leafhopper Sampling

Sweep nets were used to sample leafhopper populations. Samples were collected at each of the twelve patches and consisted of 200, 180 degree sweeps through vegetation with a 15 inch diameter net, as described by Kemp et al. (1990). In 1988, samples were collected three times per year in late May/June, late July, and late August (Appendix A). In 1991, an additional September collection was included to sample the fall leafhopper fauna (Appendix A). All sweep samples were collected between 0930 and 1600 h, under sunny skies (<15% cloud cover) and light winds (<38 kph). Leafhopper samples were placed either in alcohol (the 1988 samples) or air dried (the 1991 samples). Samples were collected in 1988 and 1991, years of very poor and fairly normal rainfall conditions, respectively. These years were selected to gather the greatest possible array of leafhopper species, as these insects are known to vary in abundance depending on seasonal rainfall (Waloff, 1973; Whitcomb et al., 1994).

Specimen Identification

Vegetation

Jeffrey Holmes (with USDA-ARS Rangeland Entomology Laboratory at Montana State University) identified all plant specimens observed during the vegetation studies. Plant specimens that could not be identified in the field were returned to the lab for analysis and comparison with voucher specimens in the Montana State University Herbarium. Most of the early spring ephemeral genera such as Besseya, Erythronium, Fritillaria, Dodecatheon, and Delphinium are conspicuously absent from the species list in Table 2. This is a result of vegetation surveys being conducted in mid-summer (to gather information during peak standing cover), when most of these spring and early summer species had senesced.

One specific taxonomic note is needed here. Gould (1947) considers all of the native North American grass species previously assigned to Agropyron to be included in Elymus. I have retained the name Agropyron here for the sake of clarity in comparisons between it and the work of Kemp and associates (1990). For leafhopper species which are reported to feed on species of Elymus, I have included Agropyron grasses as potential hosts.

Leafhoppers

When possible, all leafhopper specimens were identified to species. A few groups, however, are difficult to identify beyond genus because of similarities in adult features or unresolved taxonomic problems. Members of the genus Aceratagallia (subfamily Agalliinae) are nearly impossible to identify on the basis of females, and males are difficult as well. This genus is currently undergoing revision by K.G.A. Hamilton of the Canada Biosystematic Research Institute. For the purposes of the present study, leafhoppers in this genus were studied at the generic level. A subsample of male specimens were identified as the species A. sanguinolenta and A. uhleri. Both species are widely distributed across North America (Beirne, 1956; Delong, 1948).

The entire subfamily Typhlocybinae is also problematic, because of close similarities in external morphologic and genitalic features, especially in females. These leafhoppers are also very small (usually <3 mm in length), quite fragile and easily destroyed in sweep net samples. Within this subfamily, the genera *Empoasca* and *Erythroneura* are difficult to identify and were covered only superficially by Delong (1948) and Beirne (1956). However, Oman (1949) gives excellent keys to genera for these groups. Despite the difficulty in identifying these leafhoppers, two taxa were identified to species. Most male *Dikraneura* specimens taken in this study were identified as *D. shoshone*, a common grassland species. Given the occurrence of numerous female specimens in the samples (without accompanying males), these leafhoppers are analyzed as a genus. Another grassland species, *Forcipata loca*, is fairly distinctive and was identified to species. All other specimens of this subfamily were identified to genus in this study.

In the subfamily Deltocephalinae, females of the genera *Athysanella*, *Laevicephalus*, *Limotettix* (*Scleroracus*), and *Sorhoanus* are difficult (or impossible) to identify to species (Beirne, 1956; Blocker and Johnson, 1990; Delong, 1948; Ross and Hamilton, 1972). There are also some unresolved taxonomic problems in the genera *Scleroracus* and *Sorhoanus* (Hamilton 1992, pers. comm.).

In 1988, an attempt was made to identify specimens of these four genera to species (Appendix A). The *Athysanella* specimens from 1988 belonged to seven species, *acuticauda*, *attenuata*, *occidentalis*, *robustus*, *sinuata*, *terebrans* and *utahna*. In 1991, many females were encountered, often without associated males. Therefore, given the limitations in identifying females of this group, specimens were pooled as *Athysanella* spp. All *Laevicephalus* specimens collected during this study were females in the "*sylvestris*-group" (Ross and Hamilton, 1972).

Given the general lack of characters for identifying females of this genus to species, specimens were analyzed as Laevicephalus spp. The Sorhoanus specimens from this study were primarily debilis, although flavidus and orientalis were taken in the mid-elevation mesic patches (Appendix A). The Scleroracus specimens were largely females with few associated males. The male specimens of Scleroracus that were collected belong to the species dasidus and kryptus.

All leafhopper species identifications were made by myself and verified by K.G.A. Hamilton of the Canadian Biosystematic Research Institute in Ottawa, Ontario, Canada (except for the genus Athysanella, see above). Keys and figures given by Ball and Beamer (1940), Beamer and Tuthill (1934, 1935), Beirne (1952a, b; 1956), Blocker and Johnson (1990), Blocker and Wesley, 1985; Brown (1933), Crowder (1952), Delong (1926, 1935; 1948), Delong and Davidson (1935); Delong and Sleesman (1929), Oman (1949), Ross and Hamilton (1972), Whitcomb and Hicks (1988), and Young and Beirne (1957) were used to identify specimens sampled during this study. The taxonomy used in this paper follows these works and that of Metcalf (1964).

Voucher specimens of all leafhopper taxa identified in this study have been deposited in the entomology collection at Montana State University, my personal collection or in the Canadian National Collection at Ottawa, Ontario. A complete list of the leafhopper species (and their authors) identified during this study is contained in Appendix B.

Analysis

Correlation Analysis

To test the hypothesis that different plant assemblages have different leafhopper assemblages, I compared the relative abundance of leafhopper species between patches using Spearman's rank correlation analysis. Correlation analyses are useful in determining whether the distribution of two or more species are in some way related. A positive correlation between two species implies that when one increases in abundance, so does the other. A negative correlation implies that when one species increases in abundance, the other decreases. In community level analysis, with many species being compared between several sites, pairwise comparisons of variation in abundance can be performed to gather an overall measure of similarity (or dissimilarity) between the sample sites.

Spearman's rank correlation coefficients were computed for comparisons between each of the 12 sample patches using MSUSTAT. Spearman's rank correlation is a non-parametric test selected because it works well with non-normally distributed data (Ludwig and Reynolds, 1988). Only correlation coefficients having a probability of <0.05 (given the sample size used) were considered significant. Correlation matrices were generated for each of the two sample years (1988 and 1991) and for both years combined. Between patch comparisons did not include zero-zero matches in the data set (i.e. a leafhopper species had to be present on at least one of the two sample sites to be included in the analysis).

To test the hypothesis that the abundance of certain leafhopper species correlated with the percent cover of known or suspected food plants, I compared the total abundance (1988 and 1991 data combined) of each leafhopper species on each of the twelve sites with the percent cover of both host and non-host plant species (using Spearman's rank correlation analysis). Host plant preference was determined through a review of the literature, discussions with leafhopper experts, and personal observations.

Cluster Analysis

Cluster analyses are a multivariate procedure used to detect patterns (or groupings) in data. The relationship between data groups (samples) is usually represented in the form of a dendrogram. The length of the dendrogram branches and the width between them is representative of the degree of relatedness between the samples. Thus, the most similar groupings are closest to one another in the dendrogram. SYSTAT (Systat, Inc., 1992) was used to perform cluster analysis of the leafhopper data from each year and both years' data combined.

The most crucial part of performing cluster analyses is the selection of the distance measure used to determine the degree of relatedness between samples. By selecting the wrong distance measure, spurious results can occur which cloud the interpretation of the analyses. Given that the leafhopper data were arranged in a rank order matrix, a distance measure was chosen that is designed for use with this type of data arrangement. SYSTAT (in its "CLUSTER" package) computes the Goodman-Kruskal gamma correlation coefficient for use with rank order data sets. This distance measure was selected for use in generating dendrograms for the 1988, 1991 and combined data sets.

Descriptions of the Plant Assemblages and Patches

More than 65 taxa of plants were recorded during the 1991 sampling period (Kemp et al., unpub. data). Of these, 58 were selected for analysis (Table 2). Plant taxa were included in the analysis if they occurred in three or more of the 120 sampling plots in at least one of the four plant assemblages. The FEID/AGSP grasslands had the greatest plant diversity, with 38 species recorded. The Brin/Mesa grasslands were the least diverse, with 15 species recorded. Plant species names in the following descriptions are listed in order of abundance, from highest to lowest.

The Stipa comata/Bouteloua gracilis Association

The low elevation (1200-1400m) grasslands surveyed in this study occur on alluvial fans and plains within the Gallatin Valley and are dominated by Stipa comata and Bouteloua gracilis. The grasslands sampled in this plant assemblage are semi-arid, with annual precipitation of 20-35 cm (Mueggler and Stewart, 1980). The patches also had a relatively low diversity of plant species (29), when compared with the more mesic native grasslands occurring at higher elevations. Other important grasses and sedges in the STCO/BOGR type include Poa sandbergii, Koeleria cristata, Carex filifolia, and Agropyron smithii. Total cover by grasses ranged from 50.2% to 62.4%, with an average of 54.5% (Table 1).

The most common forb species observed in this plant assemblage include Sphaeralcea coccinea, Melilotus officinalis, various species of Antennaria and Astragalus, Vicia americana, and several species of Aster. Total cover by forbs ranged from 4.4% to 20.4%, with an average of