PUEBLO CHEMICAL DEPOT
GRASSHOPPER MONITORING: 2001 RESULTS

By

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Executive Summary

In 1998 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 influences that vegetation type, grazing disturbance (grazed vs. ungrazed), and recent changes in grazing protocol may have on the structure of invertebrate communities. The three habitat types being monitored are greasewood scrub, shortgrass prairie and sand sagebrush. To detect differences in species composition 32 invertebrate monitoring plots were established in 2000. In 2001, two new plots were incorporated into the monitoring program resulting in a total of 34 plots. Orthopteran species were selected to assess the influences that grazing and vegetation community structure might have on invertebrate community composition. See Sovell (2000) for a discussion of why orhtopterans were chosen as the emphasis of this research. In 2001, all 36 invertebrate monitoring plots were sampled four times, once each in mid-May, late June, August, and September. To understand annual variation in species composition and density we will measure the permanent plots on an annual basis from May to September through the year 2003.

This report presents the results of the 2001 monitoring season. In addition, this research presents the results of a one time pitfall trapping session conducted in 1999 and ongoing collections of tiger beetles (Coleoptera: Cicindelidae).

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 terminated in late spring of 1998 (i.e., ammunition workshop area and eastern demolition area).

Methods

Study site and disturbance regime

For information on the study site including general history, location, vegetation, climate and history of livestock grazing see Sovell (2000).

Sampling design and data analysis

The project was designed to sample greasewood scrub, shortgrass prairie and sand sagebrush habitat types for differences in grasshopper community structure. In addition, the question of whether grazing disturbance influences grasshopper composition was investigated by placing six of the greasewood scrub plots, six of the shortgrass prairie

plots and five of the sand sagebrush plots in areas that experienced past grazing by livestock. For an explanation of how plot locations were chosen see Rondeau (1999). This scheme created six sampling groups consisting of two different grazing disturbances (grazed and ungrazed) nested within the three different habitat types mentioned above.

Vegetation

For an explanation of methodology used to sample vegetation see Rondeau (1999). The plant species analyzed in this report include nine shrubs (*Chrysothamnus nauseosus, Eriogonum effusum, Ipomoea leptophylla*), greasewood (*Sarcobatus vermiculatus*), sand sagebrush (*Oligosporus* [*Artemisia*] *filifolius*) and cacti (*Opuntia macrorhiza, Opuntia polyacantha, Opuntia phaecantha, Cylindropuntia imbricata*); seven native perennial grasses (*Aristida divaricata, Aristida purpurea, Chondrosum gracile* [*Bouteloua gracilis*], *Hilaria jamesii, Sporobolus airoides, Sporobolus cryptandrus, Stipa comata*); and five annual forbs (*Bassia* [*Kochia scoparia*] *siever, Salsola australis, Pectis angustifolia, Zygophllidium hexagonum, Zinnia grandiflora*). Percent cover, frequency and density of these 21 plant species were analyzed using Multi-Response Permutation Procedure (MRPP) (McCune and Mefford 1999). MRPP is a nonparametric procedure and thus does not require assumptions associated with alternative parametric tests (multivariate normality and homogeneity of variances; Zimmerman et al. 1985). MRPP tests the hypothesis of no difference between two or more a priori groups of entities. In this case plant species composition was examined among three habitat types (greasewood, sand sagebrush and shortgrass prairie) and two past grazing histories (grazed and ungrazed). Euclidian distance and an approximated *P*-value from a Pearson type III distribution of the test statistic were used in the MRPP.

Grasshoppers

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). As previously stated grasshopper collections were made in May, June, August, and September.

Two transects placed perpendicular to one another and crossing at one end were used on each plot to estimate grasshopper densities. Each transect consisted of twenty $0.1m^2$ hoops (Onsager 1977, 1991: Onsager and Henry 1977) placed 5m apart, creating a transect 100m in length, with a sampling area of $2m^2$ per transect or $4m^2$ per plot. Densities were estimated by approaching each hoop and counting every grasshopper that jumped or flew from within it. Each hoop was then searched for grasshoppers that did not flee. Individual hoops were treated as subsamples; data from all 40 hoops on each plot were pooled and plots were used as replicate samples (13 greasewood scrub, 12 shortgrass prairie and 11 sand sagebrush. Qualitative estimates of species composition were conducted each monitoring period by intensively sweeping on every plot for approximately 30 minutes at which point a minimum of 35 grasshoppers was collected. All collected grasshoppers were frozen for later identification in the laboratory. To minimize bias in estimates of species composition between sites due to interspecific differences in behavior, whenever possible we caught each grasshopper flushed, regardless of ease of capture (Capinera and

Sechrist 1982a). Pinning and identifying the adult grasshoppers determined the species present. Grasshoppers were identified using the keys of Otte (1981), Capinera and Sechrist (1982b), Otte (1984), and Pfadt (1994). Nymphs were omitted from the analysis because of difficulties in identification.

The frequency distribution of hoop sample counts from within each habitat type by grazing disturbance was expected to approximate a Poisson distribution, and so each observed distribution was tested against a Poisson distribution. For all samples a 95% Poisson confidence interval was calculated and samples whose intervals did not overlap were declared different by inspection (*P* unspecified, but <0.05).

Species richness and evenness were compared between habitat types and grazing disturbance with Kruskal-Wallis and Wilcoxon signed ranked tests. Evenness was calculated using Pielou's (1969) measure [Shannon diversity index÷ln(richness)]. To test for differences in species composition among habitat types and between grazing disturbance types, grasshopper abundance was examined using MRPP.

The degree of association of individual grasshopper species to specific habitat types or grazing disturbance regime was measured using indicator-species analysis (Dufrene and Legendre 1997). Indicator values, which were calculated for each species and all six combinations of habitat type and grazing disturbance, combine information on relative abundance and relative frequency of occurrence (Schooley et al. 2000). Perfect indication of a habitat (indicator value=100) occurs when all individuals of a species are exclusive to only one of the habitats, and each sample from that habitat contains an occurrence of that species. The statistical significance of the maximum indicator value (i.e., highest of the six groups) was tested with Monte Carlo randomization tests (1000 iterations) in which species abundance data were randomized among all 34 study plots.

The MRPP and indicator-species analysis were conducted using PC-ORD (McCune and Mefford 1999). All other statistical analyses were conducted using SAS v.8.01 (SAS Institute 1989).

Invertebrates were collected from pitfall traps in 1999. One trapping web in each of the three habitat types, greasewood scrub, shortgrass prairie and sand sagebrush, were sampled once each in July and September of 1999. Each trapping web contained eight 45m transects emanating from a central point, with each transect containing 10 pitfall traps spaced 5 meters apart (Fig. 1). In addition tiger beetles and dipterans have been collected with sweep nets in an opportunistic manner throughout the course of this monitoring effort. This report also presents the results of those collections.

Results

Vegetation

The MRPP test revealed that plant species composition differed among the habitat types (A=0.275, P<0.0001). Grazing disturbance, however, apparently was not responsible for this difference. Differences between grazed and ungrazed plots within any one of the three habitat types (greasewood scrub, shortgrass prairie, sand sagebrush) when tested by MRPP were not significant (Table 1). The MRPP test reveals moderate evidence for differences in plant species composition between grazed and ungrazed plots only in the sand sagebrush habitat (Table 1). The differences noted in vegetative composition seem most influenced by habitat type: greasewood scrub, shortgrass prairie or sand sagebrush. The MRPP test comparing plant species composition between the three habitat types identified significant differences between all three of the possible pairings (Table 1).

Grasshopper Density

Grasshopper densities were not found to be significantly different between the three habitat types (Kruskal-Wallis χ^2=3.01, df=2, *P*=0.2217), the six treatment groups (Kruskal-Wallis χ^2=4.86, df=5, *P*=4330), or the two grazing treatments (Kruskal-Wallis χ^2=1.48, df=1, *P*=0.2239). Estimates of grasshopper density within all six study groups were extremely low (range 0.29-1.29/m^2) as were the estimates from the three habitat types (range 0.31-0.84/m^2).

Grasshopper Species Composition

A total of 4865 grasshoppers were identified to species from collections made during 2001 (Table 2). Fifty-two species of grasshoppers were identified from 32 genera and four families. *Melanoplus* (eight species) was the most species-rich genus and the four most numerous species were *Cordillacris occipitalis*, *Eritettix simplex*, *Melanoplus bowditchi*, and *Opeia obscura*. Natural heritage rankings identify *Paroplomala virgata* (Table 2) as the rarest species collected, with a known distribution that includes southeastern Colorado, New Mexico, west Texas and Chihuahua, Mexico (see appendix 1 for an explanation of natural heritage rankings). Obligate grass feeders were the most abundant grasshoppers collected followed closely by mixed feeders, comprising 47% and 43% respectively (N=4865) of the total sample (Table 3). The only significant differences in the proportion of feeding types identified were between shortgrass and sand sagebrush habitat types. The two-sample Wilcoxon Rank Sum test found that the proportion of mixed feeders (P=0.0391) and obligate grass feeders (P=0.0472) was significantly different between these two habitat types, with obligate grass feeders more numerous in shortgrass prairie habitats and mixed feeders more numerous in sand sagebrush habitats.

Analysis of grasshopper samples did not identify significant differences in grasshopper species richness (Kruskal-Wallis χ^2=10.27, df=5, *P*=0.0680) or species evenness (Kruskal-Wallis χ^2=6.99, df=5, *P*=0.221) among study plots. Also, there were no significant differences within any one of the three habitat types (greasewood, shortgrass prairie or sand sagebrush) when comparing between grazing disturbances (Table 4). However, when these two variables were compared among habitat types significant differences were noted (Table 4). Comparison between greasewood and sand sagebrush habitat types utilizing the two-sample Wilcoxon Rank Sum test, found both grasshopper species

richness (*P*=0.010) and evenness (*P*=0.029) to be significantly different (Table 4). This analysis method also found that the species richness of the greasewood habitat type was significantly different than the species richness of the shortgrass prairie habitat (*P*=0.039) type (Table 4).

MRPP analysis of the six groups of habitat type by grazing disturbance revealed that grasshopper species composition differed among treatment groups in May (T=-2.3, *P*=0.0246, n=6), June (T=-2.7, *P*=0.0124, n=6), August (T=-10.2, *P*=<0.0001, n=6), and September (T=-7.8, *P*=<0.0001, n=6); as well as cumulatively (T=-9.2, *P*=<0.0001, n=6). Differences in grasshopper community structure were then examined between the three habitat types and the two grazing treatments. This analysis revealed significant differences in grasshopper composition between greasewood samples and both sand sagebrush (T=-11.2, A=0.3915, *P*=<0.0001, n=2) and shortgrass prairie samples (T=-3.5, A=0.0931, *P*=0.0027, n=2), as well as significant differences between sand sagebrush and shortgrass prairie samples (T=-12.1, A=0.4212, *P*=<0.0001, n=2). There were no significant differences in grasshopper community structure between grazed and ungrazed samples within any of the three habitat types (shortgrass prairie: T=-0.3, *P*=0.3711; sand sagebrush: T=-0.7, *P*=0.2420; greasewood: T=0.7, *P*=0.7476; all n=2 groups), but there were significant differences between the community structure in the three habitat types within the two grazing treatments (Grazed: T=-7.6, A=0.3779, *P*=<0.0001, n=3; Ungrazed: T=-7.8, A=0.4224, *P*=<0.0001, n=3). Four of the current study plots (one greasewood and three shortgrass prairie) are subjected to current grazing disturbances by both cattle and prairie dogs. When these four plots were compared to the other 32 plots using the MRPP, significant differences in grasshopper community structure were identified (T=-2.5, A=0.0465, *P*=0.0259, n=2).

Indicator-species analysis identified 12 species (Table 2) that were associated with either the shortgrass prairie or the sand sagebrush habitat type, and only one species that was associated with the greasewood habitat. The grazed shortgrass prairie indicators were *Hadrotettix trifasciatus* (IV=52.5, *P*=0.0050), *Melanoplus gladstoni* (IV=42.9, *P*=0.0160), and *Trachyrhachys kiowa* (IV=46.9, *P*=0.0020) while the ungrazed shortgrass prairie indicator was *Aulocara femoratum* (IV=49.2, *P*=0.0070). *Trachyrhachys aspera* (IV=68.9, *P*=0.0010) and *Aulocara elliotti* (IV=64.6, *P*=0.0010) were also associated with the shortgrass prairie habitat type but this relationship was irrespective of either grazing treatment (IV (grazed/ungrazed)=32/35 and 29/34 respectively). The grazed sand sagebrush indicators were *Melanoplus bowditchi* (IV=42.7, *P*=0.0010), *Spharagemon collare* (IV=66.2, *P*=0.0010), and *Paropomala pallida* (IV=64.8, *P*=0.0010), while the ungrazed sand sagebrush indicators were *Melanoplus packardii* (IV=51.1, *P*=0.0040) and *Melanoplus augustipennis* (IV=46.9, *P*=0.0160). *Arphia conspersa* was also found associated with the sand sagebrush habitat type (IV=68.0, *P*=0.0020) but this relationship was irrespective of grazing treatment (IV (grazed/ungrazed)=32/35). The only species associated with the greasewood habitat type was *Mermiria bivittata* (IV=64.2, *P*=0.0010), which showed a slightly stronger relationship to the ungrazed treatment (IV (grazed/ungrazed)=26/39).

Other Arthropods

A total of 65 species, representing 45 genera, 17 families and four orders of arthropods were identified from the pitfall trap collections of 1999 and from ongoing and opportunistic collections of tiger beetles and dipterans (Table 5). The ground beetles, family Carabidae, had the greatest representation in the sample with 14 genera and 24 species presented. The darkling beetles, family Tenebrionidae, had the second greatest representation with six genera and 11 species present. Rarity as defined by the Natural Heritage Ranking System is presented in Table 5 (see appendix 1 for an explanation of natural heritage rankings). *Cicindela splendida* was the rarest species collected at the Pueblo Chemical Depot as defined by heritage methodology. This species is actually quite common in North America warranting a global rank of G5. This is misleading, however, because information on biogeography is lacking for most of the species collected, making attempts at ranking difficult and in some cases impossible.

Discussion

The significant statistical differences noted in plant species composition occurred among the habitat types, while differences between grazed and ungrazed samples were minimal. Cover of sagebrush in sand sagebrush and greasewood in greasewood scrub were predictably greater. There was moderate evidence of differences in species composition between the grazed and ungrazed plots in the sand sagebrush habitat. For a more thorough explanation of the differences in plant species composition see Rondeau's vegetation monitoring report for the 2001 and 2002 monitoring season at the Pueblo Chemical Depot.

Estimates of grasshopper density for all six study groups were extremely low, as was the variation between sampling periods. Habitat type and grazing disturbance appear to have a very minimal effect upon grasshopper density in this area.

Grasshopper community structure was strongly affected by temporal variation throughout the sampling season as indicated by the MRPP analysis. This is primarily due to the differing life cycles of the various grasshopper species found in this area. In analyzing grasshopper species composition it is also evident that grasshopper community structure is strongly influenced by the mosaic created by the patchy distribution of shortgrass prairie, greasewood scrub and sand sagebrush throughout the landscape. While no differences in community structure were identified among the original grazed and ungrazed treatments within each habitat type, the four plots currently subjected to grazing by cattle or prairie dogs had species compositions that were significantly different from the other 32 plots being analyzed in 2001. Species richness was greater on the ungrazed greasewood habitat and evenness was greatest on the grazed greasewood habitat (see Table 4) as compared to the other treatment groups. The indicator species analysis suggested that grasshopper species have a slightly stronger relationship with grazed habitats as six out of the nine species associated with a particular grazing treatment, were associated with grazed habitats. In

addition, 12 of the 13 species identified with significant indicator values (IV) were associated with either the shortgrass prairie or sand sagebrush habitat types. Shortgrass prairie areas had a significantly greater number of obligate grass-feeding species than did the sand sagebrush areas (Table 3). In contrast to this, the sand sagebrush areas had a significantly greater number of mixed feeding species than did the shortgrass prairie areas (Table 3).

These analyses are based upon samples collected during the months of May, June, August and September in 2001. In contrast to the 2000 season, when samples were only collected in August and September, the 2001 collection suggests that sampling throughout the late-spring and summer months is the most beneficial approach for this study due to the high temporal variability in grasshopper species composition. This approach will also allow for a more robust analysis across multiple years, which may yield more informative results.

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Table 1. The influence that habitat type and grazing disturbance have on plant species composition. Multi-Response Permutation Procedure was used to compare plant species composition between grazing disturbances within each of the three habitat types, and also for all possible pairs of habitat types (greasewood-shortgrass prairie, greasewood-sand sagebrush and shortgrass prairie-sand sagebrush). Numbers of plots sampled for each habitat type/grazing disturbance are shown in parentheses. *P*-values significant at 0.1 are given in bold type.

Grazing Disturbance Comparison	Chance Corrected within Group Agreement	*P*-value
Greasewood: ungrazed (6), grazed (6)	A=0.009	P=0.303
Shortgrass prairie; ungrazed (5), grazed (6)	A=0.021	P=0.175
Sand sagebrush: ungrazed (6), grazed (5)	A=0.06	**P=0.086**
Habitat Comparison		
Greasewood (13) by shortgrass prairie (12)	A=0.125	**P<0.0001**
Greasewood (13) by sand sagebrush (11)	A=0.358	**P<0.0001**
Shortgrass prairie (12) by sand sagebrush (11)	A=0.189	**P<0.0001**

Table 2. List of orthopteran species and their abundances given as number of individuals/habitat. SGUG: shortgrass ungrazed; SGG: shortgrass grazed; SSUG: sand sagebrush ungrazed; SSG: sand sagebrush grazed; GWUG; greasewood ungrazed; GWG: greasewood grazed; OF: obligate forb; OG: obligate grass; MF: mixed feeder. ?: Unknown feeder. * Species with significant indicator values ($P \leq 0.05$).

					SITES															
					GWG				GWUG				SSG				SSUG			
ORTHOPTERIDEA SPECIES	G-rank	S-rank	SPP. CODE	FEEDING CAT.	May	June	Aug	Sept	May	June	Aug	Sept	May	June	Aug	Sept	May	June	Aug	Sept
Gomphocerinae (Slantfaced)																				
Acrolophitus hirtipes	G5	S5		OF	0	2	0	0	0	2	0	0	0	3	0	0	0	6	0	0
Ageneotettix deorum	G5	S5	AD	OG	0	0	28	8	0	0	32	4	0	0	25	1	0	0	27	1
Amphitornus coloradus	G5	S5	AC	OG	0	19	7	0	0	15	6	0	0	13	1	0	0	15	6	0
* *Aulocara elliotti*	G5	S5	AE	OG	0	2	0	0	0	1	1	0	0	1	0	0	0	6	0	0
* *Aulocara femoratum*	G5	S5	AF	OG	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
Boopedon nubilum	G5	S4	BN	OG	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Chorthippus curtipennis	G5	S4S5		OG	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
Cordillacris crenulata	G5	S5	CC	OG	0	1	1	2	0	0	6	3	0	0	0	0	0	0	1	0
Cordillacris occipitalis	G5	S5	CO	OG	0	120	2	0	0	115	7	0	0	91	4	0	0	88	5	0
Eritettix simplex	G5	S5		OG	3	8	0	0	1	37	1	0	9	6	0	0	10	14	0	0
* *Mermiria bivittata*	G5	S5	MeB	OG	0	0	15	2	0	0	14	5	0	0	2	1	0	0	3	0
Opeia obscura	G5	S5	OO	OG	0	0	64	30	0	0	54	30	0	0	8	2	0	0	13	5
* *Paropomala pallida*	G5	S3?	PP	OG	0	0	0	0	0	0	1	0	0	0	23	0	0	0	14	0
Paropomala virgata	G4?	S2	PV	?	0	0	0	0	0	0	1	0	0	0	3	0	0	0	2	0
Paropomala wyomingensis	G5	S5	PW	OG	0	0	11	5	0	0	12	5	0	0	14	2	0	0	16	4
Phlibostroma quadrimaculatum	G5	S5	PQ	OG	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0
Psoloessa delicatula	G5	S5		OG	0	8	0	0	0	3	0	0	0	5	0	0	0	6	0	0
Psoloessa texana	G5	S5		?	46	1	0	0	9	0	0	0	12	6	0	0	48	22	1	0
Oedipodinae (Bandwinged)																				
* *Arphia conspersa*	G5	S5	AR	MF	0	0	0	0	0	0	0	0	41	1	0	0	37	7	1	0
Arphia pseudonietana	G5	S5	AP	MF	0	0	17	15	0	0	16	14	0	0	0	0	0	0	0	0
Derotmema haydeni	G5	S5		MF	0	0	2	0	0	0	3	1	0	0	0	0	0	0	0	0
Encoptolophus costalis	G5	S5		OG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
* *Hadrotettix trifasciatus*	G5	S5	HT	MF	0	0	7	1	0	0	9	1	0	0	1	1	0	0	1	1
Hippiscus ocelote	G5	S4	HO	MF	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Hippopedon capito	G5	S1	HC	?	0	0	5	0	0	0	1	0	0	0	0	0	0	0	0	0
Mestobregma plattei	G5	S5	MeP	?	0	0	7	5	0	0	7	5	0	0	2	0	0	0	3	2
Metator pardalinus	G5	S5	MetP	OG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pardalophora haldemani	G5	S5		?	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
* *Spharagemon collare*	G5	S5	SC	MF	0	0	0	0	0	0	0	0	0	0	12	0	0	0	3	0
Spharagemon equale	G5	S5	SE	MF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
* *Trachyrhachys aspera*	G5	S5	TA	OG	0	0	4	0	0	0	10	0	0	0	0	0	0	0	0	0

Table 2 (con't)

					SITES								
					SGG				SGUG				Species Total
ORTHOPTERIDEA SPECIES	G-rank	S-rank	SPP. CODE	FEEDING CAT.	May	June	Aug	Sept	May	June	Aug	Sept	
Gomphocerinae (Slantfaced)													
Acrolophitus hirtipes	G5	S5		OF	0	2	0	0	0	1	0	0	16
Ageneotettix deorum	G5	S5	AD	OG	0	0	40	5	0	0	38	5	214
Amphitornus coloradus	G5	S5	AC	OG	0	14	20	0	0	17	40	0	173
* *Aulocara elliotti*	G5	S5	AE	OG	0	2	20	0	0	1	16	0	50
* *Aulocara femoratum*	G5	S5	AF	OG	0	0	12	0	0	0	20	0	34
Boopedon nubilum	G5	S4	BN	OG	0	0	0	0	0	0	0	0	1
Chorthippus curtipennis	G5	S4S5		OG	0	0	0	0	0	0	0	0	4
Cordillacris crenulata	G5	S5	CC	OG	0	0	12	2	0	0	7	1	36
Cordillacris occipitalis	G5	S5	CO	OG	0	145	1	0	0	144	1	0	723
Eritettix simplex	G5	S5		OG	11	4	0	0	24	3	1	0	132
* *Mermiria bivittata*	G5	S5	MeB	OG	0	0	3	3	0	0	2	0	50
Opeia obscura	G5	S5	OO	OG	0	0	81	25	0	0	92	31	435
* *Paropomala pallida*	G5	S3?	PP	OG	0	0	0	0	0	0	0	0	38
Paropomala virgata	G4?	S2	PV	?	0	0	2	0	0	0	2	0	10
Paropomala wyomingensis	G5	S5	PW	OG	0	0	10	1	0	0	10	0	90
Phlibostroma quadrimaculatum	G5	S5	PQ	OG	0	0	5	1	0	0	4	0	14
Psoloessa delicatula	G5	S5		OG	0	1	0	0	0	2	0	0	25
Psoloessa texana	G5	S5		?	78	2	0	0	31	0	0	0	256
Oedipodinae (Bandwinged)													
* *Arphia conspersa*	G5	S5	AR	MF	2	1	0	0	29	0	0	0	119
Arphia pseudonietana	G5	S5	AP	MF	0	0	6	4	0	0	16	13	101
Derotmema haydeni	G5	S5		MF	0	0	0	0	0	0	0	0	6
Encoptolophus costalis	G5	S5		OG	0	0	0	0	0	0	8	8	16
* *Hadrotettix trifasciatus*	G5	S5	HT	MF	0	0	27	13	0	0	9	6	77
Hippiscus ocelote	G5	G4	HO	MF	0	0	0	0	0	0	0	0	2
Hippopedon capito	G5	S1	HC	?	0	0	0	0	0	0	0	0	6
Mestobregma plattei	G5	S5	MeP	?	0	0	3	3	0	0	1	1	39
Metator pardalinus	G5	S5	MetP	OG	0	0	0	0	0	0	0	0	0
Paradalophora haldemani	G5	S5		?	0	0	0	0	0	0	0	0	1
* *Spharagemon collare*	G5	S5	SC	MF	0	0	0	0	0	0	0	0	15
Spharagemon equale	G5	S5	SE	MF	0	0	0	0	0	0	0	0	0
* *Trachyrhachys aspera*	G5	S5	TA	OG	0	0	17	0	0	0	22	0	53

Table 2 (con't)

					S															
					GWG				GWUG				SSG				SSUG			
ORTHOPTERIDEA SPECIES	G-rank	S-rank	SPP. CODE	FEEDING CAT.	May	June	Aug	Sept	May	June	Aug	Sept	May	June	Aug	Sept	May	June	Aug	Sept
** Trachyrhachys kiowa*	G5	S5	TK	OG	0	0	4	1	0	0	7	3	0	0	0	0	0	0	0	0
Trimerotropis latifasciata	G5	S5			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Trimerotropis pallidipennis	G5	S5	TP	MF	98	1	9	1	147	3	1	0	62	3	0	0	47	0	1	0
Tropidolophus formosus	G5	S5	TF	OF	0	0	3	0	0	0	1	0	0	0	6	0	0	0	8	0
Xanthippus corallipes	G5	S5	XC	OG	29	1	1	0	29	2	1	0	13	3	1	0	17	2	0	0
Melanoplinae (Spurthroated)																				
Aeoloplides turnbulli	G5	S5	AT	OF	0	6	13	3	0	8	17	10	0	1	3	1	0	3	5	1
Dactylotum bicolor	G5	S5	DB	OF	0	0	4	0	0	5	3	0	0	3	1	0	0	3	2	0
Hesperotettix speciosus	G5	S5	HS	OF	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
Hesperotettix viridis	G5	S5	HV	OF	0	0	15	1	0	0	10	1	0	0	1	1	0	0	3	1
** Melanoplus angustipennis*	G5	S5	-	MF	0	0	5	4	0	0	7	3	0	0	15	9	0	0	40	16
Melanoplus arizonae	G5	S4	MA	MF	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0
Melanoplus bivittatus	G5	S5	MeA	?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
** Melanoplus bowditchi*	G5	S5		MF	0	0	46	11	0	0	47	15	0	3	133	54	0	5	128	45
Melanoplus confuses	G5	S5	MB	OF	0	2	0	0	0	2	0	0	0	2	0	0	0	0	0	0
Melanoplus femurrubrum	G5	S5		MF/OF	0	0	13	0	0	0	23	2	0	0	3	0	0	0	19	14
Melanoplus foedus	G5	S5			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
** Melanoplus gladstoni*	G5	S5	MF	MF	0	0	11	7	0	0	2	2	0	0	3	3	0	0	1	1
Melanoplus lakinus	G5	S5	MG	MF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Melanoplus occidentalis	G5	S5	ML	MF	0	3	5	0	0	2	6	0	0	15	6	0	0	14	2	0
** Melanoplus packardii*	G5	S5	MO	MF	0	0	9	0	0	0	10	1	0	0	40	20	0	0	66	38
Melanoplus sanguinipes	G5	S5	MP	MF	0	0	16	1	0	0	17	6	0	0	23	1	0	0	8	5
Melanoplus spp.			MS	MF	0	0	8	0	0	0	14	0	0	0	14	0	0	0	9	0
Cyrtacanthacridinae																				
Schistocerca alutacea	G5	S5		OF	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Total Species Collected					176	174	338	99	186	195	355	111	137	156	348	96	159	191	390	136

Table 2 (con't)

					SITES								
					SGG				SGUG				Species Total
ORTHOPTERIDEA SPECIES	G-rank	S-rank	SPP. CODE	FEEDING CAT.	May	June	Aug	Sept	May	June	Aug	Sept	
** Trachyrhachys kiowa*	G5	S5	TK	OG	0	0	10	7	0	0	4	1	37
Trimerotropis latifasciata	G5	S5			0	0	0	1	0	0	0	0	2
Trimerotropis pallidipennis	G5	S5	TP	MF	70	2	0	1	70	6	0	0	522
Tropidolophus formosus	G5	S5	TF	OF	0	0	1	0	0	0	0	0	19
Xanthippus corallipes	G5	S5	XC	OG	14	1	1	0	24	2	0	0	141
Melanoplinae (Spurthroated)													
Aeoloplides turnbulli	G5	S5	AT	OF	0	2	5	1	0	3	15	4	101
Dactylotum bicolor	G5	S5	DB	OF	0	0	10	0	0	0	0	0	31
Hesperotettix speciosus	G5	S5	HS	OF	0	0	0	0	0	0	0	0	2
Hesperotettix viridis	G5	S5	HV	OF	0	0	6	0	0	0	1	0	40
** Melanoplus angustipennis*	G5	S5	-	MF	0	0	5	6	0	0	4	2	116
Melanoplus arizonae	G5	S4	MA	MF	0	0	1	0	0	0	0	0	5
Melanoplus bivittatus	G5	S5	MeA	?	0	0	0	0	0	0	0	0	0
** Melanoplus bowditchi*	G5	S5		MF	0	0	6	8	0	1	2	0	504
Melanoplus confuses	G5	S5	MB	OF	0	0	0	0	0	0	0	0	6
Melanoplus femurrubrum	G5	S5		MF/OF	0	0	0	0	0	0	0	0	74
Melanoplus foedus	G5	S5			0	0	0	0	0	0	0	0	1
** Melanoplus gladstoni*	G5	S5	MF	MF	0	0	20	21	0	0	13	13	97
Melanoplus lakinus	G5	S5	MG	MF	0	0	0	0	0	0	0	0	1
Melanoplus occidentalis	G5	S5	ML	MF	0	1	12	0	0	1	4	0	71
** Melanoplus packardii*	G5	S5	MO	MF	0	0	4	3	0	0	1	1	193
Melanoplus sanguinipes	G5	S5	MP	MF	0	0	8	6	0	0	14	3	108
Melanoplus spp.			MS	MF	0	0	5	0	0	0	7	0	57
Cyrtacanthacridinae													
Schistocerca alutacea	G5	S5		OF	0	0	0	0	0	0	0	0	1
Total Species Collected					175	177	353	111	178	181	354	89	4865

Table 3. Summary of grasshopper abundance by feeding and habitat classification, and grazing disturbance.

Habitat Classification*	Feeding Type				
	Obligate Grass	Obligate Forb	Mixed Feeder	Unknown	Totals
SGUG	528	24	215	35	802
SGG	469	27	232	88	816
SSUG	254	33	511	78	876
SSG	225	23	465	24	737
GWUG	408	60	356	23	847
GWG	384	49	290	64	787
Totals	2268	216	2069	312	4865

* Habitat classifications are as defined in Table 1.

Table 4. Influence of habitat type and grazing disturbance on cumulative (seasonal total) species richness and evenness. Wilcoxon Two-Sample Tests were used to compare grasshopper species richness between grazing disturbances within habitat types and for all possible pairs of habitat types (greasewood-shortgrass prairie, greasewood-sand sagebrush and shortgrass prairie-sand sagebrush). Numbers of plots sampled for each habitat type/grazing disturbance are shown in parentheses. Significant *P*-values are given in bold type.

	Community Composition Measure				
Grazing Disturbance Comparison	Mean Richness	*P*-value		Mean Evenness	*P*-value
Greasewood					
ungrazed (6)	25.3	0.077		0.83	0.138
grazed (7)	21.0			0.87	
Shortgrass Prairie					
ungrazed (6)	20.7	0.217		0.83	0.320
grazed (6)	23.3			0.84	
Sand Sagebrush					
ungrazed (6)	21.0	0.500		0.81	0.429
grazed (5)	20.8			0.81	
Habitat Comparison					
Greasewood (13)	23.0	**0.039**		0.85	0.211
Shortgrass (12)	22.0			0.84	
Greasewood (13)	23.0	**0.010**		0.85	**0.029**
Sand Sagebrush (11)	20.9			0.81	
Shortgrass (12)	22.0	0.159		0.84	0.069
Sand Sagebrush (11)	20.9			0.81	

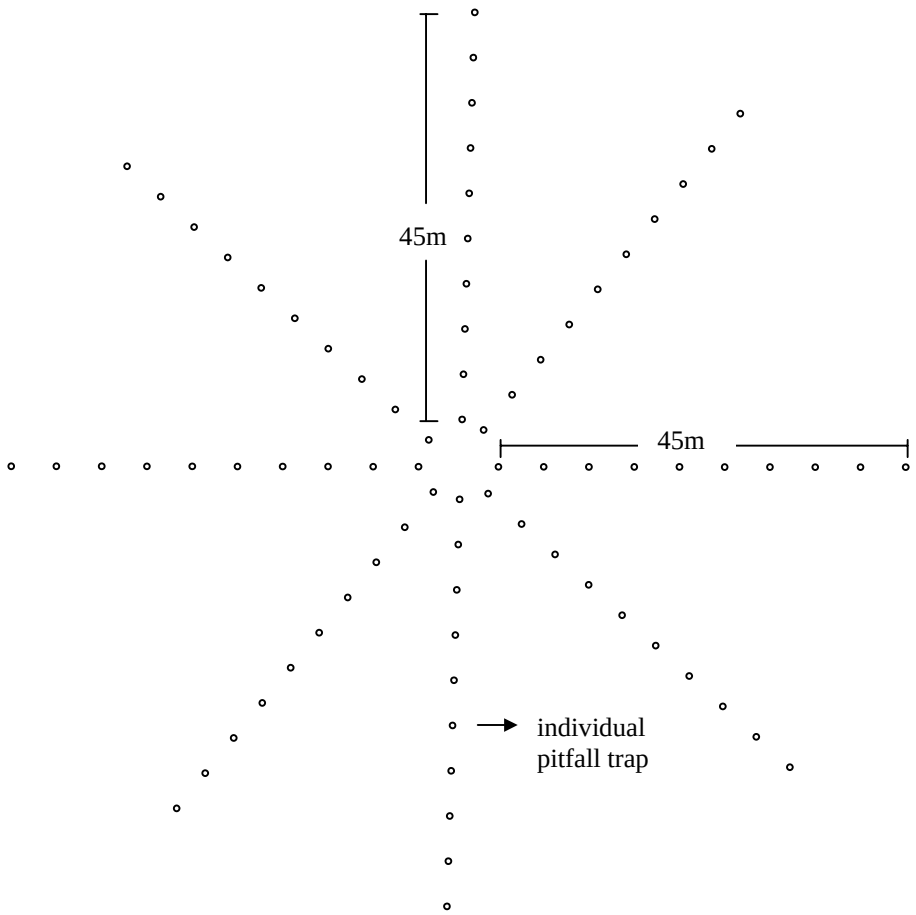
Table 5. The four orders of insects and the species represented in each order that were collected from the Pueblo Chemical Depot between 1999 and 2002.

TAXONOMY		AUTHOR	NO. OF NEW		HERITAGE RANK	
			Genera	Species	G-rank	S-rank
Order Coleoptera						
Family Carabidae – Ground Beetles						
Amara apricaria	a ground beetle	Paykull	1	1	G?	
Amara spp.	a ground beetle	Bonelli		1	G?	
Amblycheila cylindriformis	a tiger beetle	Say	1	1	G5	S5
Chlaenius spp.	a ground beetles		1	1	G?	
Cicindela circumpicta johnsoni	a tiger beetle	Fitch	1	1	G5T5	S3
Cicindela fulgida	a tiger beetle	Say		1	G5	S5
Cicindela marutha	a tiger beetle	Dow		1	G5	S3?
Cicindela nigrocoerulea	a tiger beetle	LeConte		1	G5	S5
Cicindela obsolete obsoleta	a tiger beetle	LeConte		1	G5T5	S5
Cicindela pulchra pulchra	a tiger beetle	Say		1	G4T4	S4
Cicindela punctulata	a tiger beetle	Olivier		1	G5	S5
Cicindela scutellaris	a tiger beetle	Say		1	G5	S5
Cicindela splendida	a tiger beetle	Hentz		1	G5	S1?
Cratacanthus dubiu	a beetle	Beauvois	1	1		
Cymindis spp.	a beele	Latreille	1	1		
Dicaelus laevipennis	a ground beetle	LeConte	1	1		
Diplocheila spp.	a ground beetle	Brulle	1	1		
Discoderus parallelus	a ground beetle	Haldeman	1	1		
Discoderus spp.	a ground beetle	LeConte		1		
Euryderus grossus	a ground beetle	Say	1	1		
Harpalus spp.	a ground beetle	Latreille	1	1	G?	
Pasimachus californicus	a ground beetle	Chaudoir	1	1		
Piosoma setosum	a ground beetle	LeConte	1	1		
Rhadine spp.	a ground beetle	LeConte	1	1		
TOTALS			14	24		
Family Cerambycidae – Long-Horned Beetles						
Moneilema annulatum	a long-horned beetle	Say	1	1		
Tetraopes femoratus	a long-horned beetle	LeConte	1	1		
TOTALS			2	2		
Family Chrysomelidae – Leaf Beetles						
Zygogramma conjunta pallida	a leaf beetle	Bland	1	1		
TOTALS			1	1		
Family Curculionidae – Snout Beetles or Weevils						
Calyptillus cryptops	a weevil	Horn	1	1		
Cylindrocopturus ssp.	a weevil		1	1		
Gerstaeckeria spp.	a cactus weevil		1	1		
Ophryastes sulcirostris	a weevil	Say	1	1		
TOTALS			4	4		
Family Elateridae – Click Beetles						
Agrypnus rectangularis	a click beetle	Say	1	1		
Colaulon rectangularis	a click beetle	Say	1	1		
TOTALS			2	2		
Family Geotrupidae – Earth Boring Dung Beetle						
Bradycintetulus fossatus	a dung beetle	Haldeman	1	1		
TOTALS			1	1		
Family Histeridae – Hister Beetles						
Hister spp.	a hister beetle	Linnaeus	1	1		
TOTALS			1	1		
Family Meloidae – Blister Beetles						
Epicauta fabricii	ash-gray blister beetle	LeConte	1	1		
Epicauta maculata	spotted blister beetle	Say		1		
Epicauta pennsylvanica	black blister beetle	DeGeer		1	G?	S?
Epicauta stuart	a blister beetle	LeConte		1		
TOTALS			1	4		
Family Scarabaeidae – Scarab Beetles						
Aphodius ruficlarus	a dung-feeding scarab beetle	Fall	1	1		
Boreocanthon praticola	a dung-feeding scarab beetle	LeConte	1	1	G?	

TAXONOMY		AUTHOR	NO. OF NEW		HERITAGE RANK	
			Genera	Species	G-rank	S-rank
Order Coleoptera						
Family Scarabaeidae – Scarab Beetles: continued						
Diplotaxis subangulata	a June beetle like scarab beetle	LeConte	1	1		
Euphoria kern	a bumble flower beetle	Haldeman	1	1		
Phyllophaga spp.	a dung-feeding scarab beetle		1	1		
TOTALS			5	5		
Family Tenebrionidae – Darkling Beetles						
Asidopsis opaca	a darkling beetle	Say	1	1		
Bothrotes plumbeus	a darkling beetle	LeConte	1	1		
Eleodes carbonarius obsoletus	a darkling beetle	Say	1	1		
Eleodes fusiformis	a darkling beetle	LeConte		1		
Eleodes hispilabris	a darkling beetle	Say		1	G?	
Eleodes longicollis	a darkling beetle			1		
Eleodes obscura	a darkling beetle			1		
Eleodes suturalis	a darkling beetle	Say		1		
Eusattus reticulata	a darkling beetle	Say	1	1		
Lobometopon fusiformis cribricolle	a darkling beetle	Casey	1	1		
Trimytis pruinosa	a darkling beetle	LeConte	1	1		
TOTALS			6	11		
Family Trogidae – Skin Beetles						
Trox nodosus	a skin beetle	Robinson	1	1		
Trox sonorae	a skin beetle	LeConte		1		
TOTALS			1	2		
ORDER DIPTERA						
Family Asilidae – Robber Flies						
Leptogaster altacola	a robber fly	Martin	1	1		
Leptogaster salvia	a robber fly	Martin		1		
TOTALS			1	2		
ORDER HEMIPTERA						
Family Lygaeidae – Seed Bugs						
Emblethis vicarius	a seed bug	Horvath	1	1		
TOTALS			1	1		
Family Reduviidae – Assassin Bugs						
Apiomeris spissipes	an assassin bug	Say	1	1		
TOTALS			1	1		
Family Scutelleridae – Shield-Back Bugs						
Euptychodera corrugata	a shield-back bug	Van Duzee	1	1		
TOTALS			1	1		
ORDER HYMENOPTERA						
Family Formicidae – The Ants						
Crematogaster spp.	cocktail ants	Lund	1	1		
Pogonomyrmex spp.	harvester ants	Mayr	1	1		
TOTALS			2	2		
ORDER MANTODEA						
Family Mantidae – Praying Mantids						
Litaneutria minor	a mantid	Scudder	1	1	G5	S5
TOTALS			1	1		
GRAND TOTALS			45	65		

[1] Heritage Ranks have not been assigned to species or genera where the rank is absent.

Fig 1. Design of the pitfall trapping webs used to collect ground beetles during the summer of 1999.



Appendix I: The Natural Heritage Ranking System

Each of the plant and animal species and plant communities tracked by CNHP is considered an **element of natural diversity**, or simply an **element**. Each element is assigned a rank that indicates its relative degree of imperilment on a five-point scale (e.g., 1 = extremely rare/imperiled, 5 = abundant/secure). The primary criterion for ranking elements is the number of occurrences, i.e., the number of known distinct localities or populations. This factor is weighted more heavily because an element found in one place is more imperiled than something found in twenty-one places. Also considered in the ranking is the size of the geographic range, the number of individuals, trends in population and distribution, identifiable threats, and the number of already protected occurrences.

Element imperilment ranks are assigned both in terms of the element's degree of imperilment within Colorado (its State or S-rank) and the element's imperilment over its entire range (its Global or G-rank). Taken together, these two ranks indicate the degree of imperilment of an element. For example, the lynx, which is thought to be secure in northern North America but is known from less than 5 current locations in Colorado, is ranked G5S1. Naturita milkvetch, which is known from 37 locations in the Four Corners Area, is ranked a G3S3, vulnerable both globally and in Colorado. Further, a tiger beetle that is only known from one location in the world at the Great Sand Dunes National Monument is ranked G1S1, critically imperiled both globally and in Colorado. CNHP actively collects, maps, and electronically processes specific occurrence information for elements considered extremely imperiled to vulnerable (S1 - S3). Those with a ranking of S3S4 are "watchlisted," meaning that specific occurrence data are collected and periodically analyzed to determine whether more active tracking is warranted. A complete description of each of the Natural Heritage ranks is provided in Table 1.

This single rank system works readily for all species except those that are migratory. Those animals that migrate may spend only a portion of their life cycles within the state. In these cases, it is necessary to distinguish between breeding, non-breeding, and resident species. As noted in Table 1, ranks followed by a "B", e.g., S1B, indicate that the rank applies only to the status of breeding occurrences. Similarly, ranks followed by an "N", e.g., S4N, refer to nonbreeding status, typically during migration and winter. Elements without this notation are believed to be year-round residents within the state.

Table 1. Definition of Colorado Natural Heritage Imperilment Ranks.

Global imperilment ranks are based on the range-wide status of a species. State imperilment ranks are based on the status of a species in an individual state. State and Global ranks are denoted, respectively, with an "S" or a "G" followed by a character. **These ranks should not be interpreted as legal designations.**

G/S1	Critically imperiled globally/state because of rarity (5 or fewer occurrences in the world/state; or very few remaining individuals), or because some factor of its biology makes it especially vulnerable to extinction.
G/S2	Imperiled globally/state because of rarity (6 to 20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range.
G/S3	Vulnerable throughout its range or found locally in a restricted range (21 to 100 occurrences).
G/S4	Apparently secure globally/state, though it might be quite rare in parts of its range, especially at the periphery.
G/S5	Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.
GX	Presumed extinct.
G#?	Indicates uncertainty about an assigned global rank.
G/SU	Unable to assign rank due to lack of available information.
GQ	Indicates uncertainty about taxonomic status.
G/SH	Historically known, but not verified for an extended period.
G#T#	Trinomial rank (T) is used for subspecies or varieties. These species or subspecies are ranked on the same criteria as G1-G5.
S#B	Refers to the breeding season imperilment of elements that are not permanent residents.
S#N	Refers to the non-breeding season imperilment of elements that are not permanent residents. Where no consistent location can be discerned for migrants or non-breeding populations, a rank of SZN is used
SZ	Migrant whose occurrences are too irregular, transitory, and/or dispersed to be reliably identified, mapped, and protected.
SA	Accidental in the state.
SR	Reported to occur in the state, but unverified.
S?	Unranked. Some evidence that species may be imperiled, but awaiting formal rarity ranking.

Notes: Where two numbers appear in a state or global rank (e.g., S2S3), the actual rank of the element falls between the two numbers.

Legal Designations

Natural Heritage imperilment ranks are not legal designations and should not be interpreted as such. Although most species protected under state or federal endangered species laws are extremely rare, not all rare species receive legal protection. Legal status is designated by either the U.S. Fish and Wildlife Service under the Endangered Species Act or by the Colorado Division of Wildlife under Colorado Statutes 33-2-105 Article 2. State designations apply to animals only; Colorado has no legal list of threatened and endangered plant species (Buckner and Bunin 1992).

In addition, the U.S. Forest Service recognizes some species as "Sensitive," as does the Bureau of Land Management. Table 2 defines the special status assigned by these agencies and provides a key to the abbreviations used by CNHP.

Please note that the U.S. Fish and Wildlife Service has issued a Notice of Review in the February 28, 1996 Federal Register for plants and animal species that are "candidates" for listing as endangered or threatened under the Endangered Species Act. The revised candidate list replaces an old system that listed many more species under three categories: Category 1 (C1), Category 2 (C2), and Category 3 (including 3A, 3B, 3C). Beginning with the February 28, 1996 notice, the Service will recognize as candidates for listing most species that would have been included in the former Category 1. This includes those species for which the Service has sufficient information on their biological status and threats to propose them as endangered or threatened under the Endangered Species Act.

Candidate species listed in the February 28, 1996 Federal Register are indicated with a "C". While obsolete legal status codes (Category 2 and 3) are no longer used, CNHP will continue to maintain them in its Biological and Conservation Data system for reference.

Table 2. Federal and State Agency Special Designations.

Federal Status:

1. U.S. Fis h and Wildlife Service (58 Federal Register 51147, 1993) and (61 Federal Register 7598, 1996)

LE Endangered; species or subspecies formally listed as endangered.

E(S/A) Endangered due to similarity of appearance with listed species.

LT Threatened; species or subspecies formally listed as threatened.

P Potential Endangered or Threatened; species or subspecies formally listed as potentially endangered or threatened.

PD Potential for delisting

C Candidate: species or subspecies for which the U.S. Fish and Wildlife Service has on file sufficient information on biological vulnerability and threat(s) to support proposals to list them as endangered or threatened.

2. U.S. Forest Service (Forest Service Manual 2670.5) (noted by the Forest Service as "S")

FS Sensitive: those plant and animal species identified by the Regional Forester for which population viability is a concern as evidenced by:

a. Significant current or predicted downward trends in population numbers or density.

b. Significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution.

3. Bureau of Land Management (BLM Manual 6840.06D) (noted by BLM as "S")

BLM Sensitive: those species found on public lands, designated by a State Director that could easily become endangered or extinct in a state. The protection provided for sensitive species is the same as that provided for C (candidate) species. This list does not include species that are listed endangered (LE) or threatened (LT).

State Status:

1. Colorado Division of Wildlife

CO-E Endangered

CO-T Threatened

CO-SC Special Concern