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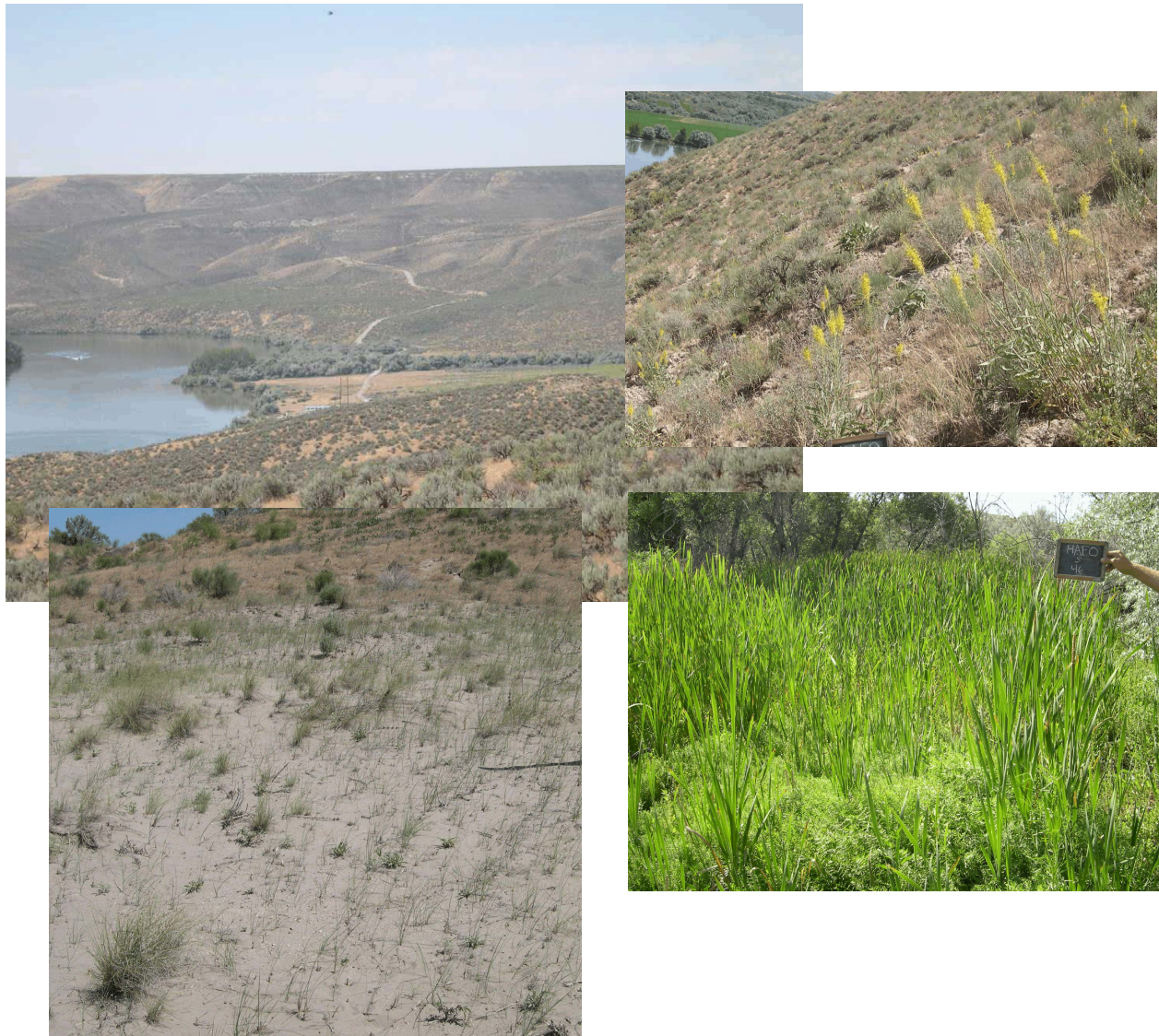
U.S. Department of the Interior

Natural Resource Program Center



Classification of the Plant Communities of Hagerman Fossil Beds National Monument, Idaho

Natural Resources Report NPS/UCBN/NRTR – 2008/097



ON THE COVER

Images of Hagerman Fossil Beds National Monument (clockwise): view southwest toward the monument; Wyoming big sagebrush shrub-steppe; open riparian shrubland; dry Indian ricegrass vegetation.

Photograph by: Northwest Management, Inc.

Classification of the Plant Communities of
Hagerman Fossil Beds National Monument,
Idaho

Natural Resource Technical Report NPS/UCBN/NRTR – 2008/097

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Moscow, Idaho

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Abstract

Work on the vegetation map for Hagerman Fossil Beds National Monument and Preserve was initiated in May 2006. Hagerman Fossil Beds National Monument lies on the Lower Snake River Plain in south-central Idaho. The study area encompasses the 1,760 ha (4,350 ft) area extending from the west shore of Snake River to the breaks of the Bruneau Plateau. The geographic setting is characterized by deep, Cenozoic flow basalt scoured and partially overlain by massive Quaternary deposits of lacustrine sand and gravel resulting from the Bonneville Flood. Initial plant community groups were identified using hierarchical cluster analysis. Plant community groups were successively partitioned to optimize within-group homogeneity, between-group difference, and the number of groups using indicator species analysis and multi-response permutation procedures. Decisions regarding the identification of plant associations within the data were informed by cross-walking candidate community groupings to the National Vegetation Classification. Classification and regression tree analysis (recursive partitioning) was employed in the development of dichotomous keys and the evaluation of cluster analysis results. Thirty-four plant communities are identified as occurring within the study area. Nearly 30% of the associations identified within the Monument are currently listed in the National Vegetation Classification. Associations described but not recognized by the National Vegetation Classification include: (1) semi-natural vegetation (19 associations) and (2) plant communities (5 associations) that have not been described previously at the association level. Plant associations that should be considered for inclusion in the National Vegetation Classification are listed. A dichotomous key to the classification is presented. Summaries of stand composition are provided.

Introduction

The National Park Service Inventory and Monitoring Program Upper Columbia Basin Network (UCBN) is working in conjunction with the Service's Vegetation Mapping Program to complete vegetation maps for each of the national park units within the network. The National Park Service vegetation mapping protocol consists of the following major phases: preliminary collection and review of existing information; field data collection, management and analysis; photo-interpretation and mapping; map validation; and accuracy assessment (The Nature Conservancy and Environmental Systems Research Institute 1994a). Work on the vegetation map for Hagerman Fossil Beds National Monument was initiated in May 2006. Field methods employed in 2006 were identical to Northwest Management Inc. (2006). The objective of this document is to report on the field data analysis phase and provide a classification of the vegetation and a dichotomous key to the classification of plant communities.

Study Area

Hagerman Fossil Beds National Monument lies on the Lower Snake River Plain in south-central Idaho, near the town of Hagerman (Figure 1). The national monument encompasses administrative, visitor, and research facilities on the east side of Snake River. The focus of this study is the 1,760 ha (4,350 ft) area extending from the west shore of Snake River to the breaks of the Bruneau Plateau. The geographic setting of the site is characterized by deep, Cenozoic flow basalt scoured and partially overlain by massive Quaternary deposits of lacustrine sand and gravel resulting from the Bonneville Flood (Farmer and Riedel 2003).

One might envision the site in the late Pleistocene near the eastern shore of ancient Lake Idaho. The accumulation of lacustrine deposits has resulted in the development of numerous sedimentary formations commonly referred to as the Idaho and Snake River groups. These sedimentary deposits form out-crops within the monument consisting of poorly consolidated clay and gravel inter-bedded with basalt, volcanic ash, and basaltic pyroclastic deposits (Farmer and Riedel 2003; Malde and Powers 1962; Malde 1968). Soils derived primarily in lacustrine deposits range in texture from loam to silty clay. The Badland-Kudlac association (30 to 60 percent slopes) is the prominent soil map unit within the area (Ames 2003). A thick caliche layer forms a rock cap on the canyon rims.

The climate is arid. Summers are hot and dry; winters are relatively cold. Average annual minimum and maximum temperatures are 2.4°C and 19.6°C, respective; mean annual precipitation is 26.2cm (Hagerman 2 SW; Western Regional Climate Center 2007). Elevation within the study area ranges from 850 m to 1,060 m (2,800 ft to 3,500 ft).

Vegetation within the monument is predominantly sagebrush steppe and salt-desert shrubland (Cole 1995; Farmer and Riedel 2003). Diverse riparian communities, including emergent wetlands and riparian woodlands and shrublands occur on a narrow band between the shore of Snake River and the river's dry canyon slopes. Vegetation within the study area has been

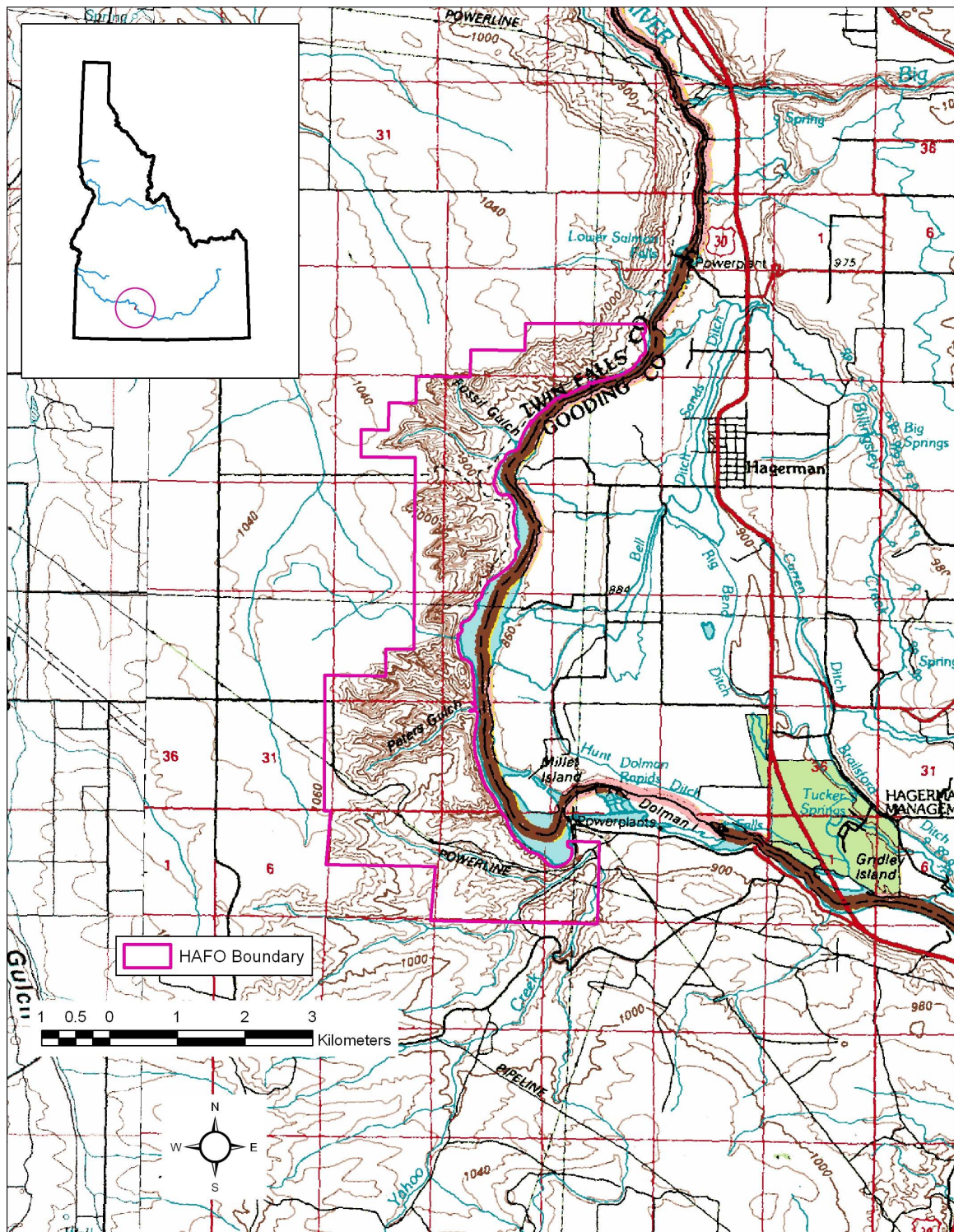


Figure 1. Study area location. The location of Hagerman Fossil Beds National Monument (HAFO) is shown in relation to major geographical features. Inset shows the location of the study area within Idaho.

modified by the introduction of numerous exotic species. Cole (1995) completed a vegetation

map and classification of stream-side and lower slope vegetation within the area. Hironaka et al. (1983) provide a classification of shrub-steppe vegetation that is applicable to the area. Jankovsky-Jones (2001) completed a wetland conservation assessment that encompasses the monument and provides pertinent classification and descriptive material.

Cole (1995), Farmer and Riedel (2003), and Yensen (1982) provide overviews of the historic development of land uses and associated influence on the vegetation of the area. The monument was likely grazed by livestock at varying intensities beginning in the 1890's. In 1984 the area was closed to grazing and off-road vehicle use.

Methods

At the onset of the vegetation mapping project a search for existing data was completed (*sensu* The Nature Conservancy 1996). No existing relevant data were located. Cole (1995), however, may be a potential source for future analyses. Classification analyses were conducted using the 137 vegetation samples collected in 2006. Field methods employed in the collection of these data are described by Northwest Management Inc. (2006).

Analytical methods were employed in a manner consistent with the objective of identifying natural associations of existing vegetation (Jennings et al. 2006, Tart et al. 2005, The Nature Conservancy and Environmental Systems Research Institute 1994b). Multivariate statistical analyses were conducted using PC-ORD (McCune and Mefford 1999). Initial plant community groups were identified using hierarchical cluster analysis. Plant community groups were successively partitioned to optimize within-group homogeneity, between-group difference, and the number of groups. These 3 factors were evaluated using statistics generated by indicator species analysis (the mean p -value and number of significant ($p \leq 0.05$) indicator species) and multi-response permutation procedures (T , a measure of separation between groups; the chance-corrected within-group agreement (A), a measure of within-group homogeneity; and the compositional similarity of samples within a group (as measured by average relative Sorensen distance)). Environmental relations, within-group homogeneity, and between-group difference were evaluated graphically using indirect gradient analysis through detrended correspondence analysis (McCune and Grace 2002). Final decisions regarding the naming of plant associations were informed by cross-walking candidate community groupings to the National Vegetation Classification (NatureServe 2007). Classification and regression tree analysis (recursive partitioning) was employed in the development of dichotomous keys and the evaluation of classification results using the `rpart` package in (R Development Core Team 2007).

The plant species nomenclature standard identified by the monument was maintained for the analysis to reflect local and regional taxonomic distinctions. Plant nomenclature of the Integrated Taxonomic Information System (ITIS) as reflected by the PLANTS Database (USDA, NRCS 2007) is employed in the naming of plant associations. This is the National Vegetation Classification standard and is necessary to discriminate differences among associations currently reported within the National Vegetation Classification.

Results

The Classification of Plant Communities

Thirty-four plant associations are identified as occurring within the study area. Table 1 provides a summary of the associations described for the monument.

Plant communities are named for the indicator (dominant or diagnostic) species of the vegetative strata present. The indicator species of the uppermost strata is listed first, followed by successively lower strata. Species that occur in the same strata (or are the same lifeform) are separated by a hyphen (-). Indicator species that occur in different strata (or are a different lifeform) are separated by a slash (/). Plant association names incorporate the physiognomic class in which the association is classified (e.g., Forest, Woodland, or Herbaceous) (FGDC 1997, 2006).

Thirty percent of the associations identified within the monument are currently listed in the National Vegetation Classification (as indicated by an assigned element code, Table 1) (NatureServe 2007). Many of these plant associations are known from other sites within the region and are well documented. This study (together with Rust and Wolken 2007), however, provides the first documentation of *Artemisia tridentata* ssp. *wyomingensis* / *Achnatherum hymenoides* Shrubland and *Atriplex confertifolia* / *Achnatherum hymenoides* Shrubland within Idaho. A summary of previous classification work regarding vegetation that occurs within the study area is provided in Appendix 1.

The *Atriplex confertifolia* - *Picrothamnus desertorum* / (*Achnatherum hymenoides*) - *Bromus tectorum* Semi-natural Shrubland association identified for Hagerman Fossil Beds National Monument is similar to *Atriplex confertifolia* - *Picrothamnus desertorum* / *Achnatherum hymenoides* Shrubland, an association recognized within the NVC (NatureServe 2007). The diagnostic species, *Achnatherum hymenoides*, is only present in 1 out of 3 observations considered here.

Approximately two thirds of the associations described in this classification are not recognized by the National Vegetation Classification or have not been described previously. These associations include: (1) semi-natural vegetation (19 associations, Table 1) that, due to the priority of conserving natural vegetation, has not been systematic reviewed nor incorporated into the National Vegetation Classification and (2) plant communities (5 associations) that have not been described previously at the association level. Distinctive plant associations that warrant further consideration for inclusion in the National Vegetation Classification include: *Chrysothamnus viscidiflorus* / *Achnatherum hymenoides* Shrubland, *Eriogonum microthecum* / *Achnatherum hymenoides* Dwarf-shrubland, and *Populus angustifolia* / *Typha latifolia* Woodland.

Table 1. Plant Community Classification. Plant associations observed at Hagerman Fossil Beds National Monument are listed alphabetically by National Vegetation Classification class with scientific name, common name, field code, element code (abbreviated as "elcode"), the total number of observations (Obs.), and the number of stands sampled (N).

Plant Community	Common Name	Code	Elcode	Obs.	N
Woodland					
<i>Elaeagnus angustifolia</i> / <i>Bromus tectorum</i> Semi-natural Woodland	Russian Olive / Cheatgrass Semi-natural Woodland	ELAN/BRTE		5	3
<i>Elaeagnus angustifolia</i> / <i>Leymus cinereus</i> Semi-natural Woodland	Russian Olive / Basin Wildrye Semi-natural Woodland	ELAN/LECI4		3	1
<i>Elaeagnus angustifolia</i> / <i>Poa secunda</i> Semi-natural Woodland	Russian Olive / Curly Bluegrass Semi-natural Woodland	ELAN/POSE		4	4
<i>Elaeagnus angustifolia</i> / <i>Purshia tridentata</i> / <i>Leymus cinereus</i> Semi-natural Woodland	Russian Olive / Bitterbrush / Great Basin Lyme Grass Semi-natural Woodland	ELAN/PUTR2/LECI4		2	2
<i>Elaeagnus angustifolia</i> / <i>Rhus trilobata</i> var. <i>trilobata</i> - <i>Rosa woodsii</i> Semi-natural Woodland	Russian Olive / Skunkbush Sumac - Woods' Rose Semi-natural Woodland	ELAN/RHTRT-ROWO		2	1
<i>Elaeagnus angustifolia</i> / <i>Sarcobatus vermiculatus</i> / Mesic Graminoids Semi-natural Woodland	Russian Olive / Black Greasewood / Mesic Graminoids Semi-natural Woodland	ELAN/SAVE4/Mesic Graminoids		3	1
<i>Populus angustifolia</i> / <i>Typha latifolia</i> Woodland	Narrowleaf Cottonwood / Broadleaf Cattail Woodland	POAN3/TYLA		4	4
<i>Populus balsamifera</i> ssp. <i>trichocarpa</i> - <i>Elaeagnus angustifolia</i> / <i>Bromus tectorum</i> Semi-natural Woodland	Black Cottonwood - Russian Olive / Cheatgrass Semi-natural Woodland	POBAT-ELAN/BRTE		1	1
<i>Ulmus americana</i> / <i>Bromus tectorum</i> Semi-natural Woodland	American Elm / Cheatgrass Semi-natural Woodland	ULAM/BRTE		3	0
Shrubland					
<i>Artemisia tridentata</i> ssp. <i>tridentata</i> / <i>Bromus tectorum</i> Semi-natural Shrubland	Basin Big Sagebrush / Cheatgrass Semi-natural Shrubland	ARTRT/BRTE		4	3
<i>Artemisia tridentata</i> ssp. <i>wyomingensis</i> / <i>Achnatherum hymenoides</i> Shrubland	Wyoming Big Sagebrush / Indian Ricegrass Shrubland	ARTRW8/ACHY	CEGL001046	7	5
<i>Artemisia tridentata</i> ssp. <i>wyomingensis</i> / <i>Bromus tectorum</i> Semi-natural Shrubland	Wyoming Big Sagebrush / Cheatgrass Semi-natural Shrubland	ARTRW8/BRTE		23	14
<i>Artemisia tridentata</i> ssp. <i>wyomingensis</i> / <i>Hesperostipa comata</i> Shrubland	Wyoming Big Sagebrush / Needle-and-Thread Shrubland	ARTRW8/HECO26	CEGL001051	2	2

Plant Community	Common Name	Code	Elcode	Obs.	N
<i>Artemisia tridentata</i> ssp. <i>wyomingensis</i> / <i>Poa secunda</i> Shrubland	Wyoming Big Sagebrush / Curly Bluegrass Shrubland	ARTRW8/POSE	CEGL001049	5	1
<i>Atriplex canescens</i> / <i>Achnatherum hymenoides</i> Shrubland	Fourwing Saltbush / Indian Ricegrass Shrubland	ATCA2/ACHY	CEGL001289	1	0
<i>Atriplex canescens</i> / <i>Bromus tectorum</i> Semi-natural Shrubland	Fourwing Saltbush / Cheatgrass Semi-natural Shrubland	ATCA2/BRTE		8	4
<i>Atriplex confertifolia</i> - <i>Picrothamnus desertorum</i> / (<i>Achnatherum hymenoides</i>) - <i>Bromus tectorum</i> Semi-natural Shrubland	Fourwing Saltbush - Bud Sagebrush / (Indian Ricegrass) - Cheatgrass Semi-natural Shrubland	ATCO-PIDE4/(ACHY)-BRTE		3	3
<i>Atriplex confertifolia</i> / <i>Achnatherum hymenoides</i> Shrubland	Shadscale / Indian Ricegrass Shrubland	ATCO/ACHY	CEGL001311	2	2
<i>Atriplex confertifolia</i> / <i>Bromus tectorum</i> Semi-natural Shrubland	Shadscale / Cheatgrass Semi-natural Shrubland	ATCO/BRTE		3	0
<i>Chrysothamnus viscidiflorus</i> / <i>Achnatherum hymenoides</i> Shrubland	Green Rabbitbrush / Indian Ricegrass Shrubland	CHV18/ACHY		5	4
<i>Ericameria nauseosa</i> - <i>Chrysothamnus viscidiflorus</i> / (<i>Achnatherum hymenoides</i>) - <i>Bromus tectorum</i> Semi-natural Shrubland	Rubber Rabbitbrush - Green Rabbitbrush / (Indian Ricegrass) - Cheatgrass Semi-natural Shrubland	ERNA10-CHV18/(ACHY)-BRTE		5	2
<i>Eriogonum microthecum</i> / <i>Achnatherum hymenoides</i> Dwarf-shrubland	Slender Wild Buckwheat / Indian Ricegrass Dwarf-shrubland	ERMI4/ACHY		6	6
<i>Eriogonum ovalifolium</i> / <i>Achnatherum hymenoides</i> Dwarf-shrubland	Cushion Wild Buckwheat / Indian Ricegrass Dwarf-shrubland	EROV/ACHY		1	0
<i>Krascheninnikovia lanata</i> / <i>Poa secunda</i> Dwarf-shrubland	Winter-fat / Curly Bluegrass Dwarf-shrubland	KRLA2/POSE	CEGL001326	1	1
<i>Purshia tridentata</i> / <i>Achnatherum hymenoides</i> Shrubland	Bitterbrush / Indian Ricegrass Shrubland	PUTR2/ACHY	CEGL001058	4	3
<i>Salix exigua</i> / Mesic Forbs Shrubland	Coyote Willow / Mesic Forbs Shrubland	SAEX/Mesic Forbs	CEGL001202	3	2
<i>Salix lucida</i> ssp. <i>caudata</i> / <i>Thinopyrum intermedium</i> Semi-natural Shrubland	Shiny Willow / Intermediate Wheatgrass Semi-natural Shrubland	SALUC/THIN6		3	1
<i>Sarcobatus vermiculatus</i> / <i>Bromus tectorum</i> Semi-natural Shrubland	Black Greasewood / Cheatgrass Semi-natural Shrubland	SAVE4/BRTE		7	5
<i>Sarcobatus vermiculatus</i> / <i>Leymus cinereus</i> Shrubland	Black Greasewood / Great Basin Lyme Grass Shrubland	SAVE4/LECI4	CEGL001366	1	0

Plant Community	Common Name	Code	Elcode	Obs.	N
Herbaceous Vegetation					
<i>Agropyron cristatum</i> / <i>Sisymbrium altissimum</i> Semi-Natural Vegetation	Crested Wheatgrass / Tall Tumblemustard Semi-natural Vegetation	AGCR/SIAL2		4	4
<i>Bromus tectorum</i> / <i>Sisymbrium altissimum</i> Semi-Natural Vegetation	Cheatgrass / Tall Tumblemustard Semi-Natural Vegetation	BRTE/SIAL2		10	5
<i>Eleocharis palustris</i> Herbaceous Vegetation	Marsh Spikerush Herbaceous Vegetation	ELPA3	CEGL001833	1	1
<i>Lactuca tatarica</i> var. <i>pulchella</i> Semi-natural Herbaceous Vegetation	Blue Lettuce Semi-natural Herbaceous Vegetation	LATAP		1	0
<i>Pascopyrum smithii</i> - <i>Achnatherum hymenoides</i> Herbaceous Vegetation	Western Wheatgrass - Indian Ricegrass Herbaceous Vegetation	PASM-ACHY		1	1

Approximately 55% (19) of the associations identified as occurring on the monument are classified as semi-natural. These associations include vegetation that is dominated by plant species that are not native to North America. The principal exotic species that contribute to the degradation of this vegetation are: *Agropyron cristatum*, *Bromus tectorum*, *Elaeagnus angustifolia*, *Lactuca serriola*, and *Sisymbrium altissimum*.

Three of the associations observed within the monument are also documented by Jankovsky-Jones (2001): *Salix exigua* / Mesic Forbs Shrubland, *Sarcobatus vermiculatus* / *Leymus cinereus* Shrubland, and *Eleocharis palustris* Herbaceous Vegetation. Cole (1995) also describes *Artemisia tridentata* ssp. *tridentata* / *Bromus tectorum* Semi-natural Shrubland.

Dichotomous Key to the Classification

The field key to plant communities of the monument follows. The key is structured into physiognomic classes (or lifeform groups). These classes do not constraint the classification *per se*, rather they are employed to assist in applying the classification. In the field, different expressions of a given plant association may occur as different physiognomic classes. Given this, several associations may be found through multiple pathways within the key.

Use of the Key

To use the field key most effectively, identify a representative, homogeneous stand of vegetation. Work through the entire hierarchy of the key, beginning with Key to Lifeform Groups to each sequential dichotomous lead. Estimate plant cover on an area of approximately 405m². If a satisfactory determination is not made in stands with low total cover consider adjusting diagnostic species cover break points downward. Assignment of individual species to lifeform follows USDA, NRCS (2007).

In the key the term relative cover is used. In this context relative cover refers to the proportional abundance of the given species (or group of species) with respect to the total abundance of the associated lifeform. The value is calculated by dividing the percent cover of the species (or group of species) under consideration by the total cover of the respective lifeform. For example, the relative cover of native grass species is calculated as follows: (sum of native grass species cover within the sample) / (total cover of all graminoids within the sample) = (relative native grass composition).

Key to Lifeform Groups

- 1a) Tree canopy cover (*Elaeagnus angustifolia*, *Fraxinus pennsylvanica*, *Populus angustifolia*, *Populus balsamifera* ssp. *trichocarpa*, *Salix amygdaloides*, or *Ulmus americana*) >10%, **Part A: Forest, Woodland, and Savannah**, lead 4a.
- 1b) Tree canopy cover <10%, lead 2a.
 - 2a) Shrub canopy cover >10%, **Part B: Shrublands and Shrub-Steppe**, lead 12a.
 - 2b) Shrub canopy cover <10%, lead 3a.
 - 3a) Vascular plant cover >10%, **Part C: Herbaceous Vegetation**, lead 31a.
 - 3b) Vascular plant cover <10%, **PASM-ACHY** (Sparse Vegetation).

Part A: Forest, Woodland, and Savannah

- 4a) *Populus balsamifera* ssp. *trichocarpa* $\geq 5\%$ cover, **POBAT-ELAN/BRTE**.
- 4b) *Populus balsamifera* ssp. *trichocarpa* $< 5\%$ cover, lead 5a.
 - 5a) *Populus angustifolia* $\geq 5\%$ cover, **POAN3/TYLA**.
 - 5b) *Populus angustifolia* $< 5\%$ cover, lead 6a.
 - 6a) *Elaeagnus angustifolia* $\geq 4\%$ cover, lead 7a.
 - 7a) *Sarcobatus vermiculatus* $\geq 1\%$ cover, **ELAN/SAVE4/Mesic Graminoids**.
 - 7b) *Sarcobatus vermiculatus* $< 1\%$ cover, lead 8a.
 - 8a) *Rhus trilobata* var. *trilobata* $\geq 4\%$ cover, **ELAN/RHTRT-ROWO**.
 - 8b) *Rhus trilobata* var. *trilobata* $< 4\%$ cover, lead 9a.
 - 9a) *Purshia tridentata* $\geq 4\%$ cover, **ELAN/PUTR2/LECI4**.
 - 9b) *Purshia tridentata* $< 4\%$ cover, 10a.
 - 10a) Native grass composition $\geq 30\%$ relative cover, lead 11a.
 - 11a) *Leymus cinereus* $\geq 1\%$ cover, **ELAN/LECI4**.
 - 11b) *Leymus cinereus* $< 1\%$ cover, **ELAN/POSE**.
 - 10b) Native grass composition $< 30\%$ relative cover, **ELAN/BRTE**.
 - 6b) *Elaeagnus angustifolia* $< 4\%$ cover, **ULAM/BRTE**.

Part B: Shrublands and Shrub-Steppe

- 12a) *Elaeagnus angustifolia* $\geq 5\%$ cover, lead 6a (above).
- 12a) *Elaeagnus angustifolia* $< 5\%$ cover, lead 13a.
 - 13a) *Salix exigua* $\geq 4\%$ cover, **SAEX/Mesic Forbs**.
 - 13a) *Salix exigua* $< 4\%$ cover, lead 14a.
 - 14a) *Salix lucida* ssp. *caudata* $> 5\%$ cover, **SALUC/THIN6**.
 - 14b) *Salix lucida* ssp. *caudata* $< 5\%$ cover, lead 7a.
 - 15a) *Artemisia tridentata* ssp. *wyomingensis* $\geq 4\%$ cover, lead 16a.
 - 16a) Native grass composition $\geq 30\%$ relative cover, lead 17a.
 - 17a) *Hesperostipa comata* ssp. *comata* is present, **ARTRW8/HECO26**.
 - 17b) *Hesperostipa comata* ssp. *comata* is absent, lead 18a.
 - 18a) *Achnatherum hymenoides* is present, **ARTRW8/ACHY**.
 - 18b) *Achnatherum hymenoides* is present, **ARTRW8/POSE**.
 - 16b) Native grass composition $< 30\%$ relative cover, **ARTRW8/BRTE**.
 - 15b) *Artemisia tridentata* ssp. *wyomingensis* $< 4\%$ cover, lead 19a.
 - 19a) *Atriplex canescens* var. *canescens* $\geq 2\%$ cover, lead 20a.
 - 20a) *Achnatherum hymenoides* $\geq 2\%$ cover, **ATCA2/ACHY**.
 - 20b) *Achnatherum hymenoides* $< 2\%$ cover, **ATCA2/BRTE**.
 - 19a) *Atriplex canescens* var. *canescens* $> 2\%$ cover, lead 21a.
 - 21a) *Eriogonum microthecum* var. *laxiflorum* $\geq 2\%$ cover, **ERMI4/ACHY**.
 - 21a) *Eriogonum microthecum* var. *laxiflorum* $< 2\%$ cover, lead 22a.
 - 22a) *Artemisia tridentata* ssp. *tridentata* $\geq 2\%$ cover, **ARTRT/BRTE**.
 - 22b) *Artemisia tridentata* ssp. *tridentata* $< 2\%$ cover, lead 23a.
 - 23a) *Sarcobatus vermiculatus* $\geq 1\%$ cover, lead 24a.
 - 24a) *Leymus cinereus* $\geq 5\%$ cover, **SAVE4/LECI4**.
 - 24b) *Leymus cinereus* $< 5\%$ cover, **SAVE4/BRTE**.
 - 23b) *Sarcobatus vermiculatus* $< 1\%$ cover, lead 25a.

- 25a) *Purshia tridentata* $\geq 2\%$ cover, **PUTR2/ACHY**.
- 25b) *Purshia tridentata* $< 2\%$ cover, lead 25a.
 - 26a) *Krascheninnikovia lanata* $\geq 2\%$ cover, **KRLA2/POSE**.
 - 26b) *Krascheninnikovia lanata* $> 2\%$ cover, lead 27a.
 - 27a) *Atriplex confertifolia* $\geq 1\%$ cover, lead 28a.
 - 28a) *Picrothamnus desertorum* is present, **ATCO-PIDE4/(ACHY)-BRTE**.
 - 28b) *Picrothamnus desertorum* is absent, lead 29a.
 - 29a) *Achnatherum hymenoides* is present, **ATCO/ACHY**.
 - 29b) *Achnatherum hymenoides* is absent, **ATCO/BRTE**.
 - 27b) *Atriplex confertifolia* $< 1\%$ cover, lead 30a.
 - 30a) *Ericameria nauseosa* $\geq 2\%$ cover, **ERNA10-CHVI8/(ACHY)-BRTE**.
 - 30b) *Ericameria nauseosa* $< 2\%$ cover, **CHVI8/ACHY**.

Part C: Herbaceous Vegetation

- 31a) Total shrub cover $\geq 3\%$ cover, lead 13a (Part B, above).
- 31a) Total shrub cover $< 3\%$ cover, lead 32a.
 - 32a) Native grass composition $\geq 50\%$ cover, lead 33a.
 - 33a) *Achnatherum hymenoides* $\geq 2\%$ cover, **EROV/ACHY**.
 - 33a) *Achnatherum hymenoides* $< 2\%$ cover, lead 34a.
 - 34a) *Eleocharis palustris* $\geq 5\%$ cover, **ELPA3**.
 - 34b) *Eleocharis palustris* $< 5\%$ cover, **POAN3/TYLA**.
 - 32b) Native grass composition $> 50\%$ cover, lead 35a.
 - 35a) *Lactuca tatarica* var. *pulchella* $> 5\%$ cover, **LATAP**.
 - 35b) *Lactuca tatarica* var. *pulchella* $< 5\%$ cover, lead 36a.
 - 36a) *Agropyron cristatum* $\geq 4\%$ cover, **AGCR/SIAL2**.
 - 36b) *Agropyron cristatum* $< 4\%$ cover, **BRTE/SIAL2**.

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Appendix 1. Summary of pertinent classification literature. Local and regional literature regarding the classification of vegetation found within Hagerman Fossil Beds National Monument is listed alphabetically by plant association within physiognomic class.

Scientific Name	References
Shrubland	
<i>Artemisia tridentata</i> ssp. <i>wyomingensis</i> - <i>Atriplex confertifolia</i> Shrubland	Reid et al. 2002
<i>Artemisia tridentata</i> ssp. <i>wyomingensis</i> / <i>Achnatherum hymenoides</i> Shrubland	Reid et al. 2002
<i>Artemisia tridentata</i> ssp. <i>wyomingensis</i> / <i>Hesperostipa comata</i> Shrubland	Hironaka et al. 1983, Kagan et al. 2004, Reid et al. 2002, Rust and Miller 2008
<i>Artemisia tridentata</i> ssp. <i>wyomingensis</i> / <i>Poa secunda</i> Shrubland	Hironaka et al. 1983, Jensen et al. 1988, Kagan et al. 2000, Kagan et al. 2004, Reid et al. 2002, Rust and Miller 2008
<i>Atriplex confertifolia</i> / <i>Achnatherum hymenoides</i> Shrubland	Kagan et al. 2000, Kagan et al. 2004
<i>Krascheninnikovia lanata</i> / <i>Poa secunda</i> Dwarf-shrubland Dwarf-shrubland	Daubenmire 1970, Kagan et al. 2000
<i>Purshia tridentata</i> / <i>Achnatherum hymenoides</i> Shrubland	Idaho Natural Heritage Program et al. 1986, Kagan et al. 2000, Kagan et al. 2004
<i>Salix exigua</i> / Mesic Forbs Shrubland	Jankovsky-Jones 2001, Jankovsky-Jones et al. 2001, Manning and Padgett 1995, Padgett et al. 1989
<i>Sarcobatus vermiculatus</i> / <i>Leymus cinereus</i> Shrubland	Jankovsky-Jones 2001, Jankovsky-Jones et al. 2001, Kagan et al. 2000, Mueggler and Stewart 1980, Tweit and Houston 1980
Herbaceous Vegetation	
<i>Eleocharis palustris</i> Herbaceous Vegetation	Carsey et al. 2003, Crawford 2003, Crowe and Clausnitzer 1997, Crowe et al. 2004, Evans 1989, Hall and Hansen 1997, Hansen et al. 1995, Jankovsky-Jones 2001, Kagan et al. 2000, Kittel et al. 1999, Kovalchik 1987, Kovalchik 1993, Padgett et al. 1989

Appendix 2. Synthesis tables. The species compositions of plant associations that were sampled on 4 or more plots are summarized. The synthesis tables are organized alphabetically by physiognomic class: Part A: Woodlands; Part B: Shrublands; and Part C: Herbaceous Vegetation. Species composition data is summarized as percent frequency followed by characteristic cover (the later shown in parentheses). For the purpose of comparison, species lists are selected by physiognomic class. In some instances blank rows will appear as the summary for a given physiognomic class may span over several pages. Please refer to Table 1 for association sample sizes.

Part A. Woodlands

Species	ELAN/BRTE	ELAN/POSE	ELAN/SAVE4/ Mes. Gram.	POAN3/TYLA
Trees				
Elaeagnus angustifolia	100 (46.3)	100 (41.7)	100 (15)	50 (8.5)
Populus angustifolia	50 (2)			100 (13)
Shrubs				
Artemisia tridentata ssp. tridentata	25 (0.1)			50 (0.1)
Artemisia tridentata ssp. wyomingensis	25 (0.1)	67 (0.1)		
Atriplex confertifolia	25 (0.1)			
Ericameria nauseosa		33 (0.1)	100 (0.1)	
Ribes aureum	25 (0.1)		100 (0.1)	25 (2)
Rosa woodsii var. ultramontana				25 (0.1)
Salix exigua	25 (0.1)			50 (3.5)
Salix melanopsis	25 (0.1)			25 (0.1)
Graminoids				
Agropyron cristatum	50 (0.6)	67 (0.1)		
Bromus tectorum	75 (10)	100 (2.7)	100 (0.1)	25 (0.1)
Eleocharis palustris			100 (1)	25 (0.1)
Hordeum jubatum		67 (0.6)		25 (0.1)
Poa secunda		100 (10.1)	100 (70)	
Polypogon monspeliensis				50 (0.1)
Forbs				
Arctium minus	25 (1)			
Asteraceae	50 (0.6)			25 (0.1)
Chenopodium album	25 (0.1)			75 (0.1)
Chenopodium fremontii var. fremontii		67 (1.1)		
Cirsium arvense	25 (1)	33 (1)		25 (2)
Cirsium canovirens			100 (0.1)	
Descurainia sophia	25 (0.1)	33 (0.1)		
Dipsacus fullonum			100 (2)	50 (0.6)
Helianthus annuus		33 (0.1)		25 (0.1)
Lactuca serriola	50 (0.1)	33 (0.1)		25 (0.1)

Species	ELAN/BRTE	ELAN/POSE	ELAN/SAVE4/ Mes. Gram.	POAN3/TYLA
Lemna minor				75 (0.4)
Rorippa nasturtium-aquaticum	25 (0.1)			25 (0.1)
Rumex crispus	50 (0.1)			50 (0.1)
Sisymbrium altissimum	50 (1.1)	67 (0.1)		25 (0.1)
Solanum dulcamara	50 (0.1)			75 (5.1)
Solidago canadensis var. salebrosa				25 (1)
Stanleya pinnata	25 (0.1)			
Trifolium repens		33 (0.1)		
Typha latifolia				75 (21.7)
Unknown species	50 (0.3)			100 (6.3)
Veronica anagallis-aquatica	25 (0.1)			50 (0.1)

Part B: Sublands

Species	ARTRT/ B RTE	ARTRW8/ ACHY	ARTRW8/ B RTE Shrub Herb.	ARTRW8/ B RTE Shrubland	ARTRW8/ HECO26
Shrubs					
Artemisia arbuscula			14 (0.1)		
Artemisia tridentata ssp. tridentata	10 0 (28.3)				
Artemisia tridentata ssp. wyomingensis		100 (8.1)	100 (10)	10 0 (28.3)	10 0 (13.8)
Atriplex canescens var. canescens	33 (0.1)	57 (0.6)	29 (1.1)		50 (1.1)
Atriplex confertifolia	67 (2)	29 (0.1)	14 (0.1)	67 (1.1)	25 (1)
Chrysothamnus viscidiflorus ssp. viscidiflorus		100 (2.6)	57 (3)	33 (5)	75 (3.4)
Ericameria nauseosa		86 (0.6)	29 (0.1)		50 (1.1)
Eriogonum microthecum var. laxiflorum		57 (1)			
Purshia tridentata		29 (0.1)			25 (0.1)
Sarcobatus vermiculatus	33 (0.1)	14 (2)	43 (5.7)	33 (2)	
Graminoids					
Agropyron cristatum		14 (0.1)	29 (0.1)	67 (2.6)	50 (0.1)
Bromus japonicus					25 (0.1)
Bromus tectorum	10 0 (23.3)	100 (1.9)	100 (15)	10 0 (11.7)	100 (8)
Elymus elymoides		100 (0.9)	71 (0.3)	33 (0.1)	100 (1.8)
Poa secunda		100 (3.5)	43 (0.2)	33 (0.2)	100 (0.7)
Forbs					
Amsinckia tessellata					25 (0.1)
Astragalus atratus var. owyheensis		14 (0.1)			
Astragalus caricinus		43 (0.1)			
Astragalus purshii var. glareosus		43 (0.1)	14 (0.1)		
Astragalus toanus		43 (0.1)			
Astragalus whitneyi var. confusus		43 (0.4)			
Balsamorhiza sagittata		71 (0.1)			
Camelina microcarpa					
Castilleja angustifolia var. angustifolia		29 (0.1)			
Chaenactis douglasii		14 (0.1)			
Cirsium arvense	33 (5)				
Crepis acuminata		71 (0.1)	29 (0.6)		50 (0.6)
Cryptantha spiculifera					
Descurainia sophia	33 (0.1)	29 (0.1)	29 (0.1)	67 (0.1)	50 (0.1)
Dipsacus fullonum					
Erigeron pumilus ssp. intermedius var. gracilior		29 (0.1)	14 (0.1)		50 (0.1)

Species	ARTRT/ B RTE	ARTRW8/ ACHY	ARTRW8/ B RTE Shrub Herb.	ARTRW8/ B RTE Shrubland	ARTRW8/ HECO26
Eriogonum ovalifolium		43 (0.1)			
Eriogonum umbellatum					
Eriogonum watsonii		14 (0.1)			
Eriophyllum lanatum var. integrifolium					
Helianthus annuus					
Lactuca serriola	67 (0.1)	86 (0.1)	71 (0.1)	33 (0.1)	75 (0.1)
Leptodactylon pungens		43 (1.3)			25 (0.1)
Lupinus leucophyllus		14 (1)			
Orthocarpus purpureoalbus		29 (0.1)			
Penstemon		14 (0.1)			
Phlox longifolia ssp. longifolia		43 (0.1)	57 (0.1)		25 (0.1)
Salsola kali	33 (1)				
Senecio					25 (0.1)
Sisymbrium altissimum	100 (0.1)	29 (0.1)	86 (3)		100 (0.1)
Stanleya pinnata	67 (0.1)	57 (0.8)	14 (0.1)		
Tragopogon dubius		14 (0.1)	14 (0.1)		

Part B: Shrublands (continued).

Species	ATCA2/ B RTE	ATCO/ ACHY	ERMI4/ ACHY	PUTR2/ ACHY	SALUC/ THIN6	SAVE4/ B RTE
Shrubs						
Artemisia arbuscula	50 (0.1)					
Artemisia tridentata ssp. tridentata				50 (1)		40 (1.5)
Artemisia tridentata ssp. wyomingensis	50 (5)	100 (0.1)	100 (0.9)	100 (1.1)	100 (0.1)	60 (2.4)
Atriplex canescens var. canescens	100 (10)		17 (0.1)			60 (2.3)
Atriplex confertifolia	50 (0.1)	100 (3)	17 (0.1)	100 (0.6)		40 (5)
Chrysothamnus viscidiflorus ssp. viscidiflorus	50 (5)	50 (0.1)	100 (2.5)	100 (1.5)		40 (0.1)
Ericameria nauseosa		100 (2)	83 (0.8)	100 (3)	100 (1)	
Eriogonum microthecum var. laxiflorum		50 (0.1)	100 (5.8)			
Purshia tridentata		50 (1)	33 (1.1)	100 (10)		
Sarcobatus vermiculatus						100 (5.6)
Graminoids						
Agropyron cristatum						20 (0.1)
Bromus japonicus						
Bromus tectorum	100 (3.5)	100 (3.5)	100 (1.6)	100 (5)	100 (1)	100 (18)
Elymus elymoides	50 (0.1)	50 (0.1)	100 (0.4)	50 (0.1)		20 (0.1)
Poa secunda	100 (1.1)		100 (5.4)			20 (0.2)
Forbs						
Amsinckia tessellata						20 (0.1)
Astragalus atratus var. owyheensis			17 (0.1)			
Astragalus caricinus						
Astragalus purshii var. glareosus		100 (0.1)	67 (0.1)	50 (0.1)		
Astragalus toanus		50 (0.1)	50 (0.1)			
Astragalus whitneyi var. confusus			17 (2)	50 (1)		
Balsamorhiza sagittata		50 (1)	83 (0.5)	100 (0.6)		
Camelina microcarpa		50 (0.1)				
Castilleja angustifolia var. angustifolia			67 (0.1)			
Chaenactis douglasii		100 (0.1)	50 (0.1)			
Cirsium arvense					100 (2)	
Crepis acuminata			33 (0.1)			
Cryptantha spiculifera			33 (0.1)			
Descurainia sophia	50 (0.1)	50 (0.1)	33 (0.1)		100 (0.1)	100 (0.1)
Dipsacus fullonum					100 (0.1)	
Erigeron pumilus ssp. intermedius var. gracilior						
Eriogonum ovalifolium		50 (1)	67 (0.1)			

Species	ATCA2/ BRTE	ATCO/ ACHY	ERM14/ ACHY	PUTR2/ ACHY	SALUC/ THIN6	SAVE4/ BRTE
Eriogonum umbellatum			17 (0.1)	50 (0.1)		
Eriogonum watsonii		100 (0.1)				
Eriophyllum lanatum var. integrifolium			50 (0.1)			
Helianthus annuus	50 (0.1)					
Lactuca serriola	100 (0.1)	50 (0.1)	83 (0.1)		100 (0.1)	40 (0.1)
Leptodactylon pungens	50 (0.1)		33 (2)	50 (0.1)		
Lupinus leucophyllus			17 (0.1)			
Orthocarpus purpureoalbus			33 (0.1)			
Penstemon			50 (0.1)			
Phlox longifolia ssp. longifolia			17 (0.1)			20 (0.1)
Salsola kali		50 (0.1)	17 (0.1)			20 (0.1)
Senecio			17 (0.1)			
Sisymbrium altissimum		50 (0.1)	17 (0.1)	50 (1)		100 (1.5)
Stanleya pinnata		100 (1.1)	67 (0.3)	100 (2.6)		40 (1)
Tragopogon dubius				50 (0.1)	100 (0.1)	

Part C: Herbaceous Vegetation.

Species	AGCR/SIAL2	BRTE/SIAL2
Shrubs		
Artemisia tridentata ssp. wyomingensis	25 (0.1)	
Atriplex confertifolia	25 (0.1)	20 (0.1)
Chrysothamnus viscidiflorus ssp. viscidiflorus	50 (1.1)	
Ericameria nauseosa		40 (0.1)
Graminoids		
Agropyron cristatum	100 (22.5)	20 (0.1)
Bromus tectorum	75 (1.3)	100 (27)
Poa secunda	75 (0.8)	
Forbs		
Astragalus whitneyi var. confusus	50 (0.1)	20 (0.1)
Chorispora tenella	25 (2)	20 (0.1)
Descurainia sophia	50 (0.1)	80 (2.6)
Lactuca serriola	100 (0.1)	80 (0.1)
Salsola kali		40 (0.1)
Sisymbrium altissimum	100 (0.8)	100 (4.6)
Tragopogon dubius		20 (0.1)

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