Plant functional group diversity as a mechanism for invasion resistance
by Monica Lynn Pokorny

A thesis submitted in partial fulfillment of the requirements for the degree of Masters of Science in Land Resources and Environmental Sciences
Montana State University
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Abstract:
The current rate of nonindigenous plant invasion has important ramifications to indigenous ecosystems. A proposed mechanism for invasion resistance is that diverse plant assemblages enhance niche occupation and preempt resources otherwise available to invaders. Unfortunately, research on diversity as a mechanism for resistance has confounding results. The purpose of this study was to quantify species and functional group diversity in a grassland plant community in Montana, investigate the ability of plant functional groups to resist invasion by a nonindigenous species, and to quantify and compare portions of the nutrient and hydrologic cycles of the following indigenous functional groups; grasses, shallow-rooted forbs, deep-rooted forbs, spikemoss, and the nonindigenous invader, Centaurea maculosa. The study consisted of a factorial combination of seven functional group removals (groups singularly or in combination) and two C maculosa treatments (seeded vs. absent) applied in a randomized-complete-block design replicated four times at two sites. Diversity by functional group was recorded in 2000. I documented a higher diversity than has previously been described for the Festuca idahoensis/Agropyron spicatum habitat type and found forbs represented the majority of the richness and biomass of the grassland community. Centaurea maculosa density was counted in 2001 and analyzed using ANOVA. Centaurea maculosa density depended upon the functional groups removed. The highest C maculosa densities occurred where all vegetation (50 plants m'2) or all forbs (18 plants m"2) were removed from plots. Centaurea maculosa densities were the lowest (2-7 plants m"2) in plots where nothing, shallow-rooted forbs, deep-rooted forbs, grass, or spikemoss were removed. Functional group biomass was collected and analyzed for N, P, K, and S. ANOVA indicated percent tissue concentration and nutrient uptake differed among functional groups. Centaurea maculosa tissue nutrient percent was most similar to shallow-rooted forbs. Similarly, indigenous forb functional groups were most similar in nutrient uptake levels to C. maculosa. This study suggests forbs are an important component to grassland community diversity, and establishing and maintaining a diversity of plant functional groups within the community enhances resistance to invasion. Indigenous forbs were particularly important to resisting invasion by nonindigenous forbs. Since indigenous forbs were functionally similar in percent tissue concentration and plant nutrient uptake to the nonindigenous forb, they may be increasing resource competition with C. maculosa and decreasing invasion success. Functional group diversity and forb diversity should be a larger consideration in invasive plant management.

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FOR INVASION RESISTANCE

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# APPROVAL

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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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## ABSTRACT

The current rate of nonindigenous plant invasion has important ramifications to indigenous ecosystems. A proposed mechanism for invasion resistance is that diverse plant assemblages enhance niche occupation and preempt resources otherwise available to invaders. Unfortunately, research on diversity as a mechanism for resistance has confounding results. The purpose of this study was to quantify species and functional group diversity in a grassland plant community in Montana, investigate the ability of plant functional groups to resist invasion by a nonindigenous species, and to quantify and compare portions of the nutrient and hydrologic cycles of the following indigenous functional groups; grasses, shallow-rooted forbs, deep-rooted forbs, spikemoss, and the nonindigenous invader, *Centaurea maculosa*. The study consisted of a factorial combination of seven functional group removals (groups singularly or in combination) and two *C. maculosa* treatments (seeded vs. absent) applied in a randomized-complete-block design replicated four times at two sites. Diversity by functional group was recorded in 2000. I documented a higher diversity than has previously been described for the *Festuca idahoensis/Agropyron spicatum* habitat type and found forbs represented the majority of the richness and biomass of the grassland community. *Centaurea maculosa* density was counted in 2001 and analyzed using ANOVA. *Centaurea maculosa* density depended upon the functional groups removed. The highest *C. maculosa* densities occurred where all vegetation (50 plants m$^{-2}$) or all forbs (18 plants m$^{-2}$) were removed from plots. *Centaurea maculosa* densities were the lowest (2-7 plants m$^{-2}$) in plots where nothing, shallow-rooted forbs, deep-rooted forbs, grass, or spikemoss were removed. Functional group biomass was collected and analyzed for N, P, K, and S. ANOVA indicated percent tissue concentration and nutrient uptake differed among functional groups. *Centaurea maculosa* tissue nutrient percent was most similar to shallow-rooted forbs. Similarly, indigenous forb functional groups were most similar in nutrient uptake levels to *C. maculosa*. This study suggests forbs are an important component to grassland community diversity, and establishing and maintaining a diversity of plant functional groups within the community enhances resistance to invasion. Indigenous forbs were particularly important to resisting invasion by nonindigenous forbs. Since indigenous forbs were functionally similar in percent tissue concentration and plant nutrient uptake to the nonindigenous forb, they may be increasing resource competition with *C. maculosa* and decreasing invasion success. Functional group diversity and forb diversity should be a larger consideration in invasive plant management.

# CHAPTER 1

## INTRODUCTION

Nonindigenous plants have invaded and now dominate millions of hectares of grasslands throughout western North America (Sheley and Petroff 1999). The current rate of nonindigenous plant invasion is an anthropogenic process with important ramifications to our native ecosystems (Rejmanek 1996, Vitousek et al. 1997). Nonindigenous plants may be permanently altering the structure and function of indigenous ecosystems (Mack and D'Antonio 1998, Olson 1999). Research implies invasive plant species can degrade soil and water resources (Lacey et al. 1989), reduces wildlife and livestock habitat and forage (Hakim 1979), and alter community structure by decreasing the density, biomass, and basal area associated with indigenous plant communities (Olson 1999, Christain and Wilson 1999, Kedzie-Webb et al. 2001).

Most current invasive plant strategies are technology or tool based and rarely meet long-term management objectives. Successful invasive plant management will require a shift from that of invasive plant control to developing and maintaining plant communities that function at a sustainable level and resist invasion. Invasive plant management must be based on the principles and concepts directing plant community dynamics (Sheley et al. 1996). These principles must be founded in ecology, the basic science behind land management, and must focus on establishing and/or maintaining desired plant communities, rather than simply controlling unwanted plants. An objective of sustainable invasive plant management will be to develop plant communities that are relatively weed-

resistant, while meeting other land use objectives, such as forage production, wildlife habitat development, or recreational land maintenance (Sheley et al. 1996).

Susceptibility of western North America grasslands to invasion may be influenced by community structure and/or resource availability (Elton 1958, Burke and Grime 1996, Stolgren et al. 1999). The composition of North American grasslands has been described in plant community classifications. The focus of these classifications has been on managing grasses for livestock production and less attention has been given to other vegetative life-form's diversity, composition, and response to management (Daubenmire 1970, Mueggler and Stewart 1980). If plant community structure can effect the invasibility of a plant community, a more thorough description is needed of indigenous species and functional group diversity throughout a growing season in western North American grasslands. This may require a change from traditional field sampling techniques. Plant community structure may also be mechanistically linked to invasion through resource availability. One of the most commonly cited mechanisms for invasion resistance is that diverse plant assemblages use resources more completely (Levine and D'Antonio 1999, Tilman 1997). Thus increased indigenous functional diversity preempts available resources (Dukes 2001, Davis and Pelsor 2001) and decreases invader recruitment (Robinson et al. 1995). Research clarifying resource-based invasion mechanisms is needed because support of these hypotheses is confounding and incomplete. The potential for a particular functional group, or combination of functional groups, to resist invasion could have important implications for invasive plant management.

If the goal of sustainable invasive plant management is to direct plant communities to a desired state, then ecologist and land managers need an understanding the ecological role of indigenous and nonindigenous functional groups. To date, little is known about the ecological role of indigenous species, or functional groups of species, and nonindigenous invaders occurring within grasslands. Furthermore, little is known about plant function and ecosystem processes as functional group diversity changes. Altering plant functional group diversity and composition may influence the nutrient and water cycling within the plant community and effect its invasibility (Hooper and Vitousek 1997, Tilman 1997, Dukes 2001). Understanding the ecological role of indigenous and nonindigenous functional groups is important because it provides basic information about plant community dynamics and ecological impacts of invaders. It also provides baseline information necessary for developing restoration goals, assessing the effects of management, and directing plant communities to a desired state (Picket et al. 1987, McLendon and Redente 1991, Sheley et al. 1996). Therefore, understanding the ecological role of various functional groups would provide a basis for designing and maintaining weed-resistant plant communities.

This research investigates ecological principles related to invasive plant management. The study had three specific objectives and several hypotheses:

I. <u>To quantify the functional diversity of a grassland ecosystem</u>. Specific objectives were to measure the richness and density of functional groups within the grassland community, measure the biomass of each functional group, and calculate diversity indices for each functional group. I hypothesized that the species and functional group diversity would be

greater than previous descriptions of the *Festuca idahoensis/Agropyron spicatum* habitat type of a given location because of my multiple-visits method of describing the community. Of the species present, I hypothesized that forb functional groups account for the majority of the richness and biomass of a grassland plant community.

II. <u>To investigate the ability of functional groups (singularly or in combination) to resist invasion by a nonindigenous species, *Centaurea maculosa* (spotted knapweed).</u> I hypothesized that removing a functional group would yield higher *C. maculosa* densities and biomass than the control, and that *C. maculosa* density and biomass would increase as functional groups were progressively removed. I also hypothesized that removing forb functional groups would increase *C. maculosa* biomass and density more than removing grasses because indigenous and nonindigenous forbs may share physiological and morphological traits and ecosystem function.

III. <u>To quantify the ecological role of indigenous functional groups and a nonindigenous invader.</u> My specific objectives were to quantify portions of the nitrogen (N), phosphorus (P), potassium (K), sulfur (S), carbon (C), and water cycles of the following indigenous functional groups: shallow-rooted forbs, deep-rooted forbs, grasses, spikemoss, and a nonindigenous invader, *Centaurea maculosa*. I hypothesized that indigenous functional groups have different ecological roles, and that removing a functional group would alter the soil nutrient and hydrologic cycles, with the impact increasing with removal intensity. I also hypothesized indigenous and nonindigenous forbs would have similar ecological roles cycling N, P, K, S, and C in plant tissue because they share morphological and physiological traits. Because nonindigenous invaders are thought to impact ecosystem

processes, I hypothesized *C. maculosa* would alter soil nutrient and water cycles, and that

the presence of *C. maculosa* would alter an indigenous functional groups ability to capture

resources.

Specific objectives and hypotheses are addressed separately in Chapters 2, 3, and

4. A general review of the results of this study are presented in Chapter 5.

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CHAPTER 2

DIVERSITY OF FUNCTIONAL GROUPS IN A GRASSLAND PLANT
COMMUNITY: EVIDENCE FOR FORBS AS A CRITICAL
MANAGEMENT CONSIDERATION

Introduction

Grasslands are the largest vegetative form on earth, comprising 24% of the worlds

vegetation, and about 125 M hectares of the United States (Sims and Risser 2000). Near

the start of the 20th century, descriptions of grasslands focused on understanding the value

of species for livestock grazing, and little quantitative data was used to describe plant

community productivity or species composition and function in the system (Kearney et al.

1914, Shantz and Piemeisel 1924). Grasslands soon began to be described by their

particular climax plant community. Clements (1920) classified and described the

grasslands of the western United States as one of five grassland formations. Since

Clements, ecologists have recognized and described finer level classifications of the

grasslands. Stoddart and Smith (1943) described 18 range types, based on presence and

abundance of characteristic plant species. More recent classifications of grassland habitat

types in the northwestern United States identified major grassland vegetation types, seral

stages of each type, and response to grazing management practices (Daubenmire 1970,

Mueggler and Stewart 1980). A common trend of these classification systems is the

vegetative type's grass species nomenclature and the emphasis on managing grass for

livestock production (Stoddart and Smith1943, Daubenmire 1970, Mueggler and Stewart 1980, Willoughby et al. 1998).

While forbs species are listed as diverse components of grassland communities (Daubenmire 1970, Sims et al. 1978, Jensen et al. 1988b, Mueggler and Stewart 1980, Hogg et al. 2001), they have not been a primary focus in classification and land management practices (Willoughby et al. 1998, Fuhlendorf and Engle 2001), perhaps because forb species composition varies with environmental and biological factors (MacCracken et al.1983), or because forbs have the greatest production variability within habitat types (Jensen et al. 1988a). Conversely, year-to-year and site-to-site variation of forbs may be a function of methodology limitations in these classifications. Vegetative classifications have historically documented species composition only once during the growing season (Stoddart and Smith1943, Daubenmire 1970, Mueggler and Stewart 1980, Jensen et al. 1988b). Depending on annual variation in climate, early or late developing forbs may have been missed in data collection for classification descriptions. Measuring diversity once, at peak standing crop, does not account for the diversity of spring or fall forbs. To estimate the actual community diversity and the diversity of forbs within a site, periodic field sampling must occur.

Ecologists and land managers have recognized the importance of diverse plant communities in maintaining healthy ecosystems (Darwin 1859, Elton 1958, MacArthur and Wilson 1967, Goodman 1975, Pimm 1991). It is possible that forbs, or groups of forbs with similar characteristics, are important management groups and play a vital role in ecosystem functions such as invasion resistance and nutrient cycling (Symstad 2000,

Dukes 2001, Tilman et al. 2001). We investigated the ecological role of indigenous groups of forbs in companion papers (Chapters 3 and 4) to further develop the concept of forb diversity as a critical management group. In spite of the potential role of forbs in plant community processes, only limited attention is given to their composition in grasslands during management practices. The role of various components, particularly forbs, need to be considered more seriously in future grassland management.

The purpose of this research was to quantify species and functional group diversity in a grassland plant community in southwestern Montana. Our first specific objective was to identify the plant species in the grassland and separate the species into functional groups, based on their morphology and physiology, to provide important management units. Other specific objectives were to measure the richness and density of functional groups within the grassland community, measure the biomass of each functional group, and calculate diversity indices for each functional group. Additionally, we classified the soils and quantified site and season soil nutrient levels. We hypothesized that the species and functional group richness would be greater than previous descriptions of the habitat type of a given location because of our multiple-visits method of quantifying the community. Of the species present, we hypothesized that forb functional groups account for the majority of the richness and biomass of a grassland plant community.

## Methods

### Study sites

This study was conducted on two sites within the *Festuca idahoensis/Agropyron spicatum* habitat type (Mueggler and Stewart 1980). This habitat type lies at the cool-wet end of grassland habitat types and can be found at elevations ranging from 1,400 to 2,300 meters. Predominant indigenous perennial grasses include Idaho fescue (*Festuca idahoensis* Elmer) and bluebunch wheatgrass (*Agropyron spicatum* Pursh). The proportion of forbs to graminiods varies with location for this habitat type (Mueggler and Stewart 1980). Some predominant indigenous forbs in the system include prairie sage (*Artemisia ludoviciana* L.), arrowleaf balsamroot (*Balsamorhiza sagittata* [Pursh] Nutt), and lupine (*Lupinus* spp.). Medium shrubs are absent from this habitat type unless it has been severely disturbed. We chose the Idaho fescue/bluebunch wheatgrass habitat type because it is widely distributed throughout the mountain grasslands in southwestern Montana and the western United States and provides a model system for applied ecological research.

Sites were located on the Flying D Ranch approximately 70 km east (45°34' N, 111° 34' W) of Bozeman, Montana. Sites lie on an east-northeast aspect of a 20 degree slope at 1,624 m elevation. Our specific sites were chosen because they were near enough to one another to be considered similar, but appeared to represent different seral stages within the Idaho fescue/bluebunch wheatgrass habitat type. Prior to plot establishment, soils were tested for the presence of picloram (4-amino-3,5,6-trichloropicolinic acid,

potassium salt) to minimize the risk that site characteristics and plant community composition were influenced by recent herbicide applications. Picloram was not detected at the 0.01 mg/kg level. Soils were classified in August, 2000. Annual average precipitation is 41 cm and annual average temperature ranges from 5.5 to 7°C.

The area has been grazed for decades, and in some years it has been heavily grazed, by either cattle or bison (*Bison bison*) in its recent history (50-60 years). Bison grazing during the past ten years has been sporadic. Windblown slopes are prime winter habitat for wildlife. In the study area, winter use by elk (*Cervus elaphus*) has steadily increased as herd size increased during the past 20 years.

## Experimental design and sampling

This study was a portion of a larger research project that involved removing functional groups of plants. Therefore, the design of this research was aimed at achieving multiple objectives. Species of grass, forbs and spikemoss were combined into functional groups based on morphological and physiological similarities. Grasses, forbs, and spikemoss were split into functional groups. Forbs were further divided into two functional groups based on average rooting depth of each species, determined by careful excavation of each species to determine root structure and rooting depth. The distinction between a shallow and a deep depth was based on a natural break within the roots sampled which occurred at about 15 cm. In cases where the average root depth was close to 15 cm, species with primarily fibrous roots were considered shallow-rooted, while tap-roots were grouped with deep-rooted forbs.

Removal treatments were arranged in a randomized-complete-block design with four replications on each of two sites. Treatments were applied by removing a functional group or groups in combination from the 2 x 2 meters plots. This study consisted of seven removal treatments 1) shallow-rooted forb, 2) deep-rooted forb, 3) all forbs, 4) grasses, 5) all plant material, 6) nothing (control) and 7) moss, lichens and spikemoss (collectively referred to as spikemoss throughout the paper) removed. While removing functional groups in 2000, species richness and density were recorded for all species removed, as well as all species on the control plots (nothing removed). Species richness was measured by counting all species present on the plot. Forb density was measured by counting the number of plants per species in the plot. Grass density was determined by counting the number of tillers per species within a 0.2 x 0.5 m frame. A single frame was placed randomly in each plot. Plant removal and data recording, continued every-other week throughout the 2000 growing season to capture seasonal variation of plant composition. For the spikemoss functional group, percent foliar cover was estimated within a 0.2 x 0.5 m frame for each species representing one percent or greater of the plot area. Forbs and Selaginella species were identified using Dorn (1984 ) while grasses follow the nomenclature in Cronquist et al. (1977). Mosses and lichens were identified using Flowers (1973) and McCune (1995).

Aboveground biomass of the shallow-rooted forbs, deep-rooted forbs and grasses was collected during the spring, summer, and fall of 2001 from all plots where their biomass was not removed as a treatment. Thus, there are different sample sizes for each group. Spring sampling occurred when the majority of the spring ephemeral forbs were in

bloom, summer sampling coincided with peak standing crop, and fall sampling occurred after 95% of the vegetation was senescent. Plots were divided into three subplots which were randomly assigned to each of the three sample periods to prevent sampling the same area twice. Plants were clipped to ground level within three 0.2 x 0.5 m frames randomly placed in each subplot. Plant aboveground biomass was separated by functional group as it was clipped. As part of the treatments, spikemoss was removed from 2 plots in each block. Plant tissues were oven dried (40° C, 160 hours) to a constant weight, weighed, and biomass was recorded.

Soils samples were collected from each control plot with a 2.2 cm diameter soil core during the spring, summer, and fall of 2001 to measure nutrient concentrations of each sites. Within each subplot, randomly located soil cores were collected. The soil cores were divided into two depths (0-15 cm and 15-40 cm) to coincide with the depths of shallow-rooted and deep-rooted forb functional groups. To capture heterogeneity of soil properties at each season, three samples per depth were collected from each plot and were combined into one sample per plot for analysis. These soils were analyzed for mass water content, total nitrogen (N), nitrate ($NO_3$-N), ammonium ($NH_4$-N), sulfur (S), phosphorus (P), potassium (K), and total carbon (C) at each site. Soil samples collected from the field were weighed wet, dried in a forced-air oven (40° C, 160 hours) to a constant weight, and weighed again to determine mass water content (Brady and Weil 1999). Soil samples were then ground to pass through a 2 mm sieve in preparation for chemical analyses. Inorganic soil N ($NO_3$-N and $NH_4$-N) was determined on 1 M KCl extracts of soils (5 g soil:50 ml extractant) (Mulvaney 1996) and total N was determine using the Kjeldahl

(TKN) method (Bremner 1996). Available P in the soil was measured by the NaHCO$_3$

extraction method (Olsen et al., 1954). Available K and S were determined by extraction

with 1 M NH$_4$OAC (Helmke and Sparks, 1996) and 0.001 M CaCl$_2$ (Hamm et al., 1973),

respectively, using a 5:1 extractant to soil ratio. Filtered extracts were analyzed for P, K,

and S by inductively coupled plasma membrane spectroscopy (Jones, 1977). Total C was

determined by loss-on-ignition (Nelson and Sommers 1996).

Data analysis

Plant. Species frequency of occurrence was calculated for each site to determine

species distribution between the sites. Richness, biomass, and density were summarized

for the shallow-rooted forb, deep-rooted forb, and grass functional groups individually and

for the total plot. Biomass was averaged over the three seasons. For the spikemoss

functional group, mean percent cover, richness, and biomass were summarized. Richness

was always summarized per plot (4 m$^{-2}$) while density, biomass, and percent cover were

averaged per meter square. Both the Simpson and Shannon-Weaver diversity indexes

were calculated for each functional group. The Simpson Diversity Index is defined as D=

1/(sum(Pi$^2$)) where Pi is the proportion of the ith species (Begon et al. 1990). The

Shannon-Weaver Index is defined as H = -sum(Pi(lnPi)) (Begon et al. 1990). Data

comparisons were conducted using the Student's $t$-test in SPSS software (SPSS version

10.0 1999).

Soil. Mean mass water content and nutrient levels were determined for each site,

season, and soil depth. C:N ratio was calculated for each site and depth. Soils were

analyzed for site differences in water and nutrient content at each soil depth using a Student's *t*-test. We used the combined means of seasons for nutrients and water site comparisons. A one-way ANOVA was used to analyze mass water content and nutrient level variations among seasons at each soil depth and site. At site 2, the deep soil depth phosphorus did not meet the assumptions of equality of variance and normality and data transformations did not improve the model. Therefore, the Mann-Whitney non-parametric test was used. We used SPSS software for the above analyses. Test results were considered significant at the $\alpha = 0.05$ level.

## Results

### Frequency, density, biomass, and cover

All functional groups and twenty-four plant families were represented on the study sites. The plant families most often encountered were Asteraceae (16 taxa), Fabaceae (7 taxa), and Poaceae (14 taxa). In total, 90 vegetative species were identified in this grassland system (Table 2.1). Of those species, 47 were shallow-rooted forbs, 22 were deep-rooted forbs, 14 were grasses, 4 were lichens, 1 was a spikemoss, and 2 were mosses. Shallow-rooted forbs (0-15 cm roots) consisted of annual, short-lived perennial, and perennial species with bulbs, rhizomes, fibrous roots and/or shallow tap-roots. Deep-rooted forbs (15-40+ cm roots) were primarily perennial tap-rooted plants with varying lateral root lengths and depths. Idaho fescue and bluebunch wheatgrass were the most commonly occurring grasses. Arrowleaf balsamroot, lupine, prairie milkvetch (*Astragalus adsurgens* Pallas), and blazing star (*Liatris punctata* Hook) are deep-rooted forbs which

**Table 2.1.** Species functional group assignment, average root depth, and frequency on site 1 and site 2, respectively.

| Species | Common Name | Functional Group | Average Root Depth (cm) | Frequency of occurrence |
|---------|-------------|------------------|-------------------------|-------------------------|
| *Achillea millefolium* L. | Yarrow | S | 10 | 0.28 / 0.21 |
| *Allium cernuum* Roth. | Nodding onion | S | 5 | 0.97 / 1.00 |
| *Alyssum alyssoides* L. | Alyssum | S | 3 | 0.06 / 0.00 |
| *Antennaria parvifolia* Nutt. | Small leaf pussytoes | S | 11 | 0.65 / 0.66 |
| *Arabis nuttallii* Robinson | Nuttall Rockcress | S | 5 | 1.00 / 0.34 |
| *Arenaria congesta* Nutt. | Ballhead sandwort | S | 4 | 0.97 / 1.00 |
| *Arnica sororia* Greene | Arnica | S | 10 | 0.28 / 0.25 |
| *Artemisia campestris* L. | Common sagewort | S | 12 | 0.09 / 0.00 |
| *Artemisia dracunculus* L. | Green sagewort | S | 3 | 0.06 / 0.00 |
| *Artemisia frigida* Willd. | Fringed sage | S | 14 | 1.00 / 0.40 |
| *Artemisia ludoviciana* L. | Man sage | S | 3 | 0.31 / 0.28 |
| *Astragalus agrestis* Dougl. Ex Hook | Field milkvetch | S | 10 | 0.00 / 0.09 |
| *Besseya wyomingensis* (A. Nels.) Rydb. | Kittentail | S | 12 | 0.97 / 0.91 |
| *Castilleja pallescens* (Gray) Greene | Pale Indian paintbrush | S | 7 | 1.00 / 1.00 |
| *Cerastium arvense* L. | Chickweed | S | 8 | 1.00 / 0.94 |
| *Chenopodium leptophyllum* Nutt. | Lambsquarter | S | 7 | 0.09 / 0.03 |
| *Comandra umbellata* (L.) Nutt. | Bastard Toadflax | S | 4 | 1.00 / 0.90 |
| *Dodecatheon conjugens* Greene | Shooting star | S | 6 | 0.97 / 0.90 |
| *Douglasia montana* Gray | Mountain Douglasia | S | 9 | 1.00 / 0.88 |
| *Erigeron caespitosus* Nutt. | Tufted Fleabane | S | 13 | 0.90 / 0.90 |
| *Erysimum asperum* Nutt DC. | Plains Wallflower | S | 5 | 0.16 / 0.00 |
| *Erysimum inconspicuum* (Wats.) MacM. | Wallflower | S | 6 | 0.09 / 0.00 |
| *Fritillaria pudica* Pursh | Yellow bell | S | 6 | 0.97 / 1.00 |
| *Gaillardia aristata* Pursh | Blanketflower | S | 6 | 1.00 / 1.00 |
| *Galium boreale* L. | Bedstraw | S | 3 | 0.22 / 0.00 |
| *Gaura coccinea* Nutt. Ex Pursh | Gaura | S | 3 | 0.09 / 0.03 |
| *Gutierrezia sarothrae* Britt. & Rusby | Broom snakeweed | S | 6 | 0.63 / 0.72 |
| *Haplopappus acaulis* Nutt. | Goldenweed | S | 7 | 0.00 / 0.03 |
| *Heterotheca villosa* Pursh | Golden aster | S | 6 | 0.59 / 0.75 |
| *Iris missouriensis* Nutt. | Bearded Iris | S | 11 | 0.90 / 0.00 |