USING CLUSTER ANALYSIS AND ORDINATION TO DESCRIBE THE HABITAT OF SPALDING'S CATCHFLY (*SILENE SPALDINGII*), A THREATENED FORB, AT GARDEN CREEK RANCH

A Thesis

Presented in Partial Fulfillment of the Requirements for the

Degree of Master of Science

With a

Major in Environmental Science

in the

College of Graduate Studies

University of Idaho

by

Mamie J. Smith

March 2007

Major Professor: Stephen C. Bunting, Ph.D.

AUTHORIZATION TO SUBMIT

THESIS

This thesis of Mamie J. Smith, submitted for the degree of Master of Science with a major in Environmental Science and titled "Using Cluster Analysis and Ordination to Describe the Habitat of Spalding's Catchfly (*Silene spaldingii*), a Threatened Forb, at Garden Creek Ranch," has been reviewed in final form. Permission, as indicated by the signatures and dates given below, is now granted to submit final copies to the College of Graduate Studies for approval.

Major Professor ______________________________ Date ________________
Stephen C. Bunting

Committee Members ______________________________ Date ________________
Steven J. Hollenhorst

______________________________ Date ________________
Paul A. McDaniel

______________________________ Date ________________
J. Michael Scott

Department Administrator ______________________________ Date ________________
Maxine Dakins

College Dean ______________________________ Date ________________
Steven Daley Laursen

Final Approval and Acceptance by the College of Graduate Studies

______________________________ Date ________________
Margit von Braun

ABSTRACT

Cluster analysis and ordination were used to describe Spalding's catchfly (*Silene spaldingii*) habitat within Garden Creek Ranch (GCR), Idaho, located within Hells Canyon. During the spring of 2006 vascular plant canopy cover, ground cover, aspect, slope, and elevation data were collected over thirty macroplots in the Corral Creek drainage. This information was input into the computer program PC-ORD and analyzed using cluster analysis and non-metric multidimensional scaling (NMS) ordination. Three community types emerged: a) late-seral bunchgrass communities with average shrub cover <1%, b) mid-seral bunchgrass communities with average shrub cover <2%, c) bunchgrass communities with average shrub cover <8%.

The community types, though distinct via cluster analysis and ordination, most likely represent the continuum of Spalding's catchfly habitat at GCR. The three community types were then qualitatively compared to the three most widely used habitat classification systems in this region for goodness-of-fit. At GCR, sites which have higher shrub cover are classified differently than those without shrubs. Spalding's catchfly habitat that is influenced by shrubs most closely resembles Daubenmire's (1970) Idaho fescue (*Festuca idahoensis*)/common snowberry (*Symphoricarpos albus*) habitat type. Sites without shrub influence more closely resemble the Idaho fescue/ prairie junegrass (*Koeleria macrantha*) plant association described by Johnson & Simon (1987) and Tisdale (1986).

ACKNOWLEDGEMENTS

I would like to extend my appreciation and thanks to the many people who helped me complete my research project and thesis. I would like to thank my major professor Stephen Bunting for his guidance. His patience and knowledge are superseded only by a tenacious commitment to his students. I would also like to thank my committee members Steven Hollenhorst, Paul McDaniel, and J. Michael Scott, for their assistance.

I would like to thank the staff, faculty, and fellow graduate students in the Rangeland Ecology and Management department for contributing to my education. I would like to thank my research partner and fellow graduate student, Brenda Guettler for her constant support. Her botanical knowledge and humor are especially appreciated.

A special thank-you goes to Janice Hill for spurring my interest in this research topic and for her assistance in editing. She and the staff of the Stillinger Herbarium were critical to the success of this project. I want to acknowledge Lynn Danly of the Cottonwood Bureau of Land Management for her support, and The Nature Conservancy who provided housing at the field site.

I would like to give a special thanks to the women of the Environmental Science department, especially Chris Dixon. I appreciate their commitment to my success and the position as a teaching assistant for the Environmental Science labs.

Finally, I would like to thank my family and friends for their constant encouragement. I am especially grateful to my husband Kevin Colburn for his commitment to my dream.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction and Objectives

In October of 2001 Spalding’s catchfly (*Silene spaldingii),* a perennial plant and member of the Caryophyllaceae family, was listed as a threatened species under the Endangered Species Act (ESA) of 1973 (U.S. Fish and Wildlife Service 2001). The Idaho Conservation and Data Center (IDCDC), a division of Idaho Department of Fish and Game, currently ranks Spalding’s catchfly at S1, “critically imperiled in the state of Idaho because of extreme rarity or because some factor of its biology makes it especially vulnerable to extinction” (2003). The Bureau of Land Management (BLM) currently ranks Spalding’s catchfly as a Type 1 Sensitive Species, that they use for all ESA threatened, endangered, proposed, and candidate species. The threats of greatest concern to Spalding’s catchfly are habitat degradation, habitat loss and fragmentation, alteration of fire regimes, predation by herbivores, herbicide drift, and climate change (Hill and Gray 2004a).

The second largest known population of Spalding’s catchfly occurs in the Craig Mountain area of Nez Perce County, ID. The majority of the Craig Mountain population, 3995 plants, occurs at Garden Creek Ranch (GCR), an area of Craig Mountain that is jointly owned and managed by the BLM and The Nature Conservancy (TNC) (Hill and Gray 2004a).

This project has four research objectives, that were achieved by gathering information on associated species, ground cover, aspect, slope, and elevation of thirty macroplots containing Spalding’s catchfly at GCR.

First objective: To investigate whether the plant communities in which Spalding's catchfly grows change as aspect, slope, and elevation change within GCR. One research need put forth in the Conservation Strategy for Spalding's catchfly is to further understand and predict Spalding's catchfly habitat in order to "develop predictive habitat assessment models for each region that utilize associated species, soil information, aspect, elevation etc." (Hill and Gray 2004a). Though not within the scope of this project, this data could, in the future, be one of many input variables for a predictive habitat model.

Second objective: To use cluster analysis and ordination techniques to evaluate the homogeneity of plant communities that support Spalding's catchfly at GCR. Numerous different communities could occur at GCR, however after statistical and ecological evaluation a few distinct community types may become evident. This may help managers recognize Spalding's catchfly habitat by its associated plant communities.

Third objective: To document the type of shrub species present as well as their prevalence within Spalding's catchfly habitat at GCR. Shrub prevalence is a determining factor in choosing the best habitat type or potential natural community classification. This information could help facilitate studies on long-term woody encroachment by documenting the current relationship between Spalding's catchfly and shrubs. This may contribute to the research need, "to determine whether woody encroachment is occurring in *S. spaldingii* habitat" (Hill and Gray 2004a).

Fourth objective: To determine which plant classification system best describes Spalding's catchfly habitat at GCR. This project will compare and contrast Spalding's catchfly communities to existing habitat types and community types used in the canyon grasslands. Categorizations of plants into plant associations help document differences in vegetation and achieve management goals (Lillybridge et al. 1995).   In the case of rare species, the use of plant associations helps managers accurately identify lands which support those species of concern. This information will contribute to the body of knowledge for the federally threatened plant Spalding's catchfly.

Literature Review

Spalding’s Catchfly Ecological Characteristics, Associated Species, and Distribution

Spalding’s catchfly is an herbaceous, perennial herb with lanceolate to oblanceolate leaves, and inconspicuous white flowers mostly concealed within a calyx (Hitchcock and Maguire 1947, 1973). Their height ranges from 20-61 cm tall (Lesica 1997, Hill and Gray 2004a) with a persistent caudex and a taproot in excess of 85 cm (Menke and Muir 2004). Spalding’s catchfly has three growth forms and a dormant stage: rosette, non-reproductive, and reproductive (Lesica 1997). The plant also experiences periods of prolonged dormancy where the plant has little or no aboveground visible biomass (Lesica 1997). The plant transitions between different forms in different years. After the initial seedling rosette the first year, any growth form may follow any other growth form in subsequent years (Hill and Gray 2006). Though rosettes were previously believed to be seedlings (Lesica 1997, Menke and Muir 2004), the rosette form is also produced by mature plants (Hill and Gray 2006).

Spalding’s catchfly is endemic to five physiographic regions within the Inland Northwest: Palouse Grasslands, Canyon Grasslands, Channeled Scablands, the Wallowa Plateau, and Intermontane Valleys of Northwestern Montana and British Columbia (Hitchcock and Maguire 1947, Hill and Gray 2004a). Unpublished data for all physiographic regions are held by the Idaho Conservation Data Center, TNC, and each state’s Natural Heritage Program. Many of the Element Occurrence records for all regions through 2003 were summarized in the U.S. Fish and Wildlife Service (USFWS) Conservation Strategy for Spalding’s Catchfly (Hill and Gray 2004a). A demographic study of the plant in Canyon Grasslands is ongoing and should be published in the near future. The USFWS published the Draft Recovery Plan for Spalding's Catchfly in 2005 to contribute to the recovery of the plant in each of the five physiographic regions (U.S. Fish and Wildlife Service 2005). The final Draft Recovery plant is due in May 2007.

Disturbance effects: Two published studies have evaluated the effect of fire on Spalding's catchfly. Menke and Muir (2004) examined the difference in vegetative cover in burned and unburned Spalding's catchfly habitat areas over 2001 and 2002 at GCR. Lesica (1999) examined the effects of fire on Spalding's catchfly in grasslands at Dancing Prairie Preserve in northwest Montana.

Spalding's catchfly and associated species were generally tolerant of fire in the short-term at GCR (Menke and Muir 2004). Idaho fescue (*Fesctuca idahoensis*) was the only plant to significantly decrease in burned plots. No native species were removed from the community. Rose (*Rosa* spp.) and snowberry (*Symphoricarpos albus*) cover decreased, though not significantly, after being burned (Menke and Muir 2004). The number of mature Spalding's catchfly plants increased in burned plots one-year post fire but flowering, mean number of flowers per stem, seed production, and mean numbers of capsules per stem had no significant difference in burned versus unburned plots. No correlation was found between heat load or aspect with catchfly vigor. At GCR, short term influence of fire on Spalding's catchfly appeared negligible (Menke and Muir 2004).

Both fire and litter were found to affect Spalding's catchfly communities at Dancing Prairie Preserve (DPP). Within the Intermontane Valley physiographic region, Lesica determined that fire acts to increase the population size of Spalding's catchfly (1999) and may play a role in its long-term persistence (1997). Only relatively mesic areas of Dancing Prairie Preserve, in which rough fescue is the dominant species, support Spalding's catchfly. In these mesic areas a decrease in rough fescue is correlated with a higher density of Spalding's catchfly. Rough fescue is known for producing large amounts of litter, thus areas with reduced litter could have could have created favorable conditions for the Spalding's catchfly (Lesica 1997). The three most dominant plant species by percent canopy cover were rough fescue (*Festuca scabrella*) (70 %), Idaho fescue (17%), and Kentucky bluegrass (*Poa pratensis*) (4%) (Lesica 1997).

Another form of disturbance that appears to influence the survival of Spalding's catchfly is rodent activity (Caplow 2001, Hill and Gray 2004b, Hill and Gray 2006). In areas with high rodent activity, visible runways exist through the bunchgrass litter exposing bare ground. Burrows and holes are also present. Pocket gophers are estimated to be involved in 7% of monitored plant removal at GCR (Hill and Gray 2000).

Observed levels of rodent activity (established runs through the grasses, bare patches of soil, and burrows) increased from 2002 to 2003 in established Spalding's catchfly research plots at GCR (Hill and Weddell 2003, Hill and Gray 2004b). Evidence of rodent runways and holes was near constant at approximately 4.8% ground cover in 2004 and 4.5% ground-cover 2005 in the Corral Creek drainage (Hill and Gray 2006). In my study, overall evidence of rodents will be qualitatively assessed and the amount of bare ground in each plot will be quantitatively assessed.

Associated species: Unburned Spalding's catchfly communities were relatively stable between two consecutive years at GCR. Between 2001 and 2002 the total makeup of unburned plant communities supporting Spalding's catchfly did not change significantly (Menke and Muir 2004). The five most dominant species in unburned plots by percent canopy cover in 2001 were Idaho fescue (26.5%), bluebunch wheatgrass (*Pseudoroegneria spicata*) (14.7%), common snowberry (6.22%), prairie junegrass (*Koeleria macrantha*) (4.75%), and silky lupine (*Lupinus sericeus*) (4.69%). Rose was present at 0.19 %. In 2002, in unburned plots, Idaho fescue (38.1%) was the most dominant plant by percent cover, then followed by bluebunch wheatgrass (19.0%), field chickweed (*Cerastium arvense*) (11.2%), common snowberry (6.69%), and silky lupine (5.53%). Rose was present at 2.06%. In 2001 and 2002 unburned plots, Spalding's catchfly cover was 1.28% and 1.13% respectively. Twin arnica (*Arnica sororia*) was the only species in unburned plots which changed significantly between the two years.

Aspect and elevation: Across the five physiographic regions, 82% of Element Occurrence records for Spalding's catchfly plants were recorded on north, north-west, or north-east aspects (Hill and Gray 2004a). At DPP in northwest Montana, Spalding's catchfly plants occupied the "bottom of shallow swales and cool slope exposures" (Lesica 1999). Potential soil moisture is influenced heavily by topography (Barbour et al. 1999). In the canyon grasslands, steep slopes influence incident radiation and soil characteristics that in turn influence moisture availability and plant community structure. North-facing slopes are more mesic than adjacent south-facing slopes, creating conditions favorable to Spalding's catchfly growth.

Elevation also influences available soil moisture, via changes in temperature, but on a coarser scale than aspect (Barbour et al. 1999). Known as factor compensation, edaphic and climatic conditions can work in conjunction with one another to create similar habitats (Daubenmire 1968a). Of the five physiographic regions, canyon grasslands have the most widely varying elevation ranges, 421 m to 1174 m (Hill and Gray 2004a). The extreme slopes, combined with elevation changes may come together to create similar habitats through factor compensation. Spalding’s catchfly plants found at DPP were located at 825 m in elevation, in rough fescue (Lesica 1999).

Soils: Soils at GCR that support Spalding’s catchfly are deep, well drained, Mollisols with loess and ash influence. Sampled macroplots were found on one of four major north-facing soil series: Linville, Waha, Broadax, or Kattenbach (moist). Properties of these four soil types as reported by the Natural Resources Conservation Service (Hahn 2004) are outlined in Table 1.

Table 1. Soils that support Spalding's catchfly at Garden Creek Ranch.

	Association			
	Linville-Kettenbach	**Linville-Kettenbach Inclusion**	**Slickpoo-Broadax**	**Kettenbach-Gwin**
Series	Linville	Waha	Broadax	Kettenbach, Moist
Location	Redemsky	Redemsky	Redemsky	North Bench
Association attributes				
Slope	45-75%	45-75%	15-25%	35-75%
Elevation	244-853 m	244-853 m	488-884 m	366-1219 m
Aspect	North and east facing	North and east facing	North and east facing	Northwest and West facing
Depth	very deep	very deep	very deep	moderately deep
Drainage	well drained	well drained	well drained	well drained
Rooting depth	> 152 cm	> 152 cm	> 152 cm	51-102 cm
Water holding capacity	high	high	moderate	low
Series attributes				
Taxonomic class	Fine-loamy, mixed, mesic, superactive Pachic Haploxerolls	Fine-loamy, mixed, superactive, mesic Pachic Argixerolls	Fine-silty, mixed, superactive, mesic Calcic Argixerolls	Loamy-skeletal, mixed, superactive, mesic Pachic Argixerolls
Parent material	Loess, colluvium from basalt	Loess, colluvium from basalt	Loess	Colluvium derived from balast with some loess
Average annual precipitation	41-46 cm	46-56 cm	38-51 cm	38-56 cm
Thickness of mollic epipedon	51-122 cm	51-76 cm	30-51 cm	51-76 cm
Typical horizons	A: 0-48 cm AB: 48-79 cm Bt:79-170 cm	A: 0-33 cm Bt:33-86 cm 2R: 86 cm	Ap:0-23 cm BA: 23-41 cm Bt: 41-84 cm BC: 84-94 cm Btkb: 94-165 cm	A: 0-10 cm BA:10-25 cm Bt: 25-53 cm 2R: 53-76 cm

Classification Nomenclature

Classifying plant communities requires the use of specific ecology terms. For this study, a *macroplot* is a sampling space of specified size, usually twenty by ten meters, and all of the attributes studied within that area. The main attribute of interest within macroplots is vegetative cover by species. The plants within a macroplot make up a *community*. A community can be further defined through some classification process. If we find the same or very similar communities in multiple places across the landscape and have reason to believe through the classification process that this group of plants has significance we can call this a *community type*. A *community type* can represent any stage of successional development – seral, potential natural vegetation, or any stage in between. A *plant association* is more restrictive than a community type. Only those community types that represent successionally complete, potential natural vegetation are called *plant associations* or *potential natural communities*. A *habitat type* is an area capable of supporting a particular plant association and is therefore not seral.

Names of plant communities are sometimes notated by shortening the scientific names of the indicator species and placing these side by side with a forward slash, i.e. FEID/SYAL. In this case, the first two letters of the genus and species of ***Fe****stuca* ***id****ahoensis* becomes FEID and ***Sy****mphoricarpos* ***al****bus* becomes SYAL. When the most specific level of classification is genus, no species information is given and the genus is written in italics, i.e. FEID/ *Rosa* spp. Two regional species of rose, Nootka rose (*Rosa nutkana*) and Woods' rose (*Rosa woodsii*) are known to hybridize and hinder classification to the species level (Johnson and Simon 1987).

Classification of Canyon Grasslands With Spalding's Catchfly

Categorizations of plants into plant associations help document differences in vegetation and achieve management goals. In the case of rare species, the use of plant associations helps managers accurately identify lands that support those species of concern. By knowing the plants that grow in association with a rare species we can more accurately predict its presence and plan appropriate management and research. Resource agencies, including the BLM, use plant association classification systems which attempt to characterize the multitude of distinct plant communities found within their management areas.

Three plant community classification systems have the potential to describe the canyon grasslands at GCR that support Spalding's catchfly. Two of these classification systems were created for canyon grassland vegetation: Tisdale (1986), and Johnson and Simon (1987). A third plant community classification system by Daubenmire (1970) primarily focuses on steppe vegetation of Eastern Washington but briefly refers to grassland habitat types in the Snake River Canyon.

Hill and Gray (2004) suggested that the plant communities in which Spalding's catchfly occur do not fit well into either of the two primary canyon grassland classifications, Tisdale (1986) or Johnson and Simon (1987). The communities that support Spalding's catchfly appear to be an Idaho fescue dominated grassland with an inconspicuous shrub component. The shrubs consist of scattered, dwarf snowberry and/or rose bushes that are primarily shorter than the grass canopy. These communities fit fairly well into the FEID-KOCR habitat type described by either Tisdale or Johnson and Simon - except for the presence of small scattered snowberry or rose bushes that are not components of the FEID-KOCR habitat types. The presence of shrubs and the subsequent impact to each of the three classification systems are explained in the subsequent sections. Table 2 summarizes Idaho fescue, snowberry, and rose plant community classification systems from Tisdale, Johnson and Simon, and Daubenmire.

Table 2. Plant associations and habitat types that potentially support Spalding's catchfly in canyon grasslands.

	Plant community				
Community Notation	**FEID/KOCR**	**FEID-KOCR (low elev.)**	**SYAL/FEID-KOCR (high elev.)**	**FEID/SYAL**	**SYAL/Rosa spp.**
Scientific names	*Festuca idahoehensis* / *Koeleria cristata*	*Festuca idahoehensis* - *Koeleria cristata*	*Symphoricarpos albus / Festuca idahoensis - Koeleria cristata*	*Festuca idahoensis* / *Symphoricarpos albus*	*Symphoricarpos albus* / *Rosa* spp.
Common names	Idaho fescue / prairie junegrass	Idaho fescue / prairie junegrass	snowberry / Idaho fescue - prairie junegrass	Idaho fescue / snowberry	snowberry / rose spp
Author	Tisdale (1986)	Johnson and Simon (1987)	Johnson and Simon (1987)	Daubenmire (1970)	Johnson and Simon (1987)
Successional stage	Potential Natural Vegetation	Variable, Usually mid to late seral	Unknown – possibly seral	Potential Natural Vegetation	Variable, Usually mid to late seral
Classification	Habitat type	Plant Association	Community type	Habitat Type	Plant Association
Shrub component	25 % or less birchleaf spirea (*Spirea betulifolia*), rose, and snowberry	None but FEID/KOCR and SYAL/Rosa spp. communities can create matrix on landscape	snowberrry is low and scattered. Bunchgrasses dominate over shrubs 4:1	"Inconspicuous" snowberry and rose	80 % or higher mean foliar cover of snowberry, and up to 35 % mean foliar cover of rose

Tisdale classification system: Tisdale (1986) classified canyon grasslands and associated shrublands in the middle Snake, lower Salmon, lower Grande Ronde, and Clearwater river valleys. GCR is within this geographical area. Five habitat types and 2 seral community types were grouped into 3 series. Each habitat type and community type is denoted by the scientific name of the dominant species/indicator species, i.e. *Festuca idahoensis / Koeleria cristata* (now *Koeleria macrantha*).

Tisdale's FEID/KOCR habitat type could potentially describe Spalding's catchfly habitat at GCR if shrubs are present but rare. The FEID/KOCR habitat type, allows for low constancy (25% or less) of birchleaf spiraea (*Spiraea betulifolia*), rose, and snowberry shrubs (Tisdale 1986). Therefore, Spalding's catchfly communities that have a shrub component with a constancy over 25% do not fit this classification. The first step in Tisdale's key is either "1: Shrubs rare or absent, graminoids dominant" Or "1: Shrubs abundant and usually dominant" (1986). Tisdale's classification system requires shrubs to either be rare or abundant; a category for moderate shrub frequency and cover does not exist. Tisdale (1986) compared his FEID/KOCR classification to Daubenmire's FEID/SYAL, noting that his FEID/KOCR had a great deal fewer snowberry and rose shrubs than FEID/SYAL.

In his preliminary research Tisdale (1979) had a third Idaho fescue habitat type, FEID/SYAL. Ultimately, Tisdale did not include the FEID/SYAL habitat type in his 1986 classification system because he found these communities to be an ecotone of snowberry dominated communities which only existed in a limited extent on the landscape.

Johnson and Simon classification system: Johnson and Simon (1987) classified north-eastern Oregon grasslands and non-alpine forests as well as a small portion of adjacent Snake River canyon vegetation. They created a finer-scale classification system than Daubenmire or Tisdale and described 11 different series, each denoted by the indicator species, i.e. bluebunch wheatgrass series. Within these series are a total of 36 seral communities which they refer to as community types and 53 communities of potential natural vegetation which they refer to as plant associations. These are denoted by the common name of the dominant species, backslash or hyphen, then an indicator species sometimes followed by an environmental caveat, i.e. Idaho fescue-prairie junegrass (high elevation). A backslash indicates that the two species are of different growth (i.e. a grass and a shrub) form while the hyphen indicates that the two species are of the same growth form (i.e. both grasses).

Johnson and Simon (1987) have 2 primary Idaho fescue plant associations, FEID/KOCR (low elevation) and SYAL/Rosa spp., that could potentially describe the plant communities at GCR which support Spalding’s catchfly. They describe situations where shrubs could exist within FEID/KOCR plant associations because of overgrazing, change in fire regime, and climate change. They also state that some “concave micro-sites that retain snow and moisture can contain SYAL-Rosa spp. within a FEID-KOCR grassland.” The third Johnson and Simon plant community type SYAL/FEID-KOCR cannot be reached through the Idaho fescue community key because it is recognized only as a limited community type. It is a seral community with bunchgrasses dominating 4:1 over snowberry; it is found above 1219 m in elevation (Johnson and Simon 1987). SYAL/FEID-KOCR is similar to Daubenmire’s FEID/SYAL but it is not synonymous.

Daubenmire classification system: Daubenmire (1970), a plant community ecologist, established a classification system based on habitat types that have the potential to support a specific plant community. Daubenmire (1970) classified potential natural vegetation in the steppe region of southeastern Washington and a small portion of adjacent Idaho near the Snake and Salmon River confluence into 40 habitat types. Habitat types are denoted by the hyphenated scientific names of the dominant and sub dominant species and sometimes joined an indicator of phase, i.e. *Festuca idahoensis-Symphoricarpos albus* habitat type, *Symphoricarpos albus* phase (Daubenmire 1968a). The phase is a habitat type whereby the dominance of a particular plant is exaggerated (Daubenmire 1970).

Daubenmire describes two Idaho fescue habitat types which include shrubs, FEID/Rosa spp. and FEID/SYAL, which were based on observations in shrub steppe were not created specifically to describe canyon grasslands. The designation FEID/SYAL includes Idaho fescue, many forbs, as well as small-stature snowberry and/or rose. Of the classification systems that exist, Hill and Gray (2004a) considered Daubenmire's FEID/SYAL to be the most closely correlated classification taxa for those Spalding's catchfly, Idaho fescue habitat types with a shrub component. FEID/Rosa spp. differs from FEID/SYAL in that: snowberry is absent, it is not associated with thickets of snowberry, it is restricted in its range, and it has a distinctive climate; because it does not contain snowberry it is unlikely to fit Spalding's catchfly sites at GCR.

Because of the way the Daubenmire, Tisdale, and Johnson and Simon classify Idaho fescue dominated communities, they have different applications for the description of Spalding's catchfly habitat at GCR. In an area where shrubs are present, Hill and Gray

(2004a) suggested that perhaps describing and classifying a given Spalding’s catchfly habitat type using the Daubenmire key would be more appropriate since it appears to fit the Daubenmire classification better than any habitat types described by Tisdale or Johnson and Simon (Hill and Gray 2004a). In an area where shrubs are absent, Hill and Gray (2004a) suggested that describing and classifying a given Spalding’s catchfly habitat type using a Johnson and Simon or Tisdale classification system might be more appropriate.

Methods

Site Description

All study locations for this research project are located within GCR in Nez Perce and Lewis Counties of Idaho. GCR is approximately 29 km south of Lewiston, ID by air and directly east of the Oregon-Washington border. It contains approximately 5643 ha of sloping canyons from 256 to 1584 m in elevation (Hill and Gray 1999). GCR is jointly managed by The Nature Conservancy (TNC) and the Bureau of Land Management (BLM). It contains three major drainages: Corral Creek, China Garden Creek, and Cave Gulch Creek. Sampling took place in the canyon grasslands of the Corral Creek drainage and the adjacent small unnamed adjacent drainages north of Corral Creek.

Access to GCR is provided by Corral Creek road, a gated, unpaved road that runs the length of the property from northeast to southwest following Corral Creek and ending at the Snake River. Two additional roads off of Corral Creek were used to access sampling areas: the North Bench road north off of Corral Creek and the Redemsky Flats Road south off Corral Creek. Subsequently, the area north of Corral Creek is commonly referred to as the “North Bench” and the area south of Corral Creek is referred to as the “Redemsky” area.

Field Methods

Macroplot sampling: Prior to 2005, researchers at GCR inventoried and mapped local populations of Spalding’s catchfly (Hill and Gray 1999, Menke and Muir 2004). Using these topographical maps I traversed areas known to have Spalding’s catchfly, in search of locations that met my requirements for macroplots. In order to be considered as a macroplot the area had to meet the following criteria:

1. Located within Corral Creek drainage or other adjacent unnamed drainage.
2. Had three or more above-ground Spalding's catchfly plants, upon visual inspection.
3. Did not contain a known population of simple campion (*Silene scouleri)* within 20m.
4. Did not knowingly overlap with other agencies' permanent Spalding's catchfly monitoring plots.
5. Was accessible and safe to sample.

I located 30 suitable macroplots that were physically recorded on topographical maps and documented using GPS coordinates. Approximately seven to ten additional potential macroplots were located but not sampled because they did not meet these criteria. Two of the 30 suitable macroplots were sampled in the June 2005 as a pilot study to help delineate the methods and feasibility of the study. Thirty macroplots were sampled between May 15 and June 15, 2006. Due to a calculation error within in macroplot 6, it was excluded from all analyses. Only 2006 data was included in the results and discussion.

For each macroplot, visible Spalding's catchfly plants were identified and temporarily marked. The visual mid-point of this area of plants was then marked with a flag. This mid-point of the patch was used to create a 10-m baseline that was placed parallel to the slope. This baseline was created from a fiberglass measuring tape staked down at either end. Then, from the 10-m baseline, random numbers were used to delineate the placement of 5 perpendicular 10-m transects. Numbers that left less than 2 m between transects were rejected to decrease trampling during sampling. Even-numbered transects started at the baseline and went out to the right 10 m and odd-numbered transects started at the baseline and went out to the left 10 m. Each 10-m transect was then sampled at 0.5-m increments using modified Daubenmire's (1959) cover classification method.

Microplot sampling: Microplot sampling followed a modified version of cover classification methods (Daubenmire 1959). Metal quadrats, 20 x 50 cm in length, were placed at 0.5-m increments along the transect. All readings were made on the uphill side of the tape measure working from the baseline out. Percent foliar cover of each individual species was recorded within the quadrat. In some cases, the foliar coverage of plants may overlap, causing the total cover estimation for the quadrat to exceed 100 %. Total foliar cover for each species was estimated into 1 of 7 cover classes: 1=.0001-1 %, 2=1-5 %, 3=5-10 %, 4=10-25 %, 5=25-50 %, 6=50-75 %, and 7= 75-100 %.

In addition to a classification of foliar cover, the total percentage of leaf litter, bare ground, rocks, and biological soil crusts were estimated for each microplot. Slope, aspect, and GPS coordinates were also collected for each macroplot. Slope was measured using a clinometer and aspect was measured with a compass. GPS coordinates were taken from the center of each macroplot with a Magellen GPS unit using the NAD 27 projection. All information was recorded in a Palm-One handheld computer using a Microsoft Excel spreadsheet.

My study plots overlapped arbitrarily with some of Menke's (2004) unburned and burned plots from the summer of 2001 and 2002. Any plant community differences between unburned and burned plots were noted. Evidence of rodents was qualitatively assessed based on visible rodent runs, bare ground, and rodent holes.

Analytical Methods

I used Daubenmire canopy-coverage methods to document the plant species that grow in and around known Spalding's catchfly populations within GCR. I used cluster analysis, a form of multivariate statistics**,** to hierarchically group the individual species of vegetation and then represent this information visually with dendrograms. This was carried out using the CLUSTR technique available in PC-ORD software (McCune and Mefford 1999). I ordinated the vegetation using nonmetric multidimensional analysis (NMS) according to similarity or dissimilarity of the macroplots**.** Ordination serves two major roles in plant community studies: data reduction and helping create hypotheses about plant community composition (Gauch et al. 1981). Correlations between slope, aspect, and elevation were analyzed within the ordination. Cluster analysis and ordination were done in PC-ORD (McCune and Grace 2002), a statistical package for species association analysis.

Classification by Cluster Analysis: Cluster analysis was used to evaluate the homogeneity of Spalding's catchfly plant communities at GCR. Williams (1971) describes clustering as the "artificial sharpening of naturally diffuse boundaries to facilitate description of the taxa concerned and hence to facilitate communication." Successful clustering simultaneously considers, for those samples taken, how similar the members of a group are and how dissimilar this group is from other individuals (Williams 1971). In other words, it is not enough for members of a group to be similar-they must also possess qualities which make them different from all other groups. It is this concurrent convergence and divergence that creates the most successful clusters.

PC-ORD's CLUSTR method was applied to cover data for the forty macroplots. This method is exclusive, intrinsic, hierarchical, agglomerative, and polythetic (McCune and Mefford 1999). It is based on a series of progressive fusions where all attributes are weighted equally (McCune and Grace 2002). I tried different combinations of linkage and distance measures. Two of these methods, Ward's with Euclidean distance and Sorenson's with flexible beta, are statistically compatible and do not have the tendency to chain (McCune and Grace 2002). Ward's linkage method, one of the few space-conserving linkage methods, was combined with Euclidean distance because this combination is known to produce viable results and are statistically robust, especially when the data is relativized (McCune and Grace 2002). The second experimental combination was the mixture of flexible beta linkage (where beta = -0.25) with Sorensen's distance measure.

A dendrogram was created to graphically represent the data from the chosen cluster analysis. Results of the cluster analysis will be evaluated based on degree of chaining, rate of successful agglomeration (measured by percent of information remaining), and overall tightness and structure of the dendrograms.

Ordination of Canyon Grasslands with Spalding's Catchfly: Ordination can be used to help accomplish 2 goals of community ecologists: 1) description and comparison of sites; 2) identification of relationships between sites or species (McPherson and DeStefano 2003). Ordination is a mathematical method of multivariate analysis that uses data reduction to elucidate similarities and dissimilarities within a data set. Stands of vegetation, or other sample data, are arranged in a multi-dimensional graph where each stand will be represented by a point along an axis. The closeness and relationship of these points to one another within the ordination space represent their similarity and/or their order (Barbour et al. 1999).

There are two forms of ordination, direct and indirect gradient analysis. Direct gradient analysis orders stands according to chosen environmental factors (McCune and Grace 2002). Indirect gradient analysis orders units based on their inherit properties and is lauded by Austin (1968) and Beals (1984) because it yields a greater amount of information without interference from the observer. The cumulative species response to environmental gradients exists within indirect gradient analysis (Beals 1984). Indirect gradient analysis will be used in this study.

NMS is a non-parametric, indirect gradient analysis, ordination method suited to the analysis of non-normal, discontinuous data sets (McCune and Mefford 1999, McCune and Grace 2002). For the analysis of community data, it is the most generally effective method of ordination (McCune and Grace 2002) and its performance using artificial data sets has been proven (Kenkel and Orloci 1986). Fasham (1977) found that NMS had superior performance compared to principal components analysis (PCA) and most reciprocal averaging (RA) ordinations. NMS attempts to configure the best position for *n*-entities on *k*-dimensions while minimizing the stress on the k-dimensions (McCune and Grace 2002.) *N* entities are iteratively moved to the place in the graph which maximizes monotonacity thus preserving the order. The difference between the original point and the new monotonatic point is measured as stress. In PC-ORD stress is calculated as a percentage and low stress is one indicator of a successful ordination solution. In this project, *n* is the cover data from the 40 macroplots.

NMS iteratively ranks the macroplots according to their differences in species composition. This was then graphically represented. The order in which the plots occur in ordination space is an abstract representation of ecological arrangement. In the case of macroplot ordination, the greater the distance between plots the more difference there is in these plots' floristic composition. As suggested by McCune and Grace (2002), the following criteria were evaluated for each ordination: Number of dimensions, level of stress, results of Monte Carlo testing, and stability of the solution. To reduce the possibility of finding local minima (rather than the overall minimum or best fit), random numbers were used as a starting point for ordinations and each ordination was run multiple times. Only ordinations which successfully mediated stress versus the number of dimensions were considered for further analysis.

Results and Discussion

General Site Description

Twenty-nine macroplots containing Spalding’s catchfly were sampled and analyzed. Elevation ranged from 482 to 951 m. The mean elevation was 800 m with a standard deviation of 107.5. The macroplots with lowest elevation also had the highest percent slope. Macroplot 19 had an elevation of 482 m and an 85% slope. Macroplot 17 was 488 m with a 90% slope and macroplot 22 was 634 m with a 75% slope. Over all macroplots, slope ranged from 27 to 90%. The mean slope was 54.1 % with a standard deviation of 16.8.

All macroplots were on north-facing slopes. Aspect ranged from 30 to 290 degrees. Twenty-two of the sampled macroplots burned in the Corral creek fire in October, 2001. Seven macroplots have no recent burn history and most likely have not burned since at least 1976 (Menke and Muir 2004) or earlier. Unburned plots ranged from 290 to 333 degrees. Burned plots ranged from 30 to 310 degrees. Unburned plots were more northwestern than the burned plots. For the cluster analysis and ordination each aspect was converted by its cosine so that northeastern and northwestern plots could be compared.

Average quantities of ground cover are shown in Figure 1. Litter was the most prevalent form of ground cover, occupying an average of 78.8% of quadrat space. Bare ground occupied an average of 4.1% of quadrat space. Mosses occupied 3.9% of ground cover and rock and lichens are less than 1% cover. Some of these areas of bare ground could be visually identified as the result of rodent activity between the bunchgrasses. In some plots, rodent scat and circular tunnels through the litter layer were observed.

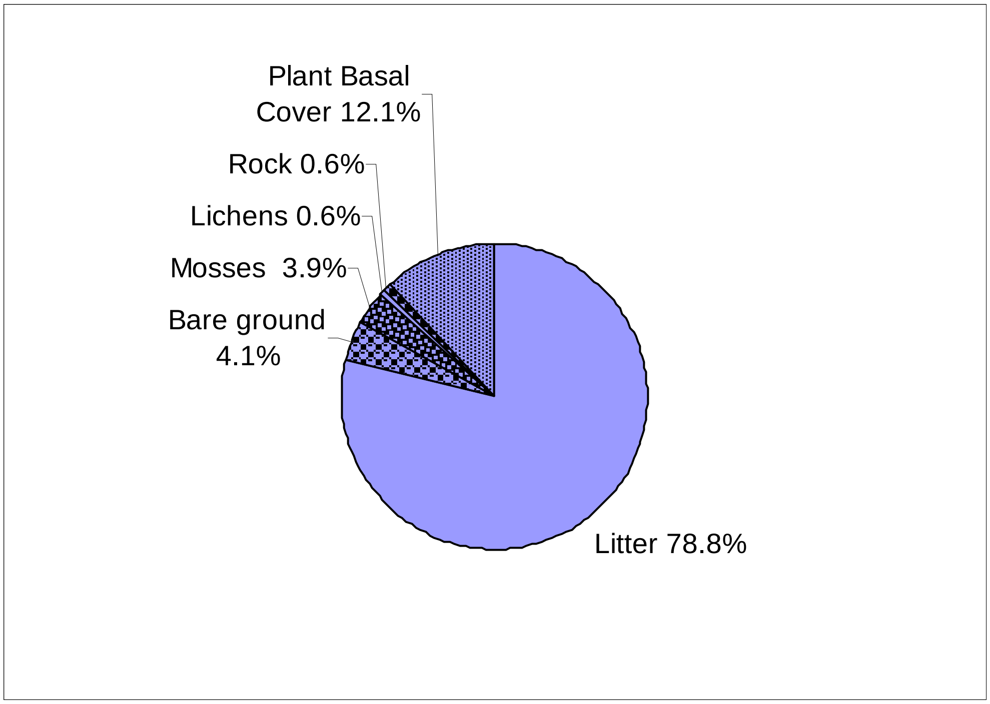


Figure 1. Average ground cover in the sampled macroplots (n = 29). Litter was the most dominant form of ground cover.

Total species richness was 77 species. The ten species with highest average cover values are shown in Figure 2; these include three perennial grasses, three perennial forbs, and four annual forbs. Four species were present in every macroplot (constancy = 100%): bluebunch wheatgrass, prairie junegrass, Idaho fescue, and common yarrow (*Achillea millefolium*). Two bunchgrasses, Idaho fescue and bluebunch wheatgrass, were ubiquitous as well as having the two highest average cover values at 9.3% and 5.4% respectively. Snowberry had the third highest average cover value at 2.0% but it was not present consistently. Introduced annuals, strict forget-me-not (*Myosotis stricta)*, thymeleaf sandwort (*Arenaria serpyllifolia*), and spring draba (*Draba verna)* had a constancy above 90% but were present in low cover amounts.

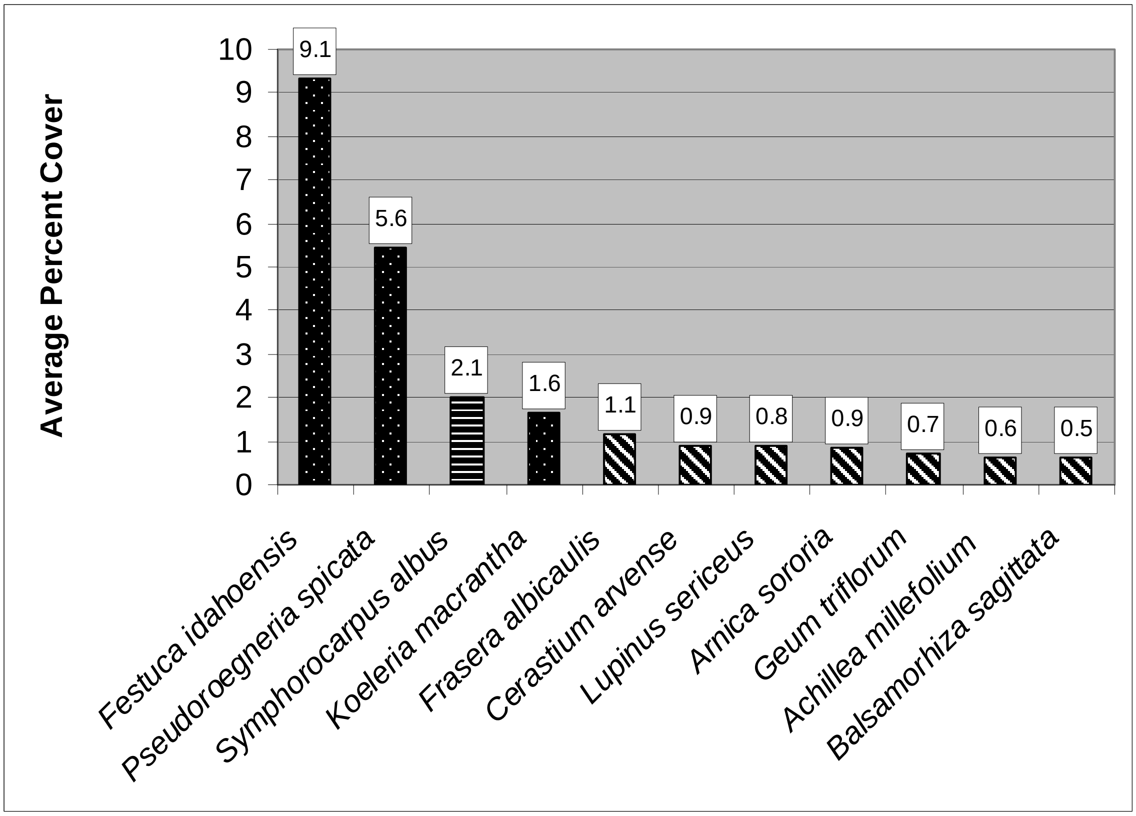


Figure 2. Most common species based on average percent cover. Grass species are represented by a black background with white dots, shrubs by horizontal lines, and forbs by diagonal lines.

Snowberry and/or rose shrubs were found in two-thirds (19 of 29) of sampled macroplots. Species distribution between macroplots was comparatively even. Of the 19 macroplots with shrubs: seven macroplots had snowberry but no rose, five macroplots had rose but no snowberry, and seven had both shrubs. Rose was more frequent than snowberry but its foliar cover was consistently lower. The average cover for rose, in the fourteen plots in which it was found, was 1.1%. In two of these plots, rose was found only on the line-intercept and not within sampled transects. The average cover for snowberry, in the thirteen plots in which it was found was 4.3%.

Spalding's catchfly was visually observed in all macroplots but it did not always fall within sampled microplots. Spalding's catchfly cover values were recorded in 16 macroplots with an average cover of 0.1% when present. Macroplot 12 had the highest average catchfly cover at 0.3%. The majority of sampled plants were in the reproductive growth stage. Six rosette stage Spalding's catchfly plants occurred within the microplots. No flowering plants were observed as all sampling was done in the spring and Spalding's catchfly plants bloom in mid-summer or later at Garden Creek (Hill and Gray 2004b).

Cluster Analysis

Mean percent cover for each species, for each macroplot, were input into five cluster analysis methods. The purpose of the methods was to order the relationship of the macroplots to one another and place them into community type groups based on plant cover similarity. Cluster analysis was completed using the CLUSTR program within PC-ORD software (McCune and Mefford 1999). Each method varied by two factors: distance measure and group linkage method. Table 3 outlines the basic attributes of the five cluster analysis methods. The most successful method was chosen based on degree of chaining, percent of information remaining, interpretability, ability of the groups to be replicated, and whether resulting taxa could be identified in the field.

Table 3. Attributes of the five cluster analysis methods used. Method 1, Euclidean distance by Ward's method, was subsequently found to be the most successful of the five cluster analysis methods.

Cluster analysis method	**1**	**2**	**3**	**4**	**5**
Distance measure	Euclidean	Sorenson's	Sorenson's	Euclidean	Euclidean
Group linkage method	Wards	Flexible Beta (-.25)	Group Average	McQuitty's	Farthest Neighbor
Number of groups created	3	3	2	2	3
Groups replicable	yes	yes	no	no	no

Each method resulted in two or three groups of related macroplots. Methods one and two created the same groups of macroplots. Group one was consistently formed in four of the methods. In two of the methods, group three was divided into two subgroups, macroplots 12, 24, 21, and 27 in one subgroup and macroplots 20, 23, and 26 in the second subgroup. Appendix three gives further details on the results of those methods.

The most successful cluster analysis method was the combination of Euclidian Distance and Ward's method (cluster analysis method one). Measurements of success are discussed below.

Chaining: The Euclidian Distance/ Ward's method had a low degree of overall chaining. Though small, group two had more chaining than the other two groups; it is also the largest group and therefore more susceptible to chaining.

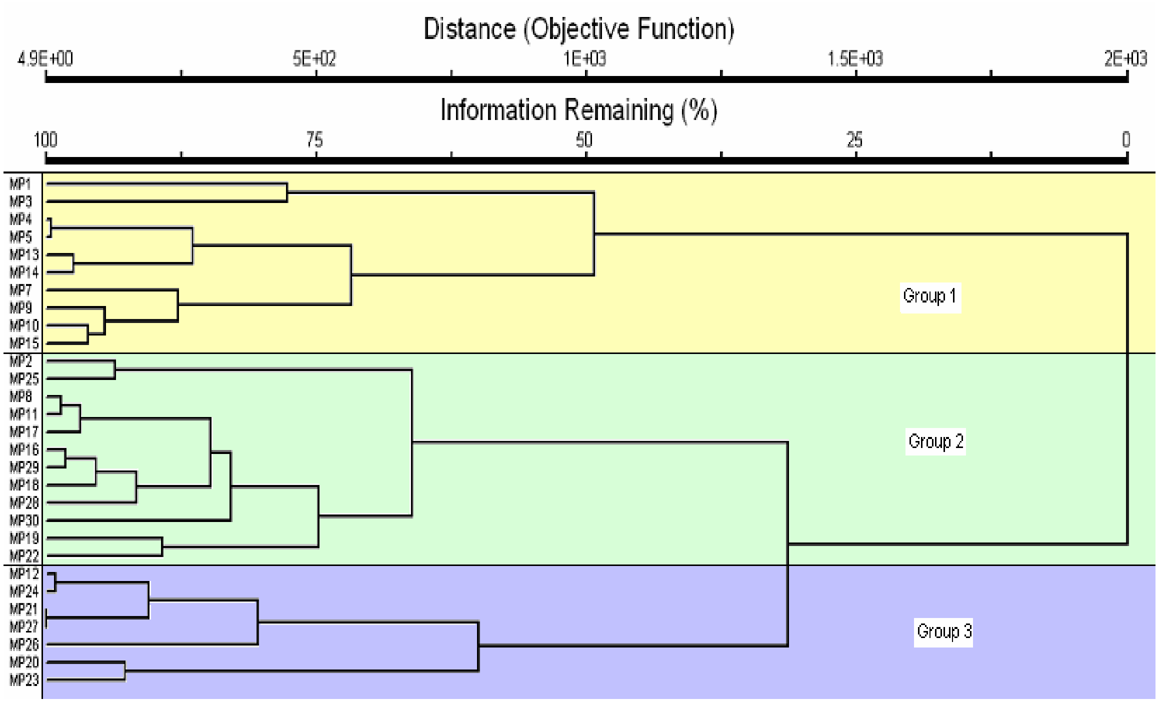


Figure 3. Dendrogram of species cover using Euclidean distance and Ward's method (cluster analysis method one). Group one is shaded yellow. Group two is shaded green. Group three is shaded blue. Each group represents a set of macroplots which have similar species cover characteristics. Macroplot numbers are listed down the left side and are abbreviated MP1-MP30.

Amount of information remaining: The Euclidian Distance/Ward's method created a dendrogram quickly with a high amount of information remaining. The faster, or higher the amount of information remaining, the more closely the macroplots within that group are ecologically linked (Grimm and Yarnold 2000, McCune and Grace 2002). Each macroplot linked quickly to another nearby macroplot in a succinct, reductionist pattern. Macroplots in group two were all linked to one another faster than the other two groups, with approximately 68% the information remaining. This is influenced by the ecological similarity of group two macroplots. Macroplots in group three were linked with approximately 60% of the information remaining. Macroplots in group one were linked with approximately 49% of the information remaining.

Consistency: The Euclidian Distance/ Ward's method outputs were consistent with the output of other methods. Sorenson's/ Flexible Beta (-.25) method created the same macroplot groupings at Euclidian Distance/ Ward's method. In each of these two methods, macroplots were connected into the same groups despite a change in linkage technique and distance measure. This consistency supports the conclusion that the groups are formed because of the underlying ecological relationship not the linkage or distance measure.

Ecological interpretation: Macroplots differ between groups based upon their amounts of shrub and bunchgrass cover. Group one consisted of macroplots with high grass cover values and shrub values less than 0.1%. Group two consisted of macroplots with high grass and low shrub cover values less than 0.2%. Group three consisted of macroplots with high grass and low to moderate shrub cover values less than 8.0%. Ecologically, group structure represents the inverse relationship of the bunchgrasses and shrubs; as shrub cover increases, bunchgrass cover values decrease and vice versa. The ordination will help elucidate other variables influencing the group structure.

Field identification: The Euclidian Distance/ Ward's method created groups that can be identified in the field. The macroplots in group one look similarly to one another because they are dominated by bunchgrasses but lack shrubs. It is unlikely that shrubs would be visible in group two macroplots unless one pushed back the bunchgrasses and looked at the plant mosaic closely. On the other hand, low-lying shrubs are visible in group three macroplots from a distance as well as at a close range.

Cluster analysis created three groups of related macroplots. Each of these groups represents a separate plant community and habitat that supports Spalding’s catchfly. Euclidean distance groups objects that are the closest in hyperspace distance. Because the differences are squared in this method, variables with the greatest magnitude of difference are weighted most heavily. Combining the cluster analysis groups with ordination will further elucidate which variables contributed most heavily to the group structure. The three groups created in the cluster analysis were applied to the ordination as a qualitative variable overlay. Used together, information on the causes and structure of the three different types of Spalding’s catchfly communities will continue to emerge.

Ordination

The configuration of macroplots in ordination space is representative of their ecological relativity to one another. Ordinations were run in the program PC-ORD (McCune and Mefford 1999) on autopilot mode using a NMS, Sorensen’s distance measure, and a random start configuration. Two matrices of information were input into PC-ORD. The main matrix consisted of square root transformed cover data for each species as well as amounts of lichens, moss, rock, bare ground, and litter for each macroplot. The secondary matrix consisted of square root transformed elevation and slope, and the cosine of aspect for each macroplot. The cluster analysis grouping variable (group 1, 2, or 3) was included in the secondary matrix as an overlay. In this way, the group category did not contribute to the configuration but it was visible in the output graphs.

Two hundred and fifty two runs were carried out via the “slow-thorough” autopilot method. The solution could have included up to six dimensions but a three dimensional solution was found to be most appropriate. Results were considered adequate based upon the four following criteria: proportion of variance represented, Monte Carlo testing, stress, and interpretability.

Proportion of variance represented: With three axes, the cumulative equivalent r^2=.85, whereby 85% of the variance is represented in the ordination graph. For axis one, the coefficient of determination was 0.08, axis two was 0.23, and axis three was 0.55. Non-parametric correlation values between each axes and the secondary matrix variables were calculated as Kendall’s *tau*. The three highest correlations are reported here. Slope was correlated with axis two at *tau*=.51. Elevation was correlated with axis two at tau=-.31. Aspect was correlated with axis three at *tau*=.31. These correlations are visually represented in the ordination graphs as vectors.

Monte Carlo testing: Over the course of 250 Monte Carlo runs on random data versus 250 runs on the actual data, stress in relation to dimensionality was minimized within three axes for real data. At three axes, the proportion of randomized runs with less stress than the real data was p=.004. Due to the low p-value, it is unlikely that such a solution would occur randomly. There was less than a one percent chance that the same final stress could have been achieved by chance. A three-dimensional solution was used because each of these three axes, when added iteratively, reduced the total stress by 5% or more.

Stress: A scree plot of iteration number versus stress shows that stress dropped quickly to a final instability of 0 after 76 iterations, Final stress stabilized at 11.53, a level which suggests a fairly successful ordination with a moderately low risk of inferential errors (Clarke 1993, McCune and Grace 2002).

Ordination graphs and interpretability: The major outputs of the ordination are two or three-dimensional graphs which arrange the macroplots and vector variables in ordination space. Figure 4 is the two-dimensional graph of axis two to axis three, the axes which together explain the highest amount of ordination variance, 78%. Figure 4 shows the influence of all of the major known gradients. Figure 5 is the two-dimensional graph of axis three to one, which together represent 63% of the variance and highlights the influence of disturbance. Interpretability of the graphs is based on two factors: logical arrangement of macroplots and vector variables. Before these two factors can be evaluated the ordination graphs will be explained.

Macroplot placement is a function of all input variables: plant species percent cover, ground cover, slope, elevation, and the cosine of aspect but is most heavily influenced by species cover. The closer two macroplots are to one another the more ecologically similar they are. Macroplots in cluster analysis group one were shaded red and represented by circles, group two was shaded black and represented by triangles, and group three was shaded blue and represented by squares. The ordination contains three vector values (secondary matrix variables): elevation, slope, and cosine of aspect. Each of these vector variables is represented by a red line that originates in the center of the plot and moves out. All three vectors are visible in Figure 4 while one is visible in Figure 5.

Placement of macroplots in Figure 4 is influenced by two axes: axis three which corresponds to the cosine of aspect vector and axis two which corresponds to slope and elevation vectors. Because disturbance by fire (burned or unburned status) was not one of the original abiotic input variables it is not on the ordination graph as a vector. But its influence is visible along axis three; successional changes initiated by fire may influence the spread of macroplots along axis three. Macroplots at the bottom of the graph are more likely to be burned in recent wildfires than those at the top of the graph. In fact, all of the group three macroplots were disturbed by a fire during the October 2001 Corral Creek fire.

In Figure 4, axis two shows the influence of slope and elevation on the macroplots. The variables of elevation and slope move out from the center in almost opposite directions of one another. A macroplot far towards the outside wall on the elevation side, like macroplot 10, would have a high elevation and lower slope. Conversely, a macroplot near the other end of the slope vector line, like macroplot 19, would have a high slope and lower elevation. Those plots in the center are more moderate on all vector variables.

Figure 5 shows the influence of axes one and three. As in Figure 4, axis three is influenced by aspect and fire disturbance. Macroplots that have a higher cosine of aspect are closer to north (0 degrees). The most north facing macroplots, such as macroplot 20, are situated at the top of the graph. Macroplots to the right and bottom of the graph, such as Macroplot 14 are further away from north. Axis three shows the influence of disturbance again. In Figure 5 unburned macroplots are shaded in a yellow polygon. These plots aggregate at the bottom of the graph.

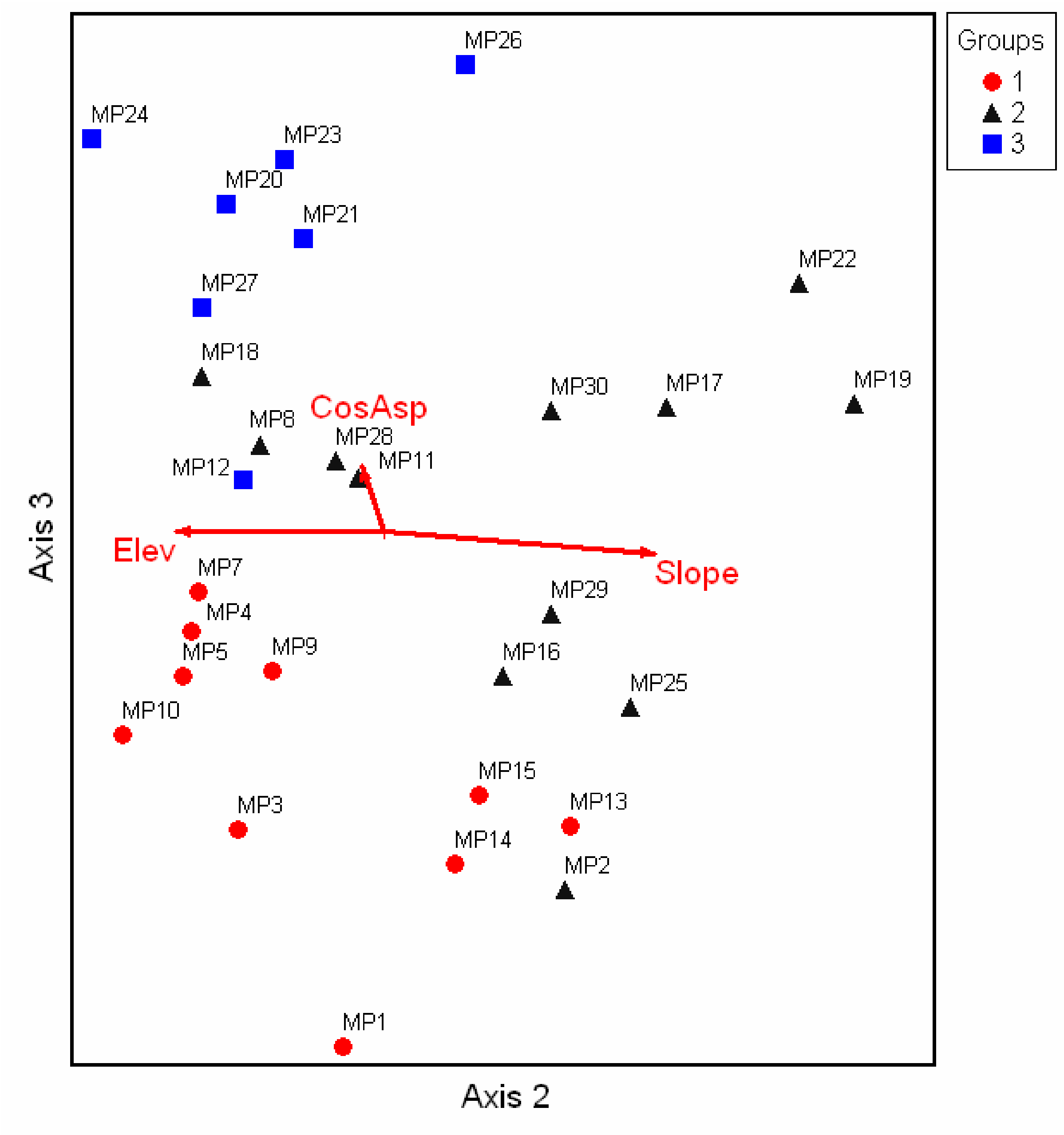


Figure 4. NMS ordination of Spalding's catchfly communities: axis two to axis three. Together these two variables account for more than 78% of the ordination variability. Group variables are overlays from the cluster analysis. Macroplot placement along axis three is influenced by fire disturbance and aspect (CosAsp) vectors. Macroplot placement along axis two is influenced by elevation and slope vectors. The arrow at the tip of each vector points in the direction of higher values.

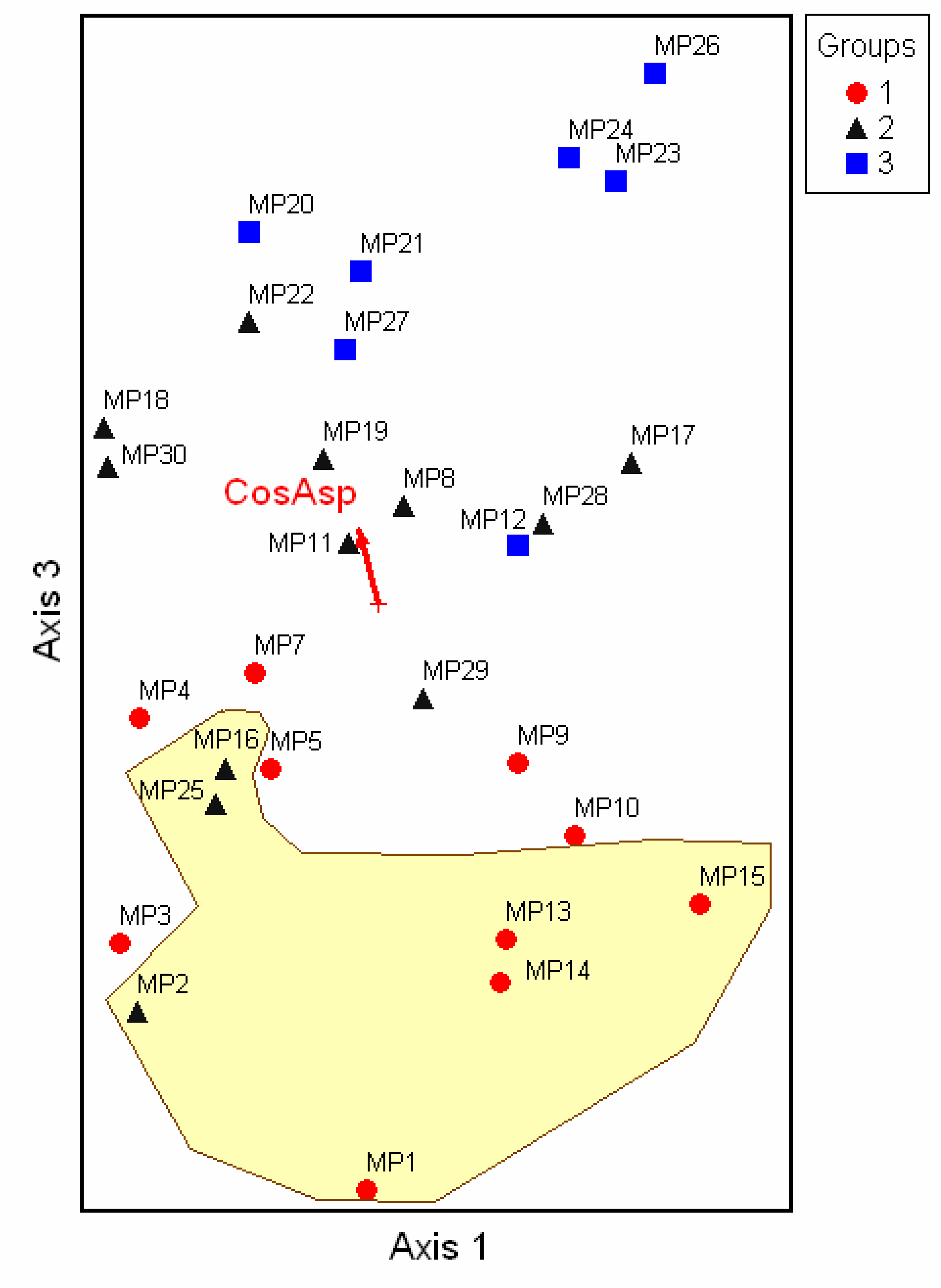


Figure 5. NMS ordination of Spalding's catchfly communities: axis one to axis three. Macroplot placement along axis three is influenced by disturbance and aspect. Unburned macroplots are shaded in the yellow polygon. The arrow at the tip of the vector points in the direction of higher values.

This ordination can be straightforwardly interpreted. Macroplots are logically grouped according to ecological similarity within the ordination graph. Aggregation of groups one, two, and three from the cluster analysis should and do re-occur spatially in the ordination. This happens because the groups are based on ecological similarity - a similarity that should transpire regardless of the statistical method. The vectors help clarify the arrangement of the macroplots. The ordination re-affirms the structure of the groups and the groups affirm the structure of the ordination.

Group analysis

The cluster analysis and ordination resulted in three groups that may represent three distinct Spalding’s catchfly community types at GCR. All three groups are a product of successional and environmental influences, and they exist in a multi-dimensional continuum. Classifying these plant communities into three community types helps further define the possible differences between Spalding’s catchfly plant communities and habitat at GCR. The upper and lower limits of these plant communities characterize the confines of exhibited habitat. As a whole, these three community types represent the breadth of known Spalding’s catchfly habitat in the Corral Creek drainage of GCR.

Group one: late-seral bunchgrasses community type: In group one, macroplots had high amounts of Idaho fescue and low to no snowberry. This group consisted of ten macroplots in which average Idaho fescue cover, 15.0%, was at least twice as high as the other two groups. Bluebunch wheatgrass cover was moderate at 4.4%. Prairie junegrass cover, 1.3%, was lower in this group than any other. Average percent cover for all grasses in group one was 21.4%. Group one had more grasses than any other group and is most likely a late-seral community (Figure 6). The group one community type most closely resembles two existing classification system taxa: 1) Johnson and Simon (1987) FEID-KOCR (low elevation) plant association and 2) Tisdale (1986) FEID-KOCR habitat type.

Group one was also distinctive due to its low shrub cover, the lowest of any group, <0.1%. Six macroplots had no snowberry while the remaining four had snowberry cover below 1% (Table 4). Rose cover was the lowest in group one at 0.1% average cover. Average forb cover for group one was 12.2%. Grasses were dominant over forbs. Common yarrow cover was lower in group one than the other two groups at 0.1%. On the contrary, cover for arrowleaf balsamroot (*Balsamorhiza sagittata*) and the invasive weed, yellow starthistle (*Centaurea solstitialis*) were highest in group one at 0.9% and 0.5% respectively.

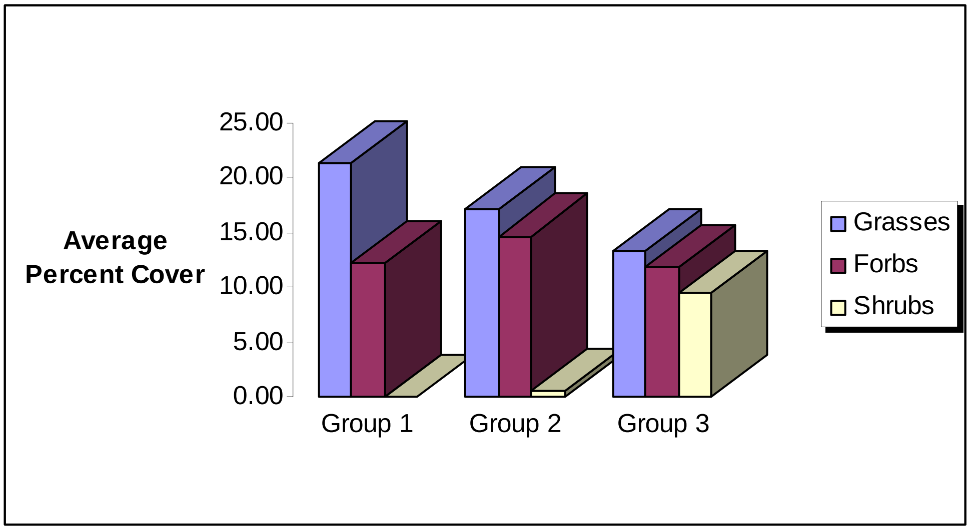


Figure 6. Grass, forb, and shrub cover by group. Group one had the highest grass cover and lowest shrub cover. Group two had more uniform grass and forb cover and low shrub cover. Group three had the highest shrub cover.

Table 4. Mean percent foliar cover and standard deviation of major species and covariate features, within cluster analysis groups one, two, and three.

Species	Group 1 Grass Group		Group 2 Mixed Group		Group 3 Shrub Group	
	Mean	SD	Mean	SD	Mean	SD
Grasses						
Festuca idahoensis	15.0	5.5	6.5	2.0	5.3	2.4
Koeleria macrantha	1.3	0.8	1.5	1.0	2.5	0.7
Poa secunda	0.6	1.0	0.6	0.5	0.3	0.4
Pseudoroegneria spicata	4.4	2.0	7.4	3.5	4.1	1.4
Forbs						
Achillea millefolium	0.2	0.1	0.9	0.6	0.9	0.6
Arenaria serphyllifolia	0.1	0.1	0.3	0.2	0.6	0.3
Arnica sororia	1.0	0.8	0.9	1.1	0.4	0.3
Artemisia ludoviciana	0.0	0.0	0.1	0.2	0.5	0.8
Balsamorhiza sagittata	0.9	0.9	0.3	0.4	0.3	0.8
Besseya rubra	0.3	0.4	0.3	0.4	0.1	0.2
Centaurea solstitialis	0.5	1.6	0.0	0.1	0.2	0.4
Cerastium arvense	0.3	0.4	1.8	1.5	0.3	0.4
Clarkia pluchella	0.4	0.6	0.3	0.7	0.0	0.0
Epilobium paniculatum	0.3	0.8	0.1	0.2	0.2	0.2
Erigeron corymbosus	0.2	0.3	0.5	0.5	0.7	0.6
Eriogonum heracleoides	0.3	0.9	0.7	1.2	0.0	0.0
Frasera albicaulis	1.3	1.1	1.0	0.9	1.2	0.4
Galium aparine	0.6	0.9	0.4	0.5	0.3	0.2
Geum triflorum	0.7	1.1	0.7	0.8	0.8	1.0
Heuchera cylindrica	0.1	0.2	0.5	0.9	0.0	0.0
Hieracium scouleri	0.7	0.9	0.7	0.6	0.3	0.2
Lithospermum ruderale	0.1	0.1	0.2	0.3	0.3	0.4
Lupinus sericeus	0.7	0.7	1.2	1.7	0.4	0.3
Myosotis stricta	0.4	0.3	0.3	0.3	0.1	0.1
Penstemon glandulosus	0.0	0.0	0.3	0.5	0.2	0.3
Phlox colubrina	0.4	0.3	0.5	0.5	0.2	0.2
Potentilla gracilis	0.5	0.4	0.3	0.4	0.2	0.2
Sisymbrium altissimum	0.0	0.0	0.1	0.3	0.3	0.3
Shrubs						
Rosa spp.	0.1	0.1	0.2	0.5	1.4	2.1
Symphoricarpos albus	0.2	0.4	0.2	0.5	8.0	4.4

Compared to the other two groups, group one was moderate in aspect, slope, and elevation (Table 5). Group one's aspect was north-facing with a 0.8 average cosine of aspect. Slope averaged 54.6% and elevation averaged 805 m. In the ordination, group one macroplots were associated with the vectors of higher elevation and lower slope (Figure 4). Group one and two appeared to be more closely affiliated to one another than groups one and three.

Table 5. Covariate features by community type group.

	Group 1 Grass Group		Group 2 Mixed Group		Group 3 Shrub Group	
Covariates	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Bare ground (%)	5.2	2.0	3.1	2.0	4.4	3.9
Lichens (%)	0.7	1.1	0.9	1.3	0.1	0.2
Moss (%)	3.3	2.4	5.4	3.5	1.9	1.3
Litter (%)	73.6	7.2	81.3	5.0	82.0	8.4
Rock (%)	< 0.1	0.1	0.2	0.4	2.1	5.2
Slope (%)	54.6	13.2	60.6	18.2	44.0	9.8
Elevation (m)	805.6	66.8	783.	176.3	815.1	20.6
Cosine of aspect	0.8	0.2	0.8	0.2	0.9	0.1

Johnson and Simon's (1987) FEID/KOCR (low elevation) plant association is found in similar slope (35-90%), elevation (366-1173m), and aspect (ENE to WNW) range as the macroplots in group one. This habitat type has ten principal indicator species.Group one macroplots contained eight of these ten species; rattlesnake brome (*Bromus brizaeformis*) and tonella (*Tonella floribunda*) were absent. Tonella, an annual forb, may be an indicator of disturbance as well as an earlier seral stage of FEID-KOCR; it has hooked barbs and is transported by animals (Johnson and Simon 1987). Also, in early-seral stages, bluebunch wheatgrass cover increases. But, late-seral stages of the FEID-KOCR plant association have greater amounts of Idaho fescue than bluebunch wheatgrass – in as much as a 4:1 ratio (Johnson and Simon 1987). Group one macroplots had a 2:1 ratio of Idaho fescue to bluebunch wheatgrass. Group one macroplots appear to be in a late seral stage.

Tisdale's (1986) FEID/KOCR habitat type also generally matches the group one community type. As the name suggests, FEID/KOCR sites have abundant Idaho fescue along with a "constant presence" of prairie junegrass. Prairie junegrass was present in all group one macroplots. For most descriptive variables, Tisdale gives the average site characteristics rather than a range. Group one characteristics of bare ground, litter, elevation, and slope most closely match Tisdale's descriptions. Tisdale also notes that FEID/KOCR habitat types have a low frequency and cover of the snowberry and rose shrubs - as was found in group one. The soils on which FEID/KOCR are found are predominantly Argixerolls and Haploxerolls, as in group one.

Group one appears to be influenced by recent disturbance more than group two. Litter, lichen, and moss cover were lower and the invasive weed, yellow starthistle, was higher. Lower litter was especially noteworthy. Group one had 73.6% cover, which is 8-9% lower than the other two groups. It appears unlikely that burning alone caused the observed disturbance in ground cover. More group one macroplots were unburned (four of ten), than group two macroplots (3 of13). Since burning decreases litter and biological soil crusts, we would expect opposite results. Burning alone does not explain why group one had less litter and biological soil crusts than group two.

Rodent activity in group one macroplots may be the disturbance causing these differences. Rodent runs, scat, and tunnels through the litter were observed and documented at GCR by the author. Johnson and Simon (1987) stated that voles used areas of FEID-KOCR habitat that contain large amounts of litter, subsequently decreasing litter and creating runways and tunnels. In my research, runways and tunnels in which soil were showing, were categorized as bare ground. Group one contained more bare ground than any other group, 5.2%. Two species of voles, the montane vole (*Microtus montanus*) and the long-tailed vole (*Microtus longicaudius*) have been found in Idaho fescue grasslands at Craig Mountain (Cassirer 1995).

At GCR, group one macroplots contained the highest levels of bunchgrasses and may therefore have the potential to support higher montane vole populations than groups one or two. Hodgson (1972) found that the montane vole (*Microtus montanus*) was associated with mesic grassland communities of southwestern Montana. In areas of 0-40% grass cover, montane vole populations increased as grass cover increased.

Decreased litter and increased bare ground, in this case from rodent disturbance, could contribute to increased yellow starthistle establishment. Roche et al. (1994) found that increased yellow starthistle in eastern Washington bunchgrass habitats was associated with increased light intensity at the soil surface and soil moisture availability. DiTomaso et al. (1999) also found that soil disturbance and high light availability favor yellow starthistle establishment.

Group 2: mid-seral bunchgrass community type: Macroplots in group two had moderate amounts of Idaho fescue and low to no snowberry. Group two consisted of 12 macroplots in which Idaho fescue had an average cover of 6.5%. Average cover for bluebunch wheatgrass was highest of the three groups at 7.4%. Overall bunchgrass cover was more even between species than in group one. Group two macroplots may be successionally younger than group one macroplots; group two macroplots are mid-seral bunchgrass community types. The group two community type most closely resembles two existing classification system taxa: 1) Johnson and Simon (1987) FEID-KOCR (low elevation) plant association and 2) Tisdale (1986) FEID-KOCR habitat type.

Because group two has higher forb cover and lower grass cover than group one it is probably a mid-seral community. Johnson and Simon (1987) state that FEID-KOCR sites with higher bluebunch wheatgrass than Idaho fescue cover are less successionally developed. In the dynamic equilibrium model, diversity is highest in mid-seral communities when neither disturbance nor competitive exclusion processes dominate (Huston 1994). Of the three groups, group two had the highest forb cover, 14.7%. Table 6 lists the unique species of each group. Group two did not have any exclusive species; if a forb was present in group one or two it was also present in group three. Overall grass cover is 4% lower than group one. The noxious weed, yellow starthistle, though present in trace amounts, had the lowest average cover value, >0.1%, in group two. Lower yellow starthistle may indicate that the group one macroplots are not influenced by as much recent disturbance as group one.

Total shrub cover was still low, 0.5%, but it was slightly higher than group one. Rose cover was higher in group two, 0.2%, than in group one. Snowberry cover was the same in group two as group one, 0.2%, but fewer plots contained snowberry. Only three of the twelve macroplots contained snowberry. Two macroplots had snowberry below 1% but in macroplot 28, the snowberry cover was 1.8%.

Group two had a more intact ground cover than group one. Lichens and mosses were highest in group two at, 0.9% and 5.4% respectfully. Group two also had the lowest amount of bare ground, 3.1%. Litter was seven percent higher than group one at 81.3%. Low bare ground, moderately high litter, and high biological soil crusts could imply that there was less rodent disturbance in group two macroplots.

Within north-facing aspects, slope and elevation changes can act together to create similar conditions. Figure 7 shows the relationship of elevation and slope over all macroplots. It appears that above 700 m Spalding's catchfly habitat can be found on many different slopes while below this elevation it is restricted to greater angled slopes. The three lowest elevation sites (all group two macroplots) were on steep slopes: 482m-85% slope, 488m-90% slope, 634m-75% slope. In this study, steep slopes may have similar conditions as more moderately-sloped, higher-elevation, north-facing macroplots. Steep north-facing slopes have a lower angle of incidence for radiation, and could have a lower moisture loss than less sloped sites at the same aspect and elevation. Though abiotic inputs differ, they act in combination through factor compensation to create a similar plant habitat (Daubenmire 1968a).

Group two macroplots fit into similar existing plant classification taxa as group one: 1) Johnson and Simon (1987) FEID-KOCR (low elevation) plant association and 2) Tisdale (1986) FEID-KOCR habitat type. Group two macroplots contain ten of the ten principal indicator species for Johnson and Simon's FEID-KOCR (low elevation) plant association and meet the criteria for slope, elevation, and aspect. Tisdale's (1986) FEID/KOCR habitat type also generally matches the group two community type in all aspects except elevation. Elevation for Tisdale's FEID/KOCR sites is given as 530-2000

m. Three macroplots in the 400 m range fall below this criteria. But, Tisdale states that FEID/KOCR sites below 800 m “are on slopes compensated in temperature by steep northern aspects.” This is the case for all of the group two macroplots below 530 m.

Table 6. Presence and absence of species within groups.

Only Present In Group 1	**Not Present in Group 1 But Present in Groups 2 and 3**
Hydrophyllum capitatum	*Artemisia ludoviciana* *Bromus brizaeformis* *Crataegus douglasii* *Penstemon glandulosus* *Tonella floribunda* *Lithophragma arvense* *Triodanis perfoliata*
Only Present in Group 2	**Not Present in Group 2 But Present in Groups 1 and 3**
Amelanchier alnifolia	None
Only Present in Group 3	**Not Present in group 3 but Present in Groups 1 and 2**
None	*Clarkia pluchella* *Eriogonum heracleoides* *Heuchera cylindrica*

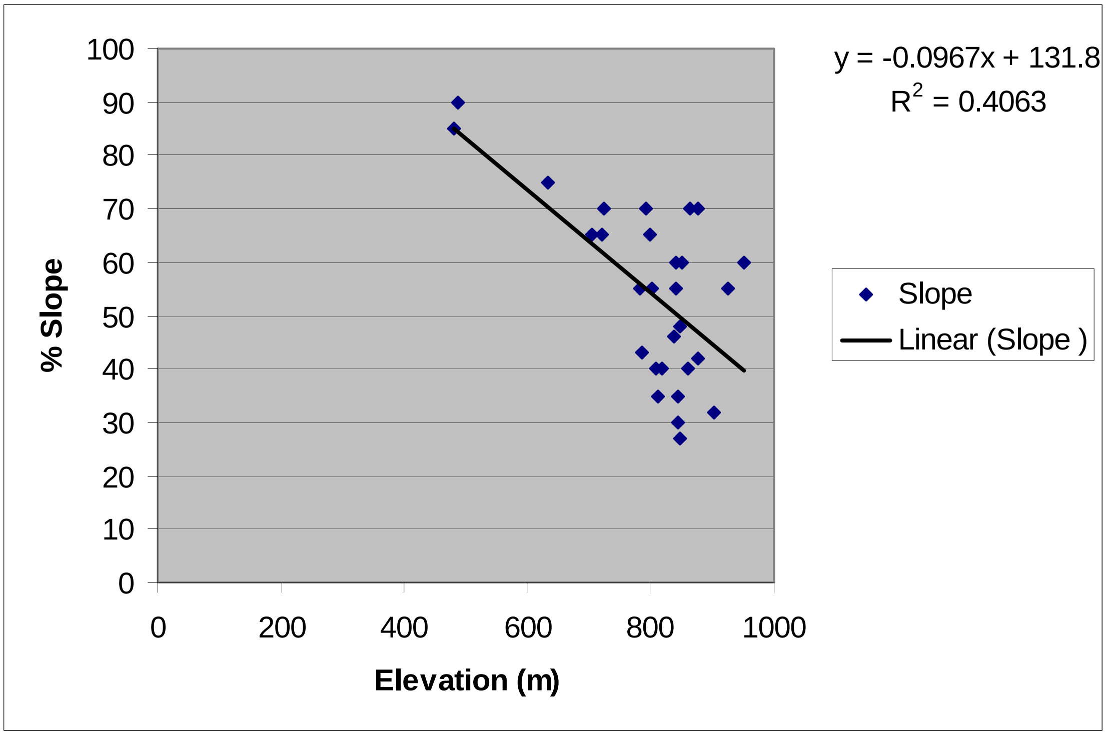


Figure 7. Relationship of elevation to slope in all macroplots (n=29). As elevation increased, slope decreased. R^2 =0.41. At lower elevations Spalding's catchfly sites were restricted to higher slopes. At higher elevations Spalding's catchfly sites were less restricted

Previous grazing pressure on group two macroplots may have influenced the present bunchgrass communities, making them different than group one. Johnson and Simon (1987) state that in FEID-KOCR communities, overgrazing may result in higher bluebunch wheatgrass cover and/or higher shrub cover. Domestic grazing has not occurred at GCR in fifteen years, though historically the site was grazed by cattle (*Bos taurus*) (Hill and Gray 1999). Thus, the higher proportion of bluebunch wheatgrass in group two than group one may have been caused by grazing, though details on the historic grazing regime are unknown. Non-domestic grazing by mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) still occurs at GCR.

Group 3: bunchgrass with shrubs community type: The most ecologically significant feature of the 7 group three macroplots is their relatively high snowberry and rose cover. Group three had moderate grass cover, 13.25 %, along with higher than average shrub cover, 9.4%. Snowberry cover for these macroplots ranged from 4.8% to 15%. Average rose cover, 1.4%, was also higher than any other group. In addition to having shrubs, all macroplots in group three burned in the 2001 Corral Creek fire. Group three macroplots have different abiotic site characteristics and successional influences than groups one and two. The group three community type most closely resembles Daubenmire's (1970), FEID/SYAL habitat type.

Group three doesn't have any plant species unique only to this group, however three species were absent from group three while present in the other groups (Table 6). Average Idaho fescue cover was 5.3%, the lowest of the three groups but prairie junegrass average cover was 2.5%, highest of the three groups. The shrub cover is greater while total bunchgrasses and forb cover is decreased. Lichen, 0.1%, and moss, 0.9 %, average cover were low while rock, 2.1%, was high. Low biological soils crusts may be the result of the 2001 Corral Creek fire, as biomass of soil crusts can still be low three to five years post fire (Johansen et al. 1984). Litter cover, 82.0%, was higher in group three than groups one or two.

In the ordination, group three macroplots occupied the top left side of Figure 4. Their placement was associated with aspect and fire disturbance. The reason for this phenomenon may be that the variable(s) which is (are) bringing them together are not included in the ordination. Though not an original input variable for the cluster analysis or ordination, all macroplots in group three were burned as is visible along axis three in Figure 5.

Shrub response to fire is dependent on fire intensity and frequency. Johnson and Simon (1987) cited fire suppression as one of the possible causes for snowberry and rose invasion into FEID-KOCR communities. Annual burning in grassland ecosystems has been shown to decrease shrub cover (Briggs et al. 2002). Menke and Muir (2004) found that shrub cover was decreased in burned Spalding's catchfly sites in the year immediately following the Corral Creek fire: 0.5% cover vs. 6.7% cover.

Though all group three macroplots have high shrub cover *and* were burned it is not clear if this relationship is causal or coincidental. The effects of burning, five years post-fire may be to help increase shrub cover in group three macroplots. In a long term study of shrub-fire interactions in the tallgrass prairie, shrub density increased substantially at a 3-5 year fire interval (Briggs et al. 2002). Conversely, another researcher it GCR conducting simultaneous research during 2006 on snowberry patches near my macroplots, found that five years post-fire, shrub cover had not reached its pre-burn status.

Burning accounts for some but not all of the shrub and grass cover variability between groups. Total snowberry and rose cover was higher in the burned macroplots, 3% in burned versus 0.3% in unburned. But, snowberry and rose constancy was lower in burned macroplots, 43%, than unburned, 57%. Analysis of burn influence is complicated by the fact that the majority of sites, n=22, were burned rather than unburned, n=7. Sixty percent of group one macroplots and 77% of group two macroplots were burned. Overgrazing and general climatic changes have also been cited as possible causes for snowberry and rose invasion into FEID-KOCR communities (Johnson and Simon 1987). Daubenmire (1970) also found that overgrazing increased snowberry in FEID-SYAL communities.

The community type represented in group three macroplots most closely matches Daubenmire's (1970) FEID-SYAL habitat type. The macroplots have dense Idaho fescue with snowberry and rose stems scattered within the forbs and grasses. FEID-SYAL also has prairie junegrass in a generally similar grass and forb concentration as adjacent FEID-KOCR grasslands. This is true for group three as well. Daubenmire (1970) found that parsnipflower buckwheat (*Eriogonum heracleoides*) is "under-represented" in the FEID-SYAL habitat type. This buckwheat species was absent from all group three macroplots but present in the other two groups.

There are a few ways in which group three does not fit Daubenmire's (1970) FEID-SYAL habitat type. Daubenmire's FEID-SYAL habitat type is not restricted to north-facing slopes, though they are often found on them. The FEID-SYAL habitat type was found on slopes ranging from 0-34%, whereas group three macroplots were occasionally in excess of 60%. Group three macroplots had the lowest average group slope, 44%. But, lower slope gradients were not significantly correlated with shrubs across all groups. One reason for the low range of slope for Daubenmire's FEID-SYAL habitat type is due to his sampling area. Whitman and Spokane county Washington generally have lower slopes than GCR canyon grasslands. Daubenmire (1970) also suggests that species diversity is maximized in the FEID-SYAL habitat type. This was not the case; group three had lower forb diversity and forb cover than group two macroplots. Forb cover was only 2% lower in group three than group two.

Group three macroplots are similar to the SYAL/FEID-KOCR community type described by Johnson and Simon (1987). They describes the bunchgrasses in a 4:1 ratio with snowberry; this fits with the ratio of bunchgrasses to shrubs found in group three macroplots. Five of the six associated forb species were present in group three macroplots: rattlesnake brome, arrowleaf balsamroot, silky lupine, common yarrow, western stoneseed. Clarkia was absent. The elevation range for this community type in Oregon, >1219 m, is higher than the sites at GCR. Johnson and Simon only had four sample site of this community type and felt its occurrence was limited in northeastern Oregon but was perhaps more extensive in southeastern Washington and northern Idaho as described by Daubenmire(1987). This community type cannot be reached through the Johnson and Simon key and is not listed in the table of contents.

Since FEID-SYAL and FEID/KOCR are different habitat types/potential natural communities, each has the ability to ultimately support a different climax community. Johnson and Simon (1987) found FEID-KOCR and SYAL-ROSA plant associations together in a matrix on mesic north-facing slopes. Site factors, not fully captured in this study likely contribute to the separation of FEID-SYAL and FEID/KOCR communities.

Group three macroplots are associated with higher elevation. Elevation and slope were more restricted within group three macroplots. Elevation ranged from 785-843 m, with an average of 815 m. Slope ranged from 35-60% with an average of 40%. Shrubs were thus correlated with flatter, upland sites. Figure 8 shows the simplified trends of elevation, slope, and aspect between groups. Tisdale (1986) stated that community vegetation patterns in the canyon grasslands are highly influenced by elevation. At GCR grasslands give way to shrubs and shrubs give way to forested communities as you increase in elevation.

Group three macroplots may be associated with higher soil moisture. Macroplots in group three may have originally had more moisture available which allowed shrubs to become established. Daubenmire (1968b) emphasizes the importance of soil moisture in differentiating Idaho fescue grasslands from neighboring snowberry habitat types. The FEID-SYAL habitat type is the wettest Idaho fescue habitat described by Daubenmire (1970). Many studies have shown that available soil moisture is higher under shrubs than adjacent grass-dominated areas (Li and Wilson 1998). Increased levels of soil moisture allow for the establishment of woody plants, which is quickly followed by interspecific competition for resources including, most importantly, light limitations that restrict graminoids (Peltzer and Kochy 2001).

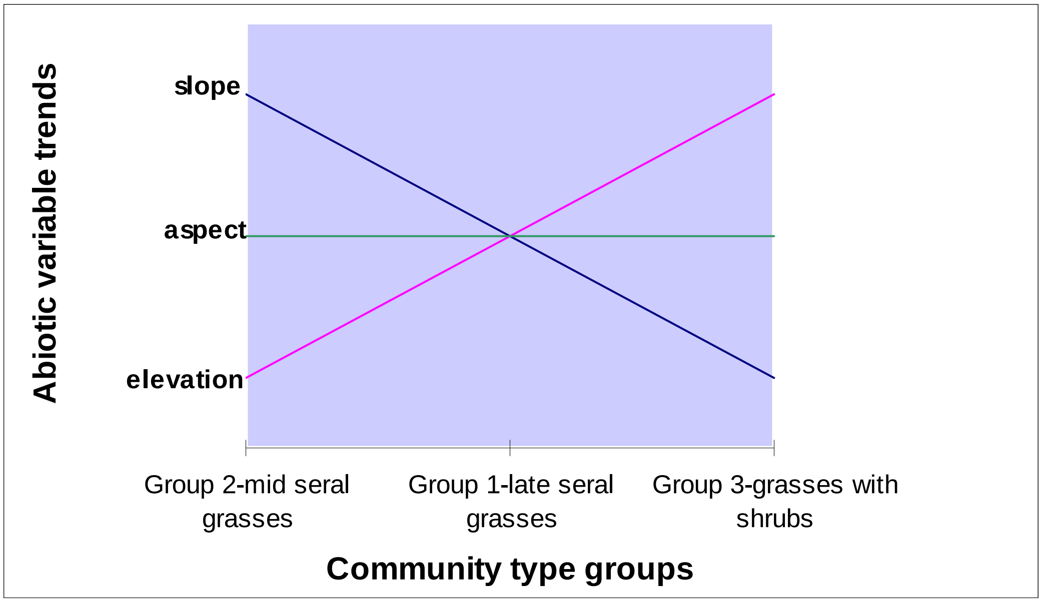


Figure 8. Abiotic variable trends by community type: elevation, slope, and aspect. From group two to three: elevation increases. From group two to three: slope decreases. Aspect is fairly constant throughout the three groups and subsequently across Spalding's catchfly sites at GCR.

Once shrubs become established they have been shown to have low competitive interactions and even some facilitation with other shrubs (Peltzer and Kochy 2001) thus creating conditions which can continue to increase total shrub cover. Another contributing factor towards the shrubs on the same slopes as FEID-KOCR communities is that these sites have deeper and more clayey soils (Johnson and Simon 1987). If soil moisture and edaphic factors had been measured in this study, they may have helped explain the ecological variance and ordination arrangement of group three macroplots.

Management Considerations

The specific combination of abiotic and biotic factors that create Spalding's catchfly habitat at GCR can also be found throughout the canyon grasslands physiographic region. It is likely that additional Spalding's catchfly populations that have not been identified exist in these areas. Canyon grassland managers can use the criteria put forth in this research in combination with previous studies to identify potential Spalding's catchfly habitat.

Land managers may benefit from using the biotic variable of community types to describe potential Spalding's catchfly habitat in other canyon grasslands. In grass dominated communities the FEID-KOCR potential natural community described by Tisdale (1986) and Johnson and Simon (1987) are more appropriate. In shrub dominated areas, Daubenmire's (1970) FEID-SYAL habitat type is a more accurate descriptor. If a manager was exclusively using Tisdale or Johnson and Simon classification systems to describe their canyon grasslands, they might overlook shrub dominated potential Spalding's catchfly habitat since no accurate descriptor for the shrub dominated

Spalding’s catchfly habitat exists within Tisdale (1986) or Johnson and Simon (1987) classification systems.

The abiotic habitat criteria presented in this study could be used to create a geographical model of potential Spalding’s catchfly habitat in canyon grasslands. By integrating minimum and maximum aspect, slope, and elevation as well as classification systems, additional prospective Spalding’s catchfly habitat could be delineated. Once prospective habitat is identified the model could then be tested by presence/absence surveys.

Managers intending to identify Spalding’s catchfly habitat should be aware of the following observations made during this study. In this study, once a plant was found, additional plants were more likely to be found up and down slope, rather than in either horizontal direction. At lower elevations, plants were restricted to steeper slopes. In shrubby areas, plants were generally found along the periphery of large shrub thickets rather than in the middle. In burned areas, Spalding’s catchfly plants were observed in the interior of shrub thickets as well as the periphery.

Summary and Conclusions

Three plant communities support Spalding's catchfly in the Corral Creek drainage of GCR. Two of these communities, groups one and two, are different successional stages of the same bunchgrass-dominated potential natural community. These community types most closely resemble the FEID-KOCR potential natural community described by Tisdale (1986) and Johnson and Simon (1987). Group three macroplots were bunchgrass communities with an average of 9.4% shrub cover. These sites are best described using Daubenmire's (1970) FEID-SYAL habitat type.

While differences in floristic composition between the three community types are clear, the abiotic habitat differences between these groups are somewhat less conclusive. Eighty-five percent of the observed variance between the three community types was represented in the ordination. Aspect variability between groups was low; Spalding's catchfly sites were found exclusively on north-facing slopes. At low elevations, Spalding's catchfly sites were restricted to steep slopes while at higher elevations, slope was more variable.

Differences between group one and two macroplots may be most highly influenced by succession and recent rodent disturbance. Group one is a late-seral bunchgrass community type which may be undergoing current changes due to ongoing rodent activity. The effects of rodent activity on the survival of Spalding's catchfly warrant further attention. Group two is a mid-seral FEID-KOCR bunchgrass community type found at lower elevations and steeper slopes than group two macroplots. While grass and shrub cover differed between groups, forb cover was fairly constant.

The group three community types may have site characteristics not measured in this study, particularly soil moisture, soil depth, and clay content that facilitate the development of minor shrub communities. The initial establishment of shrubs in group three macroplots may help to facilitate further conspecific shrub development (Li and Wilson 1998). Fire may also have some influence over the distribution of shrubs in Spalding's catchfly communities, though the relationship is complex and results somewhat contradictory in this study. The presence of shrubs was weakly associated with 1) increased burning, 2) higher elevation, and 3) decreased slope, though further studies are needed to understand these relationships.

Future investigations could study the particular mechanisms by which these three community types were formed. This study emphasized differences in abiotic factors on resulting community types. But biotic factors such as competition and facilitation influence community structure as well (Kimball et al. 2004). The role of competition and/or possible facilitation between Spalding's catchfly and snowberry may be of particular importance in the long-term survival of Spalding's catchfly.

Appendix 1. Locations, abiotic features, and classification data for Spalding's catchfly research macroplots at GCR.

Macroplot	Easting	Northing	Elevation (m)	Aspect (degrees)	Slope (%)	Burn status	Group
1	507898	5097647	783	333	55	unburned	1
2	507276	5097959	792	323	70	unburned	2
3	508906	5096479	839	10	46	burned	1
4	508925	5096465	840	15	55	burned	1
5	508935	5096442	846	3	48	burned	1
6 *	508942	5096443	851	0	40	burned	2
7	508943	5096443	843	346	30	burned	1
8	508964	5096439	848	330	27	burned	2
9	509019	5096400	877	330	70	burned	1
10	509036	5096413	878	328	42	burned	1
11	509171	5095911	903	310	32	burned	2
12	508975	5096022	843	310	35	burned	3
13	507701	5097156	703	310	65	unburned	1
14	507713	5097144	722	310	65	unburned	1
15	507727	5097146	725	300	70	unburned	1
16	507269	5097928	798	305	65	unburned	2
17	507604	5095704	488	0	90	burned	2
18	509324	5096407	925	340	55	burned	2
19	507572	5095615	482	0	85	burned	2
20	508905	5096648	817	0	40	burned	3
21	508915	5096639	812	340	35	burned	3
22	507584	5095615	634	20	75	burned	2
23	508981	5096189	840	340	60	burned	3
24	508887	5096171	807	320	40	burned	3
25	507232	5098037	852	290	60	unburned	2
26	508846	5096100	802	2	55	burned	3
27	508686	5096124	785	30	43	burned	3
28	509047	5096027	861	315	40	burned	2
29	508871	5095668	864	310	70	burned	2
30	509289	5095827	951	340	60	burned	2

* = removed from analysis

Appendix 2. Species list for plants occurring within sampled macroplots at GCR. Taxonomy follows USDA, NRCS. 2007. The PLANTS Database, (http://plants.usda.gov) [Accessed 1/30/2007]

Scientific name	Common Name	Symbol used	USDA Symbol	Duration	Origin
Achillea millefolium L.	common yarrow	ACMIL	ACMI2	P	N/I
Agoseris glauca (Pursh) Raf. var. *dasycephala* (Torr. & Gray) Jepson	pale agoseris	AGGLD	AGGLD	P	N
Amelanchier alnifolia (Nutt.)	serviceberry	AMAL	AMAL2	P	N
Amsinckia sp. Lehm.	fiddleneck	AMSINK	AMSIN	A	N
Apera interrupta L. = *Agrostis interrupta* L.	dense silkybent	AGIN3	APIN	A	I
Arabis glabra (L.) Bernh.	tower rockcress	ARGL	ARGL	A/B/P	N
Arenaria serpyllifolia L.	thymeleaf sandwort	ARSE	ARSE2	A	N
Arnica sororia Greene	twin arnica	ARSO	ARSO2	P	N
Artemisia ludoviciana Nutt.	white sagebrush	ARLU	ARLU	P	N
Astragalus cusickii Gray	Cusick's milkvetch	ASCU	ASCU5	P	N
Balsamorhiza sagittata (Pursh) Nutt.	arrowleaf balsamroot	BASA	BASA3	P	N
Besseya rubra (Dougl. ex Hook.) Rydb.	red besseya	BERU	BERU	P	N
Brodiaea douglasii S. Wats. = *Triteleia grandiflora* Lindl. var. *grandiflora*	Douglas' brodiaea	BRDO	BRDO	P	N
Bromus spp. *(tectorum* L. and/or *japonicus* Thunb. ex Murr.*)*	cheatgrass, japanese brome	Bromus	BROMU	A	I
Bromus brizaeformis Fisch. & C.A. Mey.	rattlesnake brome	BRBR	BRBR	A	I
Calochortus macrocarpus var. *maculosus*	green-banded mariposa lily	CALOC	CAMAM	P	N
Castilleja hispida Benth.	harsh Indian paintbrush	CAHI2	CAHI9	P	N
Cerastium arvense L.	field chickweed	CEAR	CEAR4	P	N

Appendix 2. Continuted.

Scientific name	Common Name	Symbol used	USDA Symbol	Duration	Origin
Cerastium viscosum auct. non L.= *Cerastium glomeratum* Thuill.	sticky chickweed	CEVI	CEGL2	A	I
Clarkia pluchella Pursh	pinkfairies	CLPU	CLPU	A	N
Claytonia perfoliata Donn ex Willd. ssp. *perfoliata*	miner's lettuce	CLPE	CLPEP	A/P	N
Collinsia parviflora Lindl.	maiden blue eyed mary	COPA	COPA3	A	N
Crataegus douglasii Lindl.	black hawthorne	CRDO	CRDO2	P	N
Delphinium sp.	larkspur	DELPH	DELPH	P	N
Dipsacus sylvestris Huds. = *Dipsacus fullonum* L.	Fuller's teasel	DISY	DISY	B	I
Draba verna L.	spring verna	DRVE2	DRVE2	A	I
Epilobium paniculatum Nutt. ex Torr. & Gray = *Epilobium brachycarpum* K. Presl	tall annual willowherb	EPPA	EPPA2	A	N
Erigeron corymbosus Nutt.	longleaf fleabane	ERCO3	ERCO5	P	N
Erigeron speciosus (Lindl.) DC.	aspen fleabane	ERSP	ERSP4	P	N
Eriogonum heracleoides Nutt.	parsnipflower buckwheat	ERHE	ERHE2	P	N
Festuca idahoensis Elmer	Idaho fescue	FEID	FEID	P	N
Frasera albicaulis Dougl. ex Griseb.	whitestem frasera	FRAL2	FRAL2	P	N
Galium aparine L.	stickywilly	GAAP	GAAP2	A	N
Geum triflorum Pursh	old man's whiskers	GETR	GETR	P	N
Heuchera cylindrica Dougl. ex Hook.	roundleaf alumroot	HECY	HECY2	P	N
Hieracium scouleri Hook. *var. albertinum* (Farr) G.W. Douglas & G.A. Allen	hawkweed	HISC	HISCA	P	N
Holosteum umbellatum L.	jagged chickweed	HOUL	HOUM	A	N
Hydrophyllum capitatum Dougl. ex Benth.	ballhead waterleaf	HYCA	HYCA4	P	N

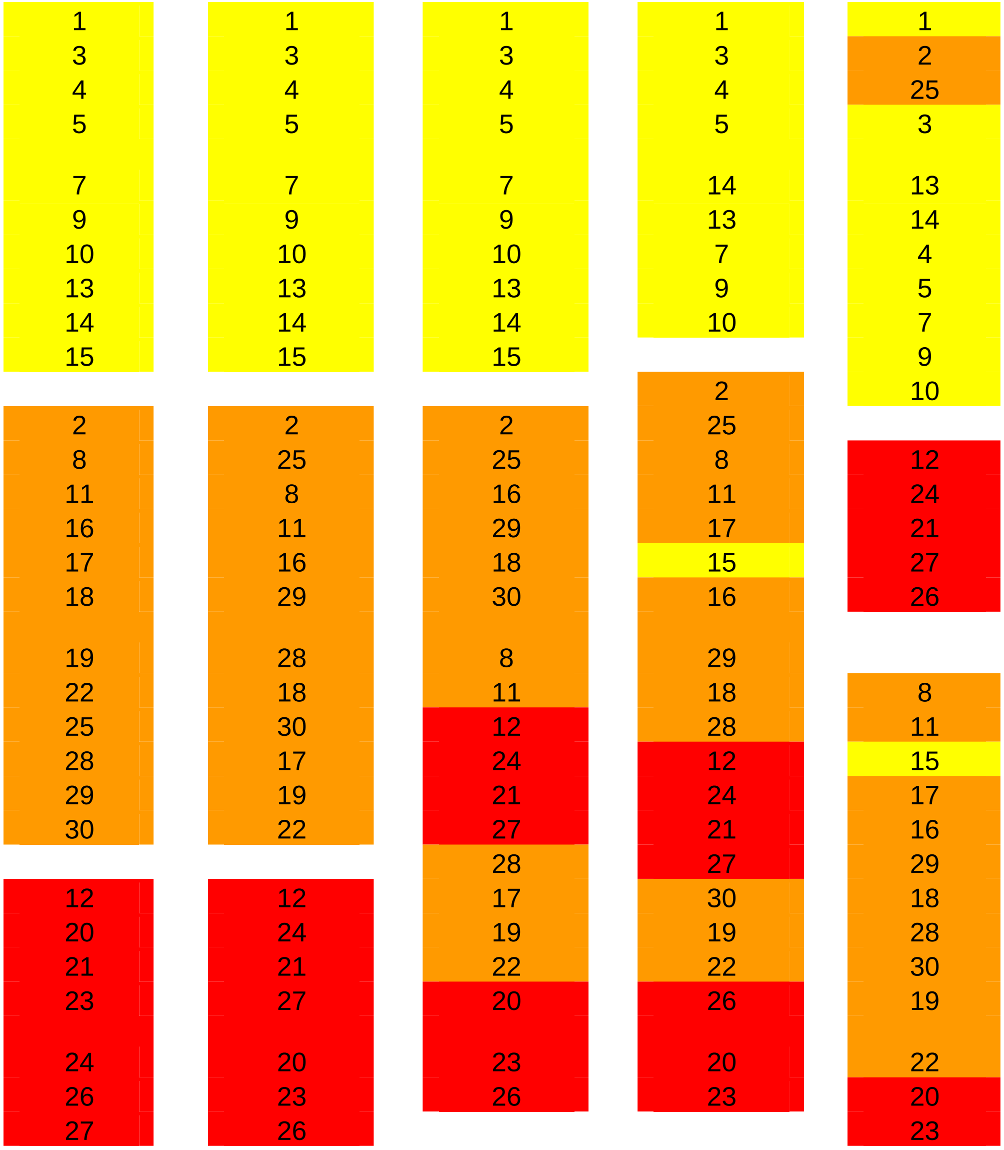
Appendix 2. Continued.

Scientific name	Common Name	Symbol used	USDA Symbol	Duration	Origin
Hypericum perforatum L.	St. John's wort	HYPE	HYPE	P	I
Koeleria macrantha L. (previously *k. cristata* in some classification systems)	prairie Junegrass	KOMC (KOCR)	KOMC	P	N
Lithophragma parviflorum (Hook.) Nutt. ex Torr. & Gray	smallflower woodland-star	LIPA	LIPA5	P	N
Lithospermum arvense L. = *Bulglossoides arvensis* (L.) I.M. Johnston	corn gromwell	Z3ULITHO	BUAR3	A	I
Lithospermum ruderale Dougl. ex Lehm.	western stoneseed	LIRU	LIRU4	P	N
Lomatium triternatum (Pursh) Coult. & Rose	nineleaf biscuitroot	LOTR	LOTR2	P	N
Lupinus sericeus Pursh	silky lupine	LUSE	LUSE4	P	N
Madia gracilis (Sm.) Keck & J. Clausen ex Applegate	grassy tarweed	MAGR	MAGR3	A	N
Myosotis stricta Link ex Roemer & J.A. Schultes	strict forget-me-not	MYST	MYST2	A	I
Orthocarpus tenuifolius (Pursh) Benth.	thinleaved owl's-clover	ORTE	ORTE2	A	N
Penstemon glandulosus Dougl.	stickystem penstemon	PEGL4	PEGL4	P	N
Perideridia gairdneri (Hook. & Arn.) Mathias	Gardner's yampah	PEGA2	PEGA2	P	N
Phlox colubrina Wherry & Constance	Snake River phlox	PHCO2	PHCO2	P	N
Poa secunda J. Presl	Sandberg bluegrass	POSE	POSE	P	N
Potentilla gracilis Dougl. ex Hook.	slender cinquefoil	POGR	POGR9	P	N
Pseudoroegneria spicata (Pursh) A. Löve	bluebunch wheatgrass	PSSP	PSSP6	P	N
Rose spp.	rose	ROSA	ROSA5	P	N

Appendix 2. Continued.

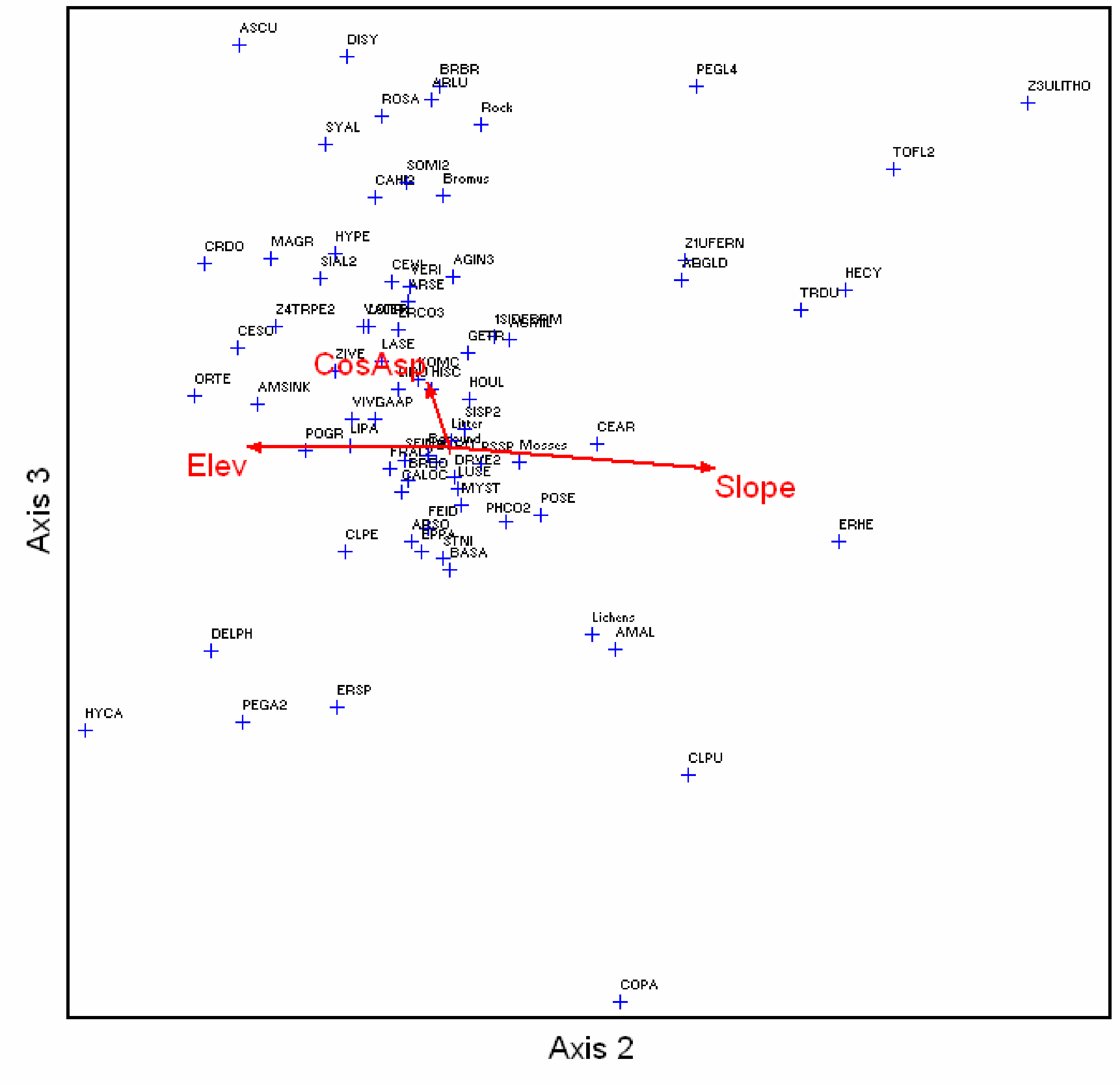
Scientific name	**Common Name**	**Symbol used**	**USDA Symbol**	**Duration**	**Origin**
Senecio integerrimus Nutt.	lambstongue ragwort	SEIN	SEIN2	B/P	N
Silene spaldingii S. Wats.	Spalding's catchfly	SISP2	SISP2	P	N
Sisymbrium altissimum L.	tall tumblemustard	SIAL2	SIAL2	A/B	I
Solidago missouriensis Nutt.	Missouri goldenrod	SOMI2	SOMI2	P	N
Stellaria nitens Nutt.	shiny chickweed	STNI	STNI	A	N
Symphoricarpos albus (L.) Blake	common snowberry	SYAL	SYAL	P	N
Tonella floribunda Gray	manyflower tonella	TOFL2	TOFL	A	N
Tragopogon dubius Scop.	yellow salsify	TRDU	TRDU	A/B	I
Triodanis perfoliata (L.) Nieuwl.	clasping Venus' looking-glass	Z4TRPE2	TRPE4	A	N
Valerianella locusta (L.) Lat.	Lewiston cornsalad	VALER	VALO	A	I
Vicia villosa Roth	winter vetch	VIVI	VIVI	B/P	I
Vulpia myuros (L.) K.C. Gmel.	rat-tail fescue	1SIDEBRM	VUMY	A	I
Woodsia oregana D.C. Eat.	Oregon cliff fern	Z1UFERN	WOOR	P	N
Zigadenus venenous S. Wats.	meadow deathcamas	ZIVE	ZIVE	P	N

Appendix 3. Results of five cluster analyses. Macroplots are color coded by group arrangement. Method one, Euclidean distance and Ward's method, was chosen as the best cluster analysis. Method 2 results match and validate Method 1 results.

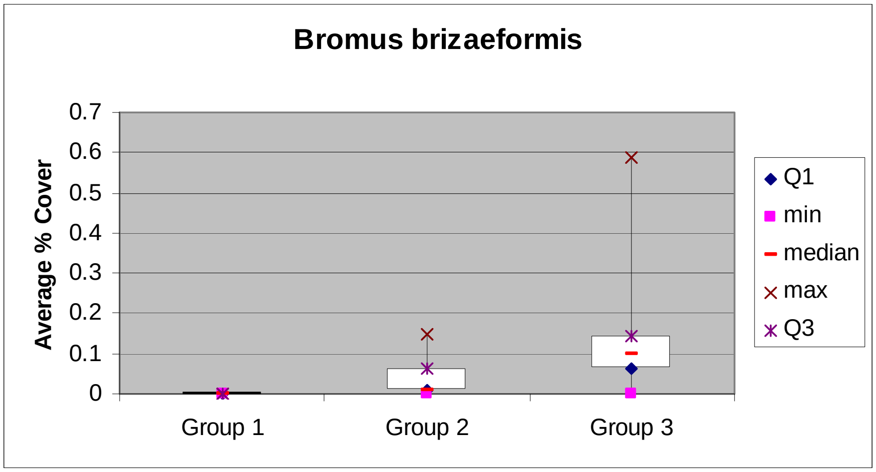


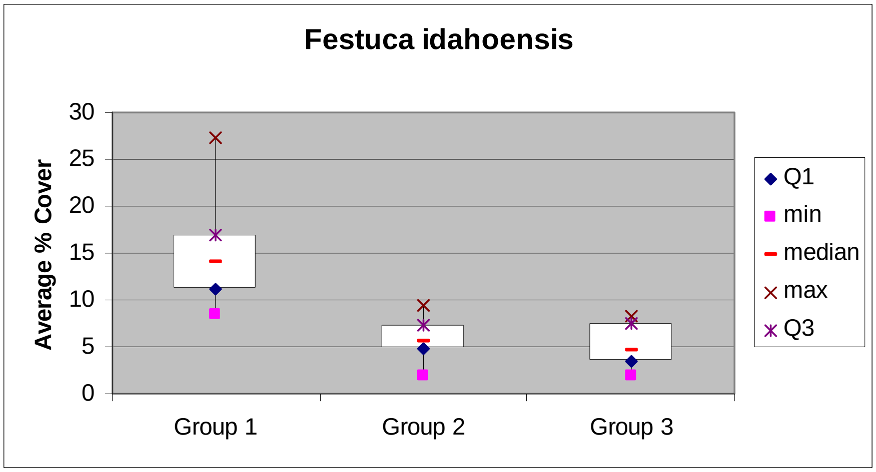
Cluster Method	1	2	3	4	5
Distance Measure	Euclidean	Sorenson's	Sorenson's	Euclidean	Euclidean
Group Linkage	Ward's	Flexible Beta (-.25)	Group Average	McQuitty's	Farthest Neighbor
Group Structure	🟨 1	🟨 1	🟨 1	🟨 1	🟨 1
	🟨 3	🟨 3	🟨 3	🟨 3	🟧 2
	🟨 4	🟨 4	🟨 4	🟨 4	🟧 25
	🟨 5	🟨 5	🟨 5	🟨 5	🟨 3
Group One = Yellow					
	🟨 7	🟨 7	🟨 7	🟨 14	🟨 13
	🟨 9	🟨 9	🟨 9	🟨 13	🟨 14
	🟨 10	🟨 10	🟨 10	🟨 7	🟨 4
	🟨 13	🟨 13	🟨 13	🟨 9	🟨 5
	🟨 14	🟨 14	🟨 14	🟨 10	🟨 7
	🟨 15	🟨 15	🟨 15		🟨 9
				🟧 2	🟨 10
	🟧 2	🟧 2	🟧 2	🟧 25	
	🟧 8	🟧 25	🟧 25	🟧 8	🟥 12
	🟧 11	🟧 8	🟧 16	🟧 11	🟥 24
	🟧 16	🟧 11	🟧 29	🟧 17	🟥 21
	🟧 17	🟧 16	🟧 18	🟨 15	🟥 27
	🟧 18	🟧 29	🟧 30	🟧 16	🟥 26
Group Two = Orange					
	🟧 19	🟧 28	🟧 8	🟧 29	
	🟧 22	🟧 18	🟧 11	🟧 18	🟧 8
	🟧 25	🟧 30	🟥 12	🟧 28	🟧 11
	🟧 28	🟧 17	🟥 24	🟥 12	🟨 15
	🟧 29	🟧 19	🟥 21	🟥 24	🟧 17
	🟧 30	🟧 22	🟥 27	🟥 21	🟧 16
			🟧 28	🟥 27	🟧 29
	🟥 12	🟥 12	🟧 17	🟧 30	🟧 18
	🟥 20	🟥 24	🟧 19	🟧 19	🟧 28
	🟥 21	🟥 21	🟧 22	🟧 22	🟧 30
	🟥 23	🟥 27	🟥 20	🟥 26	🟧 19
Group Three = Red					
	🟥 24	🟥 20	🟥 23	🟥 20	🟧 22
	🟥 26	🟥 23	🟥 26	🟥 23	🟥 20
	🟥 27	🟥 26			🟥 23

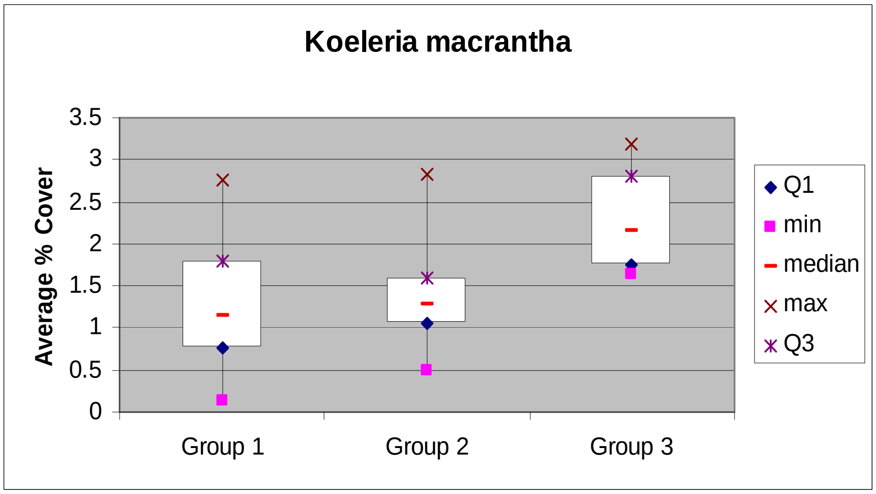
Appendix 4. Ordination graph of axis one to axis two showing species locations.



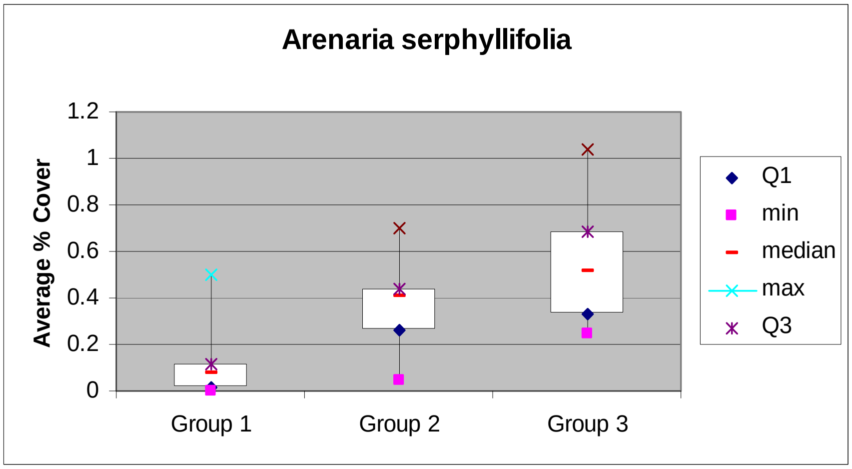
Appendix 5. Comparison of Rattlesnake brome (*Bromus brizaeformis*), Idaho fescue (*Festuca idahoensis*), and prairie junegrass (*Koeleria macrantha*) cover by groups.

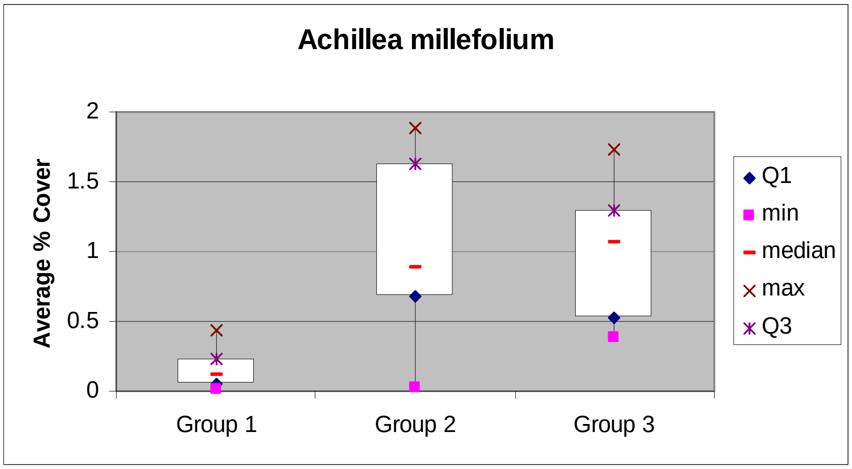


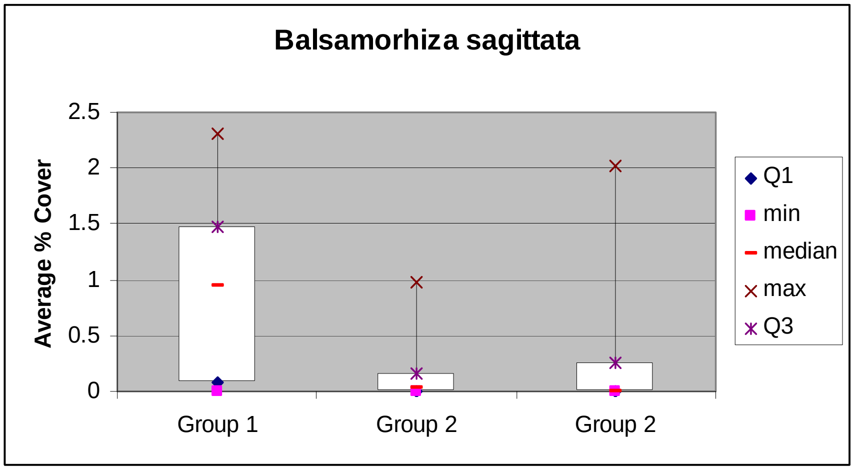




Appendix 6. Comparison of thymeleaf sandwort (*Arenaria serphyllifolia*), common yarrow (*Achillea millefolium*), and arrowleaf balsamroot (*Balsamorhiza sagittata*) cover by groups.







Literature Cited

Austin, M. P. 1968. An ordination study of a chalk grassland community. Journal of Ecology **56**:739-757.

Barbour, M. G., J. H. Burk, W. D. Pitts, F. S. Gilliam, and M. W. Schwartz. 1999. Terrestrial Plant Ecology, 3rd edition. Benjamin/Cummings, Menlo Park, CA, USA.

Beals, E. W. 1984. Bray-Curtis ordination: an effective strategy for analysis of multivariate ecological data. Advances in Ecological Research **14**:1-55.

Briggs, J. M., A. K. Knapp, and B. L. Brock. 2002. Expansion of woody plants in tallgrass prairie: a fifteen-year study of fire and fire-grazing interactions. American Midland Naturalist **147**:287-294.

Caplow, F. 2001. Annual report for Spalding's catchfly (*Silene spaldingii*) on Fairchild Air Force Base, Washington. Washington State Department of Natural Resources, Natural Heritage Program, Olympia, Washington.

Cassirer, E. F. 1995. Wildlife inventory, Craig Mountain, Idaho. Prepared for the U.S. Department of Energy, Bonneville Power Administration, Division of Environment, Fish and Wildlife. Idaho Department of Fish and Game, Lewiston Idaho.

Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology **18**:117-143.

Daubenmire, R. 1968a. Plant Communities: A textbook of plant synecology. Harper and Row Publishers, New York.

Daubenmire, R. 1968b. Soil moisture in relation to vegetation distribution in the mountains of northern Idaho. Ecology **49**:431-438.

Daubenmire, R. 1970. Steppe vegetation of Washington. Technical Bulletin 62. Washington State University, Washington Agricultural Experiment Station, College of Agriculture, Pullman, Washington.

DiTomaso, J. M., G. B. Kyser, and M. S. Hastings. 1999. Prescribed burning for control of yellow starthistle (*Centaurea solstitialis*) and enhanced native plant diversity. Weed Science **47**:233-242.

Fasham, M. J. R. 1977. A Comparison of nonmetric multidimensional scaling, principal components, and reciprocal averaging for the ordination of simulated coenoclines, and coenoplanes. Ecology **58**:551-561.

Gauch, H., Jr., R. H. Whittaker, and S. B. Singer. 1981. A comparative study of nonmetric ordinations. The Journal of Ecology **69**:135-152.

Grimm, L.G., and P.R. Yarnold, editors. 2000. Reading and understanding more multivariate statistics. American Psychological Association, Washington, DC.

Hahn, T. W. 2004. Soil survey of Lewis and Nez Perce Counties, Idaho. Natural Resources Conservation Service, United States Department of Agriculture.

Hill, J., and K. Gray. 1999. Alien and rare plant inventory and vegetation mapping, Garden Creek Ranch, Craig Mountain, ID. Prepared by: The Nature Conservancy of Idaho, Coeur d'Alene, ID For: The Bureau of Land Management, Cottonwood Resource Area Headquarters, Cottonwood, ID.

Hill, J., and K. Gray. 2006. Demographic monitoring of Spalding's catchfly (*Silene spaldingii*) in Idaho canyon grasslands: 2005 Field Season. Idaho Conservation Data Center, Idaho Department of Fish and Game, Boise.

Hill, J. L., and K. L. Gray. 2000. Conservation of Spalding's catchfly (*Silene spaldingii*) in the lower Corral Creek study area, Garden Creek Ranch, Craig Mountain, Idaho - 1999 field season. Unpublished report on file at: The Nature Conservancy of Idaho Field Office, Sun Valley, Idaho.18 pp., plus appendices.

Hill, J. L., and K. L. Gray. 2004a. Conservation strategy for Spalding's catchfly (*Silene spaldingii* Wats.). Unpublished report for U.S. Fish and Wildlife Service, Boise, ID, and Idaho Department of Fish and Game, Idaho Conservation Data Center, Boise.

Hill, J. L., and K. L. Gray. 2004b. Population dynamics of Spalding's silene (*Silene spaldingii*) in canyon grasslands at Garden Creek Ranch, Craig Mountain, Idaho - 2003 field season. Unpublished report. Challenge Cost-share for the Palouse-Clearwater Environmental Institute and the Bureau of Land Management, Cottonwood Resource Area, Cottonwood, Idaho.33 pp., plus appendices.

Hill, J. L., and B. J. Weddell. 2003. Population dynamics of Spalding's silene (*Silene spaldingii*) in canyon grasslands at the Garden Creek Ranch, Craig Mountain Idaho - 2002 field Season. Unpublished report. Challenge Cost-share for the Palouse-Clearwater Environmental institute and the Bureau of Land Management, Cottonwood Resource Area, Cottonwood, Idaho.29 pp., plus appendices.

Hitchcock, C. L., and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle.

Hitchcock, C. L., and B. Maguire. 1947. A revision of the North American species of Silene. University of Washington Publications in Biology, Seattle.

Hodgson, J. R. 1972. Local distribution of *Microtus montanus* and *M. pennsylvanicus* in southwestern Montana. Journal of Mammalogy **53**:pp. 487-499.

Huston, M.A. 1994. Biological Diversity. Cambridge University Press, Cambridge, UK.

Idaho Conservation and Data Center. 2003. Element occurrence records for *Silene spaldingii*. Idaho Department of Fish and Game, Boise, Idaho.

Johansen, J. R., L. L. St.Clair, B. L. Webb, and G. T. Nebeker. 1984. Recovery patterns of cryptogamic soil crusts in desert rangelands following fire disturbance. The Bryologist **87**:238-243.

Johnson, C. G. J., and S. A. Simon. 1987. Plant Associations of the Wallowa-Snake Province. U.S. Department of Agriculture, U.S. Forest Service, Pacific Northwest Region, Wallowa-Whitman National Forest, Baker City, OR.

Kenkel, N. C., and L. Orloci. 1986. Applying metric and nonmetric multidimensional scaling to ecological studies: some new results. Ecology **67**:919-928.

Kimball, S., P. Wilson, and J. Crowther. 2004. Local ecology and geographic ranges of plants in the Bishop Creek watershed of the eastern Sierra Nevada, California, USA. Journal of Biogeography **31**:1637-1657.

Lesica, P. 1997. Demography of the endangered plant, *Silene spaldingii* (Caryophyllaceae) In Northwest Montana. Madrono **44**:347-358.

Lesica, P. 1999. Effects of fire on the demography of the endangered, geophytic herb *Silene spaldingii* (Caryophyllaceae). American Journal of Botany **86**:996-1002.

Li, X., and S. Wilson. 1998. Facilitation among woody plants establishing in an old field. Ecology **79**:2694-2705.

Lillybridge, T. R., B. L. Kovalchik, C. K. Williams, and B. G. Smith. 1995. Field guide for forest plant associations of the Wenatchee National Forest. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Pacific Northwest Region, Wenatchee National Forest.

McCune, B., and J. B. Grace. 2002. Analysis of Ecological Communities. MjM Software Design, Gleneden Beach, OR.

McCune, B., and M. J. Mefford. 1999. PC-ORD. Multivariate analysis of ecological data, Version 4, 4th edition. MjM Software Design, Gleneden Beach, OR.

McPherson, G. R., and S. DeStefano. 2003. Applied Ecology and Natural Resource Management. Cambridge University Press, Cambridge. UK.

Menke, C. A., and P. S. Muir. 2004. Short-term influence of wildfire on canyon grassland plant communities and Spalding's catchfly, a threatened plant. Northwest Science **78**:192-203.

Peltzer, D. A., and M. Kochy. 2001. Competitive effects of grasses and woody plants in mixed-grass prairie. Journal of Ecology **89**:519-527.

Roche, B., Jr., C. Roche, and R. Chapman. 1994. Impacts of grassland habitat on yellow starthistle (*Centaurea solstitialis* L.) invasion. Northwest Science **68**:86-96.

Tisdale, E. W. 1979. A preliminary classification of Snake River canyon grasslands in Idaho. Forest, Wildlife, Range Experimental Station. University of Idaho, Moscow.

Tisdale, E. W. 1986. Canyon grasslands and associated shrublands of west-central Idaho and adjacent areas. Contribution No. 284, Forest, Wildlife, and Range Experiment Station, University of Idaho, Moscow.

U.S. Fish and Wildlife Service. 2001. Endangered and threatened wildlife and plants; final rule to list *Silene spaldingii* (Spalding's catchfly) as threatened. Pages 51598-515606 *in*. Federal Register.

U.S. Fish and Wildlife Service. 2005. Draft recovery plan for *Silene spaldingii* (Spalding's Catchfly). U.S. Fish and Wildlife Service, Portland, Oregon.

Williams, W. T. 1971. Principles of clustering. Annual Review of Ecology and Systematics **2**:303-326.