Secondary fire effects on *Symphoricarpos albus-Rosa* spp. plant association in the canyon grasslands of north-central Idaho

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AUTHORIZATION TO SUBMIT THESIS

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ABSTRACT

The snowberry-rose (*Symphoricarpos albus-Rosa* spp.) plant association is a significant component of the canyon grasslands of Hells Canyon. Fire has impacted this area in the past while the historic fire frequency is unknown. The Corral Creek fire of 2001 burned 645 ha of the Corral Creek drainage within the Garden Creek Nature Preserve which is located on the west side of Craig Mountain in Nez Perce County, Idaho. Ten unburned and 10 burned plots were sampled in order to compare cover and composition of shrubs, grasses, forbs, and ground cover. The line intercept method was used to measure shrub cover and a modified Daubenmire cover class method was used for grass and forb cover. Statistical analyses were done with the SAS statistical software package. ANCOVA (Analysis of Covariance) was used for species group analysis. Individual species were analyzed with the Wilcoxon (Mann-Whitney) nonparametric statistical test. Snowberry cover was lower on burned plots while rose cover was not different. Total grass cover was not different across treatments. Japanese brome (*Bromus arvensis*)/cheatgrass (*Bromus tectorum*), had higher cover on burned plots. Rattlesnake brome (*Bromus briziformis*) cover was higher on unburned plots. Total forb and total herbaceous cover was not different. Western yarrow (*Achillea millefolium*), slender cinquefoil (*Potentilla gracilis*), Missouri goldenrod (*Solidago missouriensis*), spring draba (*Draba verna*), and Lewiston cornsalad (*Valerianella locusta*) had higher cover on burned plots. Bedstraw (*Galium aparine*) and winter vetch (*Vicia villosa*) were higher on unburned plots. Bare ground was higher in burned plots while lichen and moss cover was lower in the burned plots. Litter was not different between treatments. Litter recovery shows resilience of this plant association following fire. Species composition was different across the treatments which probably resulted from the change in resources and

competition following the fire and variable species responses to fire. As the shrub canopy closes it can be expected that the understory species will respond to the subsequent changes in environmental conditions. Further study in these areas would be beneficial to determine future changes in these shrub communities.

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Introduction:

Disturbance is a driving factor of change in the natural world. Contrary to previous belief that ecosystems would ultimately reach a state of balance, it is now understood that ecosystems undergo constant change. The "flux of nature" describes numerous interactions between the internal and external processes of an ecosystem (Pickett and Parker 1994). Currently and throughout history many processes have transformed the natural environment and fire has been particularly influential in altering the biotic community (Ahlgren 1974). Fire is a disturbance that most ecosystems have evolved with and, whether human or naturally ignited, can play an important role in shaping vegetation structure (Brown 2000). Fire can alter ecosystem, community, and population structure by favoring certain species and changing the availability of resources (Agee 1993).

Fire effects can be classified as primary or secondary. Initial plant mortality, smoke effects, consumption of organic matter, and changes to the chemical and physical environment are examples of primary fire effects or the way fire directly impacts an area (Brown 2000). Secondary fire effects are more difficult to predict as they depend on the conditions in the environment after the fire and the nature of the primary fire effects. Changes in soil properties, microclimate, vegetation patterns, and wildlife habitat are just a few secondary fire effects (Brown 2000). Considering the composition of a community, season and severity of the fire, and the post-fire environmental conditions can help predict the length of time needed for the ecosystem to recover from a fire. For example, low, moderate, and high severity fire simulations resulted in different re-growth levels of bluebunch wheatgrass (*Pseudoroegneria spicata*) and Idaho fescue (*Festuca idahoensis*)

(Robberecht and Defosse 1995). These results show that fire severity can influence post-fire composition.

Many grassland and forest ecosystems in North America evolved with fire (Wright and Bailey 1982), and while we know that fire has influenced vegetation, historical fire regimes are variable and depend largely on climate and vegetation type (Brown 2000). In arid ecosystems decomposition is slow allowing for a buildup of organic material (Brown 2000). Fire releases nutrients that have been tied up in detritus and living plant material making it an important part of the nutrient cycling process in some ecosystems (Barbour et al. 1999). If not utilized quickly the nutrients may erode or leach out of the soil rapidly following the fire.

Most grasslands and shrublands historically burned but the frequency varied widely depending on climate as a driving influence (Brown 2000). Without fire scar data from woody vegetation there is little certainty as to how often these fires burned. Zlatnik (1999) cites Craig Johnson's study on early spring prescribed burning of big game winter range in the Snake River Canyon where it was estimated that the pre-suppression fire interval in the grasslands was 10-25 years. Historically it is thought that native cultures used fire to increase wild plant foods, forage, and shrub control (Shinn 1980). In a study on western wildfires between 1776-1900 it was found that fire was indeed a driving factor of change for ecosystems in the Interior West and it was noted that "many of the fires were set by Indians" (Gruell 1985). Personal discussions with A.G. Marshall who studied the Nez Perce revealed anecdotal evidence that the Nez Perce set intentional fires in order to enhance wild food plants and improve forage for elk in the canyon grasslands of the northern intermountain steppe (Weddell 2001).

With the influx of Europeans into the western United States came new ideas for land management. By the late 1800s, fire suppression became a common land management practice (Shinn 1980). Biomass accumulation from decades of fire suppression has caused some fires to burn more severely than those with which fire-adapted species evolved.

In the absence of fire, studies have shown that plant communities that have evolved with fire can be displaced by those that have not (Ahlgren 1974). Shrubs and other woody species often encroach on grassland communities in the absence of fire. A study in the tallgrass prairie found that the best explanation for the increase in woody species was the decline in fire frequency (Briggs et al. 2002). Vogl (1974) cites several studies in grassland ecotones that show woody species consistently encroaching on herbaceous species with the elimination of fire. In mountain grasslands, shrub encroachment was controlled by repeated fires (Paysen et al. 2000). Shrubs can advance even in drought conditions. However, fire an override climatic conditions as the determining factor for vegetation change (Vogl 1974).

This paper focuses on fire effects in the shrublands of the Garden Creek Nature Preserve (Garden Creek) in north-central Idaho. Specifically**,** this research looked at secondary fire effects within the snowberry-rose (*Symphoricarpos albus*-*Rosa* spp.) plant association at Garden Creek following the Corral Creek fire of 2001. Specifically burned and unburned plots were compared with the following objectives:

1. Assessing fire effects on composition and canopy cover of shrubs, grasses, and forbs.
2. Measuring and comparing incidence and canopy cover of invasive plants.
3. Measuring and comparing coverage of bare ground, cryptogams, litter, and rock.

Literature Review:

Snowberry-rose plant association

The snowberry-rose plant association was described by Johnson and Simon (1987). The inclusion of *Rosa* spp. within this plant association is due to the presence and extensive hybridization of nootka rose (*Rosa nutkana*) and Woods' rose (*Rosa woodsii).* The snowberry-rose plant association is typically found on moderate to steep north-facing footslopes around 900 m and also can be found in more mesic sites of Idaho fescue-prairie junegrass (*Koeleria micrantha*) plant association (Johnson and Simon 1987). This plant association is similar to Daubenmire's (1970) snowberry phase of the Idaho fescue-snowberry habitat type and Tisdale's (1986) snowberry series. Tisdale's snowberry series is broad and lacks the distinct definition and constancy tables necessary for this study. Daubenmire's snowberry phase is well defined as a phase within the Idaho fescue-snowberry habitat type but considering the significance of these shrub communities at Garden Creek it is more appropriate to view these communities independently. Using Daubenmire's snowberry phase to classify these shrub communities, Franklin and Dyrness (1988) observe that these shrub patches are usually 0.5-3 m tall and 4-25 m in diameter. They also noted that the shrub composition varied from snowberry alone, snowberry surrounding a center patch of rose (1 m tall), and/or snowberry and rose "belts" surrounding larger shrubs like chokecherry (*Prunus virginiana*). It is also suggested that these patches are stable within the grassland and not spreading. Johnson and Simon's description of the snowberry-rose plant association seems most similar to the communities in Garden Creek but these other similar classifications help understand the variability found within this shrub community.

Snowberry and rose shrubs form dense thickets with a sparse understory, however small openings within the patch provide space and light for other species to occur (Tisdale 1986, Johnson and Simon 1987). In the Palouse region of Idaho and Washington, snowberry and rose are found together, with rose dominant in sampled areas (Aller et al. 1981). In the Palouse soil profiles differed significantly in the rose communities when compared to other shrub communities (Aller et al. 1981). Soils associated with the snowberry-rose plant association are typically deep, silt loam, or silty clay; and were formed from basalt, colluvium, and loess (Johnson and Simon 1987). A study on soil moisture in eastern Washington showed that snowberry, nootka rose, and Woods' rose were only found "where soil drouth does not extend below the reach of their shallowly placed roots" (Daubenmire 1972). The authors infer that soil moisture and temperature have the greatest influence on the distribution of vegetation in this area.

Idaho fescue, bluebunch wheatgrass, silky lupine (*Lupinus sericeus*), and Missouri goldenrod (*Solidago missouriensis*) are a few of the commonly associated species within this plant association. An increase of snowberry-rose in Garden Creek has been noted, which could be due to a reduction in fire frequency, climate change, a response to past grazing practices, or a combination of several factors (Johnson and Simon 1987).

Introduced plant species

Introduced species have become a problem in many ecosystems by out-competing and occasionally displacing native plants. Many of these plants are able to take advantage of the openings created by disturbance more quickly than the natives (Bunting 1996). In arid regions an increase in fire frequency can favor introduced plants like cheatgrass (*Bromus tectorum*) (Brown 2000). In the Pacific Northwest, cheatgrass and yellow starthistle

(*Centaurea solstitialis*) dominate more than 250,000 ha of rangeland (Sheley and Larson 1997), and in Garden Creek, yellow starthistle and cheatgrass have displaced a large portion of the native canyon grassland vegetation. St. Johnswort (*Hypericum perforatum*) is a common exotic in snowberry-rose plant associations (Johnson and Simon 1987). Yellow starthistle, cheatgrass, and Japanese brome (*Bromus arvensis*) are also common within the snowberry-rose plant association found in Garden Creek.

According to the Nature Serve Explorer Comprehensive Report (2006), the snowberry-rose plant association is only found within the canyon grasslands of the Imnaha and Snake Rivers in portions of Idaho, Washington, and Oregon. The global status is listed as G3-Vulnerable due to threats in these areas from noxious and exotic weeds and changes in fire and grazing regimes.

Fire effects on shrubs

Fire affects vegetation differently depending on the plant's adaptations to fire, and the season and nature of the fire. Therefore, the variety of species present within the snowberry-rose plant association may respond in different ways to fire events.

Snowberry is a deciduous shrub that produces pink, bell-shaped flowers and white berries; average height is 0.5-1 m (Francis 2004). Snowberry thrives on moist well-drained soils in full sunlight but tolerates light to medium shade (Rowe 1983, Francis 2004). Snowberry is fire resistant and resprouts vigorously from rhizomes (McLean 1968, Johnson and Simon 1987, McWilliams 2000, Francis 2004). The rhizomes tend to be between 5-13 cm below the surface of the mineral soil (McLean 1968). Another author suggests that the rhizomes can extend out horizontally as much as 60 cm out from the base at approximately 2-5 cm underground (Gilbert 1995). As soil is typically a poor conductor of heat, the substrate provides the rhizomes protection from the heat of fire. The vertical stems (ramets) connected by rhizomes are dynamic and few are older than five years (Kinateder 1998). A study in eastern Washington shows that snowberry resprouts with equal vigor regardless of disturbance (Kinateder 1998). Several studies show increasing canopy cover of snowberry after fire (McWilliams 2000). In a Douglas-fir-ninebark (*Pseudotsuga menziesii-Physocarpus malvaceus*) plant association snowberry increased significantly following fire when compared to unburned sites (Cholewa and Johnson 1983). Snowberry grows best in full sunlight and while it can tolerate some shade, the removal of overstory species allows for rapid snowberry expansion (Gilbert 1995). Thinning and burning treatments in ponderosa pine (*Pinus ponderosa*) and Douglas-fir forests in northeast Oregon showed an increase in dominance and cover of snowberry (Youngblood et al. in press). In some situations snowberry cover and spread may be temporarily reduced post-fire (Agee 1993). This is supported by a study in an Oregon grassland where after 10 years snowberry was increasing but still had not returned to pre-burn levels (Johnson 1998). Daubenmire (1970) suggests that shrubs recover within three years of the fire in the snowberry phase of the Idaho fescue-snowberry habitat type .

Snowberry is palatable to ungulates and may be eliminated if overgrazed (Johnson and Simon 1987). A study on cattle grazing in Oregon showed that snowberry comprised 11% of the cattle's diet (Holechek et al. 1982). Deer and elk browsed three times more heavily on burned plants than unburned plants in eastern Washington as a result of the increased palatability of the snowberry following fire (Kinateder 1998). Both burning and clipping resulted in "increased shoot vigor and increased ramet density."

Woods' rose and nootka rose are both well armed with compound serrate leaves and exhibit pink flowers followed by a red hip. Woods' rose has flowers born in clusters (3-5), has smaller round hips, and blooms later than the nootka rose which has solitary flowers and larger hips (Christopher Loony, graduate student, University of Idaho, pers. comm). Rose species tolerate a wide variety of conditions but favor moist conditions (Mozingo 1987).

Both Woods' rose and nootka rose are moderately resistant to fire and sprout from underground rhizomes and from the root crown (Wright and Bailey 1982, Johnson and Simon 1987, Tesky 1992). Wright and Bailey (1982) cite a study by Mckell (1950) in a Gambel oak community in Utah where Woods' rose cover was greater on burned plots two years following a fire than on unburned plots. In a Douglas-fir-ninebark plant association Woods' rose cover remained constant following fire while nootka rose cover increased, 0.4-1.9% (Cholewa and Johnson 1983). Prescribed fire in aspen (*Populus tremuloides*) woodlands near Jackson, Wyoming showed lower production of Woods' rose under low and high severity burn conditions, whereas production in moderately burned areas remained the same as three years following the fires (Bartos and Mueggler 1981). Twelve years after these fires Woods' rose production exceeded pre-burn conditions in moderately burned aspen communities (Bartos et al. 1994). In snowberry-rose communities in northeastern Oregon, rose cover increased from pre-burn levels (10% to 13%) five years following the fire event (Johnson 1998).

Fire effects on grasses

Idaho fescue is a cool season, perennial bunchgrass with a panicle inflorescence. Spikelets have 5-7 florets and the leaf blades are filiform (Davis 1952). The seeds are typically mature by midsummer and most of the leaves are basal (Stubbendieck et al. 2003).

Idaho fescue is susceptible to fire damage but is less harmed in early spring or winter fires when moisture levels are higher (Johnson and Simon 1987). The location of buds above ground or at surface level is one reason for Idaho fescue's high mortality when burned (Conrad and Poulton 1966). Canopy cover of Idaho fescue was significantly less in burned plots versus unburned plots following a late June fire in western Montana (Antos et al. 1983).

Bluebunch wheatgrass is a cool season perennial bunchgrass with a spike inflorescence. Spikelets have 6-8 florets and leaves are 1-4 mm wide (Davis 1952). Reproduction generally occurs from seed, tillers, and occasionally rhizomes (Stubbendieck et al. 2003). Bluebunch wheatgrass buds are usually covered by soil or parent material that protect the meristematic tissue from being severely damaged by fire (Conrad and Poulton 1966, Zlatnik 1999, Weddell 2001). A fire in Oregon caused little mortality in bluebunch wheatgrass although plant size was reduced (Conrad and Poulton 1966). Paysen et al. (2000) cite studies indicating that bluebunch wheatgrass is less damaged by fall burns that occur when the plant is dormant in comparison with spring burns.

Cheatgrass is an introduced cool season annual that germinates in the fall or spring and produces mature seeds approximately two months after germination (Stubbendieck et al. 2003). Flowers are arranged in a panicle inflorescence, and the nodding spikelets are 12-20 mm long and occasionally purple (Davis 1952). Completing its life cycle quickly, cheatgrass dries out early in the spring which can provide continuous fuel for fires to move through a landscape more frequently than historically occurred (D'Antonio and Vitousek 1992). In the canyon grasslands of Garden Creek, cheatgrass canopy cover increased more on burned plots than unburned plots (Gucker 2004). Cheatgrass roots also compete effectively for available soil water and nutrients and can reduce root biomass of native perennials (Melgoza and

Nowak 1991). Once invaded, the landscape can be difficult to restore to historical conditions given cheatgrass' "competitive and flammable nature" (Menakis et al. 2003). Cheatgrass does provide forage for wildlife and livestock in the early spring before flowering (Stubbendieck et al. 2003). Repeated fires can favor cheatgrass while reducing perennial natives (Paysen et al. 2000).

Japanese brome is an introduced cool season annual. The leaf blades are hairy and the inflorescence is a diffuse panicle. It is often confused with cheatgrass but can be identified by its longer and wider awns (Whitson et al. 2002). Fire typically reduces recruitment, germination, and establishment of Japanese brome in dry years by reducing litter (Whisenant 1990). Although the plant and some seeds can initially be killed by fire, Japanese brome usually recovers by the second year post-fire (Whisenant et al. 1984).

Rattlesnake brome (*Bromus briziformis*) is an introduced annual with a panicle inflorescence. The spikelets are awnless and are reminiscent of a rattlesnake's rattle in sound and appearance. Rattlesnake brome and Japanese brome occur on more mesic sites than other annual bromes present (Huschle and Hironaka 1980).

Fires effects on forbs

Forbs are usually fire tolerant depending on their "regenerative structures" (Miller 2000). If these structures are protected by the substrate then the plant has a greater chance of survival than those with above ground reproductive systems (Miller 2000). Season of fire will also influence fire resistance.

Western yarrow (*Achillea millefolium*) is a native perennial forb in the family Asteraceae which displays white flowers in a compound corymb inflorescence (Stubbendieck et al. 2003). The leaves are alternate and pinnately dissected (Davis 1952). Reproduction is by seed and rhizome (Stubbendieck et al. 2003).

Slender cinquefoil (*Potentilla gracilis*) in the family Rosaceae is a native perennial forb with yellow flowers. The leaves are palmate and grayish on the underside. A study in a seral stand of ponderosa pine in Benewah County, ID showed that slender cinquefoil was more frequent on low intensity prescribed burn sites when compared to unburned (control) and high intensity sites (Armour et al. 1984). A prescribed burn in aspen woodlands in the Bridger-Teton National Forest showed that slender cinquefoil increased in production on moderate severity burns three years post fire (Bartos and Mueggler 1981), but by the 12th year following the fire slender cinquefoil remained solely on the low severity site (Bartos et al. 1994). Slender cinquefoil increased post-fire in a western Montana grassland (Antos et al. 1983).

Missouri goldenrod is a native warm season perennial forb in the Asteraceae family that exhibits radiate heads in a thyrsiform panicle with yellow ray and disk flowers (Stubbendieck et al. 2003). Basal leaves are oblanceolate, 30 cm long and 3 cm wide, and become smaller and sessile as they occur further up the stem (Davis 1952). Reproduction is by rhizome and seed (Walsh 1994). Missouri goldenrod is widespread from British Columbia to Tennessee, is found in a variety of habitats, and in several areas it has been shown to increase post fire (Walsh 1994).

Yellow starthistle is a winter annual forb in the Asteraceae family. The discoid heads exhibit yellow flowers with spines on the involucular bracts that are 11-22 mm (Hitchcock and Cronquist 1973). Stature is typically from 2-8 dm tall (Davis 1952). Yellow starthistle has infested large portions of the canyon grasslands in Garden Creek, but has had limited influence in the shrublands due to its high light requirements (Hill 2002, Zouhar 2002). Areas dominated by this invasive plant have diminished resource values (Sheley and Larson 1994). Yellow starthistle canopy coverage increased post-fire in burned plots compared to unburned plots after the Maloney Creek Fire of 2000 in Garden Creek (Gucker 2004).

Silky lupine is a perennial forb in the family Fabaceae with blue to purple papilionaceous flowers (Hitchcock and Cronquist 1973). The leaves are palmately compound with 7-9 leaflets (Davis 1952). Silky lupine is considered a principal species in the snowberry-rose plant association (Johnson and Simon 1987). Fall burns can enhance lupine (Johnson and Simon 1987). Often legumes like lupine that host nitrogen-fixing bacteria on root nodules increase in number following a disturbance (Agee 1993). Successful reproduction from seed and its deep rooting system increase lupine's ability to withstand fire (Matthews 1993).

St. Johnswort is an introduced warm season perennial with a densely flowered cyme inflorescence (Stubbendieck et al. 2003). Flowers are yellowish and the simple opposite leaves are glandular-punctate (Davis 1952). The woody taproot can penetrate 1-1.5 m deep and the lateral roots can extend approximately 1 m out 5-8 cm below the soil surface (Tisdale et al. 1959). St. Johnswort is prevalent in snowberry-rose patches disturbed by ungulates (Johnson and Simon 1987). In 1945 a chrysomelid beetle (*Chrysolina quadrigemina*) was introduced as a biological control agent, and within five years St. Johnswort had been significantly reduced in the western United States (Vila et al. 2003). Studies have shown that St. Johnswort increases following fire by drawing on resources stored in the "tough, extensive root system" (Buckley et al. 2003) and resprouting from these rootstocks and lateral roots (Briese 1996). St. Johnswort favors sunny exposures and well-drained soils and while it will grow in varying conditions, it normally does not do well in densely shaded areas (Piper 1999).

Ground cover in the form of litter (Gardiner and Miller 2004) and biological soil crusts (Anderson et al. 1985, Belnap 2003) can help protect soil stability and fertility. Removal of ground cover for extended periods of time can increase erosion rates and cause soil degradation (Whisenant 1999). Litter removal by fire can initially create openings for some species to establish while others need the safe sites created by litter for successful germination of seedlings (Whisenant 1999). Litter cover is used as a parameter to assess rangeland health as it is important for nutrient cycling and soil stability in these systems (National Research Council 1994).

The biological soil crust, made up of mosses, lichens, and cyanobacteria, functions as ground cover in the interspaces between plants and serves as a soil protector by helping prevent erosion (Belnap 2003). Biological soil crusts are susceptible to disturbances like fire, herbivore trampling, and weed invasion and may take hundreds of years to recover. Columbia Basin biological crusts are dominated by tall mosses and green algae and crust morphology is rolling (Belnap et al. 2001). Tortula moss (*Tortula ruralis*), grimmia dry rock moss (*Grimmia anodon*), and bright copper homalothecium moss (*Homalothecium aeneum*) are common components of the biological soil crusts within the canyon grasslands (Sampselle 2004). The *Peltigera* lichen communities and the *Brachythecium-Ceratodon-Tortula* bryophyte communities were found within the snowberry-fescue plant association in Washington (Cooke 1955).

Justification:

Study of the snowberry-rose plant association is warranted as it is an important component of the landscape at Garden Creek. The shrubs provide cover and forage for a variety of wildlife (Johnson and Simon 1987) and offer soil protection as well (Francis 2004). In many places prescribed fire is being used as a management tool to facilitate restoration of natural disturbance regimes. In order to use fire in a positive and efficient way, more needs to be understood about vegetation and ecosystem interactions with fire. Given the inherent “variable nature” of fire, further research on a variety of landscapes and vegetation types will better enable land managers to predict these effects (Vogl 1974). In addition, invasive plants are a complex problem and attempts are being made to control or eradicate them in Garden Creek. It is generally accepted that perennial grasslands converted to cheatgrass-and yellow starthistle-dominated areas have reduced resource values (Sheley and Larson 1994). Weed invasion in perennial grasslands diminishes forage for wildlife and compromises other ecological processes (Sheley and Larson 1994). Therefore, this study will be useful to inform these questions and will provide useful data for further study.

Hypothesis:

I expect to find decreased snowberry and rose canopy cover on burned plots when compared to unburned plots. Also, the openings in the canopy resulting from the fire on burned plots would allow for higher incidence and cover of grasses, forbs, and introduced plants. Basal cover of mosses and lichens would be lower and bare ground would be higher on burned plots when compared with unburned plots.

Methods:

Study Site

The study site is within Garden Creek which occupies a portion of the Craig Mountain Wildlife Area. Garden Creek is co-owned and managed by the Bureau of Land Management (BLM) and The Nature Conservancy (TNC). Garden Creek is located in north central Idaho approximately 48 km south of Lewiston in Nez Perce County (Figure 1). It comprises 5668 ha of predominantly steep canyon grasslands on the west side of Craig Mountain. The Snake River provides the western boundary of Garden Creek. Elevation varies from 240 m at the Snake River to over 1500 m in just 5-6 km (Hill 2002). The vegetation is a mix of grasslands, shrublands, and forests and has been impacted by fire in the recent past, but the historical frequency of fire is unclear (Weddell 2001).

This area has a xeric soil moisture regime and mesic soil temperature regime (Hahn 2004). Average precipitation and temperature varies with elevation. At 1100 m average precipitation is 57 cm per year and average temperature is 8°C. At 400 m average precipitation is 32 cm per year and average temperature is 11.3°C (Western Regional Climate Center 2006). The Cottonwood portable weather station located on Redemsky road in Garden Creek gives temperature and precipitation data in close proximity to study sites for this research (Figure 1). Data became available for this weather station in February 2002 (Table 1 and Figure 2).

Soils supporting the snowberry-rose plant association are the deepest of any of the associations found within the steppe region and are similar to soils described within the Idaho fescue-prairie junegrass plant association (Johnson and Simon 1987). Similarly soils within Tisdale's snowberry series are difficult to differentiate from soils supporting the neighboring grasslands (Tisdale 1986). Daubenmire (1970) concurs that the differences between soils of the snowberry phase and the Idaho fescue-snowberry habitat type are "slight". Because of the relatively small size of the snowberry-rose communities, rarely greater than 30 m in length, soils supporting these specific communities are not delineated within the most recent 1:24,000-scale soil survey published by the Natural Resources Conservation Service.

According to the most recent soil survey for Lewis and Nez Perce counties, soils on the canyon slopes around Garden Creek area are predominantly mapped as the Lickskillet-Limekiln-Crowers and Kettenbach-Linville soil map units (Hahn 2004). Soils in this area are mostly formed from weathering basalt and loess deposits (Hahn 2004). All unburned plots are mapped as the Kettenbach-Gwin Complex, and burned plots occur in Slickpoo-Broadax (6 plots), Linville-Kettenbach (3 plots), and Limekiln-Crowers (1 plot) map units.

Gwin and Limekiln soils are both characteristically shallow soils and therefore can be eliminated as possibilities for soils associated with the snowberry-rose plant association. The remaining soils are deep to very deep Mollisols with loess and colluvium as the parent materials. They typically have a thick, dark surface horizon with high base status (mollic epipedon) and are classified as Calcic or Pachic Argixerolls or Haploxerolls (Hahn 2004). See Appendix 1 and Appendix 2 for detailed information on plot location and soil characteristics.

Canyon grasslands and canyon shrublands occupy 189,968 ha (0.88%) and 117,981 ha (0.54%) of Idaho, respectively (Caicco et al. 1995). Garden Creek is dominated by 3555 ha (63%) canyon grassland, 564 ha (10%) shrubland, 508 ha (9%) coniferous forest, and 113 ha (2%) riparian vegetation with weeds and rock, primarily basalt, comprising the remainder of the total land area (Hill and Gray 1999). Of the 10% total land area which is shrubland, 52% is considered snowberry-rose plant association. In 1999 invasive plant species occupied approximately 16% of the total land area at Garden Creek with the majority of this occurring within the grasslands. Invasive plants at Garden Creek are less significant in the shrublands due to light requirements but they are present.

Corral Creek, China Garden Creek and Cave Gulch are the three main drainages within Garden Creek. Between 30 September and 3 October 2001 the Corral Creek fire burned approximately 645 ha of the Corral Creek drainage. Twelve hectares burned were forested and the remaining encompassed grasslands and shrublands. The fire began as a result of friction heat from an excavator colliding with a rock. Weather at the start of the fire was 30° C and 14°10 Relative Humidity with light upslope winds. The majority of the area burned within the first day of the fire (Idaho Department of Lands 2001). The Corral Creek fire burned under moderate severity (Lynn Danly, Natural Resource Specialist, BLM, pers. comm.). The grasslands present little obvious evidence of this fire. However, skeletons and charred branches and trunks remain in the burned shrublands.

Plot selection

In order to study the fire effects on snowberry-rose plant association 10 burned and 10 unburned plots were located to compare species coverage. Data collected measure fire effects five years after the fire. Unburned plots were located north of Corral Creek road while burned plots were south of the road (Figure 1).

The following criteria were used to choose plots. First, all plots were located within Garden Creek with snowberry and rose dominating the vegetation. Burned plots were located within the fire boundary of the 2001 Corral Creek fire. Aspect was northerly (90-270°) and slope less than 70%. Length of the plot was determined to be at least 30 m to provide a 2.5-m edge buffer. The width of the plot varied but was at least 15 m to provide a minimum 2.5-m edge buffer. Plots were within 530-960 m elevation. Plots too close to draws were avoided in order to reduce the variability associated with riparian vegetation. These requirements were determined upon completion of the summer 2005 field season where time was spent locating potential plots, noting important characteristics of snowberry-rose patches, and learning the vegetation and plant taxonomy in the area.

Sampling methods

Once an appropriate site was found, UTM coordinates, elevation, aspect, and slope were recorded. The baseline was established by stretching a tape measure down slope while avoiding the edges of the shrub patch. The baseline was between 10 and 30 m in length. A random number table was used to determine the locations of the four 25-m transects along the baseline. Due to the irregularity in shape of many snowberry-rose patches, the baseline was located in the center of some patches and the edge of others.

The line intercept method (Canfield 1941) was used to estimate canopy cover of shrubs and a modified cover class method (Daubenmire 1959) was used to estimate canopy cover of forbs and grasses. Gaps between shrubs intersecting the tape less than 10 cm were included in the shrub cover measurement. However, gaps exceeding 10 cm necessitated resuming measurement at the location of the next shrub intersection.

Utilizing a 20x50-cm quadrat, 25 microplots were sampled per transect line. The microplots were placed on the uphill slope of the tape. The microplots began at the 1-m mark and were laid to the left of the meter mark. Seven cover classes were used to estimate percent foliar cover for all grasses and forbs present. The cover classes were defined as: class 1 = 0-1%, 2 = 1-5%, 3 = 5-10%, 4 = 10-25%, 5 = 25-50%, 6 = 50-75%, and 7 = 75-

100%. Any plant growing within or hanging over into the microplot was recorded. Ground cover was measured by approximating the percentage of bare ground, litter, mosses, lichens and rock within the microplot.

To calculate the percent cover of each species for a plot the number of times each species occurred per cover class within the microplots per transect was multiplied by the midpoint for that class. Midpoints were as follows: class 1 = 0.5%, 2 = 3%, 3 = 7.5%, 4 = 17.5%, 5 = 37.5%, 6 = 62.5%, 7 = 87.5%. This was repeated for all species found within the plot by transect line. The resulting numbers gave the percent cover for each species by transect. Averaging these numbers gave the percent cover per plot.

During the summer 2005 field season two plots, one burned and one unburned, were sampled as part of a pilot study which helped determine number and length of transects needed to ensure statistical significance and learn site vegetation. Data were collected in the 2006 field season.

Data analysis

PROC GLM in SAS (SAS Institute 2003), was used to determine normal distribution of individual species and groups of species. Due to the presence of zeros in the data set for individual species and a high amount of variability within the cover values, non-normality was determined for individual species. Therefore, the Monte Carlo two-sided test within the Wilcoxon (Mann-Whitney) nonparametric statistical test was used to determine significant differences between burned and unburned treatments. This test does a permutation on the rank data to test for differences within the dataset. Due to the non-normality of the data covariates are not included within this test and therefore location information (elevation, slope, and aspect) was assumed to be the same for these plots. According to the central limit theorem the grouped species data should be approximately normal (Ott and Longnecker 2001). A log transformation of the perennial native forbs and annual introduced grasses data was used to normalize these groups. A square root transformation was used to normalize the perennial introduced forbs and perennial native grasses groups. It was not necessary to transform the remaining groups. Analysis of Covariance (ANCOVA) was used to determine a significant difference between burned and unburned plots for the groups. Elevation, aspect, and slope were input as covariates in order to reduce error and account for differences due to variations on the landscape. These covariates were input as continuous variables. The level of significance used for all statistical tests was $P \leq .05$.

As I sampled vegetation from one fire event this study utilized one treatment. While random sampling was used within this treatment, the lack of a replicate suggests that this study was pseudoreplicated as described by Hurlbert (1984). However, comparing results from this study with other similar studies will bring added validity to conclusions drawn concerning species response to fire within the canyon grasslands of Hells Canyon. Nomenclature follows the USDA Plants Database (http://plants.usda.gov/) accessed in December 2006.

Results:

Three different shrubs were found on both burned and unburned plots. Ten grasses were found on unburned plots while 16 different grass species were found on burned. Fifty six forbs were found on unburned plots while 62 were found on burned. Of the 56 forbs found on unburned plots 27 had average cover ≥ 0.1%. The remaining species were present in trace amounts. Of the 62 forbs found on burned plots 30 had average cover ≥ 0.1%. Twenty one non-native plants were found in unburned plots while 23 were found on burned. Non-natives comprised <1% of the understory in both treatments.

Plot B8 was removed from the data set following initial analysis that showed this plot to be in violation of some plot criteria. For example, unusually high moss cover (41%) and slope >70% indicate that this plot varies from the other plots in ecologically significant ways. Therefore, this plot was removed from the analysis.

Winter vetch (*Vicia villosa*) was removed from group analyses because of the variability associated with this plant due to timing of sampling. Winter vetch was analyzed individually but was left out of the annual introduced forb group and total herbaceous group due to its high cover value in macroplot U9 (Appendix 3) of 30%. Plots U1 and U2 (sampled on May 17 and May 30 respectively) were located in the same vicinity as U9 (sampled on June 16) (Figure 1). U1 and U2 would most likely have displayed much higher values of winter vetch if sampled later as well. Winter vetch was nearly absent from burned plots (Appendix 4). It is uncertain whether this was a function of the fire or location on the landscape. Winter vetch was brought to the United States as a rotation crop (Whitson et al. 2002). It is possible that this plant was common off of the North Bench Road as a result of historical farming on these benches. Portions of Garden Creek that burned in the Corral

Creek fire had large patches of winter vetch during the summer of 2006 (Becky Chaffee, Range Technician, BLM, pers. comm.).

Shrubs

Shrub cover was higher in unburned plots (*P*=0.019) (Figure 3). Snowberry cover was greater on unburned plots (*P*=0.003). Rose cover was higher in magnitude on burned plots than unburned plots, 8% versus 6.8%, but statistical significance was not detected (*P*=0.215).

Grasses

Grasses comprised 18.3% of total herbaceous cover in unburned and 19.7% in burned plots. Total grass cover was not different between burned and unburned plots (*P*=0.431) (Table 2). No annual native grasses were found in these plots, and annual introduced grass cover was not different (*P*=0.572). The perennial native grass group was normalized with a square root transformation and was not significantly different (p=0.079), but cover values of 0.4% in unburned and 1.1% in burned show that average cover was higher in magnitude in burned plots. Three perennial introduced grasses were found; smooth brome (*Bromus inermis*), bulbous bluegrass (*Poa bulbosa*), and Kentucky bluegrass (*Poa pratensis*), but were not analyzed due to their low average cover and sporadic occurrence (Appendix 3 and Appendix 4).

Japanese brome and cheatgrass coverage were combined given the difficulty in distinguishing them before flowering. This combination was analyzed as an individual species. Cover of these annual introduced bromes was higher on burned plots (*P*=0.024) (Figure 4). Rattlesnake brome (*B. briziformis*) had higher cover in unburned than burned (*P*=0.045). Bentgrass (*Apera interrupta*) cover was higher in magnitude on burned plots but was not statistically significant (*P*=0.053). Neither Idaho fescue nor bluebunch wheatgrass showed a difference in cover values (*P*=0.946 and *P*=0.224, respectively) (Table 3).

Forbs

Forbs comprised the majority of the understory cover in both burned and unburned plots. Forbs were 81.7% of total herbaceous material in unburned and 83.6% in burned. None of the forb groups were different (Table 2). The forb group came close to being statistically different with cover values of 15.1% in burned and 20.7% in unburned plots (*P*=0.085). Aspect was significant (*P*=0.041) within the forb group. Also, perennial native forbs normalized with log approached statistical significance with cover averages of 6.6% in unburned and 10.5% in burned (*P*=0.087). Aspect was significant within the perennial native forb group as well (*P*=0.04) as well. Perennial introduced forbs were normalized with a square root transformation and were not different (*P*=0.63).

Western yarrow (*P*<0.001), slender cinquefoil (*P*=0.001), Missouri goldenrod (*P*=0.002), spring draba (*Draba verna*) (*P*=0.05), and Lewiston cornsalad (*Valerianella locusta*) (*P*=0.011) all had higher cover in burned plots (Figure 5). Slender cinquefoil was present in 9 of the 10 burned plots and only 1 of 10 unburned plots. Bedstraw (*Galium aparine*) (*P*=0.011) and winter vetch (*P*=0.001) both had higher cover in unburned plots (Figure 6). Yellow starthistle also had higher cover values in unburned plots (1.1% compared to 0.2%) although it was not significant (*P*=0.059). Similarly, miners lettuce (*Claytonia perfoliata*) (*P*=0.079) and sticky chickweed (*Cerastium glomeratum*) (*P*=0.067) came close to having statistically higher cover in unburned plots (Table 3). Silky lupine (*P*=0.244) and St. Johnswort (*P*=0.461) cover were not different. Also, thymeleaf sandwort (*Arenaria serpyllifolia*) (*P*=0.205), willoweed (*Epilobium brachycarpum*) (*P*=0.916), strict forget-me-not (*Myosotis stricta*) (*P*=0.366), and threadstalk speedwell (*Veronica filiformis*) (*P*=0.661) were present in 100% of the plots and were not different across the treatments. Grasses and forbs were combined to create an herbaceous group and no difference was found (*P*=0.135) (Table 2). Also, all introduced plants were combined and no difference was found (*P*=0.564).

Ground cover

Total ground cover which included litter, lichen, moss, and rock was higher in unburned plots (*P*=0.015) (Figure 7). Bare ground was higher in burned (*P*=0.028) while lichens (*P*=0.037) and moss (*P*<0.001) were both lower in the burned plots. Litter was not different between treatments (*P*=0.967).

Discussion:

Shrubs

It has been shown that when snowberry is growing in the understory of a forest, removal of the overstory results in a marked increase in snowberry cover following the fire (Cholewa and Johnson 1983, Youngblood et al. in press). This suggests that the increase in light and nutrients provided by the fire disturbance increase snowberry cover in these situations. However, when growing in grasslands where light is not limiting, it has been shown that, while snowberry resprouts following fire, it can take more than 10 years for the shrub canopy to regain pre-burn levels (Johnson 1998). This is supported by the results found in this study which show that five years following the Corral Creek fire the snowberry shows significantly less cover on burned plots (Table 3).

Rose species were highly variable within these shrub plots and although cover was higher in burned plots statistical significance was not detected. A similar increase in rose was detected in Oregon within the snowberry-rose plant association (Johnson 1998). Other studies show nootka rose and Woods' rose response to fire as variable. Hauessler et al. (1990) cite several studies which have shown that the nootka rose commonly increases initially post-fire and then declines in the subsequent years. However it is their opinion that rose does not typically increase following light/moderate fire events. Woods' rose was lower on light and severe burns but remained constant on moderate burns in a western Wyoming aspen community (Bartos and Mueggler 1981). It should be noted that most of the studies investigated fire effects on the nootka and Woods' rose in forested communities.

Grasses

In a western Montana grassland total grass cover came close to preburn levels 3 years after the fire (Antos et al. 1983). This supports the findings in this study where no difference in grass cover occurred was shown. Similarly, four years after prescribed burns in aspen communities grass cover did not differ from the control (Bartos et al. 1994). Grasses respond differently to fire and in order to predict species response to fire individual species characteristics, season and severity of fire should be considered (Paysen et al. 2000).

Idaho fescue and bluebunch wheatgrass cover values were not different (Table 3). Similarly, in a bluebunch wheatgrass-Idaho fescue habitat type, neither bluebunch wheatgrass nor Idaho fescue were different on burned sites (Daubenmire 1970). No difference of bluebunch wheatgrass canopy cover was found between burned and unburned plots in a study from western Montana (Antos et al. 1983). Also, following the Maloney Creek fire of 2001 in Garden Creek, bluebunch wheatgrass showed less canopy coverage one year after the fire as compared to the pre-burn coverage, but by 2003 there was no significant difference (Gucker 2004).

A fire study in the Selway-Bitterroot Wilderness showed that annual grasses (primarily cheatgrass) were higher on burned plots four years following the fire while perennial grasses were not different (Merrill et al. 1980). Also, annual brome cover increased five years after a fire in northeastern Oregon (Johnson 1998). Similar results were found here as the Japanese brome/cheatgrass pairing had higher cover on burned plots. These findings are consistent with other research on Japanese brome as well which show that although an initial decrease is usually seen recovery to preburn levels normally occurs two and three years post-fire (Armour et al. 1984, Whisenant et al. 1984). However, 12 years following a fire Japanese brome had not returned to pre-fire levels in southeastern Washington (Daubenmire 1975).

Rattlesnake brome cover was higher on the unburned plots. Rattlesnake brome did not change in burned plots following the Maloney Creek fire at Garden Creek (Menke and Muir 2004).

Forbs

No difference of total forb cover was found in this study. Similarly, in the Selway-Bitterroot Wilderness annual forbs were not different on unburned and burned plots four years following the fire while perennial forbs were higher on burned (Merrill et al. 1980). In an Arizona grassland forbs increased the first year following a fire but by the second growing season no statistical difference was detected (Bock and Bock 1992). Also forb coverage was not different following fires of varying intensities in ponderosa pine forests (Armour et al. 1984) and in a fescue prairie in Saskatchewan (Archibold et al. 2003).

Individual forb response varied by species. Western yarrow cover was greater on burned plots which is a response supported by other studies. Western yarrow cover doubled following fire on a western Montana grassland (Antos et al. 1983) and after three years had returned to pre-burn levels in a ponderosa pine community (Armour et al. 1984). Also, western yarrow cover was greater on burned plots two years following a fire in the Selway-Bitterroot Wilderness, Idaho (Merrill et al. 1980) as well as in spring and fall burned plots on a fescue prairie in Saskatchewan (Archibold et al. 2003).

Slender cinquefoil was present in 90% of the burned plots and 10% of the burned. Average cover was significantly higher on burned. These results are corroborated by an increase on the burn in a Montana grassland (Antos et al. 1983) and an increase following a low intensity fire treatment in ponderosa pine understory (Armour et al. 1984). Also, slender cinquefoil emergence was greater on burned plots following a prescribed fire on a western Oregon prairie (Maret and Wilson 2000) and increased following a moderate burn on a western Wyoming aspen community (Bartos and Mueggler 1981).

Missouri goldenrod was present in more burned plots with higher average cover than the unburned. This is supported by Wright and Bailey (1982) who cite a study by Anderson and Bailey (1980) that shows Missouri goldenrod increased (frequency increased 18% to 50% and canopy cover increased 1.7% to 27%) post-fire in grasslands and shrublands of Canada. Also an increase was shown following a summer burn in a fescue prairie in Saskatchewan (Archibold et al. 2003).

Spring draba cover was higher on burned sites. In a Montana grassland however spring draba was less in the burn (Antos et al. 1983). Also, in the sagebrush steppe of southeastern Washington spring draba decreased initially but the population had recovered by the fourth year after the fire (Daubenmire 1975). This species is most commonly found on open and disturbed sites (Tenaglia 2006).

Lewiston cornsalad cover was higher in the burned plots which is supported by the fact that this introduced annual is more commonly found in open and disturbed locations (Hitchcock and Cronquist 1973). Lewiston cornsalad increased following disturbance in a study on perennial grasses in southwestern British Colombia (MacDougall 2002).

Bedstraw cover was higher in unburned plots in this study. Five years after a fire in a snowberry-rose community in northeastern Oregon bedstraw cover exceeded pre-fire levels (Johnson 1998). Bedstraw was present in unburned plots but was absent from burned plots following a fire near Missoula, Montana (Antos et al. 1983). No significant difference of bedstraw cover was found following the Maloney Creek fire of 2000 which burned portions of China Garden Creek and Lower Corral Creek within Garden Creek (Menke and Muir 2004).

Winter vetch was higher in unburned plots but it is inconclusive as to whether this was due to location or treatment. Fire effects on winter vetch were not found in the literature. However Sarrantino and Scott (1988) state that winter vetch was planted as a cover crop. This supports the idea that the higher cover on some of the unburned plots was due to being located below a bench at Garden Creek that was historically farmed.

Yellow starthistle has had limited influence in the shrublands due to its high light requirements (Hill 2002, Zouhar 2002) thus it was expected that cover would have been higher on burned plots. However, no statistical difference in cover was found (P=0.059). Cover was actually higher in magnitude on unburned plots (1.05%) when compared to burned plots (0.20%). Although it is thought by some that “burning is an ineffective method for controlling yellow starthistle” (Sheley et al. 1999), fire has been shown to reduce yellow starthistle with repeated burns (DiTomaso et al. 1999). An increase in competition from other forbs and grasses could explain the decrease in yellow starthistle cover in burned plots.

Silky lupine cover was not different in this study. Similarly a fire in Montana occurring before lupine dormancy showed no change in lupine canopy cover (Antos et al. 1983). Research in ponderosa pine forests of the Selway-Bitterroot Wilderness also found no change in silky lupine cover following a fire event (Merrill et al. 1980). Studies in the grasslands of Garden Creek, however, show an increase in silky lupine following fire (Gucker 2004, Menke and Muir 2004). These results reflected silky lupine cover one to three years following the fires. Lupine species did not change following prescribed burns in a ponderosa pine forest in northern Idaho (Armour et al. 1984) and declined after fire in an aspen community (Bartos and Mueggler 1981).

St. Johnswort cover was not different in this study. Similarly, St. Johnswort cover did not change following a fire study within the grasslands of Garden Creek (Menke and Muir 2004). However, in Australia fires resulted in an increase in St. Johnswort (Briese 1996) and much of the literature suggests that this plant is enhanced by fire (Zouhar 2004).

Ground cover

Lichen and moss cover were both higher on unburned plots while bare ground was lower. In support of these findings, studies have shown lower lichen and moss cover on burned sites when compared with unburned (Antos et al. 1983, Johansen et al. 1984). Some species of moss were able to take advantage of additional nutrients released following a wildfire while lichens had "slow and very limited re-establishment" in grasslands in the Netherlands (Ketner-Oostra et al. 2006). Lichen cover was greater on control (unburned) plots than burned in a fire study in the sagebrush shrub steppe (Hilty et al. 2004). The recovery of biological soil crusts is especially slow in arid environments but the cooler and moister microclimate provided by shrub canopies can help speed recovery rates (Belnap 2003).

Litter cover on unburned plots was not different from burned plots. Similarly litter had returned to pre-burn levels five years after a wildfire in a snowberry-rose community in northeastern Oregon (Johnson 1998). Recovery of a continuous litter layer following a disturbance is an indicator of a healthy system (Natural Research Council 1994). The soil stability provided by the litter layer is particularly important in the canyon grasslands of

Garden Creek where slopes are often >50%. See Appendix 5 for a more complete view of all analyzed data on individual species not discussed in the text.

Summary:

Given the results found in this study it is shown that the snowberry-rose plant association within Garden Creek is resilient but has not recovered within five years to pre-burn conditions. Litter replacement on the ground and no differences in group herbaceous cover, show that the understory is not significantly changed five years following the fire. However, the dominant herbaceous plants are different between the two treatments. The five most abundant understory species by percent cover in unburned plots were: 1) bedstraw, 2) Japanese brome/cheatgrass, 3) silky lupine, 4) rattlesnake brome, and 5) yellow starthistle. The five most abundant understory species by percent cover in burned plots were 1) Missouri goldenrod, 2) Japanese brome/cheatgrass, 3) Lewiston cornsalad, 4) western yarrow, and 5) bedstraw. Often species respond positively when resources such as additional light and nutrients are available accompanied with a reduction in competition by other species (Bunting 1996). Given time it seems likely that shrub cover will increase and species composition will respond to the changes in resources provided by a closed canopy. For example, it is thought that Missouri goldenrod decreases with shading (Werner 1976). Therefore, it seems likely that as the snowberry recovers, Missouri goldenrod will decrease in the future. This study shows that although fire alters these communities, they are adapted to recover given enough time between fire events.

Further study of this plant association and these plots in particular would be beneficial to determine the fire interval which maintains these shrub communities in this area. Also, further study is needed as little research was located concerning fire and the snowberry-rose plant association. Follow up data collected 10 and 15 years following the Corral Creek fire on these specific plots would help track recovery rate and changes within the community and the area. Continued vegetation sampling in these shrub communities would also provide valuable pre-burn data should another fire affect this area in the future.

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APPENDIX 1. Plot location data and associated soils.

Plot #	UTM E	UTM N	Elevation (m)	Aspect (°)	Slope (%)	Map Unit # & Name
B1	509102	5096106	872	272	38	117- Slickpoo-Broadax
B2	509285	5096160	912	290	30	117- Slickpoo-Broadax
B3	508883	5096062	752	310	40	117- Slickpoo-Broadax
B4	508925	5096146	820	310	45	117- Slickpoo-Broadax
B5	508860	5096172	798	290	25	117- Slickpoo-Broadax
B6	508938	5096926	798	270	30	81-Linville-Kettenbach
B7	507663	5095527	519	350	55	79-Limekiln-Crowers
B8 [1]	508598	5096973	634	285	72	81-Linville Kettenbach
B9	509354	5096456	922	295	35	117-Slickpoo-Broadax
B10	509222	5096611	885	310	15	81-Linville-Kettenbach
U1	507993	5097840	792	290	50	57-Kettenbach-Gwin Complex
U2	507854	5097744	739	290	25	57-Kettenbach-Gwin Complex
U3	507786	5097632	721	310	50	57-Kettenbach-Gwin Complex
U4	507245	5099298	837	280	32	57-Kettenbach-Gwin Complex
U5	508975	5098753	823	70	65	57-Kettenbach-Gwin Complex
U6	507493	5099318	891	295	38	57-Kettenbach-Gwin Complex
U7	507528	5098535	852	290	40	57-Kettenbach-Gwin Complex
U8	508859	5098752	874	50	40	57-Kettenbach-Gwin Complex
U9	507951	5097818	769	285	52	57-Kettenbach-Gwin Complex
U10	508927	5098725	855	70	50	57-Kettenbach-Gwin Complex

[1] plot removed from data analysis

APPENDIX 2. Soil characteristics of soils associated with snowberry-rose plots from NRCS soil survey (Hahn 2004)

# of plots	Map Unit	Component	Elev. Range (m)	Aspect	Slope Range(%)	Avg. precip. (cm)	Depth class	PNC[1]	Parent Material	Classification
10	57	Kettenbach	366-1220	S & W	35 to 75	46	mod. deep	PSSP6/BASA3	colluvium, loess	Pachic Argixeroll
		Kettenbach moist	366-1220	W, NW, & SE	35 to 75	46	mod. deep	FEID/PSSP6	colluvium, loess	Pachic Argixeroll
		Gwin	366-1220	Ridges and convex slopes	35 to 75	46	shallow	PSSP6/POSE	colluvium mixed with loess	Lithic Argixeroll
1	79	Limekiln	230-790	S & W	45 to 60	36	shallow	PSSP6/prickly pear	loess, colluvium	Lithic Haploxeroll
		Crowers	230-790	N & E	45 to 80	36	very deep	FEID/PSSP6	loess over colluvium	Calcic Pachic Haploxeroll
3	81	Linville	245-850	N & E	45-75	43	very deep	FEID/forbs	loess, colluvium	Pachic Haploxeroll
		Kettenbach	245-850	N & E, some nw and se	45-75	43	mod. deep	PSSP6/BASA3	colluvium, loess	Pachic Argixeroll
6	117	Slickpoo	490-885	S & W	15 to 25	41	deep	FEID/PSSP6	loess	Calcic Pachic Argixeroll
		Broadax	490-885	N & E	15 to 25	41	very deep	FEID/PSSP6	loess	Calcic Argixeroll

[1] Plant abbreviations listed in Appendix 6. Plant symbols for PNC updated to current plant symbols. For example PSSP6 was updated from AGSP which was the symbol used in the NRCS soil survey that this appendix references.

APPENDIX 3. Percent average species cover for unburned plots.

Shrubs:	**U1**	**U2**	**U3**	**U4**	**U5**	**U6**	**U7**	**U8**	**U9**	**U10**
Crataegus douglasii	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.100
Rosa spp.	0.160	0.000	1.700	0.450	0.000	0.000	11.700	5.200	5.750	44.000
Symphoricarpos albus	93.080	96.420	89.350	85.020	81.550	95.100	81.950	96.000	89.650	63.200
Grasses:										
Apera interrupta	0.000	0.105	0.065	0.035	0.045	0.120	0.040	0.090	0.090	0.355
Bromus arvensis	0.000	0.400	0.775	0.895	1.105	0.115	0.615	2.720	2.485	3.540
Bromus arvensis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bromus briziformis	0.000	0.175	0.585	0.005	0.205	0.915	2.510	0.510	4.955	3.105
Bromus inermis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bromus tectorum	1.045	0.225	0.575	0.000	0.250	0.095	0.200	0.255	0.210	0.105
Elymus canadensis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.420	0.000
Elymus glaucus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Festuca idahoensis	0.500	0.000	0.030	0.000	0.215	0.000	0.355	0.220	0.000	0.105
Koeleria macrantha	0.030	0.000	0.000	0.000	0.040	0.000	0.415	0.230	0.000	0.005
Poa bulbosa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Poa pratensis	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Poa secunda	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.030
Pseudoroegneria spicata	0.315	0.000	0.120	0.000	0.160	0.000	0.430	0.320	0.170	0.070
Ventanata dubia	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Vulpia c.a. *myuros*	0.000	0.015	0.015	0.015	0.000	0.005	0.000	0.000	0.005	0.000
unk fescue [1]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Forbs:										
Achillea millefolium	0.610	0.155	0.295	0.225	0.450	0.340	0.665	0.870	0.185	0.725
Agoseris glauca var. *dasycephala*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Amsinckia	0.100	0.075	0.000	0.000	0.000	0.000	0.000	0.165	0.000	0.000
Anthriscus caucalis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Arabis glabra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Arenaria serpyllifolia	0.455	0.620	0.530	0.530	0.650	0.770	0.925	1.160	1.020	1.900
Arnica sororia	0.000	0.000	0.090	0.030	0.005	1.340	2.715	0.095	0.175	0.000

Appendix 3. Continued

Artemisia ludoviciana	0.175	0.000	0.095	0.165	0.000	0.225	0.825	0.000	0.075	0.000
Astragalus cusickii	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Balsamorhiza sagittata	0.000	0.875	0.000	0.000	3.100	0.000	0.075	0.000	0.000	2.505
Besseya rubra	0.000	0.000	0.000	0.000	0.000	0.000	0.235	0.325	0.000	0.000
Buglossoides arvensis	0.000	0.000	0.000	0.000	0.225	0.000	0.000	0.000	0.000	0.000
Calochortus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cardamine	0.000	0.235	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Castilleja hispida	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Centaurea solstitialis	1.515	4.035	0.170	0.150	0.240	0.280	0.300	0.220	3.520	0.080
Cerastium arvense	0.030	0.000	0.000	0.925	0.100	0.000	1.670	0.105	0.000	0.000
Cerastium glomeratum	0.000	0.020	0.050	0.730	0.050	0.085	0.020	0.070	0.105	0.485
Clarkia pulchella	0.000	0.000	0.000	0.055	0.010	0.000	0.010	0.000	0.000	0.000
Claytonia perfoliata	1.015	0.210	0.005	0.000	0.165	0.475	0.320	1.285	0.620	0.885
Delphinium	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.060	0.000
Dipsacus sylvestris	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.030	0.000	0.000
Draba verna	0.000	0.010	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000
Epilobium brachycarpum	0.110	0.035	0.140	0.210	0.785	0.040	0.060	0.125	0.035	0.145
Erigeron corymbosus	0.180	0.000	0.030	0.000	0.240	0.000	0.090	0.030	0.075	0.000
Eriogonum heracleoides	0.000	0.000	2.185	3.255	0.000	0.030	0.080	0.705	0.000	0.000
Erodium cicutarium	0.000	0.265	0.035	0.010	0.000	0.000	0.000	0.000	0.130	0.000
Erythronium grandiflorum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Euphorbia esula	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Frasera albicaulis	0.250	0.000	0.000	0.135	0.000	0.000	0.385	1.345	0.000	1.335
Galium aparine	4.340	2.375	2.195	1.535	2.175	3.040	1.905	3.415	9.250	5.090
Geranium pusillum	0.000	0.000	0.000	0.530	0.000	0.000	0.000	0.000	0.005	0.000
Geum triflorum	0.015	0.000	0.000	0.000	0.000	0.000	2.915	0.075	0.000	0.000
Heuchera cylindrica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hieracium scouleri var. *albertinum*	0.000	0.005	0.000	0.000	0.030	0.000	0.035	0.175	0.000	0.000
Holosteum umbellatum	0.000	0.035	0.010	0.015	0.030	0.000	0.010	0.000	0.000	0.000
Hydrophyllum capitatum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hypericum perforatum	0.000	0.490	0.465	1.330	1.420	0.960	0.275	1.160	0.915	1.365

Appendix 3. Continued

Lactuca serriola	0.030	0.005	0.070	0.135	0.045	0.005	0.030	0.020	0.180	0.030
Lathyrus bijugatus	0.000	0.000	0.000	0.000	0.000	0.000	0.165	0.000	0.000	0.000
Lithophragma parviflorum	0.655	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.030	0.000
Lithospermum ruderale	0.080	0.000	0.460	0.000	0.665	0.600	0.525	0.075	0.075	0.000
Lomatium dissectum	0.000	0.000	0.060	0.000	0.210	0.000	0.000	0.010	0.000	0.725
Lomatium triternatum	0.000	0.000	0.000	0.000	0.005	0.000	0.010	0.000	0.000	0.060
Lotus unifoliolatus var. *unifoliolatus*	0.000	0.000	0.000	0.225	0.000	0.000	0.000	0.000	0.120	0.000
Lupinus sericeus	0.505	0.290	0.770	0.290	0.695	0.730	3.930	4.070	0.330	1.505
Madia gracilis	0.005	0.525	0.030	0.035	0.230	0.010	0.000	0.075	0.065	0.145
Microsteris gracilis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Myosotis stricta	0.605	0.615	0.185	0.290	0.325	0.330	0.320	0.375	0.330	0.340
Nepeta cataria	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Oxalis corniculata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Penstemon glandulosus	0.000	0.000	0.310	0.030	1.010	0.000	0.135	0.000	0.000	0.910
Phlox colubrina	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.080
Polemonium micranthum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Potentilla gracilis	0.000	0.000	0.000	0.000	0.000	1.290	0.000	0.000	0.000	0.000
Senecio integerrimus	1.340	0.355	3.265	0.300	1.065	0.720	0.000	0.000	0.170	0.135
Silene scouleri	0.000	0.000	0.030	0.000	0.000	0.000	0.695	0.000	0.000	0.000
Sisymbrium altissimum	0.300	0.030	0.005	0.000	0.005	0.000	0.095	0.720	1.110	0.255
Solidago missouriensis	0.000	0.000	0.000	1.030	0.000	0.000	0.400	0.000	0.000	0.000
Stellaria	0.060	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000
Tonella floribunda	0.000	0.000	0.030	0.000	0.005	0.000	0.000	0.000	0.005	0.000
Tragopogon dubius	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Triodanis perfoliata	0.000	0.000	0.000	0.000	0.000	0.000	0.065	0.115	0.000	0.000
Triteleia grandiflora var. *grandiflora*	0.550	0.010	0.005	0.065	0.005	0.010	0.000	0.030	0.000	0.000
Valerianella locusta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.060	0.000	0.000
Veronica filiformis	0.005	0.335	0.325	0.175	0.225	0.075	0.220	0.490	0.375	1.035
Vicia villosa	2.665	1.745	0.555	1.320	0.005	1.610	0.000	0.000	30.120	0.075
Woodsia oregana	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.030
Zigadenus venenosus	0.000	0.005	0.050	0.015	0.000	0.020	0.010	0.000	0.000	0.000

Appendix 3. Continued

unk mint [1]	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
unk sessile [1]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
unk white underside thistle [1]	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.110	0.000	0.000
unk wooly thistle [1]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ground Cover:										
Bare ground	9.570	3.420	1.670	5.020	6.710	1.950	1.800	3.550	2.790	1.410
lichens	0.220	0.000	0.000	0.000	0.100	0.060	0.210	0.000	0.100	0.190
moss	10.090	10.620	7.180	4.500	9.450	12.190	24.640	5.600	21.280	13.400
litter	68.820	77.800	81.850	78.700	72.900	79.200	65.950	79.300	70.500	80.700
rock	0.698	0.000	0.390	0.000	1.670	0.150	0.770	0.000	0.130	0.180

[1] unable to identify

APPENDIX 4. Percent average species cover for burned plots.

Shrubs:	B1	B2	B3	B4	B5	B6	B7	B8 [1]	B9	B10
Crataegus douglasii	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.100
Rosa spp.	3.500	21.830	0.000	1.610	12.200	17.050	4.070	32.420	7.400	4.350
Symphoricarpos albus	78.880	32.590	70.390	62.800	84.690	41.620	88.650	62.350	66.900	70.550
Grasses:										
Apera interrupta	0.000	0.445	0.410	0.340	0.055	0.120	0.175	0.170	0.210	0.140
Bromus arvensis	0.775	0.975	1.420	1.920	0.650	2.720	0.410	3.695	5.750	5.235
Bromus arvensis	0.000	0.000	0.000	0.000	0.000	0.295	0.000	0.000	0.000	0.000
Bromus briziformis	0.000	0.000	0.000	0.010	0.005	0.000	1.220	0.235	0.280	0.460
Bromus inermis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.225	0.000	0.000
Bromus tectorum	2.820	0.485	0.365	0.705	1.420	0.815	0.710	1.615	1.130	0.065
Elymus canadensis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Elymus glaucus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.870	3.985
Festuca idahoensis	0.075	0.005	0.075	1.100	0.140	0.000	0.775	0.280	0.000	0.000
Koeleria macrantha	0.000	0.030	0.000	0.035	0.010	0.000	0.030	0.000	0.635	0.310
Poa bulbosa	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000
Poa pratensis	0.000	0.005	0.040	0.280	0.000	0.000	0.000	0.000	0.070	0.000
Poa secunda	0.000	0.005	0.000	0.000	0.000	0.000	0.060	0.000	0.075	0.000
Pseudoroegneria spicata	0.005	0.050	0.030	1.090	0.000	0.000	0.100	0.030	0.000	0.000
Ventanata dubia	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.670
Vulpia c.a. *myuros*	0.395	0.130	0.110	0.420	0.000	0.000	0.000	0.000	0.000	0.000
unk fescue [2]	0.090	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Forbs:										
Achillea millefolium	2.355	2.160	1.420	0.970	1.200	3.455	2.950	0.165	4.130	2.920
Agoseris glauca var. *dasycephala*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.370	0.735
Amsinckia	0.000	0.000	0.000	0.030	0.000	0.030	0.000	0.000	0.000	0.000
Anthriscus caucalis	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Arabis glabra	0.000	0.010	0.030	0.000	0.000	0.000	0.000	0.000	0.065	0.000
Arenaria serpyllifolia	1.680	1.180	1.190	1.870	1.405	0.405	0.525	1.810	0.590	0.885
Arnica sororia	0.000	0.000	0.000	0.240	0.000	0.000	0.060	0.000	0.000	0.000

Appendix 4. Continued

Artemisia ludoviciana	0.155	0.000	0.000	1.835	1.665	0.000	0.000	0.000	0.000	0.175
Astragalus cusickii	0.000	0.375	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Balsamorhiza sagittata	0.005	0.000	0.000	0.000	0.000	0.000	0.000	1.250	0.000	0.175
Besseya rubra	0.000	0.000	0.000	1.145	0.000	0.000	0.000	0.030	0.000	0.000
Buglossoides arvensis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Calochortus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.025	0.010
Cardamine	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.080	0.000	0.000
Castilleja hispida	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Centaurea solstitialis	0.115	0.115	0.230	0.055	0.105	0.650	0.000	0.175	0.440	0.075
Cerastium arvense	0.000	0.000	0.000	0.000	0.000	0.000	0.455	3.015	0.030	0.000
Cerastium glomeratum	0.000	0.000	0.000	0.000	0.010	0.175	0.070	1.470	0.040	0.030
Clarkia pulchella	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Claytonia perfoliata	0.110	0.035	0.005	0.005	0.555	0.205	0.000	1.830	0.325	0.085
Delphinium	0.000	0.000	0.000	0.000	0.030	0.000	0.000	0.000	0.000	0.000
Dipsacus sylvestris	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.240	0.000
Draba verna	0.010	0.135	0.100	0.345	0.050	0.000	0.000	0.005	0.000	0.000
Epilobium brachycarpum	0.115	0.685	0.090	0.030	0.035	0.275	0.010	0.355	1.020	0.295
Erigeron corymbosus	0.000	0.000	0.000	0.065	0.215	0.000	0.075	0.000	0.000	0.000
Eriogonum heracleoides	0.000	0.000	0.000	0.000	0.000	0.000	1.615	0.000	0.000	0.000
Erodium cicutarium	0.005	0.000	0.070	0.085	0.105	0.000	0.000	0.000	0.000	0.000
Erythronium grandiflorum	0.000	0.000	0.000	0.000	0.000	0.040	0.000	0.000	0.000	0.000
Euphorbia esula	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.075	0.000	0.000
Frasera albicaulis	0.075	0.005	0.000	0.810	0.215	0.000	0.005	0.030	0.000	0.205
Galium aparine	1.290	0.395	3.350	0.665	3.315	0.270	0.235	2.595	1.850	2.085
Geranium pusillum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Geum triflorum	0.000	0.000	0.000	0.680	0.000	0.000	0.495	0.000	0.000	0.000
Heuchera cylindrica	0.000	0.000	0.000	0.000	0.000	0.000	0.075	0.000	0.000	0.000
Hieracium scouleri var. *albertinum*	0.075	0.030	0.000	0.175	0.210	0.000	0.000	0.000	0.000	0.510
Holosteum umbellatum	0.000	0.135	0.335	0.020	0.020	0.000	0.070	0.000	0.005	0.000
Hydrophyllum capitatum	0.000	0.000	0.000	0.030	0.030	0.000	0.000	0.000	0.000	0.000
Hypericum perforatum	0.015	0.395	0.120	0.235	0.210	1.260	0.365	6.590	1.580	2.985

Appendix 4. Continued

Lactuca serriola	0.260	0.490	0.180	0.340	0.000	0.000	0.005	0.195	0.030	0.000
Lathyrus bijugatus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lithophragma parviflorum	0.070	0.050	0.050	0.035	0.025	0.000	0.010	0.000	0.000	0.000
Lithospermum ruderale	0.000	0.205	0.340	0.110	0.315	0.960	0.000	0.000	0.005	0.175
Lomatium dissectum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lomatium triternatum	0.055	0.000	0.000	0.000	0.025	0.035	0.035	0.000	0.000	0.030
Lotus unifoliolatus var. *unifoliolatus*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lupinus sericeus	0.500	0.665	0.210	0.415	2.050	0.080	5.780	0.000	0.340	0.240
Madia gracilis	3.455	0.050	0.060	0.290	0.000	0.785	0.030	0.000	1.640	0.125
Microsteris gracilis	0.000	0.000	0.000	0.000	0.035	0.000	0.000	0.000	0.000	0.000
Myosotis stricta	0.140	0.345	0.400	0.555	0.290	0.260	0.495	1.075	0.115	0.065
Nepeta cataria	0.000	0.000	0.000	0.000	0.000	0.130	0.000	0.000	0.080	0.000
Oxalis corniculata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Penstemon glandulosus	0.000	0.000	0.000	0.380	0.000	0.000	0.150	3.115	0.000	0.000
Phlox colubrina	0.000	0.000	0.000	0.060	0.000	0.000	0.105	0.030	0.000	0.000
Polemonium micranthum	0.005	0.000	0.060	0.005	0.000	0.000	0.000	0.000	0.000	0.000
Potentilla gracilis	0.080	0.385	0.395	0.350	0.110	0.090	1.130	0.000	0.245	0.595
Senecio integerrimus	0.030	0.000	0.000	0.460	0.075	0.395	0.280	1.390	0.000	0.075
Silene scouleri	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000
Sisymbrium altissimum	0.290	1.565	0.975	0.015	0.030	0.125	0.000	0.005	0.000	0.030
Solidago missouriensis	2.550	11.855	1.055	1.710	0.000	0.000	3.935	0.000	8.995	11.420
Stellaria	0.075	0.010	0.010	0.005	0.000	0.000	0.045	0.000	0.000	0.000
Tonella floribunda	0.000	0.000	0.000	0.000	0.000	4.635	0.165	1.940	0.000	0.030
Tragopogon dubius	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Triodanis perfoliata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.290	0.000	0.005
Triteleia grandiflora var. *grandiflora*	0.095	0.085	0.070	0.035	0.040	0.000	0.000	0.000	0.000	0.030
Valerianella locusta	0.295	0.010	11.330	0.210	0.005	0.000	0.000	0.000	0.000	11.970
Veronica filiformis	0.035	0.045	0.175	0.535	0.465	0.240	0.430	0.500	0.360	0.730
Vicia villosa	0.000	0.000	0.060	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Woodsia oregana	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zigadenus venenosus	0.000	0.000	0.005	0.005	0.000	0.000	0.000	0.000	0.000	0.000

Appendix 4. Continued

unk mint [2]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
unk sessile [2]	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
unk white underside thistle [2]	0.000	0.000	0.000	0.030	0.000	0.090	0.000	0.000	0.060	0.000
unk wooly thistle [2]	0.000	0.000	0.000	0.000	0.000	0.030	0.000	0.000	0.000	0.000
Ground Cover:										
Bare ground	15.250	21.930	14.060	6.370	3.820	5.560	2.270	2.290	10.700	3.340
lichens	0.100	0.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000
moss	0.010	1.700	0.820	0.940	1.310	1.470	40.990	4.300	0.050	0.130
litter	67.580	62.630	71.600	80.510	86.830	83.000	47.050	81.500	67.850	76.200
rock	0.210	0.300	0.000	0.340	0.120	0.580	0.630	0.310	0.000	0.000

[1] B8 removed from data analysis
[2] unable to identify

APPENDIX 5. Individual species mean cover, variance, and constancy. P-value shows results of Wilcoxon permutation test on rank sums comparing unburned versus burned coverage. *P*-value, burned mean, and burned variance reflect analysis without plot B8.

		Unburned			Burned		
	p-value (Monte Carlo two-sided test)	**Mean**	**Variance**	**Constancy (%)**	**Mean**	**Variance**	**Constancy (%)**
Shrubs:							
Symphoricarpos albus	**0.003** [1]	86.699	91.025	100	66.341	348.603	100
Rosa spp.	**0.215**	6.771	166.056	70	8.001	55.628	90
Grasses:							
Agrostis interrupta	**0.053**	0.092	0.009	90	0.211	0.024	90
Bromus briziformis	**0.045** [1]	1.239	2.520	90	0.219	0.168	60
B. tectorum and *B. japonicus*	**0.025** [1]	1.561	1.168	100	3.152	3.706	100
Festuca idahoensis	**0.946**	0.140	0.028	60	0.241	0.165	70
Psuedoroegneria spicata	**0.224**	0.147	0.021	70	0.142	0.128	60
Forbs:							
Achillea millefolium	**0.000** [1]	0.445	0.057	100	2.396	1.148	100
Arenaria serpyllifolia	**0.205**	0.856	0.169	100	1.081	0.269	100
Centaurea solstitialis	**0.059**	1.049	2.025	100	0.198	0.045	90
Cerastium viscosum	**0.067**	0.230	0.054	90	0.036	0.003	60
Draba verna	**0.050** [1]	0.002	0.000	20	0.071	0.013	60
Epilobium paniculatum	**0.916**	0.176	0.045	100	0.284	0.121	100
Frasera albicaulis	**0.844**	0.359	0.263	50	0.146	0.070	70
Galium aparine	**0.011** [1]	3.466	4.763	100	1.495	1.532	100
Holosteum umbellatum	**0.273**	0.011	0.000	50	0.065	0.012	60
Hypericum perforatum	**0.461**	0.925	0.226	90	0.796	0.962	100
Lupinus sericeus	**0.244**	1.264	1.922	100	1.142	3.370	90
Madia gracilis	**0.237**	0.113	0.024	90	0.715	1.344	80
Montia perfoliata	**0.079**	0.498	0.177	90	0.147	0.035	90
Myosotis stricta	**0.366**	0.382	0.017	100	0.296	0.029	100
Potentilla gracilis	**0.001** [1]	0.129	0.150	10	0.376	0.109	90

Appendix 5. Continued

Senecio integerrimus	**0.098**	0.439	0.897	80	0.146	0.033	70
Sisymbrium altissimum	**0.899**	0.252	0.128	80	0.337	0.310	80
Solidago missouriensis	**0.002** [1]	0.246	0.102	20	4.613	23.293	70
Triteleia grandiflora var. *grandiflora*	**0.423**	0.074	0.026	70	0.039	0.001	60
Valerianella locusta	**0.011** [1]	0.006	0.000	10	2.647	26.092	60
Veronica filiformis	**0.661**	0.311	0.074	100	0.335	0.054	100
Vicia villosa	**0.001** [1]	3.886	77.689	80	0.007	0.000	10
Ground Cover:							
Bare ground	**0.028** [1]	4.124	6.215	100	9.258	44.598	100
lichens	**0.037** [1]	0.088	0.008	60	0.011	0.001	20
moss	**0.000** [1]	11.627	38.027	100	1.192	1.755	100
litter	**0.967**	75.257	27.856	100	75.300	68.493	100
rock	**0.620**	0.360	0.250	70	0.207	0.039	70

[1] significantly different at $p \leq 0.05$

APPENDIX 6. Plant master list with plant symbol, common name, family, duration, and nativity. Nomenclature based on USDA PLANTS Database.

Shrubs:	**Plant Symbol**	**Common name**	**Family**	**Perennial/ Annual**	**Native/Introd uced**
Crataegus douglasii Lindl.	CRDO2	black hawthorn	Rosaceae	P	N
Rosa L.	ROSA5	rose	Rosaceae	P	N
Symphoricarpos albus (L.) Blake	SYAL	common snowberry	Caprifoliaceae	P	N
Grasses:					
Apera interrupta (L.) Beauv. = *Agrostis interrupta* (L.) Beauv.	APIN	bentgrass	Poaceae	A	N
Bromus arvensis L. = *Bromus japonicus* Thunb ex Murr.	BRAR5	Japanese brome	Poaceae	A	I
Bromus briziformis Fisch. & C.A. Mey.	BRBR5	rattlesnake brome	Poaceae	A	I
Bromus inermis Leyss.	BRIN2	smooth brome	Poaceae	P	I
Bromus tectorum L.	BRTE	cheatgrass	Poaceae	A	I
Elymus canadensis L.	ELCA4	Canada wildrye	Poaceae	P	N
Elymus glaucus Buckl.	ELGL	blue wildrye	Poaceae	P	N
Festuca idahoensis Elmer	FEID	Idaho fescue	Poaceae	P	N
Koeleria macrantha (Ledeb.) J.A. Schultes = *Koeleria cristata* auct. p.p., non Pers.	KOMA	prairie Junegrass	Poaceae	P	N
Poa bulbosa L.	POBU	bulbous bluegrass	Poaceae	P	I
Poa pratensis L.	POPR	Kentucky bluegrass	Poaceae	P	I
Poa secunda J. Presl	POSE	Sandberg bluegrass	Poaceae	P	N
Pseudoroegneria spicata (Pursh) A. Love	PSSP6	bluebunch wheatgrass	Poaceae	P	N
Ventenata dubia (Leers) Coss.	VEDU	North Africa grass	Poaceae	A	I
Vulpia myuros (L.) K.C. Gmel. = *Festuca* c.a. *myuros* L.	VUMY	rat-tail fescue	Poaceae	A	I
Forbs:					
Achillea millefolium L.	ACMI2	western yarrow	Asteraceae	P	N
Agoseris glauca (Pursh) Raf. var. *dasycephala* (Torr. & Gray) Jepson	AGGLD	agoseris	Asteraceae	P	N

Appendix 6. Continued

Amsinckia Lehm.	AMSIN	fiddleneck	Boraginaceae	A	N
Anthriscus caucalis Bieb.	ANCA14	burr chervil	Apiaceae	A	I
Arabis glabra (L.) Bernh.	ARGL	tower rockcress	Apiaceae	A/Bi	N
Arenaria serpyllifolia (L.)	ARSE2	thymeleaf sandwort	Caryophyllaceae	A	I
Arnica sororia Greene	ARSO2	twin arnica	Asteraceae	P	N
Artemisia ludoviciana Nutt.	ARLU	white sagebrush	Asteraceae	P	N
Astragalus cusickii Gray	ASCU5	Cusick's milkvetch	Fabaceae	P	N
Balsamorhiza sagittata (Pursh) Nutt.	BASA3	arrowleaf balsamroot	Asteraceae	P	N
Besseya rubra (Dougl. ex Hook.) Rydb.	BERU	red besseya	Scrophulariaceae	P	N
Buglossoides arvensis (L.) I.M. Johnston = *Lithospermum arvense* L.	BUAR3	corn gromwell	Boraginaceae	A	I
Calochortus Pursh.	CALOC	mariposa lily	Liliaceae	P	N
Cardamine L.	CARDA	bittercress	Apiaceae	A	N
Castilleja hispida Benth.	CAHI9	harsh Indian paintbrush	Scrophulariaceae	P	N
Centaurea solstitialis L.	CESO3	yellow star-thistle	Asteraceae	A	I
Cerastium arvense L.	CEAR4	field chickweed	Caryophyllaceae	P	N
Cerastium glomeratum Thuill.	CEGL2	sticky chickweed	Caryophyllaceae	A	I
Clarkia pulchella Pursh	CLPU	pinkfairies	Onagraceae	A	N
Claytonia perfoliata Donn ex Willd. ssp. *perfoliata* = *Montia perfoliata* (Donn ex Willd.) T.J. Howell	CLPEP	miner's lettuce	Portulacaceae	A	N
Delphinium L.	DELPH	larkspur	Ranunculaceae	P	N
Dipsacus fullonum L.	DIFU2	teasel	Dipsacaceae	Bi	I
Draba verna L.	DRVE2	spring draba	Brassicaceae	A	I
Epilobium brachycarpum K. Presl = *Epilobium paniculatum* Nutt. ex Torr. & Gray	EPBR3	willoweed	Onagraceae	A	N
Erigeron corymbosus Nutt.	ERCO5	longleaf fleabane	Asteraceae	P	N
Eriogonum heracleoides Nutt.	ERHE2	parsnipflower buckwheat	Polygonaceae	P	N
Erodium cicutarium (L.) L'Hér. ex Ait.	ERCI6	redstem stork's bill	Geraniaceae	A	I
Erythronium grandiflorum Pursh	ERGR9	glacier lilly	Liliaceae	P	N
Euphorbia esula L.	EUES	leafy spurge	Euphorbiaceae	P	I
Frasera albicaulis Dougl. ex Griseb.	FRAL2	whitestem frasera	Gentianaceae	P	N

Appendix 6. Continued

Galium aparine L.	GAAP2	bedstraw	Rubiaceae	A	N
Geranium pusillum L.	GEPU2	small geranium	Geraniaceae	A	I
Geum triflorum Pursh	GETR	prairie smoke	Rosaceae	P	N
Heuchera cylindrica Dougl. ex Hook.	HECY2	roundleaf alumroot	Saxifragaceae	P	N
Hieracium scouleri Hook. var. *albertinum* (Farr) G.W. Douglas & G.A. Allen	HISCA	hairy Albert	Asteraceae	P	N
Holosteum umbellatum L.	HOUM	jagged chickweed	Caryophyllaceae	A	I
Hydrophyllum capitatum Dougl. ex Benth.	HYCA4	ballhead waterleaf	Hydrophyllaceae	P	N
Hypericum perforatum L.	HYPE	St. Johnswort	Hypericaceae	P	I
Lactuca serriola L.	LASE	prickly lettuce	Asteraceae	A	I
Lathyrus bijugatus White	LABI2	drypark pea	Fabaceae	P	N
Lithophragma parviflorum (Hook.) Nutt. ex Torr. & Gray	LIPA5	smallflower woodland-star	Saxifragaceae	P	N
Lithospermum ruderale Dougl. ex Lehm.	LIRU4	stoneseed	Boraginaceae	P	N
Lomatium dissectum (Nutt.) Mathias & Constance	LODI	fernleaf biscuitroot	Apiaceae	P	N
Lomatium triternatum (Pursh) Coult. & Rose	LOTR2	nineleaf biscuitroot	Apiaceae	P	N
Lotus unifoliolatus (Hook.) Benth. var. *unifoliolatus*	LOUNU	trefoil	Fabaceae	A	N
Lupinus sericeus Pursh	LUSE4	silky lupine	Fabaceae	P	N
Madia gracilis (Sm.) Keck & J. Clausen ex Applegate	MAGR3	tarweed	Asteraceae	A	N
Microsteris gracilis (Hook.) Greene	MIGR	slender phlox	Polemoniaceae	A	N
Myosotis stricta Link ex Roemer & J.A. Schultes	MYST2	strict forget-me-not	Boraginaceae	A	I
Nepeta cataria L.	NECA2	catnip	Lamiaceae	P	I
Penstemon glandulosus Dougl.	PEGL4	stickystem penstemon	Scrophulariaceae	P	N
Phlox colubrina Wherry & Constance	PHCO10	Snake River phlox	Polemoniaceae	P	N
Polemonium micranthum Benth.	POMI	annual polemonium	Polemoniaceae	A	N
Potentilla gracilis Dougl. ex Hook.	POGR9	slender cinquefoil	Rosaceae	P	N

Appendix 6. Continued

Senecio integerrimus Nutt.	SEIN2	lambstongue ragwort	Asteraceae	P	N
Silene scouleri Hook.	SISC7	simple campion	Caryophyllaceae	P	N
Sisymbrium altissimum L.	SIAL2	tall tumblemustard	Apiaceae	A	I
Solidago missouriensis Nutt.	SOMI2	Missouri goldenrod	Asteraceae	P	N
Stellaria L.	STELL	starwort	Caryophyllaceae	A	N
Tonella floribunda Gray	TOFL	manyflower tonella	Scrophulariaceae	A	N
Tragopogon dubius Scop.	TRDU	yellow salsify	Asteraceae	A	I
Triodanis perfoliata (L.) Nieuwl.	TRPE	clasping Venus' looking-glass	Asteraceae	A	N
Triteleia grandiflora Lindl. var. *grandiflora* = *Brodiaea douglasii* S. Wats.	TRGRG2	brodiaea	Liliaceae	P	N
Valerianella locusta (L.) Lat.	VALU	Lewiston cornsalad	Valerianaceae	A	I
Veronica filiformis Sm.	VEFI	threadstalk speedwell	Scrophulariaceae	P	I
Vicia villosa Roth	VIVI	winter vetch	Fabaceae	A	I
Woodsia oregana D.C. Eat.	WOOR	Oregon cliff fern	Polypodiaceae	P	N
Zigadenus venenosus S. Wats.	ZIVE	meadow deathcamas	Liliaceae	P	N
unk mint [1]	-	-	-	-	-
unk sessile [1]	-	-	-	-	-
unk white underside thistle [1]	-	-	-	-	-
unk wooly thistle [1]	-	-	-	-	-

[1] unable to identify