Evaluating Trampling Impacts of Horses and Llamas in Wilderness and Backcountry Meadows

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Abstract

A study was conducted on a subalpine meadow to evaluate trampling impacts of horses and llamas when used as recreational packstock. Animals were confined to plots for 24 hours and soil compaction was measured before and after grazing. Soil moisture was measured along with compaction and used as a covariate in the analysis. Soil compaction increased significantly after trampling by both animal types. Soil surface roughness was measured before and after grazing using a contact profiling device. No significant change in soil surface roughness was found after grazing by either animal type. Recommendations for further research are outlined.

Introduction

Recreational packstock use is an accepted traditional activity in many Wilderness, park, and natural areas. Preservation of natural resources is often a primary management objective in these areas and managers are faced with the challenge of providing for recreational stock use while maintaining ecological integrity.

Llamas (*Lama glama*) have joined the traditionally used horse (*Equus caballus*) and are becoming an increasingly popular choice for recreational packing. Although llama use accounts for less than five percent of overall packstock use in the United States, llamas constitute more than 20 percent of the stock in several Wilderness areas (McClaran and Cole 1993). Between 1985 and 1990, fifty-seven percent of Wilderness areas permitting stock use, experienced some llama use (McClaran and Cole 1993). The increased popularity of llamas has been attributed to their ease of handling and transport as well as claims that they cause less impact to the backcountry environment (Daugherty 1989, Markham 1990). These claims have not yet been substantiated by research.

Recreational pack animals impact backcountry sites by trampling, especially when stock are confined to one area. Trampling impacts have the potential to alter foraging areas by affecting vegetative cover and composition and by changing soil characteristics (Chappell *et al.* 1971; Cole 1981; Whinam *et al.* 1994). Mechanical damage to above-ground plant structures and root damage caused by stock hooves shearing the soil reduces plant vigor which can lead to a reduction in plant cover (DeBenedetti and Parsons 1979; Liddle 1975; McClaran and Cole 1993). Decreased plant cover can favor establishment or expansion of native colonizer species or more seriously, exotic species inadvertently brought to the area by recreationists and their stock (Cole 1993; Whinam *et al.* 1994). Plant compositional change also occurs because some plant species are more resistant to trampling damage (Cole 1995; Sun and Liddle 1993).

Trampling also affects backcountry sites and vegetation by changing characteristics of the soil medium. Trampling causes soil compaction (Bryant *et al.* 1972; Lull 1959), which decreases soil porosity, oxygen diffusion, root penetration (Bengough 1991), nutrient availability, and water infiltration into the soil (Gamougoun *et al.* 1984; Kuss and Graefe 1985; Liddle 1975), and may increase soil erosion (Chappell *et al.* 1971; Packer 1953). Soil compaction inhibits seed germination and seedling establishment (Kuss and Graefe 1985). Soil dwelling biota, important for developing soil structure and nutrient cycling, are negatively impacted by soil compaction (Chappell *et al.* 1971; Murphy *et al.* 1995). Changes in soil surface roughness change the microclimates available to mature plants and seedlings thus having the potential to alter plant species cover and composition (DeBenedetti and Parsons 1979). Soil surface roughness is also related to water infiltration and sediment production (Hanson *et al.* 1970).

Cole (1989) points out that our understanding of recreational stock impacts in areas where stock are kept overnight and allowed to graze is fragmentary at best. This study was conducted to address this research need by evaluating the trampling impacts of horses and llamas when used as recreational packstock. The intent of this exploratory study was to contribute to effective wildland management by providing information to land managers. This study investigated the trampling impacts of horses and llamas by focusing on soil compaction and soil surface roughness because of the influence these variables have on many of the soil characteristics and plant growth factors described above.

Study Site

This study was conducted at Hard Creek Meadow, a dry, subalpine meadow in the Payette National Forest of Central Idaho (NW 1/4 S. 12, T. 21 N., R. 2 E.). Hard Creek Meadow was chosen because it parallels Wilderness conditions and represents an area typically visited by recreational stock users in western North America. The meadow is located at approximately 2135 m in elevation, in an area that receives dispersed camping and stock use. The meadow is part of an active sheep grazing allotment, being periodically grazed in early autumn. The meadow has been historically used by recreational stock and U.S. Forest Service administrative horses.

Hard Creek Meadow lies in an area which was lightly scoured by glacial action followed by cryoplanation, resulting in localized transportation of materials. The dominant soil type is classified as a loamy, skeletal, mixed, Typic Cryumbrebt. Surface layers are silt loam with a fine moderate granular structure, nonsticky, with 10-15% angular gravel and a depth of 20-40 cm. Subsoil layers are gravelly silt loam to very gravelly loam with massive to coarse moderate subangular blocky structure, nonsticky, with 30-50% angular gravel and a depth of 50-120 cm. The granitic bedrock is composed of well to extremely well-fractured weakly andesitic rocks (USDA 1973). The meadow is generally flat, with slopes ranging from 0-10%.

The vegetation at Hard Creek Meadow is composed primarily of grasses, grass-likes, and forbs. Common grass species included *Deschampsia caespitosa*, *Agrostis* spp., *Muhlenbergia filiformis*, *Calamagrostis canadensis*, and *Elymus glaucus*. Grass-likes included *Carex* spp., *Juncus* spp., and *Luzula campestris*. Dominant forbs included *Agoseris glauca*, *Aster integrifolius*, *Ligusticum grayi*, *Ranunculus alismaefolius*, and *Arabis* spp. Woody plants included *Abies lasiocarpa*, *Picea engelmannii*, *Sambucus* sp., and *Ribes* sp.

Methods

Three individuals of each animal type were used in the study to typify recreational packstock. The three pack horses were shod and weighed approximately 450 - 500 kg each. Two mares, ages 26 and 9 years, and one 21 year old gelding were used. The three pack llamas chosen for the study included two intact males and a gelding, all between the age of 5.5 and 6 years, and weighing approximately 160 kg each.

Study plots were chosen to be as homogenous as possible in terms of soil characteristics, topography, and vegetation. Plots were enclosed by portable electric fencing, and water and mineral supplement were provided *ad libitum* in the center of each plot. Each group of three animals was held on a plot for 24 hours and the plots were replicated four times.

The plot size of 0.05 ha was based on 35% forage utilization by three horses weighing 500 kg each and consuming 1.5% of their body weight per day (Hintz pers. comm.)[1], given a meadow forage production of 1250 kg/ha. Thirty-five percent forage utilization was used because it has been recommended for some Wilderness and backcountry areas, including the Payette National Forest, where this study was done. On a 0.05 ha plot with 1250 kg/ha forage, three llamas weighing 160 kg each and consuming 2.0% of their body weight per day (Markham 1990) would utilize approximately 15.5% of available forage in a day.

Equally sized plots were used to reflect current grazing practices of recreational stock users in U.S. Forest Service administered Wilderness areas. When recreationists turn their stock out to graze on a mountain meadow they do not restrict the area of grazing based on animal size and forage utilization. The unequal utilization rate prevents standardized comparison of trampling impacts between horses and llamas. Differences in impacts due to animal type cannot be distinguished from differences due to unequal utilization rates. Given this, trampling impact data will be reported separately for each animal type.

Soil compaction was measured before and after trampling using a proving ring penetrometer (Soiltest Model CN-970), following the procedures outlined by Bradford (1986). The penetrometer was selected for its ease of use and because its measurements of soil strength are adequately correlated with soil core bulk density (Gifford *et al.* 1977). Soil compaction was measured on the soil surface only (top 3.2 cm) because penetration resistance at deeper soil levels was too high to obtain an accurate static reading.

Each plot was subdivided into 16, 5.5 m^2 subplots for compaction measurements. Within each subplot a sampling location was randomly selected and three penetrometer readings were taken within 20 cm of each other. Rocks and other anomalies (e.g. rodent burrows) were avoided and the mean of the three readings was used. Soil moisture (% relative saturation) was measured with each set of penetrometer readings using a soil

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moisture meter (Kelway Model HB-2). A repeated measures analysis of covariance, with soil moisture as the covariate, was used to analyze the soil compaction data.

Soil surface roughness was measured before and after grazing using a contact profiling device as described by Tessier *et al.* (1989). The device consisted of a 60 cm single row of movable 3.2 mm pins held together by a retaining frame (See Figure 2, Section IV). The device was lowered onto the ground surface and the two dimensional profile created was traced on paper and later digitized. Linear regression was used to fit a straight line to the profile curve and to calculate residuals. The standard deviation of the residuals (SDR) for each profile was calculated as an index to roughness (Currence and Lovely 1970).

Each plot area was divided in half for the roughness measurements, with half the area being in the center of the plot and half forming the perimeter. This was done to test for unequal utilization of the plots, such as animals walking the fenceline. Within each area, 20 random locations were chosen and a profile was made. A repeated measures analysis of variance, with time (before, after) and area (center, perimeter) as within-subject factors, was used to analyze the surface roughness data.

Results

Mean soil compaction increased significantly following grazing by horses ($p = .017$) and llamas ($p = .027$) (Table 1, 2). No significant difference was found in mean soil surface roughness (SDR) following grazing by either animal. Also, no significant differences were found in mean soil surface roughness between center and perimeter plot areas (Table 1, 2).

Table 1. Mean soil compaction (kg/cm^2, (S.E.)) and mean soil surface roughness (SDR, (S.E.)) for horses, before and after grazing.

	Before Grazing	After Grazing
Mean Soil Compaction	7.25 (0.29)	8.93 (0.27)

	Before Grazing		After Grazing	
	Center Area	Perimeter Area	Center Area	Perimeter Area
Mean Soil Surface Roughness	3.79 (0.25)	3.82 (0.23)	3.82 (0.23)	3.69 (0.21)

Table 2. Mean soil compaction (kg/cm^2, (S.E.)) and mean soil surface roughness (SDR, (S.E.)) for llamas, before and after grazing.

	Before Grazing	After Grazing
Mean Soil Compaction	7.06 (0.28)	8.08 (0.30)

	Before Grazing		After Grazing	
	Center Area	Perimeter Area	Center Area	Perimeter Area
Mean Soil Surface Roughness	3.73 (0.21)	4.36 (0.26)	3.77 (0.23)	3.75 (0.22)

Discussion

The hypothesis that llamas may cause less impact to backcountry soils than horses centers around differences in hoof morphology and animal weight. In contrast to the horse's hard and typically shod hoof, llamas have a split-toed foot with a soft, leathery pad covering each digit and a hard toenail on the end of each toe. This foot structure, along with the llama's lighter body weight, has led to speculations that they may cause less impact to soils.

The results of this study show that trampling by both animals increased soil compaction on the meadow. Further research based on equal utilization rates is needed to make a direct comparison of soil compaction and plant impacts due to horse and llama trampling. Additional research is also needed to determine the role that hoof morphology plays in soil and plant impacts. For example, the soft pad of the llama's foot may mean less impact to plant structures and less soil shearing than the horse's hoof, but the smaller surface area may mean more force is being exerted on the soil surface resulting in greater compaction.

Given the relatively dry soil conditions during this study, it was hypothesized that soil surface roughness would decrease due to animal hoof action crushing the surface layer. The finding that there was no difference in roughness on horse or llama plots may be related to several factors. First, the animals were on trampling plots for only 24 hours. Under this short-term grazing, changes in roughness may not be discernible. Typically, recreational stock is moved every 8-12 hours. Given this, changes in roughness may not be of concern to managers unless areas receive heavy repeated use. Secondly, there was a great deal of gopher (*Thomomys talpoides*) activity on the meadow. The churning, burrowing action of these rodents may counteract the smoothing action of stock hooves. It may be more important to study differences in soil surface roughness on meadows with wet soils, where stock hooves sinking into the soil may increase roughness.

Field observations from this study identified a potential difference in how horses and llamas impact meadow vegetation. Horses appeared to impact plants through trampling relatively evenly across the plots with some areas of more intense impact, while llama impact appeared to be concentrated in small wallow areas, which were generally cleared of vegetation. This apparent difference in impact distribution deserves further research. Concentrated and dispersed impacts may have different consequences in terms of long-term soil and vegetation impacts to a site (e.g. changes in species composition or invasion of exotic plant species).

The difference in impact distribution may arise from differences in behavior. Horses seemed to spend more of their time walking around the plots and interacting with each other, while llamas spent a great deal of time loafing singly in dust wallows. This behavior may have been in response to the high populations of biting insects at the study site. Although the horses were treated regularly with insect repellent, they were probably agitated by the insects. Llamas may have spent more time laying in dust wallows as it protects their undersides which are most vulnerable to insect bites. Olson-Rutz *et al.* (1996) studied the behavior of picketed horses and found grazing, with continual movement, to be the dominant activity. A similar study looking at llama behavior would be useful. A greater understanding of animal behavior and resulting impacts would assist managers in developing stock use guidelines which would minimize impacts.

In summary, recreational packstock use causes ecological impacts which must be managed to keep environmental changes within acceptable limits. Additional research is needed to directly compare soil and vegetation impacts of horses and llamas based on equal utilization. More research is also needed to examine the role of foot morphology on soil and plant impacts. Finally, more research concerning animal behavior and its influence on site impacts would provide managers with more information to develop stock use guidelines which minimize long-term impacts.

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SECTION IV

Additional Information on Research Methods and Field Observations

Determining Meadow Forage Production

Prior to determining plot size, the forage production of the meadow was estimated. This was accomplished using clipped plots to calibrate a forage meter, which was then used to non-destructively sample forage production throughout the study period.

The forage meter was constructed and operated following instructions outlined by Agri-fax/Alberta (1986). The meter consisted of a circular plate of press board, with a 25.0 cm radius, an area of 0.2 m^2, and weighted to 1.5 kg. A section of PVC tubing was inserted through the center of the circle and marked at 0.5 cm intervals. To use the meter, the plate was lowered until it touched the tallest piece of living plant material. The plate was then dropped, allowed to settle for 10 - 15 seconds, and the height reading was recorded.

The forage meter was calibrated for Hard Creek Meadow by collecting height readings and clipping vegetation quadrats for the same plot. Two, 30 m transects were laid out along the north and south borders of the sample area. Three random locations along each of these transects were chosen. At each of these six locations, a 30 m transect was laid out perpendicularly, extending from the edge into the center of the sample plot. Of the three transects along each side of the sample area, two were randomly selected to have 10 quadrats clipped while the third had five quadrats clipped. Quadrat locations were randomly selected along the transects. This resulted in 25 quadrats being clipped from each half of the sample area for a total of 50 quadrats. For each quadrat, the living vegetation was clipped to within 2.0 cm of the ground surface and placed in a paper bag. A 700 watt microwave oven was used to dry the samples utilizing the methods described by Farmer and Brusewitz (1980). Each dried sample was then weighed. The mean height reading for the plot was then compared with the mean biomass (kg/ha) for the clipped quadrats.

The major concern in this study was that the biomass production be 1250 kg/ha or greater, and the methods used here were adequate to make this determination. If more precise measurements are needed, a regression line can be computed between dry matter forage yield and forage meter height readings. Approximately 20 - 30 correlations, in which forage meter readings are taken and quadrats are clipped at the same location, are suggested to compute such an equation (Agri-fax/Alberta 1986).

Forage Preference vs. Selection

All grazing animals feed selectively from the range of plant materials available to them (Heady 1964; Skiles 1984). An animal may select different plant species, different individuals within a species, or different parts of a plant (Vallentine 1990). Selectivity in grazing involves both palatability and preference. Palatability is the collection of plant species characteristics which illicit a selective response by an herbivore (Heady 1964; Vallentine 1990). Palatability of a plant species is determined by the complex interaction of animal, plant, and environmental factors (Marten 1978). Preference is the selective response made by a grazing animal and is behavioral (Heady 1964). Preference is influenced by use of the senses and animal experience, and can vary between herbivore species and within species (Vallentine 1990). Palatability and preference are always relative to the available forage (Vallentine 1990).

Plot Size Calculation

The following method was used to estimate the size of the plots. The horses had an average weight of about 450-500 kg, and each horse consumes approximately 1.5% of its body weight per day on a dry matter basis (Hintz, pers. comm.)[2]. The llamas had an average weight of 160 kg, and consume approximately 2.0% of their body weight per day (Markham 1990). Given this, the following calculations can be made to determine plot size:

[animal weight (kg)] X [% body weight consumed per day] = kg forage consumed/day
[kg forage consumed/day] X [no. of days to be spent on plot] = total kg forage
[total kg forage] / [desired utilization level (%)] = total kg forage needed
[total kg forage needed] / [kg forage production /ha] = plot size required (ha)

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The trampling plots used to measure changes in soil surface roughness were divided in half, with half the area being in the center of the plot and half forming the perimeter (Figure 1). This was done to test for unequal plot use due to animal behaviors such as walking the fenceline.

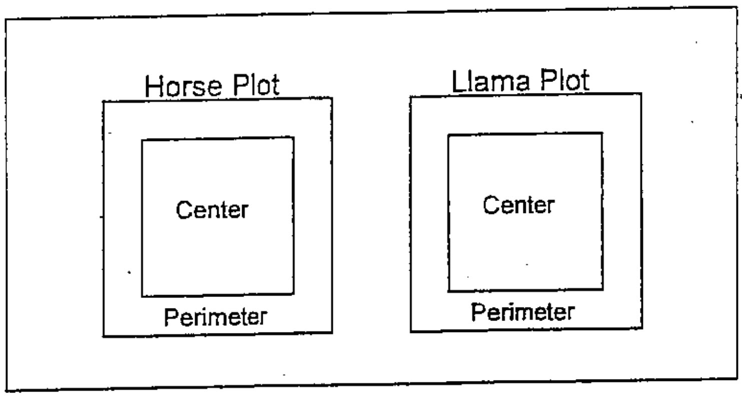

Figure 1. Plot layout for soil surface roughness measurements.

Measuring Soil Surface Roughness with a Contact Profiling Device

Soil surface roughness was measured using a contact profiling device (Tessier *et al.* 1989), constructed based on plans provided by Agriculture Canada, P.O. Box 1030, Swift Current, Sask, Canada, S9H 3X2 (Figure 2). The device consists of a 60 cm row of 3.2 mm steel pins (available from welding suppliers) held in place by an aluminum retaining frame. The frame is held together with heavy springs so that pins are kept in place by tension which can be released.

The profiler was held over the ground surface and the tension on the pins released allowing them to fall to the ground surface. Because the plots in this study were vegetated, the pins were carefully lowered or pushed down to insure that they rested on the soil surface and were not impeded by vegetation. Tension was reapplied to the pins to hold them in place. The profiler was laid on a sheet of paper and the profile traced. The profiles were later digitized using a computerized imaging system and SigmaScan (1996). A straight line was fitted to the profile using linear regression. The differences between the height readings of the profile and the line were determined. The standard deviation of these residuals was then calculated as the roughness index (Currence and Lovely 1970; Tessier *et al.* 1989).

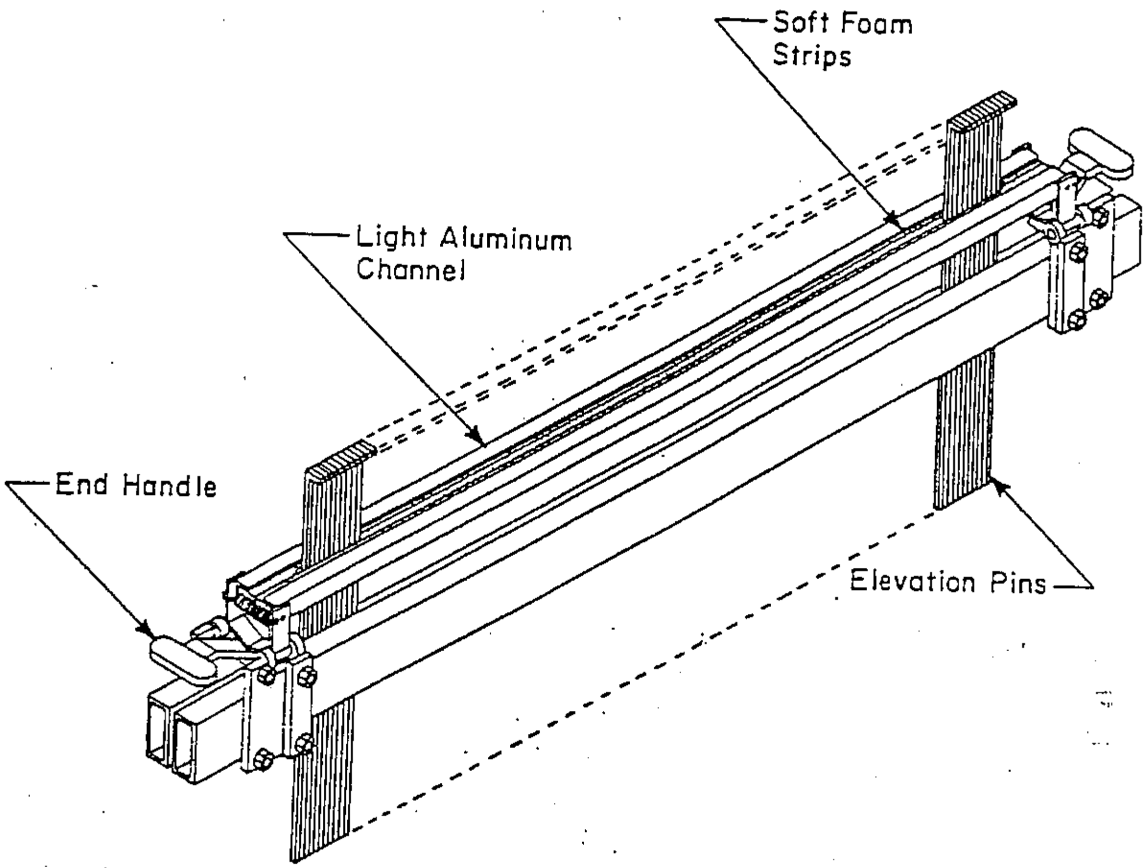

Figure 2. Contact profiling device for measuring soil surface roughness (Tessier *et al.* 1989).

Calculating Kulcyznski's Similarity Index

Kulcyznski's Similarity Index (Oosting 1956, Olsen and Hansen 1977) was calculated to examine dietary overlap between horses and llamas. This index provides a measure of the common proportionality between two diets and is expressed as:

$$S = [(2)(w)(100)]/(A + B)$$

where: S = Similarity of the two diets

w = The sum of the quantity of each plant species that the two diets share, or in other words, it is equal to: $2\,\Sigma \min(P_{ij}, P_{ik})$, where P_{ij} and P_{ik} are percentages of the plant species in diets *j* and *k* (Hansen and Reid 1975).

A = Total quantity of all shared species in diet a

B = Total quantity of all shared species in diet b

In this study, similarity indices were calculated two ways. First, the mean percent diet composition of plant species for the two animal types were used to compare horse and llama groups. Second, differences between individuals within an herbivore species were investigated by calculating similarity indices for each pairwise comparison of individual animal diets, on each plot, within each herbivore species. This resulted in 9 pairwise comparisons for each animal type. Similarity indices for all horse:llama pairwise comparisons on each plot were also calculated which resulted in a slightly lower index than when mean percent diet composition was used.

Differences in plant parts consumed

Field observations suggest that horses and llamas may be selecting different parts of plants. *Deschampsia caespitosa* showed up in the diets of both horses and llamas. Horses readily consumed the inflorescence of *Deschampsia* while llamas appeared to leave them uneaten, perhaps selecting leaves instead. This difference was readily visible on a set of plots with a heavy cover of flowering *Deschampsia*. Three horses grazed on one plot and three llamas on the other. Following grazing, the horse plot was virtually cleared of *Deschampsia* inflorescences while the llama plot appeared unchanged.

Feces Distribution

The dung and urine deposited by grazing animals on meadows has the potential to alter the meadow's productivity and species composition (Watkin and Clements 1978). Llamas are known to use communal dung piles which could lead to nutrient dislocation on meadows. In this study, descriptive information concerning feces distribution was collected for both llamas and horses. Feces distribution was mapped following grazing on each trampling plot. Observations confirmed that the group of three llamas created one to several communal dung piles while horse feces were more evenly distributed across the plots. To avoid potential problems associated with the concentration of animal feces on pastures, a management recommendation is that packstock users scatter dung piles.

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APPENDIX A

Plant Species on Forage Selection Plots

Table 1. Plant species frequencies on forage selection plots.

Plant Species	Frequency (% quadrats in which species occurred)		
	Plot 1	Plot 2	Plot 3
Agrostis spp.	47	52	53
Calamagrostis canadensis	30	58	35
Danthonia intermedia	-	8	-
Deschampsia spp.	73	55	24
Elymus glaucus	*	1	46
Melica spectabilis	-	*	*
Muhlenbergia filiformis	41	74	58
Phleum alpinum	1	-	*
Stipa lettermanii	-	1	1
Trisetum spicatum	-	-	1
Carex spp.	-	9	6
Juncus spp.	17	18	3
Luzula campestris	5	5	*
Aconitum columbianum	-	-	1
Agoseris glauca	80	95	66
Antennaria corymbosa	15	10	*
Arabis sp.	31	32	33
Aster integrifolius	74	39	67
Dodecatheon sp.	-	-	*
Ligusticum grayi	19	40	10
Lupinus spp.	1	2	3
Pedicularis groenlandica	2	-	*
Penstemon globosus	3	7	-
Polygonum sp.	2	4	-
Potentilla gracilis	4	-	4
Ranunculus alismaefolius	23	23	15
Rumex acetosella	5	1	-
Saussurea americana	-	-	1
Senecio triangularis	1	1	22
Unknown forbs	2	6	11
Picea engelmannii	-	-	*
Ribes sp.	-	-	*
Sambucus sp.	-	*	*

* Species were present on plots but did not occur in frequency quadrats, they were rare or localized.