Horse Ranching Increases Biodiversity in a Foothills Parkland Prairie in Northern Kananaskis Country, Western Alberta

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Vascular plant biodiversity was evaluated in two adjacent sections of a continuous prairie glade. One section has been subject to moderate grazing by feral horses (*Equus ferus caballus*) in late summer and fall for the past 25 years, while the other has been protected. From 28 June to 2 July 2009, we recorded cover for all vascular plants present in ten 1-m^2 quadrats along five transects in each section. We calculated biodiversity measures, including species richness, evenness, and Shannon-Wiener and Simpson's diversity indexes. Horse grazing did not affect richness but significantly increased evenness. Grazing increased the Shannon-Wiener index, but did not affect the Simpson's index. Cover and frequency values for most species differed significantly between the two sites. Mountain Rough Fescue (*Festuca campestris* Rydberg) dominated the non-grazed site but several shorter grasses and different forbs dominated the grazed site. The plant community in the grazed areas can be seen as an earlier seral stage of the fescue community with a different contingent of plant species. Light grazing in part of the prairie glade increased overall plant diversity so that it provided more diverse animal habitat.

Key Words: Horses; Feral Horse; *Equus ferus caballus*; Mountain Rough Fescue; Festuca campestris; grazing; rangeland; vascular plants; biodiversity; richness; heterogeneity; eveness; Alberta; prairie foothills; Kananaskis; fescue grassland; shifting mosaic; patch dynamics; management

Introduction

A huge ecological cost is associated with livestock grazing in western North America, and continuing interest from conservation biologists is essential to ensure that management protects biodiversity (Fleischner 1994). The extensive literature on maintenance of healthy rangeland for livestock production in western Canada has led to an understanding that many rangeland species may benefit from moderate grazing (e.g., Tannas 2003a,b, 2004). However, the effects of grazing on biodiversity overall have not been sufficiently studied in Canada (Ollf and Ritchie 1998; Bai *et al.* 2001), although some important research is underway (e.g., the long-term east block grazing experiment in Grasslands National Park, see http://www.pc.gc.ca/eng/progs/np-pn/re-er/ec-cs/ec-cs01.aspx). Research to date has involved mostly cattle on the prairies and parklands and suggests that rangelands can be important in protecting biodiversity, although ecological integrity cannot be maintained if grazing pressure is too high (Trottier 1993; West 1993; McLaughlin and Mineau 1995).

The grazing ecology of the prairies of the Rocky Mountain foothills has been poorly studied, although they are the most diverse and complex of the fescue grasslands in Canada (Tannas 2003a, P.M.C. personal observation) and among the most productive grasslands in North America (Willms *et al.* 1996). The response of fescue grasslands to cattle stocking rates has been studied intensively at one site in the Porcupine Hills near Stavely, Alberta (Willms *et al.* 1985), but this site may not represent the foothills grasslands well. Only 5% of the grasslands remain in a pre-settlement condition (Vujnovic 1998), and they are now recognized as an endangered ecosystem (Trottier 2002). Increased precipitation in foothills prairies may make them more susceptible to grazing (Lauenroth *et al.* 1994).

There are currently over 350 000 feral horses (*Equus ferus caballus*) in Alberta, mostly used in recreation, and the number is increasing (Westar 2003*). Consequently, the demands for grazing land are also increasing, particularly in the foothills region. Grazing by horses has been shown to reduce plant species richness in some situations (Beever and Brussard 2000; Beever *et al.* 2008), but not in others (Detling 1998). These differences are likely a result of different grazing pressures.

With the effects of grazing generally requiring more study, especially in the foothills, and especially concerning feral horses, any situation providing data is an important study opportunity. We encountered such an opportunity in a foothills parkland prairie in northern Kananaskis Country of western Alberta. Here feral horses had been excluded for 25 years from half of a continuous fescue prairie glade, but rest–rotation grazing at a specific carrying capacity was continued in the adjacent half. Data was collected to elucidate the effects of grazing by the horses on floristic diversity, as well as to obtain information for conservation and management.

Study Area

The area studied was within the Kananaskis Country in Bow Valley Provincial Park, at 51.0789°N and 115.0384°W. It consisted of a 5-ha prairie glade separated into two parts by a 10-m wide road allowance. The glade was surrounded by a semi-open woodland that included Trembling Aspen (*Populus tremuloides* Michaux), Lodgepole Pine (*Pinus contorta* var. *latifolia* Engelmann), Douglas Fir (*Pseudotsuga menziesii* var. *glauca* [Beissner] Franco), and White Spruce (*Picea glauca* [Moench] Voss). The park is a significant natural area with a rich diversity of flora and fauna (Pinel 1985*; Wallis and Wershler 1972*; Williams 1988*).

Requirements for comparison

To be able to attribute differences in vascular plant composition between the two sections to differences in grazing by feral horses, all other characteristics should be nearly the same. There is good evidence that this was the case. The two sections, "grazed" and "non-grazed," had similar gradual slopes, elevation, and very stony substrates, and the geology of the area was uniform (Rutherford 1927; Greenlee 1974; P.M.C. personal observation). The sections were separated only by a road and roadside fences, which clearly split a formerly continuous prairie glade, the edges of which remained well defined.

The entire glade was grazed by feral horses until 1984 (G. Cowley, Rafter Six guest ranch, personal communication) when grazing was discontinued on the south side (2.2 ha). On the north side (2.8 ha), grazing by horses was permitted at a moderate stocking level in the fall (15 August to 15 October) for 652 horse-days on approximately 22 ha of prairie which included the north half of the glade as well as open woods and other glades nearby. Over this period, both halves were subject to very light grazing by free-ranging Rocky Mountain Elk (*Cervus elaphus nelsoni*) and grazing to an even lesser extent by both Mule Deer (*Odocoileus hemionus*) and White-tailed Deer (*Odocoileus virginianus*) (R. Jaeger, park conservation officer, personal communication). The Rocky Mountain Elk (n = 100–160) also used the area from December to February as one of a large series of openings preferred because characteristic high wind and chinooks reduce snow accumulation and adjacent wooded areas provide cover (R. Jaeger, personal communication). Other grazing mammals, including various rodents, are scarce in this area of gravelly soils and are thought to have little impact on flora (P.M.C., personal observation).

Methods

Data collection and identification

Between 28 June and 2 July 2009, in each section (grazed and non-grazed), data on the presence and cover of species were gathered from 1-m^2 quadrats along five parallel transects at a 45° angle from the road. Ten quadrats, each 10 m apart, were placed on each transect, resulting in 50 quadrats on either side of the road (i.e., in each section). Cover for each species in each quadrat was estimated as a percentage of the 1-m^2 ground surface covered by living material of that species. The results were tallied so that species in the two sections could be compared with respect to both frequency and cover. No new species were recorded after 35 quadrats in either section suggesting that 50 was an adequate sample to describe the vegetation.

As grazing may sometimes result in more-or-less stable, heavily grazed and non-grazed patches, and increased heterogeneity may exist on a broad scale but not on a small scale (Willms *et al.* 1988), a relatively extensive sampling procedure, such as that used here, is advantageous in biodiversity comparison.

Most species were flowering at the time of sampling, and this aided in identification; the few exceptions were *Gentianella amarella*, *Solidago simplex* ssp., and *Symphyotrichum laeve* var. *geyeri*. Plants were identified using Packer (1994), Kuijt (1982), Hallworth and Chinappa (1997), and Tannas (2003a,b, 2004) as well as the online *Flora of North America* series (1993–2009).

The names mostly follow the recent compilation of Kartesz and Meachum (1999*) with some more recent changes from Brouillet et al. (2010+*). All species recorded in the prairie glade are listed in Appendix Table 1 with authorities, scientific names and frequently used common names. Voucher specimens are preserved in the National Collection of Vascular Plants of Agriculture and Agri-Food Canada in Ottawa (acronym DAO). Although the identifications are considered accurate, there were limitations. Some species were too immature to identify with certainty to the infraspecific level (e.g., *Solidago simplex*).

The dominant grass in the non-grazed area appeared to be *Festuca campestris* Rydberg, but this could be confirmed in only a few quadrats where it was flowering. As we believed that only one species of the rough fescue complex was present, all non-flowering plants were assumed to be this species. The site is near the boundary of the ranges of *Fesctuca campestris* and *F. altaica*. Kananaskis is located at 51° N, very close to the southern limit of *F. altaica* in the Canadian Cordillera (Pavlick and Looman 1984). Bowden (1960) determined that the chromosome number of rough fescue plants at other sites near Banff, Alberta, was $2n$ = 56, which is characteristic of *F. campestris* (F. altaica is reported with 2n=28). However, we observed some plants with characteristics of *F. altaica* but nevertheless best placed with *F. campestris*.

Data analysis

Mean cover (including zeros) for each species was calculated for each of the five, 10-quadrat transects for each grazing treatment. Frequency was the percentage of the 10 quadrats in a transect that contained that species. Covers and frequencies of each species were compared with a Proc T-test using the five transects as replicates. This test was generated with SAS software (SAS 2003*). The summary function of PC-Ord

TABLE 1. Mean cover and frequency of the more abundant (≥ 1% mean cover in either group) of 91 species in adjacent sections of prairie either grazed or non-grazed by Feral Horses (*Equus ferus caballus*), northern Kananaskis Country, Alberta.

	Cover (%)		Frequency (%)	
Species	Grazed	Non-grazed	Grazed	Non-grazed
Grasses and sedges				
Carex obtusata	4.14*	0.32*	76*	12*
Elymus lanceolatus	9.48*	3.06*	76*	30*
Festuca campestris	0.42*	30.26*	48*	98*
Koeleria macrantha	8.24*	1.78*	88*	48*
Muhlenbergia richardsonis	0.26*	3.36*	6*	26*
Poa secunda	5.32*	0.72*	84*	22*
Forbs				
Anemone multifida	0.16*	1.08*	8*	40*
Antennaria parvifolia	2.64*	0.26*	40*	8*
Artemisia frigida	3.34*	0.04*	56*	2*
Anticlea elegans	2.20*	0.066*	56*	28*
Campanula rotundifolia	2.28	1.14	52*	40*
Cerastium arvense	3.76*	1.90*	94*	60*
Comandra umbellata	1.40*	0.30*	36*	14*
Erigeron caespitosus	1.48*	0.16*	44*	6*
Galium boreale	3.98	4.36	90	82
Geum triflorum	0.06*	2.24*	22*	52*
Hedysarum boreale	0.84	1.26	2*	18*
Oxytropis monticola	4.60*	1.36*	68*	46*
Oxytropis sericea	2.62*	0.06*	58*	8*
Potentilla concinna	1.02	0.46	28	22
Primula conjugens	0.16*	1.00*	10*	42*
Pulsatilla patens	2.66*	0.98*	58	46
Toxicoscordion venenosus	1.92*	0.06*	52*	4*
Vicia americana	0.08*	1.94*	2*	40*
Shrubs				
Arctostaphylos uva-ursi	0.80*	14.84*	10*	42*
Dasiphora fruticosa	0.40*	1.82*	6	16
Juniperus horizontalis	15.46	14.46	46	52
Other				
Selaginella densa	7.54*	1.04*	68*	18*

*Significant difference between grazed and non-grazed sections ($P < 0.05$, Student's t test).

(McCune and Grace 2002*) was used to determine the two components of diversity (species richness and evenness) as well as two indices of diversity (Shannon-Wiener and Simpson's indexes) for each transect using mean species covers. The diversity variables were compared between grazing treatments (Proc T-TEST of SAS) using the results for the five transects as replicates.

Results

A total of 91 species were recorded in the 100 quadrats and 96 species (not including surrounding trees) were recorded in the entire prairie glade including the quadrats. The full species list is presented in Appendix I (along with authorities, common names and the accession numbers of voucher specimens at DAO). There were only five introduced species, and these were present in trace amounts.

The plant communities in grazed and non-grazed areas appeared different (Figure 1). The mean cover and mean frequency of species with a cover of at least 1% are listed in Table 1 by major group. There was considerable divergence in the species composition between the grazed and non-grazed sites. *Festuca campestris* and *Arctostaphylos uva-ursi* dominated the non-grazed site where covers were much greater than in the grazed site (30.26% versus 0.42% and 14.84% versus 0.8%, respectively). Other species with greater cover in the non-grazed areas included *Mulhenbergia richardsonis*, *Geum triflorum*, *Vicia americana*, and *Dasiphora fruiticosa*.

With grazing, the cover of many species increased. Among the graminoids, *Carex obstusata, Elymus lanceolatus* ssp. *lanceolatus, Koeleria macrantha,* and *Poa secunda ssp. secunda* increased. Among the forbs *Anemone patens* var. *multifida, Antennaria parvifolia*, *Anticlea elegans, Artemisia frigida*, *Cerastium arvense*, *Oxytropis monticola*, *O. sericea*, and *Toxicoscordion venosum var. venenosum* were more abundant in the grazed sites. *Selaginella densa* increased considerably with grazing. Several species including *Astragalus laxmannii* var. *robustior*, *Galium boreale*, *Potentilla concinna*, and *Juniperus horizontalis* had similar covers

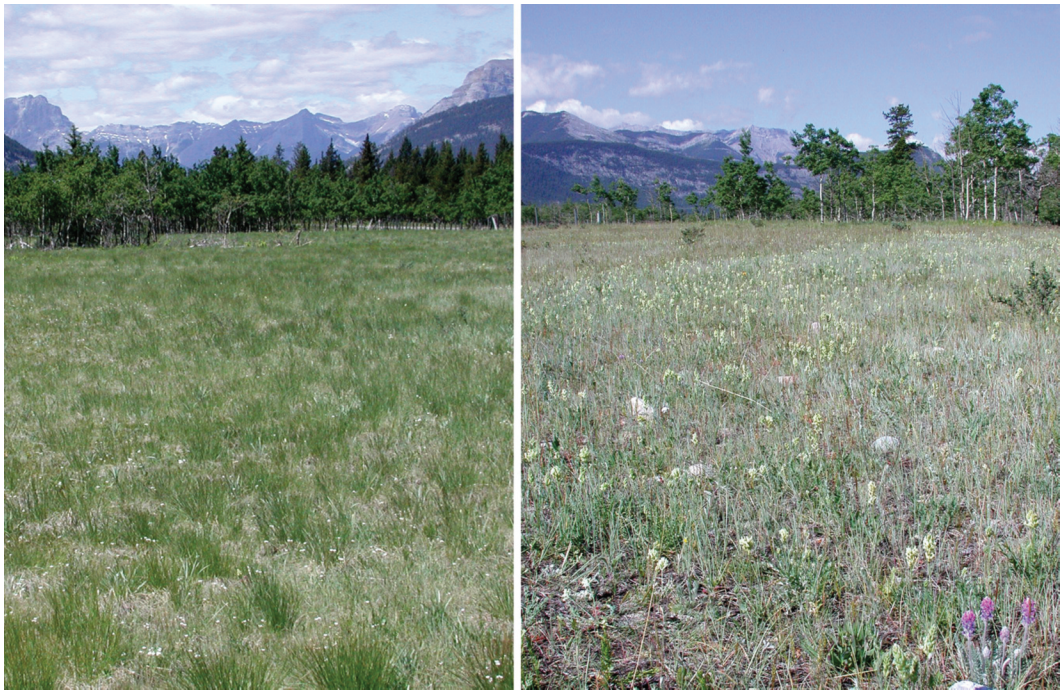

FIGURE 1. Area in northern Kananaskis Country, Alberta, non-grazed by Horses (*Equus ferus caballus*) (left) showing clumps of *Festuca campestris* Rydberg and grazed area (right) showing more abundant wildflowers, including, in particular, the yellow-flowered species of *Oxytropis*, *O. monticola* and *O. sericea*). The blue-green colour of the prairie on the right is a result of more open-ground and pale plants such as *Artemisia frigida* and *Elymus lanceolatus*. Although still present as scattered culms, clumps of *Festuca campestris* are absent from the photo on the right. Photo by Paul M. Catling.

in both grazing treatments.

The mean number of species (species richness) did not differ between the grazing treatments (Table 2). Evenness was significantly greater with horse grazing. The Shannon-Wiener index indicated that feral horse grazing increased the species diversity of the plant community, whereas Simpson's index showed no effect.

TABLE 2. Effect of Feral Horse (*Equus ferus caballus*) grazing on mean diversity components determined from species covers in northern Kananaskis Country, Alberta.

	Grazed	Not grazed
Species number	44.6	48.8
Evenness	0.802*	0.685*
Shannon–Wiener index	3.041*	2.661*
Simpson's index	0.805	0.849

*Significant difference between grazed and not-grazed section ($P < 0.05$, Student's t test).

Discussion

Our list (Appendix 1) contains many species that have been observed in the various seral stages of the *F. campestris* grassland at the Stavely site in the Porcupine hills of southern Alberta (Willms *et al.* 1985). On the other hand, some species common in that grassland were either not present or were present in only trace amounts, including *Danthonia parryi* Scribner and *F. idahoensis* Elmer. Our site is at the northern limit of the former and beyond the northern limit of the latter (Packer 1994).

The low abundance of introduced species (5 of 94 in Appendix 1) suggests that, even with grazing, this is a relatively pristine plant community. Most important, only trace amounts of *Poa pratensis* L., one of the main species seen to increase with grazing at many *F. campestris* sites, were found here. Greater evenness with grazing reflects the great reduction in *F. campestris* and *Arctostaphylous uva-ursi* cover that favours a diversity of other species. Rough Fescue is known to be grazing sensitive (Willms *et al.* 1985), but why *A. uva-ursi* declines is not clear, as it is seldom grazed by horses. Trampling may be a factor.

Many of the species that increased with grazing have a more prostrate growth form and, thus, may partly avoid grazing. With grazing, four graminoids increased at the expense of *F. campestris*. The "increasers" did not include *Danthonia parryi*, which was the main increaser at the Stavely site (Willms *et al.* 1985). The cover of many of the lower growing forbs was also greater at the grazed site, including *Antennaria parvifolia*, *Anticlea elegans,*

Artemisia frigida, *Cerastium arvense*, *Oxytropis* spp., and *Toxicoscordion venenosum var. venenosum*. Two palatable legumes (*Hedysarum boreale* and *Vicia americana*) increased with protection from grazing. Because of their high nutritive value, these are likely favoured by horses.

A short stature helps some species tolerate grazing, but makes them more susceptible to competition from robust grasses like *Festuca campestris*; thus, they would be expected to decline with protection from grazing. Competitive exclusion occurs when removal of disturbances, such as livestock grazing, allows a highly competitive species such as *F. campestris* to restrict the growth of other species through rapid canopy and root development, which limit both light and moisture availability, and litter accumulation, which reduces recruitment from tillers or seed (Grime 1973). The reduced evenness without horse grazing suggests that this had occurred to some extent. It might take longer for competitive exclusion to reduce the species number, or there may be sufficient grazing by wild ungulates in the "non-grazed" area to slow it. Studies of recovery of rough fescue grasslands (Willms *et al.* 1985; McLean and Tisdale 1972) show that, after several decades of recovery, species number was not reduced. However, in the longer term, *Festuca campestris* dominates to the exclusion of most other species (McLean and Tisdale 1972).

We found an increase in the Shannon-Wiener index with grazing, as shown by Bai *et al.* (2001) in Saskatchewan. Also similar to Bai *et al.*, we found no change in species richness with moderate grazing. The Simpson's index is less sensitive to the contribution of less-abundant species (DeJong 1975) and, thus, did not increase with grazing.

The results of this study correspond to those of many others (Trottier 1993; West 1993; McLaughlin and Mineau 1995) in suggesting some biodiversity benefits of moderate grazing. Studies of grazing effects at many sites throughout Alberta would determine whether grazing affects biodiversity in all grassland types. A study conducted in the mixed prairie (Willms *et al.* 2002) suggests that grazing does not always improve diversity.

General observations

The species of vascular plants that were much more abundant in grazed areas are known to increase with increased grazing pressure and are mostly not grasses. These species are likely those previously avoided by bison and currently avoided to some extent by feral horses. Both of these ungulates are grass specialists. Some of the plants that apparently increased with horse grazing are toxic to horses (e.g., *Oxytropis sericea* and *Toxicoscordion venenosum var. venenosum*; Majak *et al.* 2008) and were possibly avoided for this reason. Allowing only moderate grazing by horses may also be beneficial to the horses as they may avoid toxic plants while alternatives are available.

Both the area grazed by horses and the area free of horses were significant in terms of overall biodiversity, with different species present and different abundance values of shared species and high biodiversity values according to different indexes. The grazed area favoured wildflowers that serve pollinators including numerous bees and butterflies (most of the forbs listed in Table 1). The Greenish Blue butterfly (*Plebejus saepiolus amica* [W. H. Edwards, 1863]; Figure 2) was abundant in the grazed area, with up to 10 in view at any one time, but entirely absent from the non-grazed area. A population of Speckle-winged Rangeland Grasshoppers (*Arphia conspersa* Scudder, 1875), which prefer areas with bare soil (P. M. C. personal observation), was present in the grazed area but entirely absent from the adjacent non-grazed area. The dominance of clumped grasses in the horse-free area provided structural cover for nesting birds such as Vesper Sparrows (*Pooecetes gramineus*) that were absent in the grazed area. Other studies have shown that below-ground arthropods, scavenging arthropods, and grasshoppers increase with grazing (Laycock 1994) and that birds are variously adapted to the extent of the grazing (Knopf 1996). The differences in biodiversity between the two sections may be much greater for other groups than for vascular plants, further supporting the high biodiversity value of the presence of both grazing regimes.

Management implications

Based on studies of recovery from grazing in rough fescue communities (Willms *et al* 1985; McLean and Tisdale 1972), the non-grazed area is likely at a mid-seral stage. There may be a number of distinct biodiversity-rich intermediate stages of succession in foothills prairies based on different levels of grazing pressure and other factors. Biodiversity was not necessarily greatest at the apparent intermediate level of disturbance, as might be expected (Bai *et al.* 2001; Vujnovic *et al.* 2002). However, succession and disturbance levels may not provide the most informative view of prairies.

In pre-settlement times, prairies were likely a shifting mosaic of heterogeneous patches where fire and grazing played major roles, along with periodic drought (Fuhlendorf and Engle 2004). Other important factors affecting diversity may have been spatial and temporal variation in movements of wandering bison herds, and fluctuations in numbers of ungulate predators, as well as variation in their distributions. For example, bison traces would have been heavily grazed, but areas where predator risk was high would not have been grazed. Drought and fire would have influenced both of these factors. In the case of our study site, biodiversity was increased by the creation of two patches with different grazing regimes. An improvement in management would involve changing the patches over space and time by applying different ecological situations, especially using fire as well as grazing, as suggested by Fuhlendorf and Engle (2004). With the loss of free-

FIGURE 2. The Greenish Blue (*Plebejus saepiolus amica* (W.H. Edwards, 1863) was an abundant visitor to flowers of *Oxytropis* spp., which were much more abundant in the area of prairie subject to moderate grazing by feral Horses (*Equus ferus caballus*) than in an adjacent grazed area in northern Kananaskis Country, Alberta. Photo by Paul M. Catling.

ranging bison and the patch dynamics on which prairie diversity is based, the use of an increasing number of feral horses to achieve various levels of grazing is a potentially useful management tool that deserves widespread but well-planned application. Grazing by horses in foothills prairies at moderate to light levels can be beneficial in terms of biodiversity.

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APPENDIX 1. Total list of species recorded (including quadrats) in a prairie glade in northern Kananaskis Country, Alberta, with scientific name, common name, some synonyms, and accession number of specimens preserved in the National Collection of Vascular Plants, Agriculture and Agri-Food Canada.

Scientific name	Common name	Accession number
Achillea millefolium L.	Common Yarrow	843223
Achnatherum richardsonii (Link) Barkworth	Richardson's Needlegrass	843236, 843298
Agoseris glauca (Pursh) Rafinesque	Pale Goat-chicory	843264
Allium cernuum Roth	Nodding Onion	843301
Androsace chamaejasme Wulfén ex Host	Sweet-flowered Rock Jasmine	843271
Androsace septentrionalis L.	Pygmyflower Rock jasmine	843228
Anemone multifida Poiret	Red Windflower	843221
Anemone patens L. var. *multifida* Pritzel (syn. *Pulsatilla patens*)	Prairie Crocus	843267
Antennaria anaphaloides Rydberg	Tall Pussytoes	843296
Antennaria parvifolia Nuttall	Little-leaved Pussytoes	843319
Anticlea elegans (Pursh) Rydberg (syn. *Zigadenus elegans*)	Mountain Death Camas	843320
Arabis hirsuta M. Hopkins var. *pycnocarpa* (M. Hopkins) Rollins	Hairy Rockcress	843250
Arctostaphylos uva-ursi (L.) Sprengel	Red Bearberry	
Artemisia campestris L.	Pacific Wormwood	843315
Artemisia frigida Willdenow	Prairie Sagebrush	843316
Astragalus agrestis Douglas ex G. Don	Cock's-head	843278
Astragalus australis (L.) Lamarck	Indian Milk-vetch	843286, 843298
Astragalus laxmanii Jacquin var. *robustior* (Hooker) Barneby and S.L. Welsh	Ascending Purple Milk-vetch	
**Bromus inermis* Leysser	Smooth Brome	
Campanula rotundifolia L.	Round-leaf Harebell	
Carex duriuscula C. A. Meyer	Spikerush Sedge	843252
Carex filifolia Nuttall	Thread-leaved Sedge	843238, 843275
Carex obtusata Liljeblad	Blunt Sedge	843277
Carex richardsonii R. Brown	Richardson's Sedge	843302
Carex rossii Boott	Ross' Sedge	843240, 843260
Carex scirpoidea Michaux	Canadian Single-spike Sedge	843272
Castilleja rhexifolia Rydberg	Rosy Indian-paintbrush	843297
Cerastium arvense L.	Field Mouse-ear Chickweed	843262
Comandra umbellata (L.) Nuttall ssp. *pallida* (A. de Candolle) Piehl	Pale Bastard-toadflax	843279
Crepis runcinata (E. James) Torrey & A. Gray	Fiddle-leaved Hawksbeard	843306
Dactylorhiza viridis (L.) R.M. Bateman, Pridgeon & M.W. Chase (syn. *Coeloglossum viride* var. *virescens*)	Frog Orchid	843314
Dasiphora fruticosa (L.) Rydberg (syn. *Dasiphora fruticosa* ssp. *floribunda* (Pursh) Kartesz)	Shrubby Cinquefoil	843239
Delphinium bicolor Nuttall	Flathead Larkspur	843219
Draba cana Rydberg (syn. *Draba breweri* var. *cana*)	Cushion Whitlowgrass	843292, 843318
Draba nemorosa L.	Woodland Whitlowgrass	843253, 843323
Elymus glaucus Buckley	Blue Wildrye	843237
Elymus lanceolatus (Scribner & J.G. Smith) Gould ssp. *lanceolatus*	Streamside Wildrye	843243
Erigeron caespitosus Nuttall	Tufted Fleabane	843224
Erigeron glabellus Nuttall var. *glabellus* (syn. *Erigeron asper* Nuttall)	Rough Fleabane	843220
Eriogonum flavum Nuttall	Alpine Golden Wild Buckwheat	843300
Erysimum inconspicuum (S. Watson) MacMillan	Shy Wallflower	843258
Festuca campestris Rydberg	Northern Rough Fescue	843231, 843273
**Festuca* cf. *ovina* L.	Sheep Fescue	843291, 843295
Festuca saximontana Rydberg var. *purpusiana* (Saint-Yves) Frederiksen & Pavlick	Rocky Mountain Fescue	843241, 843313, 843324
Fragaria virginiana Miller	Wild Strawberry	
Gaillardia aristata Pursh	Great Blanketflower	843288, 843310
Galium boreale L.	Northern Bedstraw	
Geum triflorum Pursh	Prairie Smoke	843255
Hedysarum alpinum L. (syn *Hedysarum alpinum* ssp. *americanum* (Michaux ex Pursh) B. Fedtschenko)	Alpine Sweet-vetch	843225, 843268, 843304
Gentianella amarella (L.) Börner	Autumn Dwarf Gentian	843256

APPENDIX 1. *(continued)*

Scientific name	Common name	Accession number
Hedysarum boreale Nuttall	Northern Hedysarum	
Hedysarum sulphurescens Rydberg	Yellow Sweet-vetch	843227
Helictotrichon hookeri (Scribner) Holub	Hooker's Alpine Oatgrass	843230, 843232, 843299, 843311, 843321
Heuchera cylindrica Douglas	Poker Alumroot	843274
Juniperus communis var. *depressa* Pursh	Common Juniper	
Juniperus horizontalis Moench	Creeping Juniper	
Koeleria macrantha (Ledebour) Schultes	Junegrass	843234, 843261
**Lappula squarrosa* (Retzius) Dumortier	Bristly Sheepburr	843218
Lilium philadelphicum L. (syn. *Lilium philadelphicum* var. *andinum* (Nuttall) Ker Gawler)	Wood Lily	843293
Lithospermum ruderale Douglas ex Lehmann	Columbia Puccoon	843308
Maianthemum stellatum (L.) Link	Starry False Solomon's Seal	
Muhlenbergia richardsonis (Trinius) Rydberg	Mat Muhly	843354
Oxytropis borealis de Candolle *var. viscida* (Nuttall) S.L. Welsh	Boreal Locoweed	843305
Oxytropis deflexa (Pallas) de Candolle ssp. *sericea* (Torrey & A. Gray) Cody (syn. *Oxytropis deflexa* var. *sericea* Torrey & A. Gray)	White Pendant-pod Locoweed	843222, 843247
Oxytropis monticola A. Gray	Yellow-flower Locoweed	843249, 843276, 843282, 843283
Oxytropis sericea Nuttall	Rocky Mountain Locoweed	843248, 843280
Oxytropis splendens Douglas ex Hooker	Whorled Locoweed	
Packera cana (Hooker) W.A Weber & Á. Löve	Silvery Groundsel	843287
Penstemon confertus Douglas ex Lindley	Lesser Yellow Beardtongue	843294
**Phleum pratense* L.	Common Timothy	
Poa cusickii Vasey	Cusick's Bluegrass	843254, 843303
Poa pratensis L.	Kentucky Bluegrass	843269
Poa secunda J. Presl ssp. *secunda* (syn. *Poa sandbergii* Vasey)	Sandberg's Bluegrass	843233, 843235, 843246, 843281
Poa sp.	Bluegrass (unknown)	843322
Populus tremuloides Michaux	Trembling Aspen	
Potentilla concinna Richardson	Red Cinquefoil	843244
Potentilla pensylvanica L.	Pennsylvania Cinquefoil	843245
Primula conjugens (Greene) A.R. Mast & Reveal var. *conjugens* (syn. *Dodecatheon conjugens*)	Bonneville Shootingstar	843290
Primula pauciflora (Greene) A.R. Mast & Reveal var. *pauciflora (*syn. *Dodecatheon pulchellum*)	Dark-throat Shootingstar	843298
Rhinanthus minor L.	Little Yellow Rattle	
Sabulina rubella (Wahlenberg) Dillenberger & Kadereit (syn. *Minuartia rubella*)	Boreal Stitchwort	843259
Selaginella densa Rydberg	Dense Spikemoss	843242
Silene parryi (S. Watson) C.L. Hitchcock & Maguire	Parry's Catchfly	843317
Sisyrinchium montanum Greene	Strict Blue-eyed Grass	843251
Sisyrinchium septentrionale E.P. Bicknell	Northern Blue-eyed Grass	843257
Solidago simplex ssp.	Mt. Albert Goldenrod	
Symphoricarpos sp.	Snowberry	843309
Symphyotrichum laeve (L.) A. Löve & D. Löve var. *geyeri* (A. Gray) G.L. Nesom	Smooth Blue Aster	
**Taraxacum officinale* F.W. Wiggers	Common Dandelion	843226
Thalictrum venulosum Trelease	Veiny-leaved Meadow-rue	843263
Toxicoscordion venenosum (S. Watson) Rydberg var. *venensoum*	Meadow Death Camas	843265, 843312
Vicia americana Muhlenberg ex Willdenow	American Purple Vetch	843229
Viola canadensis L.,	Canada Violet	
Zizia aptera (A. Gray) Fernald	Heart-leaved Alexanders	843266

*Non-native species.