Festuca campestris Rydberg (rough fescue): A Technical Conservation Assessment

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Author's Biography

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Cover Photo Credit

The Spanish Peaks, on the border of Las Animas and Huerfano counties, Colorado. Cordova Pass, where *Festuca campestris* has been reported to occur, is at the far right. Photograph by author.

The fields are wider,
harvest over.
Hot, cloudless skies; and the air is a bubble.
Suddenly, a hawk rising
out of the summer fallow up into
the returning wind
shatters the land for miles around.
Bunch grass flows uphill.
Dragonflies bounce through the air.
A butterfly flies
sideways on the wind, trying not to slide off.
Another falters in mid-flight,
folds her wings, drops,
then flares again, buoyed up in her own delight.
A jet plane
bores a thundering tunnel through the sky,
and behind it
the sky rumbles down, filling the tunnel with silence.
The fields are quiet again,
still as stones
cooling in the grass.
I wish a cricket would sing.
And sing and sing,
and know
why men go
to live on cold mountains.

-Robert Sund (from Bunch Grass)

Summary of Key Components for Conservation of *Festuca campestris*

Status

The range of *Festuca campestris* Rydberg (Poaceae) (rough fescue) centers in the prairies of the Pacific Northwest and northern Rocky Mountains in Oregon, Washington, Idaho, Montana, British Columbia, and Alberta. The global NatureServe rank for *F. campestris* is G5? (probably globally secure).

In 2003, *Festuca campestris* was added to the USDA Forest Service Region 2 sensitive species list due to possible threats from grazing, competition from exotics, and other habitat disturbance, and due to its rarity and limited distribution in Region 2, where it was known from an historic record at Cordova Pass on the San Isabel National Forest in Colorado, and from a dubious record in Weld County, Colorado. However, research for this species assessment and recent visits to the Cordova Pass location suggest that *F. campestris* does not occur in Region 2. The plants at Cordova Pass are *F. hallii* (Vasey) Piper, which is also a sensitive species in Region 2.

Primary Threats

Threats to the Cordova Pass location are most likely to result from grazing, fire and fire suppression, invasion by exotic species, residential development, recreation, effects of small population size, pollution, handling, and global climate change. Grazing, agriculture, and nitrogen pollution have all been shown to decrease habitat quality for *Festuca campestris* outside of Region 2.

Primary Conservation Elements, Management Implications and Considerations

Because there is now strong evidence that the plants at Cordova Pass are *Festuca hallii*, management implications and considerations for *F. campestris* in Region 2 are limited. There remains some possibility that *F. campestris* is present but undiscovered in Region 2, but it will not be possible to conserve this species in Region 2 unless it is proven to exist there.

Festuca campestris, *F. hallii*, or the species they were both formerly included within, *F. scabrella* Torr. ex Hook., have been documented at six locations in Colorado. Of these locations, five are likely to have, at least historically, supported *F. hallii*. The location at Cordova Pass was visited recently, but the remaining Colorado *F. scabrella* occurrences have not been relocated in many years. These observations were made between 1862 (when the type specimen of *F. hallii* was collected in South Park) and 1956 (when it was found on Cameron Mountain on the Roosevelt National Forest). The locations of all but two occurrences are imprecise, and targeted inventories are required before it can be determined whether they are extant. Species distribution modeling techniques have been used to identify likely locations for *F. hallii* and *F. campestris* in Alberta, Canada and in Wyoming. These techniques are also potentially useful for identifying areas likely to support occurrences of *F. campestris* in Colorado.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Festuca campestris* (rough fescue) is the focus of an assessment because it is designated a sensitive species in Region 2. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce a species' distribution (FSM 2670.5(19)). A sensitive species requires special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Festuca campestris* throughout its range in Region 2. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines to goal of the assessment, outlines its scope, and describes the process used in its production.

Goal of Assessment

Species assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope of Assessment

The assessment examines the biology, ecology, conservation status, and management of *Festuca campestris* with specific reference to the geographic and ecological characteristics of Region 2. Although a majority of the literature on this species derives from field investigations outside the region, this document places that literature in the ecological and social contexts of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *F. campestris* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, experts on this species were consulted, and refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies and other investigators were reviewed. Herbaria searched for specimens include the University of Colorado Herbarium (COLO), CSU Herbarium (CS), Rocky Mountain Herbarium (RM), Kalmbach Herbarium, Denver Botanic Gardens (KHD), San Juan College Herbarium (SJNM), Carter Herbarium (COCO), University of Northern Colorado Herbarium (GREE), New Mexico State University Range Science Herbarium (NMCR), University of New Mexico Herbarium (UNM), U.S. National Herbarium (US), and the Arnold Arboretum (A). All available specimens of members of the *Festuca scabrella* complex in Region 2 were viewed to verify their identity and to obtain specimen label data. The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were regarded with greater skepticism, but they were used in the assessment when published information was deficient. Unpublished data (e.g., Natural Heritage Program records, reports to state and federal agencies, specimen labels) were crucial in estimating the geographic distribution of this species. These data required special attention because of the diversity of persons and methods used in collection.

Treatment of Uncertainty in Assessment

A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, observations, inference, good thinking, and models must be relied on to guide our understanding of ecological relations.

In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling,

critical assessment of observations, and inference are accepted as sound approaches to understanding.

There is a large body of literature (mostly prior to 1984) in which *Festuca campestris*, *F. hallii*, and *F. altaica* are treated collectively as *F. scabrella*. After a paper by Pavlick and Looman in 1984 in which *F. scabrella* was split into three taxa, it became more common for authors to refer to the segregate taxa in the published literature. When authors refer to *F. scabrella* in the broad sense, it sometimes cannot be determined which of the three taxa is being discussed. In this assessment, when it is not clear to which species a source is referring, the information is discussed in the context of *F. scabrella*, or as the "*F. scabrella* complex." Literature dealing specifically with *F. campestris* was given priority whenever possible. See the Classification and description section for details regarding the taxonomy of *F. campestris* and of the *F. scabrella* complex.

Research for this assessment led the author to conclude that it is unlikely that *Festuca campestris* is present within Region 2. However, there remains some possibility that it exists within the Region because not all reports of *F. scabrella* have been re-evaluated in light of contemporary taxonomic thinking on this group. Therefore, reference to the presence of *F. campestris* in Region 2 is treated with some uncertainty in this assessment. See the Distribution and abundance section for details and documentation regarding the status of *F. campestris* in Region 2.

Treatment of This Document as a Web Publication

To facilitate use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site. Placing the documents on the Internet makes them available to agency biologists and the public more rapidly than publishing them as reports. Web publication also facilitates revision of the assessments through greater and more rapid accessibility and ease of publication. Revision will be accomplished based on guidelines established by Region 2.

Peer Review of This Document

Assessments developed for the Species Conservation Project were peer reviewed prior to release on the Internet. This assessment was reviewed through a process administered by the Society for Conservation Biology, employing two recognized experts on this or related taxa. Peer review was designed to improve the quality of the writing and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

USDA Forest Service Region 2 added *Festuca campestris* to its sensitive species list in 2003 (USDA Forest Service 2003). Species are designated as sensitive when they meet one or more of these criteria:

1) the species is declining in numbers or occurrences, and evidence indicates it could be proposed for federal listing as threatened or endangered under the Endangered Species Act if action is not taken to reverse or stop the downward trend

2) the species' habitat is declining, and continued loss could result in population declines that lead to federal listing as threatened or endangered under the Endangered Species Act if action is not taken to reverse or stop the decline

3) the species' population or habitat is stable but limited (USDA Forest Service 2003).

It was determined that *F. campestris* warranted sensitive species status due to possible threats from grazing, competition from exotics, and other habitat disturbance, and due to its rarity and limited distribution (Warren and Redders 2002). However, this sensitive species designation was based on a false report from Cordova Pass in Colorado.

Because *Festuca campestris* is designated sensitive in Region 2, if it is found on National Forest System land, the Regional Forester must take into account maintaining its habitat and occurrences (see Forest Service Manual 2670). Issues regarding sensitive species must be addressed in all environmental assessments for projects planned within suitable habitat. The collection of sensitive species is prohibited without a permit (see Forest Service Manual 2670). The USFS can modify allotment management plans, projects, or contracts to consider *F. campestris* on a discretionary basis. Biological assessments and evaluations are conducted when applications for permits for various

land uses are considered; biological assessments provide a means by which impacts to sensitive species can be mitigated.

Festuca campestris is not included on the Bureau of Land Management's sensitive species list for Colorado (Bureau of Land Management 2000).

The global conservation status rank for *Festuca campestris* is G5? (Colorado Natural Heritage Program 2005, NatureServe Explorer 2005). The global (G) rank is based on the status of a taxon throughout its range. A rank of G5 is given to taxa that are demonstrably abundant, widespread, and secure globally. These species may be uncommon or rare in portions of their range. The question mark (?) indicates uncertainty regarding the global rank due to inexact knowledge of its distribution, abundance, and threats (NatureServe 2005).

The subnational (S) rank is based on the status of a taxon in an individual state or province, using the same criteria as those used to determine the global rank. In Colorado, *Festuca campestris* was ranked SH (Colorado Natural Heritage Program 2005). This rank is applied to taxa that have not been observed to be extant within the state in more than 20 years, and are possibly extirpated. SH was applied to *F. campestris* because there had been no revisit of the single occurrence in Colorado since 1978. Research conducted to complete this assessment and a recent visit to the reported locality of this species suggests that this occurrence is actually *F. hallii*, a close relative of *F. campestris* (see the Distribution and abundance section for details). Because of evidence that *F. campestris* is not present in Colorado, it will no longer be given a subnational rank there.

Festuca campestris is not listed as threatened or endangered under the federal Endangered Species Act. *Festuca hallii*, a close relative of *F. campestris*, was once thought to be limited to Colorado. It was considered a Category 2 species prior to the realization that it ranged widely across the northern Great Plains (O'Kane 1988). Category 2 taxa were defined as those for which information now in possession of the U.S. Fish and Wildlife Service (USFWS) indicated that proposing to list the taxa as endangered or threatened was possibly appropriate, but for which substantial data on biological vulnerability and threat(s) were not currently known or on file to support proposed rules (Hassinger 2002). O'Kane (1988) recommended downgrading *F. hallii* to Category 3C, which included taxa that have proven to be more abundant or widespread than was previously believed and/or those that are not subject to any identifiable threat (Hassinger 2002). These categories are no longer used by the USFWS. *Festuca campestris* is not listed as endangered or vulnerable by the International Union for Conservation of Nature and Natural Resources (Ayensu and DeFilipps 1978).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Adequacy of current laws and regulations

No federal or state laws explicitly protect *Festuca campestris* in Region 2. On privately owned lands, current laws and regulations may be inadequate to prevent damage or destruction to occurrences and habitat. In the absence of formal laws, regulations, or a detailed conservation strategy, assessing the adequacy of current management practices is difficult due to the lack of quantitative information on population trends for *F. campestris*.

Adequacy of current enforcement of laws and regulations

Outside Region 2, *Festuca campestris* has been locally extirpated throughout much of its historic range by overgrazing and conversion of habitat to agriculture, but this was not the result of inadequate enforcement of laws and regulations. Likewise, the apparent absence of this species from Region 2 is probably not the result of inadequate enforcement.

Biology and Ecology

Classification and description

Festuca campestris is in the Poaceae (Gramineae), a large and diverse family that includes all grasses. This species has numerous common names, including buffalo bunchgrass, big buffalo bunchgrass, rough fescue, mountain rough fescue, foothills rough fescue, and big rough fescue (USDA Forest Service 1937, Aiken et al. 1996, Tirmenstein 2000). The name buffalo bunchgrass originated from observations that bison (*Bison bison*) frequently grazed this species (Aiken et al. 1996).

The genus *Festuca* contains approximately 450 species worldwide, and it is widely distributed in the polar, temperate, and alpine regions of both hemispheres (Clayton and Renvoize 1986, Aiken and Darbyshire 1990). The name *Festuca* is derived from a Latin word meaning "weedy grass" (Aiken and Darbyshire 1990). However, only a few species are serious agricultural

pests. Members of *Festuca* (and other members of the tribe Poeae) are cool-season grasses, utilizing the C_3 pathway in photosynthesis (Gould and Shaw 1983, Cory 2005). In the subgeneric classification of Alexeev (1980), *F. campestris* and the members of the *F. scabrella* complex are included in subgenus *Leucopoa* (Grisebach) Hackel (Aiken and Darbyshire 1990, Aiken et al. 1996).

Early taxonomic work within the genus *Festuca* produced very broad species concepts (Aiken and Darbyshire 1990). *Festuca scabrella* is an example of such a taxon. What was formerly called *F. scabrella* is now recognized to be three distinct species: *F. hallii*, *F. campestris*, and *F. altaica* (Pavlick and Looman 1984, Aiken and Darbyshire 1990, Aiken et al. 1996). These species are collectively referred to in the literature (and in this assessment where no distinctions can be resolved) as "the *Festuca scabrella* complex", or less often, as "the *Festuca altaica* complex" (e.g., Harms 1985). Prior to the taxonomic revisions of Pavlick and Looman (1984) and Harms (1985), most authors simply used *F. scabrella* in the broad sense (often citing the circumscription of Hitchcock and Cronquist 1972) and did not distinguish these taxa. Because of this practice, there are many older papers in which it is unclear which taxon is being discussed.

There has been much disagreement about the number of rough fescue taxa in North America and about the correct nomenclature of recognized taxa (Pavlick and Looman 1984). Many synonyms have been assigned to these taxa at the rank of species, subspecies, variety, and subvariety (**Table 1**). The species concepts and nomenclature that are most widely (but not universally) applied today are those of Pavlick and Looman (1984). These authors recognized three taxa at the rank of full species within what was formerly called *Festuca scabrella*; they applied the names *F. altaica*, *F. campestris*, and *F. hallii* to these species. Each of these species can be distinguished by reliable (but somewhat overlapping) differences in their morphology, ecology, and distribution. The close relationship between *F. altaica*, *F. campestris*, and *F. hallii* has been confirmed by a study of the seed proteins of *Festuca* (Aiken and Gardiner 1991).

History of knowledge

As noted above, *Festuca campestris* was long known, with *F. hallii* and *F. altaica*, under the name *F. scabrella*. John Torrey (1840) first described *F. scabrella*. Harms (1985) provided an interesting version of the story of the collection of the type specimen of *F. scabrella*. The type was collected in 1825 or 1826 by Thomas Drummond, a member of the second Franklin Expedition. Because the specimens collected by Drummond were not mature and of poor quality, later botanists have been uncertain as to which member of the *F. scabrella* complex he actually collected. By retracing the probable location of the expedition at the time of this collection, Harms (1985) deduced that Drummond most likely collected *F. campestris*, which would therefore give the name *F. scabrella* priority over *F. campestris* for this taxon because the name *F. campestris* was not published until 1900. Harms (1985) followed Hultén's circumscription of *F. campestris* as a subspecies, using the name, *F. altaica* ssp. *scabrella* (Torrey) Hultén, but according to Aiken et al. (1996), this treatment was based on a type specimen that is now considered *F. altaica* by Susan Aiken.

George Vasey first described *Festuca campestris* as a distinct taxon under the published name *F. scabrella* var. *major* (Vasey 1893). The type specimen of *F. scabrella* var. *major* was collected in 1884 by W.N. Suksdorf (*118*), in Spokane County, Washington ("on prairies"), and it is housed at the Smithsonian Institution (US). Rydberg (1900) first applied the name *F. campestris* as a synonym of *F. scabrella* var. *major* Vasey, also based on the Suksdorf specimen (Aiken et al. 1996).

Table 1. Synonyms for *Festuca campestris*. Sources cited are not necessarily the original source.

Name	Source
Festuca altaica ssp. *scabrella* (Torr.) Hultén	Aiken and Darbyshire 1990
Festuca altaica var. *major* (Vasey) Gleason	Aiken and Darbyshire 1990
Festuca altaica var. *scabrella* (Torr.) Breitung	Aiken and Darbyshire 1990
Festuca doreana Looman	Looman and Best 1979, Aiken and Darbyshire 1990
Festuca scabrella var. *major* Vasey	Aiken and Darbyshire 1990, Aiken et al. 1997
Festuca scabrella Torrey ex Hook (pro parte)	Hitchcock et al. 1969
Festuca altaica ssp. *scabrella* (Vasey) Harms	Harms 1985

Members of the genus *Festuca* are of great economic importance. They are extremely important forage for livestock and wildlife, because they are highly nutritious and productive. Grasslands dominated by *F. campestris* and *F. hallii* are some of the most productive grasslands in Canada (Willms et al. 1986, Aiken and Darbyshire 1990, King et al. 1995). *Festuca campestris* has been extensively studied by rangeland ecologists and botanists (Aiken and Darbyshire 1990). The fescue grasslands of the northern Great Plains and southern Canada have received increased interest due to better recognition of their vulnerability to human impacts and declining quality and distribution. Rough fescue (*F. scabrella*) is the official grass emblem for the province of Alberta (Travel Alberta 2003).

Technical description of Festuca campestris (from Aiken et al. 1996)

Habit. Plants bluish gray-green, (30) 40 to 90 cm high, densely tufted (in Montana it grows in tussocks 30 to 40 (60) cm in diameter), tiller bases stiffly erect, bases purplish, horizontal rooting stems present (rarely as short rhizomes) or absent.

Vegetative morphology. Vegetative shoots arising from within existing sheaths, or arising outside, or breaking through the base of existing sheaths. Sheaths glabrous or glabrescent, conspicuous at the base of the plant, persisting for more than 1 year, remaining entire, not conspicuously splitting between the veins, open more than half their length (prophylls 2 to 5.5 cm long with glabrescent trichomes on the veins occur among the sheaths; a prophyll, 5.5 cm long, was found on a collection from Alberta, CAN *215039*). Collars glabrous. Auricles represented by distinct, erect, swellings (usually) or absent. Ligules 0.1 to 0.5 mm long, ciliate. Leaf blades 10 to 60 cm long, erect, stiffish. Adaxial blade surfaces with trichomes, abaxial blade surfaces with trichomes (illustrated Aiken and Lefkovitch 1984, p. 1868 and in the image library). Leaf blades flat (rarely) or plicate (usually), 1.6 to 3 mm wide (when flat or loosely rolled); 0.6 to 0.95 to 1.75 mm wide, 0.8 to 1.02 to 1.9 mm deep. Veins 7 to 10. Adaxial to abaxial sclerenchyma strands present. Abaxial sclerenchyma well developed, in broad bands or continuous. Ribs 6 to 10 (prominent). Uppermost culm leaf sheaths not inflated. Flag leaf blades 2.5 to 7.5 cm long. Culm nodes never exposed; internodes glabrous, or scabrous-hirsute.

Floral morphology and chromosome number. Inflorescence 5 to 18 cm long. Inflorescence branches at the lowest node 1 to 3, spreading ("open to somewhat contracted at anthesis," Looman and Best 1979, p. 128), 2.5 to 7 (13) cm long (tending to be stiffer than in *F. altaica* and not secund). Rachis rounded in cross section or angular in cross section, trichomes over the entire surface. Spikelets loosely scattered in an open panicle with slender branches (usually greenish); 2 to 6 on the longest branches; 8 to 12(16) mm long, 2.5 to 7 mm wide. Proliferating spikelets absent. Florets (3) 4 to 5 (7). Glumes unequal (usually, but rarely approaching subequal), glabrous or with trichomes, vestiture at the apex only, margins ciliate (border less conspicuously translucent than in plants of *Festuca altaica*). First glume 4.5 to 7.5 (8.5) mm long, veins 1 (3). Second glume shorter than the first lemma, 5.3 to 8.2 (9) mm long, veins (1) 3. Rachilla internodes antrorsely scabrous. Lemma callus not elongated. Lemma (6.2) 7 to 8.5 (10) mm long, with 5 distinct veins in dorsal view or nerveless in dorsal view or sometimes with only the centre vein distinct, with trichomes, trichomes over the entire surface; apex entire (illustrated by Pavlick and Looman 1984, p. 1742 and in the image library; the Suksdorf 118 type specimen (US) has a limited number of florets, but several have dried with the veins of the lemma relatively prominent). Lemma awn 0.5 to 1.5 mm long. Palea 6 to 9 mm long, distinctly pubescent between the keels. Lodicules with marginal teeth, glabrous (rarely) or ciliate, 1 to 1.5 mm long. Anthers (3.3) 4.5 to 6 mm long. Ovary apex pubescent. Caryopsis 3.5 to 4.5 mm long. 2n = 56.

Non-technical description

Festuca campestris is bluish gray-green and rarely has rhizomes (Pavlick and Looman 1984, Harms 1985). It forms large bunches of up to 25 culms that generally range from 40 to 90 cm in height (Pavlick and Looman 1984, Aiken and Darbyshire 1990, Aiken et al. 1996). Large individuals in undisturbed sites in Alberta can reach crown diameters of 10 to 20 inches (25 to 50 cm) (Moss and Campbell 1947). *Festuca campestris* has stiff and even slightly ascending inflorescence branches (Aiken et al. 1996). In the Raunkiaer Life Form classification system (Raunkiaer 1934), *F. campestris* is a chamaephyte, with overwintering buds at or near ground level (Tirmenstein 2000). *Festuca campestris* is an octoploid (2n = 8x = 56) (Aiken and Fedak 1991, Aiken et al. 1996). The spikelets of *Festuca* species, including *F. campestris*, disarticulate above the glumes (Aiken and Darbyshire 1990).

In Region 2, *Festuca campestris* and *F. hallii* are most likely to occur with either *F. idahoensis* or *F. arizonica*. Both *F. idahoensis* and *F. arizonica* have spikelets containing numerous florets (4 to 6,

and occasionally 8 in *F. arizonica*, and (2) 3 to 7 (9) in *F. idahoensis*) that are subtended by relatively short glumes that leave the adjacent lemmas exposed, whereas *F. hallii* and *F. campestris* have relatively long glumes. *Festuca hallii* has no more than four florets per spikelet, while *F. campestris* typically has (3) 4 to 5 (7) florets per spikelet. The awns of *F. idahoensis* are usually considerably longer than those of *F. campestris* or *F. hallii*, while those of *F. arizonica* more often fall within the range of *F. campestris* and *F. hallii*. In mature plants, the culm nodes are visible in *F. idahoensis* and *F. arizonica*, but not in *F. campestris* and *F. hallii*. Although *F. campestris* tends to be a much more robust plant than *F. idahoensis* (**Figure 1**) and *F. arizonica*, there is considerable overlap between the two species. *Festuca thurberi* can be readily distinguished from *F. campestris* and *F. hallii* by its extremely long ligules, which can reach 9 mm in length (Aiken et al. 1996).

That *Festuca campestris* and *F. hallii* were long considered the same species illustrates the challenges of identifying them. These species were known for more than a century before the differences between them were clearly recognized, and overlapping characteristics can make definitive identification difficult. However, these taxa are delimited from one another by a set of consistent morphological characters that, once learned, greatly facilitate their identification.

In general, *Festuca campestris* tends to be more robust than *F. hallii* (Aiken personal communication 2005). If rhizomes are present, they are short in *F. campestris*, while *F. hallii* typically has long rhizomes and a much less bunch-forming habit. Characteristics observed in leaf cross sections, the number of florets, and relative glume length are the most useful for distinguishing *F. campestris* from *F. hallii* (**Figure 2**, **Figure 3**, **Table 2**; Aiken personal communication 2005). Leaf cross sections are relatively unambiguous (Aiken and Consaul 1995), and they can be readily made with a razor or scalpel. For a dried specimen, soaking a leaf section in water with a small amount of detergent or Pohl's solution to hydrate it will permit diagnosis. Aiken (personal communication 2005) noted that if the tops had been chewed off *F. campestris*, the regrowth is much weaker and can make leaf cross sections of *F. campestris* look like *F. hallii*. A similar response can occur following fire, when plants are also less robust (Aiken et al. 1996). However, in these cases the floral characteristics remain consistent. **Table 2** summarizes the most useful diagnostic characteristics for *F. campestris*, *F. hallii*, and *F. idahoensis*.

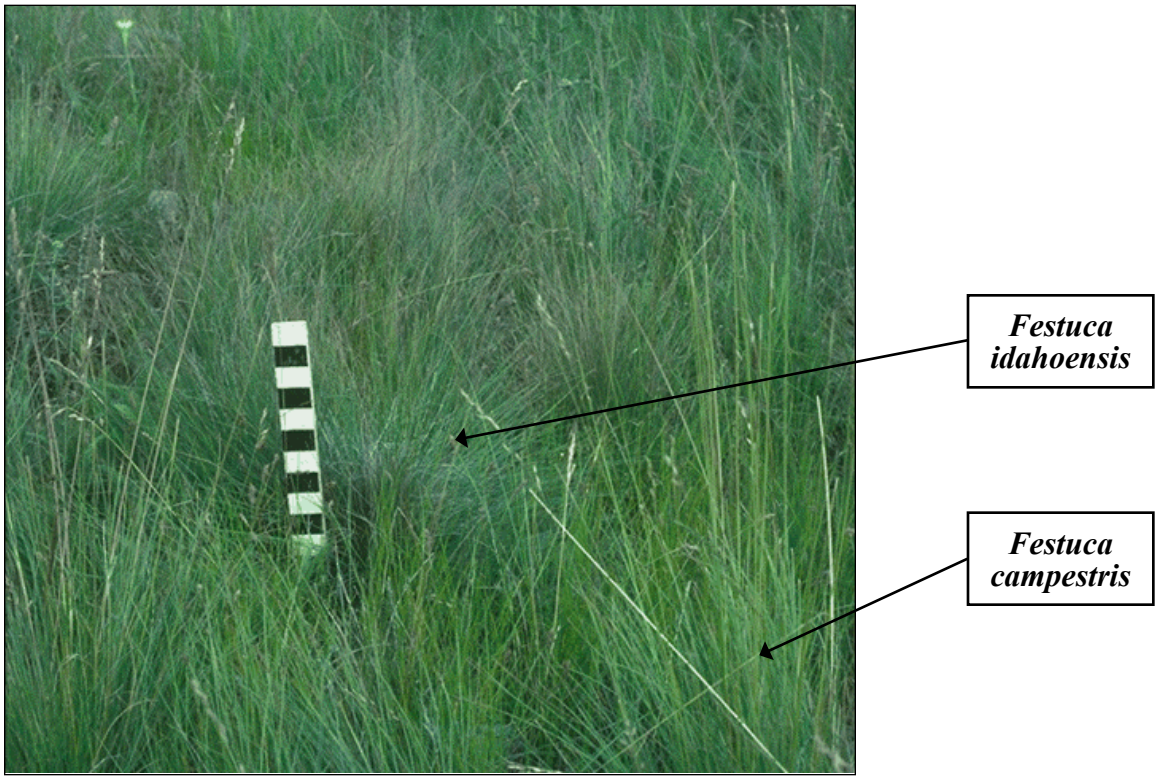

Figure 1. *Festuca campestris* and *F. idahoensis*. The taller grass in the foreground is *F. campestris*. The grass beside the marker, divided into 10 cm units, is *F. idahoensis*. Photograph from Aiken et al. (1996), used with permission.

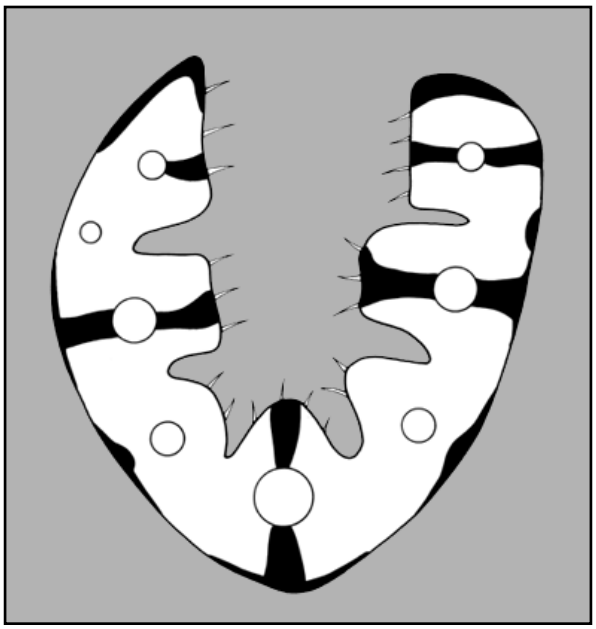

Figure 2. Diagram of the cross section of a leaf of *Festuca campestris*. Note the presence of five major vascular bundles with sclerenchymatous strands (darkened areas) adjacent to them, and the somewhat loosely involute blade. Illustration from Aiken et al. (1996). Used with permission of Susan Aiken.

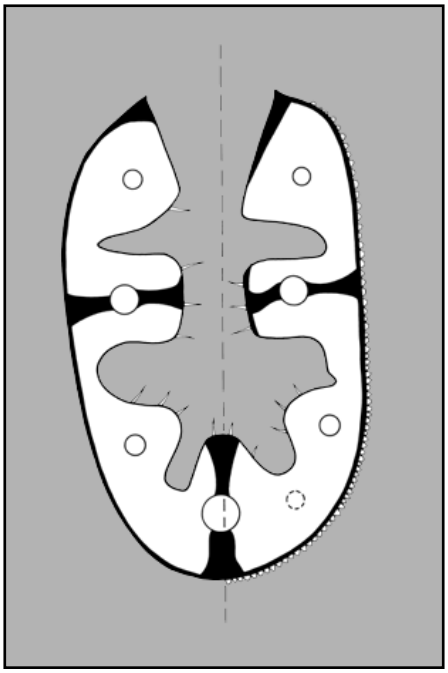

Figure 3. Diagram of the cross section of a leaf of *Festuca hallii*. Note the presence of three major vascular bundles with adjacent sclerenchymatous strands (darkened areas), and the more tightly involute blade. Illustration from Aiken et al. (1996). Used with permission of Susan Aiken.

Table 2. A comparison of diagnostic characteristics of *Festuca campestris*, *F. hallii*, and *F. idahoensis* (from Rydberg 1922, Aiken and Darbyshire 1990, Aiken et al. 1996, Aiken personal communication 2005).

	Festuca campestris	***Festuca hallii***	***Festuca idahoensis***
Height	(30) 40 to 90 cm	(18) 20 to 65 (85) cm	30 to 100 cm
Rhizomes	short, if present	well developed	absent
Culms	up to 25 slanting at an angle of 45 to 50 degrees from horizontal	usually 3 to 5 erect culms slanting 70 to 80 degrees from horizontal	no data
Culm nodes	never exposed	never exposed	becoming exposed
Ligule	0.1 to 0.5 mm long, ciliate	0.3 to 0.6 mm long, ciliate	0.3 to 0.6 mm long, ciliate
Leaf cross section	(3) 5 to 7 large and 5 to 11 small veins, leaf less tightly rolled	3 large, 4 to 5 small veins, leaf tightly rolled	3 to 5 large and 2 to 5 small veins
Relative glume length	usually conspicuously unequal, upper glume is consistently shorter than adjacent lemma	usually subequal, upper glume is as long on longer than adjacent lemma	much shorter than spikelets, second glume shorter than first lemma
Spikelet	(3) 4 to 5 (7) florets	2 to 3 fertile and 0 to 2 sterile (or with anthers only) florets	(2) 3 to 7 (9) florets
Lemma	very scabrous, callus not elongated, (6.2)7 to 8.5(10) mm long, with 5 distinct veins in dorsal view or nerveless in dorsal view or sometimes with only the centre vein distinct, apex entire	scabrous, callous not elongated, 5 to 6.5 (8.5) mm long, nerveless in dorsal view or sometimes only the center vein distinct, apex entire	dorsally rounded and glabrous at base, keeled towards scaberulous apex, callus not elongated, (5) 6 to 8 (10) mm long, nerveless in dorsal view or sometimes with only the centre vein distinct, apex entire
Awn	0.5 to 1.5 mm, rarely awnless	0.5 to 1.3 mm long	over 2 mm long
Ploidy	2n = 8x = 56	2n = 4x = 28	2n = 4x = 28

Aiken and Lefkovitch (1984) determined that epidermal peels can be readily made on members of the *Festuca scabrella* complex, but that unlike other grass taxa, the epidermal characteristics are highly variable and were not useful in resolving species identification among members of this complex.

Descriptions, photographs, keys, and illustrations

Because *Festuca campestris* is an important rangeland species, there are numerous sources of descriptions, photographs, keys, and illustrations available. However, many of these resources refer to *F. scabrella* without distinguishing *F. campestris*. The illustrations in USDA Forest Service (1937), Hitchcock et al. (1969), Cronquist et al. (1977), Lackschewitz (1991), and Stubbendieck et al. (1994) reference *F. scabrella*, but they portray what is now recognized as *F. campestris*.

More recent botanical resources are generally better for distinguishing *Festuca campestris* and *F. hallii*. Unfortunately, the keys in Wingate (1994) and Weber and Wittmann (2001), which are excellent tools for identification of most grasses in Colorado, do not include critical diagnostic features regarding spikelets and leaf morphology, so they cannot be used to distinguish *F. hallii* and *F. campestris* reliably. However, there are several readily available sources to help make this distinction. Pavlick and Looman (1984), Aiken and Darbyshire (1990), and Aiken et al. (1996) are the best sources for distinguishing *F. campestris* and *F. hallii*. The taxonomic treatment of Pavlick and Looman (1984) includes a range map (which does not include Wyoming or Colorado), a key for distinguishing the three members of the *F. scabrella* complex, tables comparing diagnostic features, and illustrations and photographs showing diagnostic features of these species. Aiken and Darbyshire (1990) contains detailed illustrations, descriptions, keys, and diagrams of leaf cross-sections (included in this assessment). Aiken et al. (1996) includes a description (included in this assessment), useful characters for distinguishing *F. campestris* and *F. hallii*, and many photographs of *F. campestris* and its habitat (included in this assessment where relevant). This resource includes a key that can be used with Delta IntKey software. Cory (2005) includes good photographs and descriptions of *F. campestris* and *F. hallii*. Stewart and Hebda (2005) provide useful

diagnostic characteristics, an illustration, a range map, and habitat information.

Distribution and abundance

Distribution outside of Region 2

Members of the *Festuca scabrella* complex range widely across northern North America. *Festuca altaica* is distributed through the mountains of British Columbia, western Alberta, Yukon Territory, western Northwest Territory, and Alaska, with disjunct stations in Michigan and eastern Canada (Rydberg 1922, Aiken et al. 1996); it is not known from the states of Region 2. *Festuca hallii* is distributed from eastern British Columbia east to Manitoba, and south to Montana and North Dakota. Disjunct populations are also known from Ontario, Wyoming, and Colorado (Pavlick and Looman 1984, Aiken et al. 1996, Tirmenstein 2000). The range of *F. campestris* is more restricted than the ranges of the other two species. It is centered in the prairies of the Pacific Northwest and northern Rocky Mountains in Oregon, Washington, Idaho, Montana, British Columbia, and Alberta (**Figure 4**, **Figure 5**; Anderson and Franzen 1983, Pavlick and Looman 1984, Aiken et al. 1996, NatureServe 2005). There is some overlap of the ranges of the three taxa in the *F. scabrella* complex in the Rocky Mountain Cordillera (Aiken et al. 1996, Tirmenstein 2000). However, where populations of these species occur near one another, they are always ecologically separated (Aiken et al. 1996). See the Habitat section for details regarding the habitats of *F. campestris*.

Distribution within Region 2

Festuca campestris is known from two records in Region 2. One record comes from the Huerfano and Las Animas County line on the San Isabel National Forest in Colorado (Johnston 2002). However, new evidence suggests that *F. campestris* does not occur in Region 2. The details supporting this conclusion are discussed elsewhere in this document. The second is a dubious record from Weld County, Colorado. While the distribution of *F. campestris* in Colorado is now uncertain, there remains a small chance that this taxon occurs in Colorado or Wyoming. Data for both *F. campestris* and *F. hallii* in Colorado are sparse, consisting of many old and/or vague records. The available information is summarized in **Table 3**. **Figure 6** shows the distribution of reported locations of *F. scabrella*, *F. hallii*, and *F. campestris* in Colorado and Wyoming in relation to National Forest System land in Region 2. The distribution of these taxa is shown in greater detail, with respect to all land status types, in **Figure 7**. USDA Forest Service (1937) reported that old records of *F. scabrella* from Colorado have mostly been determined to be *F. thurberi*. All records included here that are based on herbarium specimens were annotated recently (mostly as *F. hallii*) and are probably not *F. thurberi*.

There are no records of *Festuca campestris* from Wyoming. *Festuca campestris* is known from montane grasslands in Montana, where it has been documented within 100 miles of the Shoshone National Forest (**Figure 5**; Aiken et al. 1996). Recent surveys discovered many new localities of *F. hallii* in Wyoming (Fertig 2002). The distribution of *F. hallii* in Wyoming, though also still somewhat poorly understood, is better known than in Colorado. In Colorado, uncertainty remains regarding the identity of the plants from five of the seven reports. In four cases, the uncertainty is the result of the taxonomic revision of *F. scabrella*. Because these occurrences were reported as *F. scabrella*, it is possible that they are *F. campestris*. In another case (Weld County), it appears that *F. campestris* was reported erroneously.

For the reasons stated above, this assessment does not provide details regarding the distribution of *Festuca hallii* in Wyoming. These are provided in the Technical Conservation Assessment for that species (Anderson 2006). Details regarding the seven reports of members of the *F. scabrella* complex in Colorado are discussed below.

The presence of *Festuca hallii* (and possibly *F. campestris*) in Wyoming and Colorado is probably relictual. The southward movement of vegetation zones during the Pleistocene probably created suitable conditions for fescue grasslands at lower latitudes. Warmer conditions following glacial retreat beginning approximately 10,000 years ago caused vegetation zones to move north again but left remnant populations in patches of suitable habitat (Johnston 1958).

Weld County, Colorado

Rubright (2000) included a location (accurate to within 30 miles) for *Festuca campestris* in western Weld County (**Figure 7**). Rubright (2000) did not indicate a source for this record, but it was probably from incorrectly identified specimens at the University of Northern Colorado herbarium. Two specimens collected by Earl Lynd Johnston (*536*, collected in 1909, and *48*, collected in 1925) were annotated as *F. campestris* by someone with the initials "MAL."

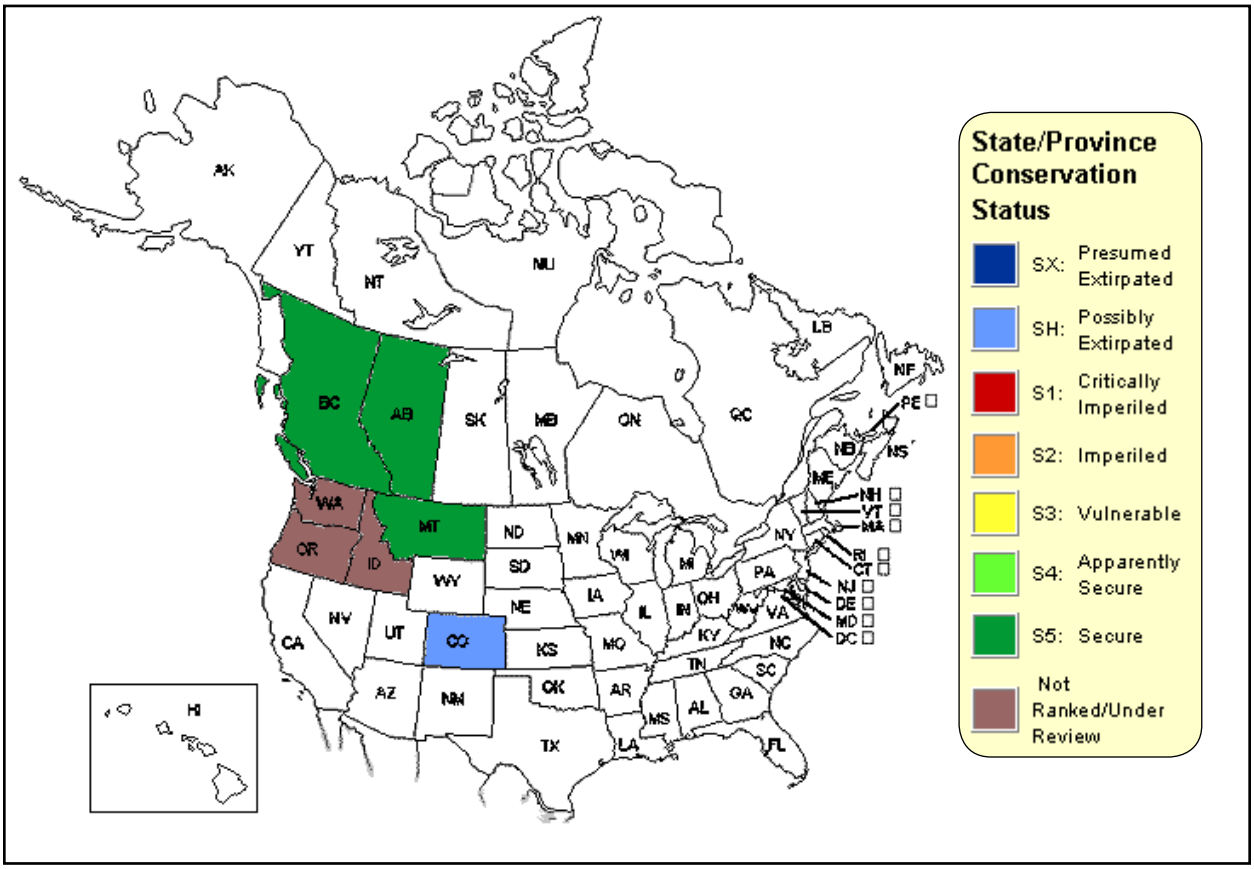

Figure 4. State and province conservation status ranks of NatureServe member programs throughout the range of *Festuca campestris* (NatureServe Explorer 2005). The global conservation status rank of *F. campestris* is G5?. *Festuca campestris* is no longer ranked in Colorado.

Johnson 536, first identified as *F. elatior*, was collected at "Evans, Colorado." This specimen was annotated to *F. campestris* in 1993 by MAL, then to *F. pratensis* in 2006 by Neil Snow. *Johnson 48* was collected at "Briggsdale" as *Calamovilfa longifolia*, and was subsequently annotated as *F. elatior* by Harrington in 1944, then to *F. campestris* by MAL in 1993, and finally to *F. pratensis* by Neil Snow in 2006 (Snow personal communication 2004, 2006). Both of these specimens would have been labeled *F. campestris* at the time that Rubright was compiling her *Atlas of the Grasses of Colorado*.

Given what is known about the preferred habitats of *Festuca campestris*, it is highly unlikely that it grew in Weld County within the last 100 years. The moisture requirements of this species are unlikely to exist in the shortgrass prairie occupying these locations, where annual precipitation is 10 to 12 inches per year (Bureau of Land Management 1998), lower than occurs anywhere within the known range of *F. campestris*. The area around Evans, Colorado is also densely populated and heavily cultivated (Comer et al. 2003).

Park County, Colorado

Weber (1961) retraced the route of Elihu Hall and J.P. Harbour through the mountains of central Colorado in 1862. It was on this trip that Hall and Harbour collected the type specimens of numerous species (Ewan and Ewan 1981), including *Festuca hallii*. The type specimen for *F. hallii* (*Hall and Harbour 621* at US) is labeled simply as "Rocky Mountains, lat. 39°-41°." Considering the collectors' itinerary and probable location, it is likely that this specimen was collected around the north end of South Park (Colorado Native Plant Society 1997, Weber and Wittmann 2001), possibly on what is now the Pike National Forest. This occurrence has not been seen since 1862 (Colorado Native Plant Society 1997), and its precise location remains unknown.

Larimer County, Colorado

Harrington's notes, which are remarkably well organized, are housed at the University of Colorado Herbarium (COLO). Among Harrington's notes is a

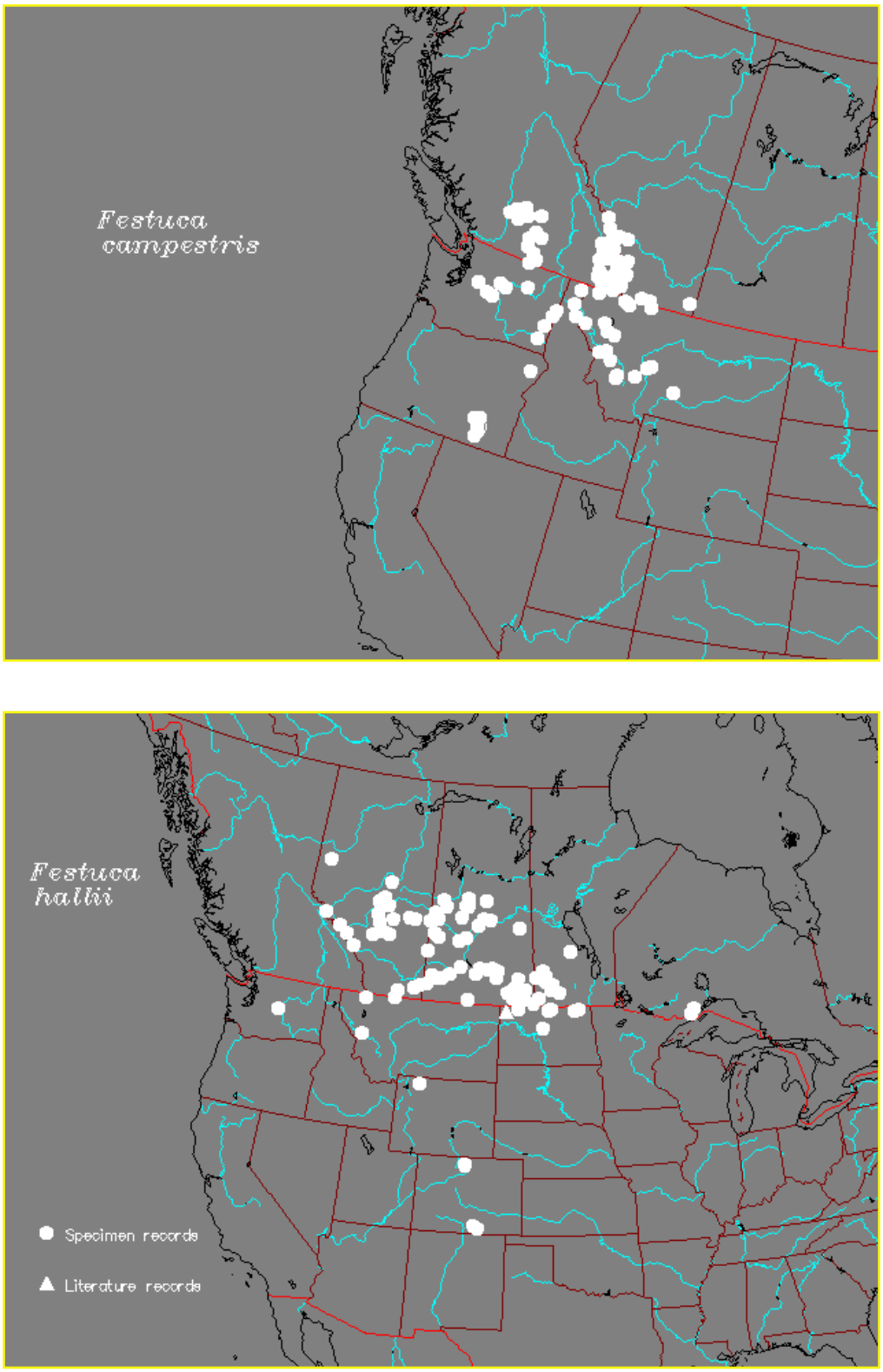

Figure 5. The known distributions of *Festuca campestris* and *F. hallii* (from Aiken et al. 1996, used with permission).

Table 3. Summary information for the known reports of *Festuca scabrella sensu lato* (from old records), *F. campestris,* and *F. hallii* in Colorado. Source ID is Colorado Natural Heritage Program element occurrence number unless otherwise noted. Occurrences on National Forest System land are in bold type.

Source ID[1]	Species ID	County/ State	Location	Owner	Date last observed	Abundance	Elevation (ft.)	Habitat and notes
CO EO #1; *W.A. Weber and J. Wingate 15442* (COLO, RM); *Elliott 13597 and 13609* (RM, COLO, CS); *Sherman 61* (CS)	*F. campestris/ F. hallii* (annotated by Aiken)	Huerfano CO	Cordova Pass	**USDA Forest Service (USFS) San Isabel National Forest**	01-Jul-2004	Infrequent and scattered, probably spread over several acres but full extent is not known	11,248	Weber and Wingate 1978: In large grassy area, probably severely overgrazed, now dominated by *Trifolium attenuatum*, mostly lying around gopher "gardens." It occurs sparsely on a grassy saddle along the trail from the pass toward West Spanish Peak. Weber et al. 1979: The saddle is dominated by *T. attenuatum* Greene and *Festuca arizonica*, various species of *Carex* and subalpine perennials and appears to have had a history of overgrazing and recovery. The few large bunches of *F. scabrella* are best developed in deep loose soils churned up by gophers. Elliott (personal communication 2005) reported very few cow fecal pats and little evidence of recent cattle grazing. Surrounding forests are dominated by *Picea engelmannii* and *Pinus aristata*. The grassland area is dominated by *T. attenuatum*, *Lomatium* sp., *Fragaria virginiana*, and *Achillea lanulosa*. South aspect, slope 5 degrees. *Festuca* is scattered in montane meadow; not in dense patches. Usually on or around disturbed gopher gardens.
Harrington 1954	*F. scabrella* (possibly referring to *F. campestris*)	Custer CO	Unknown	**Possibly USFS San Isabel National Forest**	Unknown	Unknown	8,500	Not known.
Hall and Harbour 621 (US)	*F. hallii*	Probably Park CO	Latitude 39-41 degrees	**Unknown**	1862	Not reported	Not reported	Not reported.
CO EO #1; *W.A. Weber and G.D. Pickford 9694* (US)	*F. hallii*	Larimer CO	Chambers Lake/ Cameron Mountain	**USFS Roosevelt National Forest**	25-Aug-1956	"Dominant"	11,600	Dominant in scattered stands of climax *Kobresia myosuroides* tundra, east and north slope of Cameron Mountain. Rhizomatous, sod-forming perennial species with broad reddish basal sheaths, strongly contracted panicles and few flowered, awnless spikelets

Table 3 (concluded).

Source ID[1]	Species ID	County/ State	Location	Owner	Date last observed	Abundance	Elevation (ft.)	Habitat and notes
A. Chase 5359 (US)	*F. scabrella* (probably *F. hallii*)	Unknown CO	Spanish Peaks, West head of Apishapa Canyon	**USFS San Isabel National Forest**	09-Sep-1908	not reported	11,000-11,500	In scattered spruce and aspen.
J.R. Swallen 1302 (US)	*F. hallii* (annotated by Aiken)	Unknown CO	Spanish Peaks	Unknown	28-Jul-1928	Not reported	not reported	Small grassy area above timberline.
G.B. Van Schaack 2499 (US)	*F. hallii* (annotated by Aiken)	Las Animas CO	Cordova Pass	**USFS San Isabel National Forest**	28-Jul-1949	Not reported	11,400	Decumbent in small tight tufts in rich soil among gravel.
Wasser (1954)	*F. scabrella*	Larimer CO	Shipman Park	**USFS Roosevelt National Forest**	before 20-Sep-1954	Not reported	9,500	Not known.
Rubright (2000)	*F. campestris*	Weld CO	Unknown	**Probably private**	Unknown	Unknown	Unknown	This report is probably a misidentification

[1]Herbarium abbreviation:

COLO: The University of Colorado Herbarium.
CS: Colorado State University Herbarium.
RM: Rocky Mountain Herbarium.
US: US National Herbarium.

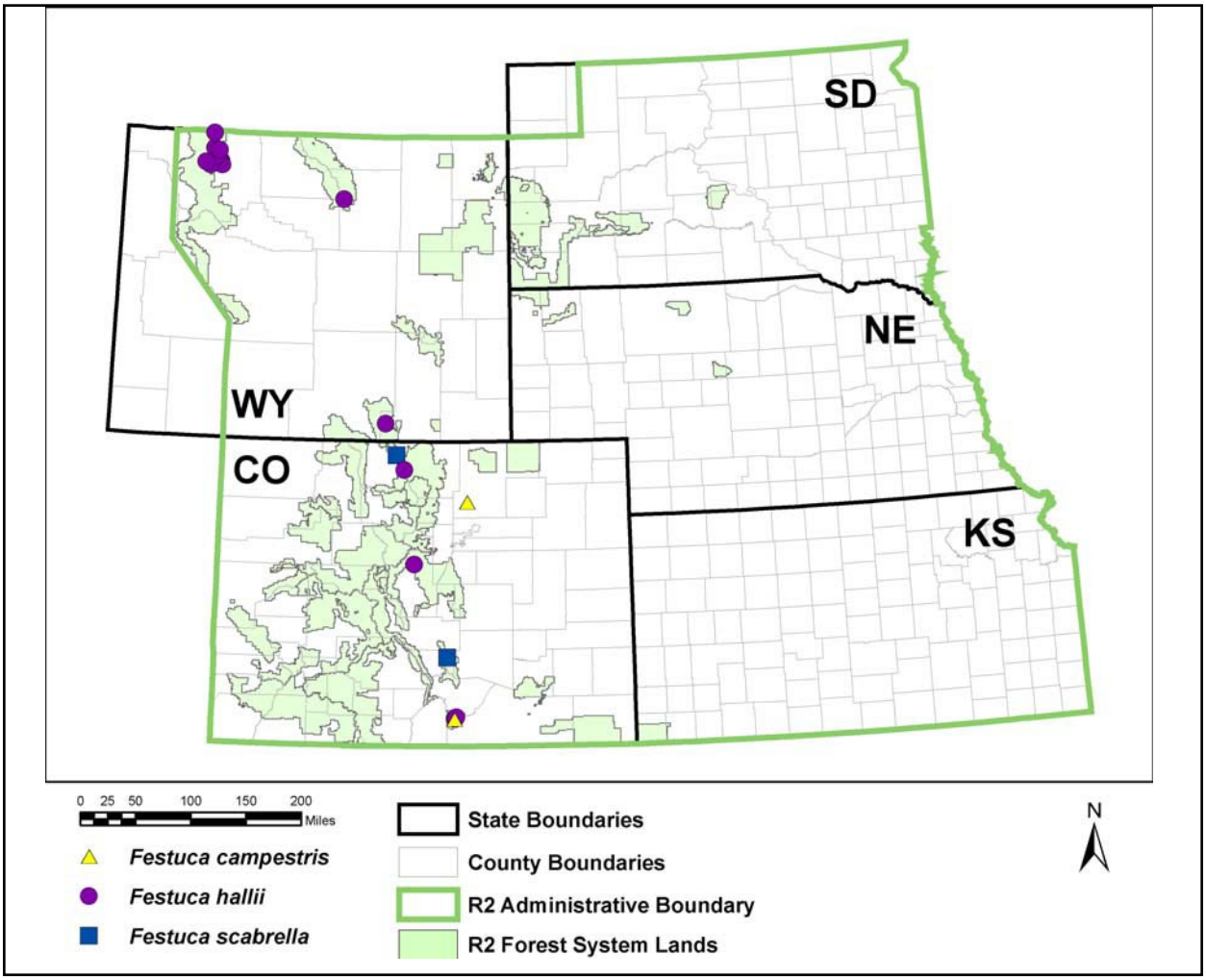

Figure 6. The distribution of reports of members of the *Festuca scabrella* complex in the states of USDA Forest Service Region 2.

memo (dated September 20, 1954) from Clinton H. Wasser, then a professor in the Forestry Department at Colorado State University. The memo, regarding a *Festuca scabrella* specimen, reads as follows:

> "You may recall that I was over checking a *Festuca scabrella* specimen with you. Upon checking I find that this was collected on the Roosevelt National Forest, between the Laramie River and Medicine Bow Range in Shipman Park, at about 9,500 feet elevation, by Assistant Supervisor Robert Gardner. They promised to collect enough for some herbarium collections."

There are no known specimens from this occurrence at any of the herbaria searched. Attempts were made to contact Dr. Wasser, who now resides in California (Shaw personal communication 2005), but these were not successful. Because it was originally identified as *F. scabrella* and has not been seen since 1954 or earlier, the identity of the plants described in this report remains uncertain.

One of the best documented locations of a member of the *Festuca scabrella* complex in Colorado is that of Weber and Pickford (*9694*) collected August 25, 1956 on the north and east sides of Cameron Mountain at approximately 11,600 ft. on the Roosevelt National Forest. This specimen became the type for *F. scabrella* Torrey ex. Hooker ssp. *hallii* (Piper) W.A. Weber. In describing this new combination, Weber (1961) wrote:

> "In the summer of 1956, Mr. G.D. Pickford, then supervisor of the Roosevelt National Forest, showed me a stand of mature *Kobresia myosuroides* tundra on the north slope of Cameron Mountain which contained a species of *Festuca* as a co-dominant. This in itself

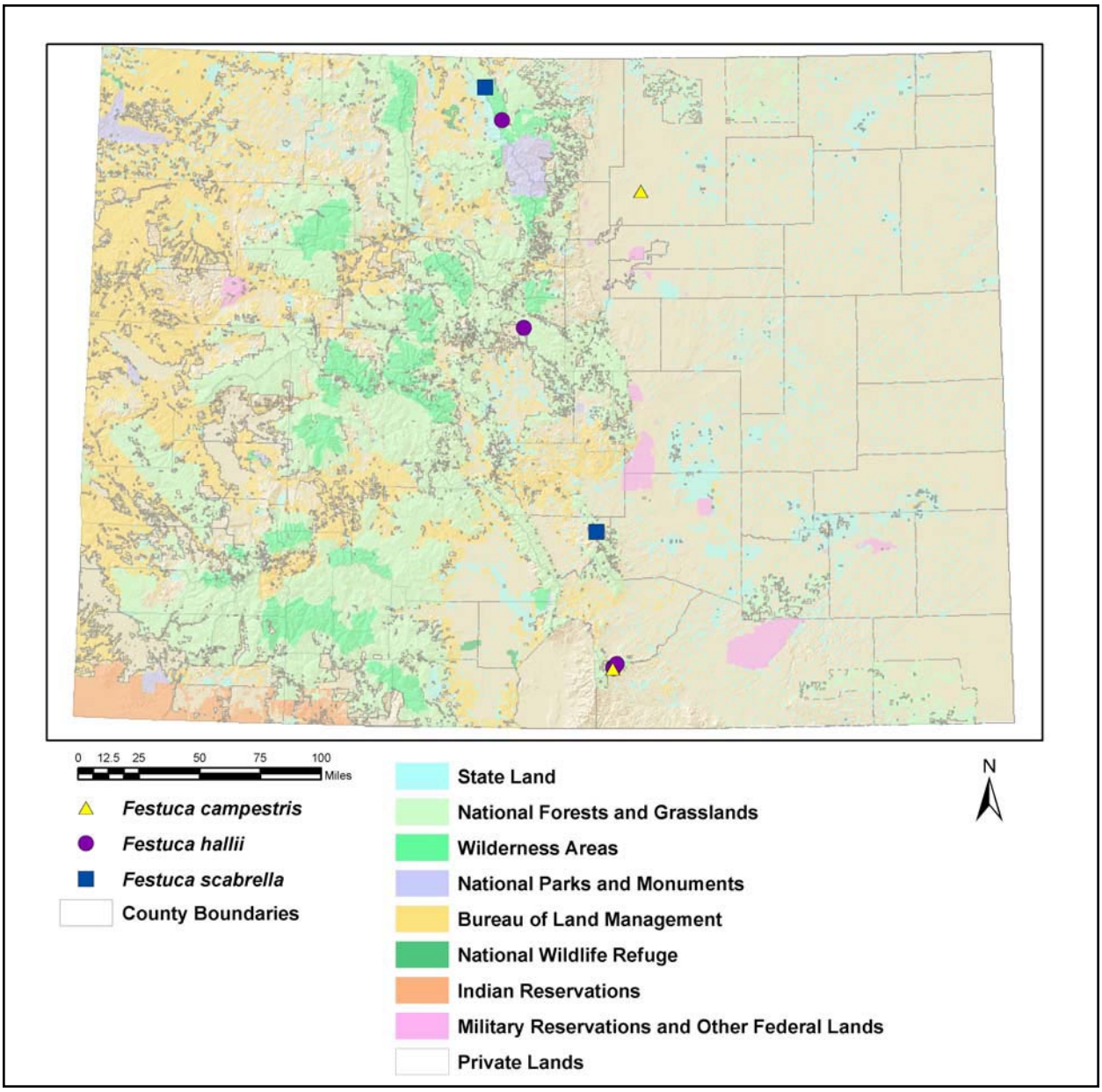

Figure 7. The distribution of reports of members of the *Festuca scabrella* complex in Colorado in relation to land ownership.

was most unusual because the *Kobresia* characteristically produces a very dense closed stand. The *Festuca* was a rhizomatous, sod-forming perennial species with broad reddish basal sheaths, strongly contracted panicles and few-flowered, awnless spikelets.

This is the plant which has been called *Festuca hallii* (Vasey) Piper. The type specimen, collected by Hall and Harbour, "Rocky Mountains, lat. 39°-41°" (US) exactly matches our collection. Presumably it is on the basis of this taxon that *F. scabrella* [referring to *F. campestris*] is said to be rarely rhizomatous (Hitchcock and Chase 1950, p. 70).

"…The alpine race of the Colorado Rockies is at least as different from *F. scabrella* as the latter is from *F. altaica*; in fact, I feel that the combination proposed is possibly too conservative. However, the entire *F. altaica* group deserves a thorough world-wide study…

"…But regardless of the taxonomic status of the taxon, it is most interesting to discover this new element in the *Kobresia* stand. This

> fact alone should stimulate ecologists to investigate the extent and importance of this phytosociological phenomenon. As far as I am aware, the alpine race is the only representative of *F. scabrella* occurring in Colorado. Therefore, the statement in the Manual of its distribution- "Prairies, hillsides and open woods" (page 49) is incorrect."

This specimen was annotated by Jan Looman in 1976 and by Susan Aiken in 1983 as *F. hallii*.

Huerfano, Las Animas, and Custer counties, Colorado

The earliest record that indicates the presence of *Festuca campestris* specifically in Colorado is that of Harrington (1954). In his Manual of the Plants of Colorado, he noted the presence of *F. scabrella* (with which he offered *F. campestris* Rydberg as a synonym) "from Huerfano County at 11,250 feet and Custer County at 8,500 feet." The description offered by Harrington (1954) fits that of *F. campestris* better than that of *F. hallii* ("no rhizomes; culms densely tufted…spikelets 3-6 flowered…lemmas 7-10 mm long, fairly definitely 5-nerved"). It is not known if he based this description on Colorado material or on descriptions from other floras, but it is likely that the latter is true.

Harrington included some details in his notes about the Huerfano County and Custer County records of *Festuca scabrella* included in his Manual (Harrington 1954). On a map of locations in Colorado, he noted "US" (the US National Herbarium at the Smithsonian Institution) as the source of the material in Huerfano County (**Figure 8**). The specimens from the *F. scabrella* complex from Colorado that are currently housed at US were collected by Agnes Chase (September 9, 1908), J.R. Swallen (July 28, 1928), and G.B. Van Schaak (July 28, 1949) in the Spanish Peaks, in Huerfano and Las Animas counties, on the San Isabel National Forest. These specimens are probably those upon which the range map of *F. scabrella* (which includes Colorado) in Chase's revision of Hitchcock's *Manual of the Grasses*

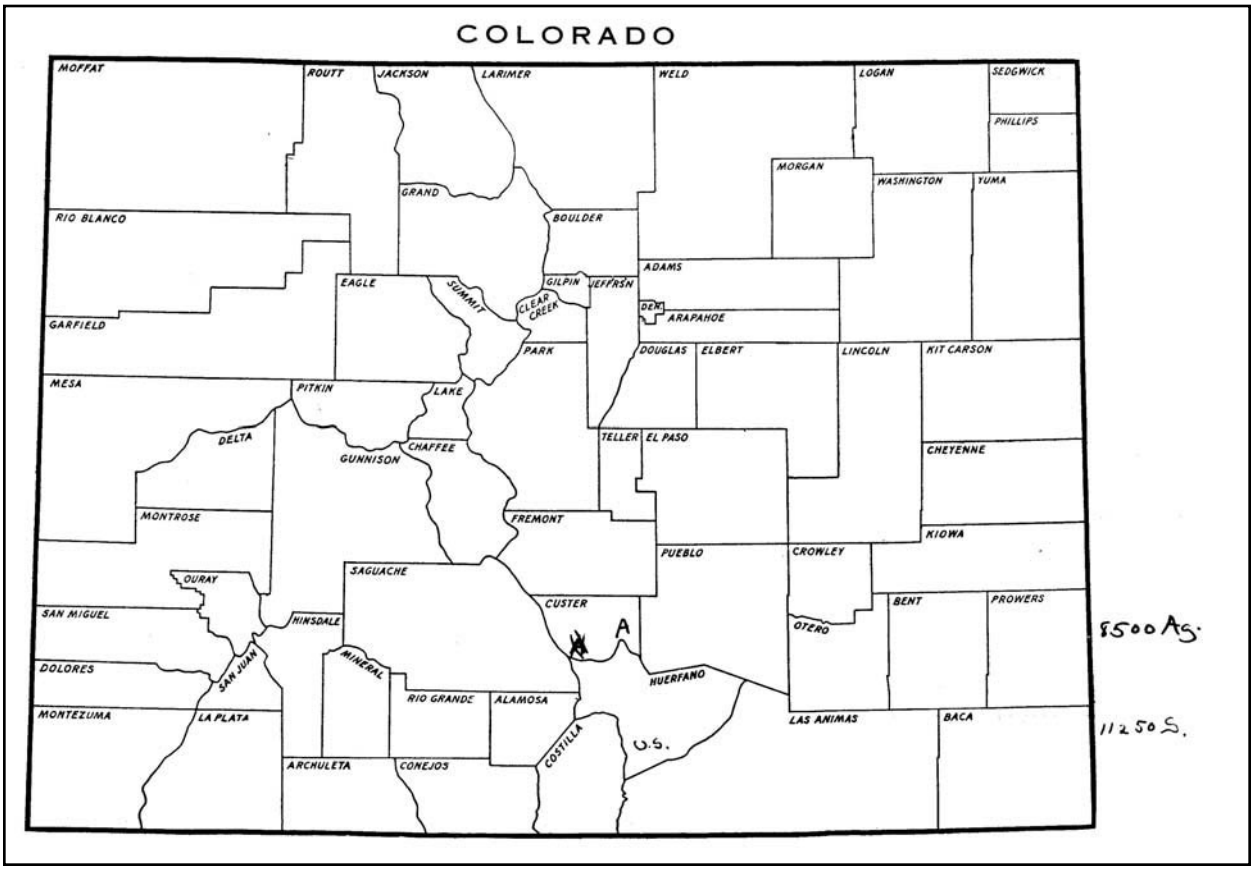

Figure 8. Map of the distribution of *Festuca scabrella* in Colorado from H.D. Harrington's notes. Letters denote locations and the institution housing the specimen at that location. A=Arnold Arboretum, US= US National Herbarium. Specimens at US have all been annotated to *F. hallii*. There are no specimens of any *Festuca* species from Custer County, Colorado currently housed at A.

of the United States is based (Hitchcock and Chase 1950). Two of these specimens (*Swallen 1302* and *Van Schaak 2499*) were annotated by Susan Aiken as *F. hallii*. The *Chase 5359* specimen was not annotated by Aiken, but it P.F. Stickney's 1965 annotation agreed with Chase's identification. This specimen also appears to be *F. hallii* (Soreng personal communication 2005).

From Harrington's notes, it appears that the record in Harrington (1954) for *Festuca scabrella* in Custer County is based on a specimen housed at the Arnold Arboretum (A). This herbarium was searched unsuccessfully for any specimens in the genus *Festuca* in Custer County, Colorado (Kittridge personal communication 2005). Specimens originally cataloged at the Arnold Arboretum have been integrated into the collections at the Gray Herbarium (GH), but no specimens of *Festuca* were found at GH for Custer County either. Thus, the record on which Harrington based this statement remains unknown. Harrington had initially indicated on his map that the occurrence was in southwestern Custer County, but he corrected this by placing an "A" in east-central Custer County (**Figure 8**). He indicated that this location is at 8,500 ft. in elevation. Using Harrington's notes and the 8,500 foot contour line in eastern Custer County, some of the locational uncertainty of this report can be resolved (**Figure 9**), although the exact location of *F. scabrella* remains unknown. This historical occurrence may be on the San Isabel National Forest.

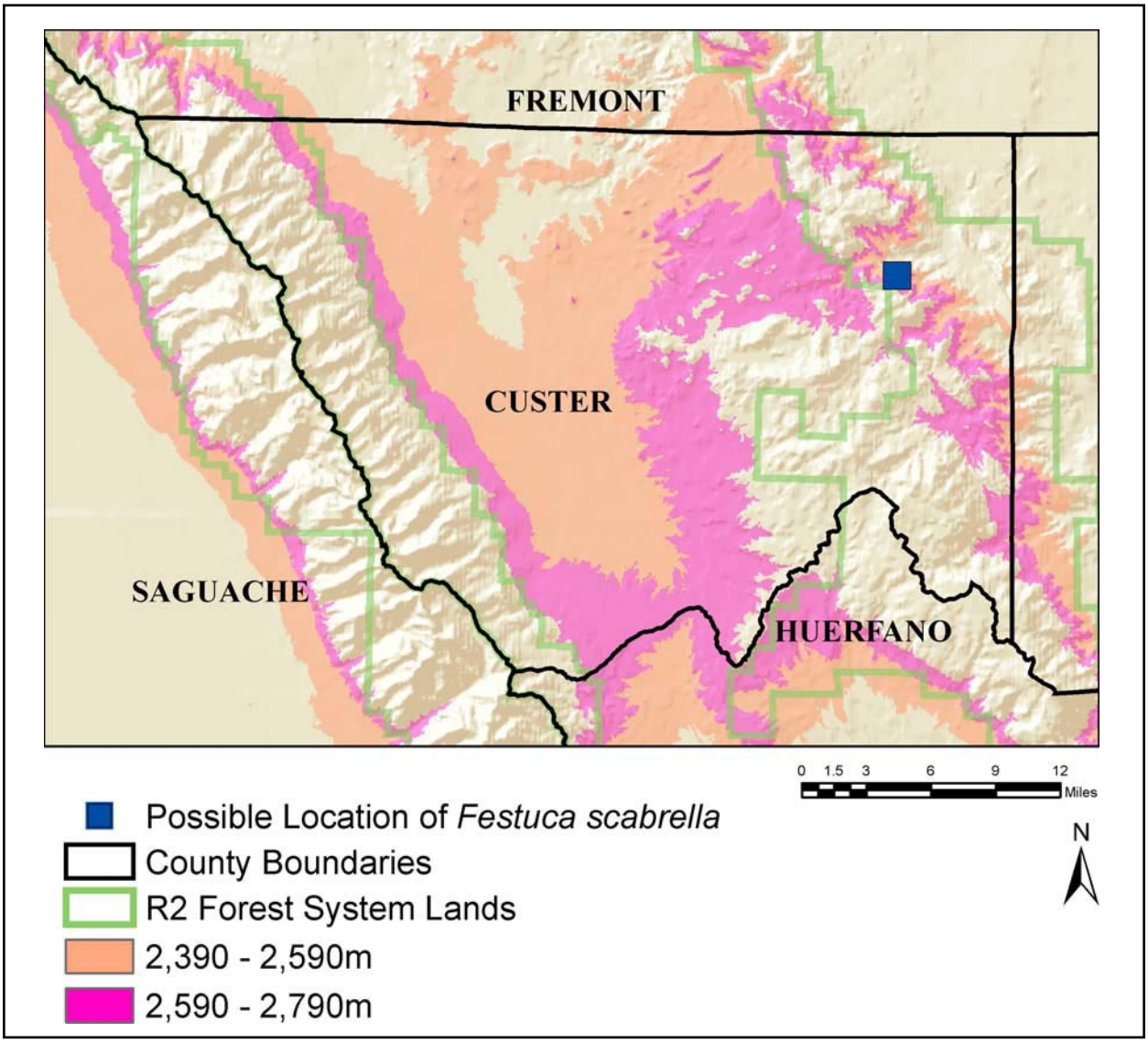

Figure 9. Map of Custer County, Colorado, showing a possible location of *Festuca scabrella* (based on Harrington's elevation notes; see **Figure 8**). The elevation surfaces shown are 200 m below and 200 m above that reported by Harrington. Thus, the most likely locations are in eastern Custer County where these two surfaces meet.

On July 6, 1978, Drs. William A. Weber and Janet Wingate made a collection (*15442*) on Apishapa Pass (now known as Cordova Pass), at the headwaters of the Apishapa River, west of West Spanish Peak on the boundary between Huerfano and Las Animas counties, on the San Isabel National Forest. This is the only specimen suggesting that *Festuca campestris* is present in Colorado (and all of Region 2). Numerous sources that are probably based on this specimen report the presence of *F. campestris* in Colorado (e.g., NatureServe 2005, USDA Natural Resources Conservation Service 2005) or specifically in Huerfano County, Colorado (e.g., Barkworth and Long 2005). Of this collection, Weber et al. (1979) wrote:

> "I erred (Weber 1961) in suggesting that *F. hallii* (Vasey) Piper [*F. scabrella* ssp. *hallii* (Piper) W.A. Weber] is the only member of the *F. scabrella* group occurring in Colorado. Harrington's report (1954) of *F. scabrella* from Huerfano County at 11,250 ft. and from Custer County at 8,500 ft. was correct, and his description certainly applies to the species proper [referring, at least in part, to *F. campestris* as it was later circumscribed by Pavlick and Looman 1984] and not to the rhizomatous *F. hallii*. I recently had the opportunity of seeing the species in the field (Huerfano Co.: Apishapa Pass. 2240 msm, 6 July 1978, *Weber and Wingate 15442*)… The dense bunches lacking any rhizome development, the very high reddish leaf sheaths, long and tightly involute blades and large heavy spikelets easily distinguish *F. scabrella* from *F. hallii*. It is not impossible that *F. scabrella* might have been introduced for range restoration."

Susan Aiken annotated the Weber and Wingate (*15442*) specimens deposited at RM and COLO in 1983. The specimen at COLO was annotated as *F. campestris*, but the specimen at RM was annotated as *F. hallii*. Aiken (personal communication 2005) stated that at that time she was less aware of critical diagnostic features, and thus believes that one of these annotations may be a misidentification. It is important to note that in 1979 when Weber wrote the article quoted above, and in 1983 when Aiken annotated Weber and Wingate's specimen, the differences between *F. campestris* and *F. hallii* were still being worked out. A definitive taxonomic treatment of the *F. scabrella* complex was not available until 1984, and it was not widely applied until the late 1980s.

In a visit to Cordova Pass in July 2004, Brian Elliott (personal communication 2005) observed *Festuca hallii* (**Figure 10**) at the location described by Weber and Wingate. Limited time was spent at this site in 2004, but it was re-visited in 2005 and 2006. Specimens were collected (*Elliott 13597*, *Elliott 13609*, and *Sherman 61*) that were assessed by Drs. Ron Hartman, Robert Shaw, and Michael Curto. These experts all agreed that the material collected at Cordova Pass is *F. hallii* (Curto personal communication 2006, Elliott personal communication 2006).

Due to the growing uncertainty regarding the identity of the *Weber and Wingate 15442* sheets at COLO, they were viewed by the author to apply diagnostic characteristics developed by Aiken (personal communication 2005) and other experts (Pavlick and Looman 1984, Aiken et al. 1996), which reflect a more modern concept of *Festuca campestris* and *F. hallii* than could be applied when they were annotated in 1983. The diagnostic features of plants on both sheets appear to place this material fairly unambiguously in *F. hallii* (**Table 4**). Digital photographs of diagnostic features (**Figure 11**) were sent to Susan Aiken, who agreed that this specimen appears to be *F. hallii*.

The duplicate specimen at RM (already annotated as *Festuca hallii*) was also re-assessed by the author, and it also fits into the modern circumscription of this taxon. Dr. Ron Hartman also assessed the Weber and Wingate specimen at RM and concurred that it appears to be *F. hallii* (Elliott personal communication 2005).

Vernon Harms also looked at the Weber and Wingate specimen and diagnosed it as *Festuca hallii*. Harms (1985, p. 6) wrote that "Upon examination of the lectotype of *F. hallii* and duplicates of it, as well as several later collections by W.A. Weber et al. from Larimer and Huerfano Counties, Colorado, it is apparent that all of these do indeed belong to the same taxon as does the rough-fescue of the northern Great Plains and Eastern Foothills grasslands." Despite this statement, it appears that Harms did not annotate the specimens at COLO as *F. altaica* ssp. *hallii*. Perhaps following Harms' statements about *Weber and Wingate 15442* (or possibly his own, as he was in Colorado at the time), O'Kane (1988) lists *Weber and Wingate 15442* among two other specimens of *F. hallii* in Colorado.

All three of the specimens at US that were identified as *Festuca hallii* (discussed above and

Figure 10. Plant observed at Cordova Pass, at the probable location of Weber and Wingate's collection (*15442*). Elliott (personal communication 2005) determined this to be *Festuca hallii*. Photograph provided by Brian Elliott, used with permission.

Table 4. Diagnostic data for Weber and Wingate 15442 at COLO. These data suggest that this specimen is *Festuca hallii*. See also **Table 2** and **Figure 11**.

Characteristic	Description
Height	49 to 50 cm (n = 2)
Rhizomes	None apparent (specimen may not have been fully excavated)
Culms	2 to 4, apparently erect
Leaf Cross Section	Leaves tightly rolled; 7 vascular bundles, probably 3 major bundles but difficult to distinguish at 45x magnification (n = 1)
Relative Glume Length	Glumes subequal, second glume concealing the adjacent lemma
Spikelet	Three fertile spikelets (n = 2)

Figure 11. Close-up of spikelets on *Weber and Wingate 15442*. Increments below are 1mm. The second glume (A) entirely conceals the lemma of the adjacent floret (B). Each spikelet has no more than three florets. These and other characteristics suggest that this is *Festuca hallii*.

in **Table 3**) were collected near the Spanish Peaks. The Chase specimen ("Spanish Peaks, west head of Apishapa Canyon") and the Van Schaak specimen ("Cordova Pass") were apparently collected at almost the exact location where Weber and Wingate made their collection.

Conclusions

There is now considerable evidence suggesting that the plants at Cordova Pass are in fact *Festuca hallii*. Expert verifications of the Weber and Wingate specimen (*15442*) as *F. hallii* and recent surveys at Cordova Pass leave little reason to suspect that *F. campestris* is present in Colorado. To make a definitive determination, careful collection and expert verification of more material, gathered during a more extensive survey of the Cordova Pass area, is needed (Elliott personal communication 2005). While it is possible that both *F. campestris* and *F. hallii* occur together at Cordova Pass, observations of these species in the heart of their range suggest that this is unlikely. *Festuca campestris* and *F. hallii* are found

near one another in British Columbia and elsewhere, but they never occur together (Stewart and Hebda 2005).

Abundance

There is no information on which to base estimates of population size of *Festuca campestris* or *F. hallii* in Region 2. Elliott (personal communication 2005) reported that the *Festuca* at Cordova Pass (now believed to be *F. hallii*) is scattered and not in dense patches, and that the full extent is not known. Hundreds or thousands of ramets are distributed patchily among the three locations known on Cordova Pass, where there is probably 100 to 200 acres of potential habitat on the San Isabel National Forest and surrounding private lands.

Population trend

Because there are no confirmed occurrences of *Festuca campestris* in Region 2, the population trend of this species in Region 2 is unknown. Human activities, primarily agricultural conversion, intensive grazing, and fire suppression, have resulted in a range-wide decline in the extent of grasslands dominated by *F. campestris*. Given the economic and ecological importance of these grasslands, there is a large body of literature (from outside Region 2) discussing the effects of human activities on them. Much of the area once occupied by *F. campestris* grasslands has been converted to wheat or other agricultural production (Woolfolk et al. 1948). Unsustainable grazing practices led to the decline of *F. campestris* grasslands in extent and quality (Dormaar and Willms 1990). Referring to the practices of cutting *F. scabrella* for hay, and of grazing, USDA Forest Service (1937) noted "excessive volume utilization has decreased the abundance of this valuable species so that now it is not so prevalent as it once was." *Festuca scabrella* was dominant in many mountain grasslands and intermountain valleys in northwestern and north-central Montana before it was largely eliminated by grazing and agriculture (Stickney 1961, Antos et al. 1983). Looman (1969) wrote, "Already an estimated 90 percent of fescue grasslands have been greatly or moderately modified, and much of the surrounding forest suffers damage to some extent. Unless some suitable areas are placed in 'Nature Preserves,' the time is not far off when the fescue grassland will have followed the true prairie into extinction."

Habitat

Habitats range-wide

Rydberg (1900) described the habitat of *Festuca campestris* in Montana as "Dry valleys, plains, and hillsides up to an altitude of 2000 m." Later, he added dry valleys, benchlands, hogbacks, and dry ridges of the northern Rockies to the range of habitats it occupies (Rydberg 1915). USDA Forest Service (1937) reported the habitats of *F. scabrella* as including "Prairies, open, sunny, hill and mountain slopes up to 10,000 ft. elevation, rocky cliffs, and dry, open woods are its most frequent habitats, especially on dry, deep, sandy loam soils. Often it is so abundant locally as to form one of the chief features of the landscape; in extensive mountain park areas it may grow to the exclusion of other grasses." In Region 2, habitats of members of the *F. scabrella* complex have been described as prairies, hillsides, and open woods (Harrington 1954), but these areas are far more likely to support occurrences of *F. hallii*.

In resolving the taxonomic differences between *Festuca campestris* and *F. hallii*, consistent differences in their habitats were noted where they are most abundant in the northern Rocky Mountains and northern Great Plains. *Festuca campestris* occurs in open forests, glades, and grass balds in montane forests, and in the subalpine zone; *F. hallii* occurs in plains habitats at lower elevations and latitudes (Pavlik and Looman 1984). Where these species overlap geographically in Alberta, they are separated elevationally with *F. campestris* occurring at higher elevations than *F. hallii*. *Festuca campestris* usually grows on the montane slopes of the foothills in Alberta and British Columbia (**Figure 12**; Stout et al. 1981, Cory 2005).

Region 2 habitats

Table 3 summarizes all available documentation of the habitats of members of the *Festuca scabrella* complex in Colorado. Wyoming is not included since all Wyoming sites have been verified as *F. hallii*. Because there are no confirmed occurrences of *F. campestris* in Region 2, the habitat cannot be described with any certainty. See Anderson (2006) for detailed descriptions of habitats occupied by *F. hallii* in Region 2.

Figure 12. A grassland dominated by *Festuca campestris* in British Columbia. Photograph from Aiken et al. 1996, used with permission.

All reports of *Festuca campestris*, *F. hallii*, and *F. scabrella* in Colorado for which habitat data are available are from open sites. These include sites above treeline as well as meadows in the subalpine zone. Meadows are treeless areas dominated by various species of grasses, sedges, and forbs that are scattered throughout the forests of the Rocky Mountains (Peet 2000). There is little agreement on what ecological processes are responsible for the creation and maintenance of meadows. Meadows in Rocky Mountain National Park are maintained by a combination of saturated soils, high snow accumulation, cold air drainage, and fine-textured soils (Peet 2000). The unforested areas on Cordova Pass are probably glades that are maintained by deep snowdrifts.

Climate

Festuca campestris is a cool-season grass that is adapted to a short growing season. The effects of temperature and moisture on the performance of *F. campestris* have been studied extensively and are well known. Weaver (1979) and King et al. (1998) conducted the most comprehensive studies of the climatological requirements of members of the *F. scabrella* complex.

The fescue grasslands of North America share similar climate attributes. Mean temperatures in the coldest month range between –3 and –10 °C; mean temperatures in the warmest month range between 14 and 18 °C. The growing season includes two to four months with fewer than six frost days, and usually less than two months in which evapotranspiration exceeds precipitation (Weaver 1979). *Festuca scabrella* is associated with mesic grassland sites having annual precipitation of more than 14 inches and a short, cool growing season (Weaver 1979). *Festuca campestris* occurs in more mesic and cooler sites than *F. hallii* and *F. altaica* (Aiken and Darbyshire 1990). It also requires a minimum of 90 frost-free days during the growing season (USDA Natural Resources Conservation Service 2005).

In comparing the climates of fescue grasslands with those of other vegetation types, Weaver (1979) noted that the climate of fescue grasslands is similar to those of some coniferous forest types. This suggests that other factors besides temperature and precipitation are responsible for maintaining fescue prairies, including possibly wind, snow cover, soil characteristics, or fire frequency. Gould and Shaw (1983) noted climatological distinctions between fescue grasslands and mixed-grass prairie. Fescue grasslands occur in regions of greater moisture efficiency than do mixed prairie communities. The availability of moisture is enhanced by lower temperatures, lower

evaporation rates, and slightly higher precipitation in fescue grasslands. A short growing season is also associated with the lower temperatures in fescue grasslands. *Festuca scabrella* is found in wetter sites than *F. idahoensis* (Antos et al. 1983).

King et al. (1995, 1998) observed differences in biomass allocation under different temperature regimes in *Festuca altaica*, *F. hallii*, and *F. campestris*. They shared a similar temperature for optimal growth, but the relative performance of each species differed. *Festuca campestris* grew better (measured by harvested biomass, tiller number, and leaf area) than the other two species at the coolest temperature (approximately 12 °C mean daily maximum) and worse at warmer temperatures, where *F. altaica* and *F. hallii* performed best (approximately 17 °C mean daily maximum). This is advantageous to *F. campestris* by enabling it to grow at low temperatures prior to the onset of summer drought that restricts the growing season in most of its range. This contrasts with *F. altaica* and *F. hallii*, for which summer precipitation is generally adequate to support growth (King et al. 1995, Hill et al. 1997).

There are many differences between the climate regime at the heart of the range of *Festuca campestris* and the site at Cordova Pass, Colorado. *Festuca campestris* requires moist soil; therefore, it is most commonly found on north- and east-facing slopes in the foothills region of the northern Rocky Mountains (Stout et al. 1981). At Cordova Pass, the meadow visited by Elliott (personal communication 2005) slopes 5 degrees to the south. The minimum precipitation requirement for *F. campestris* is 16 inches per year (USDA Natural Resources Conservation Service 2005). Precipitation requirements for *F. campestris* are met at Cordova Pass, where annual precipitation is approximately 25 to 30 inches per year (Bureau of Land Management 1998). In Colorado, open sites on Cordova Pass are probably glades maintained by heavy snow cover. As snow melts in the spring, the wet spring conditions preferred by *F. campestris* are likely, and monsoonal summer rains are likely to ameliorate summer drought conditions in many years.

Soil

Festuca scabrella grows on a number of soil types, including loams and silty loams (Koterba and Habeck 1971). *Festuca scabrella* is dominant on deep, black chernozemic (mollisol) soils of western Canada (Willms 1988). Soils at Cordova Pass are in the Moran, Leadville, Aschcroft, and Rogert families (Pike-San Isabel National Forest no date). They tend to be well to excessively drained, with a rooting depth exceeding 20 inches. They have low to moderate available water capacity, rapid runoff, and slow to moderately rapid permeability. These soil families occur on moderate to steep slopes.

Elevation

Elevation ranges of the *Festuca scabrella* complex are summarized by Tirmenstein (2000), but are not species-specific. The lowest elevations (1,900 ft.) are occupied by *F. hallii* in Saskatchewan, while the highest elevations outside Region 2 are occupied by *F. campestris* in Oregon (9,500 ft.).

Succession

Festuca campestris is a climax species of fescue grasslands (Willms and Fraser 1992), but it can occur in early, mid-seral, and climax communities (Tirmenstein 2000). It is characteristic of many late-successional mountain grassland and fescue prairie communities (Tirmenstein 2000). In the *F. campestris* grasslands of Alberta, complete recovery following light grazing took approximately 14 years (Willms et al. 1985), while succession to a near climax state required more than 20 years following heavy grazing (Dormaar and Willms 1990). *Festuca scabrella* is a component of early seral communities following fire because of plant survival (Moss and Campbell 1947).

Fire

There has been extensive study of the effects of fire on *Festuca campestris*. Tirmenstein (2000) provided a comprehensive review of this literature, and is recommended for further information on this topic.

The dense, tufted habit of *Festuca campestris* suggests that it is adapted to low-intensity, periodic burning (Aiken and Darbyshire 1990). However, *F. campestris* and *F. altaica* are more susceptible to fire damage than is the rhizomatous *F. hallii* (Tirmenstein 2000). Although densely packed tiller accumulation helps to insulate the perennating buds when fire severity is low, under dry burning conditions, dense tiller litter may encourage hot fires (Thompson 1990), which can penetrate the organic layer, burn into root crowns, and damage the belowground portions of the plant (Thompson 1990, Bork et al. 1996). Antos et al. (1983) suggest that the historical fire return interval of 5 to 10 years is probably most beneficial to *F. scabrella* in Montana. A shorter fire return interval tends to impede re-establishment (Anderson and Bailey 1980), while

longer return intervals result in higher mortality of individuals due to fuel buildup.

Festuca campestris is initially reduced by fire regardless of the season of burning, and productivity may be reduced for one to three years (Redmann et al. 1993, Cory 2005). Reduction in primary production is due to injury to the plant, as well as decreased soil water potential on burned sites (Willms 1988). Most plants survive fires under the high-moisture conditions associated with spring and fall burns (Bailey and Anderson 1978, Jourdonnais and Bedunah 1986). *Festuca scabrella* is unharmed by light burning during dormancy (Anderson and Franzen 1983), but it can be severely reduced when burning occurs during the growing season (Bailey and Anderson 1978). In aspen parklands of southern Alberta, Bailey and Anderson (1978) reported a 26 percent decline one year after a spring burn, compared to a 6 percent decline after fall burning. Despite burning at high temperatures, *F. scabrella* can sometimes initiate conspicuous green shoots within a week after the fire (Tirmenstein 2000). Jourdonnais and Bedunah (1990) and Redmann et al. (1993) recommend periodic burning of *F. scabrella* to reduce invasion of woody species such as aspen, and to remove litter accumulations.

Reproductive biology and autecology

Festuca campestris, like many grasses that are community dominants in productive ecosystems, fits into the competitive category in the Competitive/Stress-Tolerant/Ruderal (CSR) model of Grime (2001). *Festuca campestris* is capable of rapid primary growth during the most productive portions of the growing season. *Festuca scabrella* can produce more than 2000 kg per ha of forage (Willms et al. 1986). The negative response of *F. campestris* to disturbance (e.g., fire, soil movement, grazing) is also typical of competitive strategists in the CSR model. Soil disturbance by grazing is likely to result in a seral community dominated by annual forbs than a *F. campestris* dominated grassland (Willms and Quinton 1995). Grazing led to local extirpation of *F. campestris* (Dormaar and Willms 1990), and fire, although it appears to be necessary to prevent the encroachment of woody perennials, also results in lasting impacts when it occurs during the growing season (Bailey and Anderson 1978).

As a long-lived perennial species that probably devotes several years to vegetative growth before reproducing, and that lives in a stable environment at or near its carrying capacity, *Festuca campestris* can be regarded as a K-selected species in the classification scheme of MacArthur and Wilson (1967).

Reproduction

Festuca campestris reproduces primarily by seed (Pavlick and Looman 1984, Aiken et al. 1996, USDA Natural Resources Conservation Service 2005). It produces seed very erratically, and several years may pass without appreciable seed set (Johnston and MacDonald 1967, Tirmenstein 2000). In southern Alberta, Johnston and MacDonald (1967) reported large amounts of seed production in 1902, 1952, 1964, and 1966. Seeds of most *Festuca* species are dispersed by wind and animals (Johnston 2002). They apparently germinate over a wide range of temperatures (Tirmenstein 2000), but germinate best at 13 °C (Baskin and Baskin 2002).

Festuca campestris does not spread vegetatively as does *F. hallii* (Aiken et al. 1996). It is a bunchgrass and rarely produces rhizomes (Pavlick and Looman 1984, Harms 1985). This species does produce tillers, but these are typically vegetative and lack flowering culms (Willms 1988).

Virtually all fescues, and many other grasses, are capable of producing leafy bulbils or plantlets in place of the floral bracts. This is most common in stressed plants, where it is initiated by the disruption of hormonal regulation. This is sometimes called "vivipary," but these structures are not derived from the sexual portions of the flower as the term might suggest (Aiken and Darbyshire 1990).

Pollination ecology

Most grasses, including members of *Festuca*, are anemophilous, with pollen transfer mediated entirely by wind. The use of wind as a pollen vector requires the production large amounts of pollen. In a study of the effects of distance and density on gene flow in *F. pratensis*, pollen capture from donor plants declined steeply beyond a distance of 15 m, but measurable pollen quantities were still detected at distances of 155 m (Rognli et al. 2000). This study illustrates the decline in effectiveness in wind-mediated pollen transfer with distance that is likely in *F. campestris*, although this effect has not been studied in this or other members of the *F. scabrella* complex.

Phenology

Stout et al. (1981) studied the phenology of *Festuca campestris* in interior British Columbia, from which the following summary is derived unless otherwise noted. *Festuca campestris* typically initiates growth immediately following snowmelt, completes growth before the onset of summer drought, and is dormant by October. Growth usually begins by mid-April and ceases by late June. Culm growth begins in late May and ceases by the time leaf growth has ended. Onset of growth in the spring appears to be controlled by soil temperature rather than soil water content or air temperature (Johnston and MacDonald 1967, Stout et al. 1981). Flowering occurs from mid-May to mid-June, with seed dispersal in mid to late July. As is the case for most cool-season grasses, the seed crop is initiated in August and early September and partially develops during the fall, with final seed head maturation occurring the next summer. Rapid culm elongation occurs during May and early June (Tirmenstein 2000).

Fertility and propagule viability

The germination rate of seeds of *Festuca scabrella* is relatively high, ranging from 86 to 97 percent (Johnston and MacDonald 1967). Bailey and Anderson (1978) observed drastic reductions in seed production following spring burning. They suggested that floral initiation is not affected by spring burns, but by May, the greater height of reproductive growing points leaves them susceptible to fire damage. Fall burning did not affect seed head development the following year. USDA Natural Resources Conservation Service (2005) describes seedling vigor as "medium."

Phenotypic plasticity

Festuca campestris is morphologically plastic. Aiken et al. (1996) note that "leaf morphology is phenotypically plastic and many factors appear to result in reduced numbers of sclerenchyma strands, for example, when the leaves (a) have developed early in the growing season, (b) are relatively long, (c) come from a plant that has grown at high altitudes, (d) have regrown from tussocks that have been burnt or, (e) been severely grazed. This is shown in specimens towards the southern end of the distribution range and well documented in a U.S. collection of specimens from Eastern Washington and Northern Montana. These specimens sometimes have leaves that are similar to those of *F. hallii*, but inflorescences and spikelets of *F. campestris*."

Mycorrhizae

The response of *Festuca campestris* to infection with mycorrhizal fungi may include larger size or the production of wide, flat leaves. Aiken and Fedak (1992) describe two plants of *F. campestris* in Alberta that were growing close together but were conspicuously different in size and morphology. The arbuscular mycorrhizal (AM) fungus *Glomus fasiculatus* was found in the roots of the larger individual.

In greenhouse experiments, AM fungi had strong indirect effects on the outcome of competitive interactions between *Festuca idahoensis* and a noxious weed, spotted knapweed (*Centaurea stoebe* ssp. *micranthos*; Marler et al. 1998). In these experiments, non-mycorrhizal *F. idahoensis* was 171 percent larger than mycorrhizal individuals were when grown with spotted knapweed, suggesting that AM fungi mediate the competitive interactions between these species and give a competitive advantage to spotted knapweed. These results suggest that AM fungi may increase the susceptibility of fescue grasslands to invasion by spotted knapweed.

Hybridization

Taxa within the *Festuca scabrella* complex are not listed among members of *Festuca* that hybridize (Aiken and Darbyshire 1990). Because *F. campestris* has twice the number of chromosomes of *F. hallii* and *F. altaica*, it is possible that it arose from a hybridization event involving these or other taxa. *Festuca campestris* is not an autoploid of either *F. hallii* or *F. altaica* (Aiken and Gardiner 1991, Aiken et al. 1996). It is possible that *F. campestris* is an allopolyploid of *F. altaica* x *F. hallii*. Aiken and Gardiner (1991) investigated this possibility, but the results were not conclusive.

Demography

While there has been a considerable amount of research on other aspects of *Festuca campestris* and *F. hallii*, there have been few studies dealing with the demography of any member of the *F. scabrella* complex. Most research involving these species has dealt with the impacts of grazing on demographic variables (e.g., Johnston et al. 1969, Willms and Quinton 1995, May et al. 2003). The vital rates (i.e., recruitment, survival, age at which individuals become reproductive, lifespan, proportion of populations reproducing) have not been measured for *F. campestris* or *F. hallii*. The population genetic characteristics of these species also have not

been investigated. No population viability analysis (PVA) has been performed for *F. campestris*. **Figure 13** is a life cycle graph (after Caswell 2001) of *F. campestris* based on available information.

The best-studied species of *Festuca* in terms of demography are *F. rubra* and *F. trachyphylla*, from which some very general inferences can be made regarding the life history characteristics of *F. campestris*. *Festuca rubra* is rhizomatous, while *F. trachyphylla*, like *F. campestris*, is a non-rhizomatous bunchgrass that reproduces only by seed (Winkler and Klotz 1997). Winkler and Klotz (1997) determined that *F. trachyphylla* becomes reproductive after a period of approximately four years. After 13 years, the survival rate of *F. trachyphylla* begins to decline, with a maximum age of approximately 20 years (Winkler and Klotz 1997).

Most fescues are obligate outcrossers (Johnston 2002), leaving small populations potentially vulnerable to inbreeding depression. Genetic variability within and among populations has not been measured directly in *Festuca campestris* or *F. hallii*. By measuring phenotypic variation and performance in plants grown under controlled conditions over a period of four years, May et al. (2003) observed evidence of genetic variability sufficient to "allow successful establishment over a greater range of environmental variability than present at their origins." Another test suggested inconclusively that selection pressure induced by grazing has resulted in genotypes that are more winter-hardy (May et al. 2003).

Festuca campestris is a polycarpic (iteroparous) perennial that flowers multiple times throughout its lifespan. The recruitment rate and periodicity of recruitment events are not known for *F. campestris* or *F. hallii*. Both species produce seed sporadically (Johnston and MacDonald 1967). Very little is known about the character of the seed bank, and the longevity of seeds in the seed bank is not known. Willms and Quinton (1995) observed the effects of various grazing intensities on the seed bank of *F. campestris*, and they found that grazing

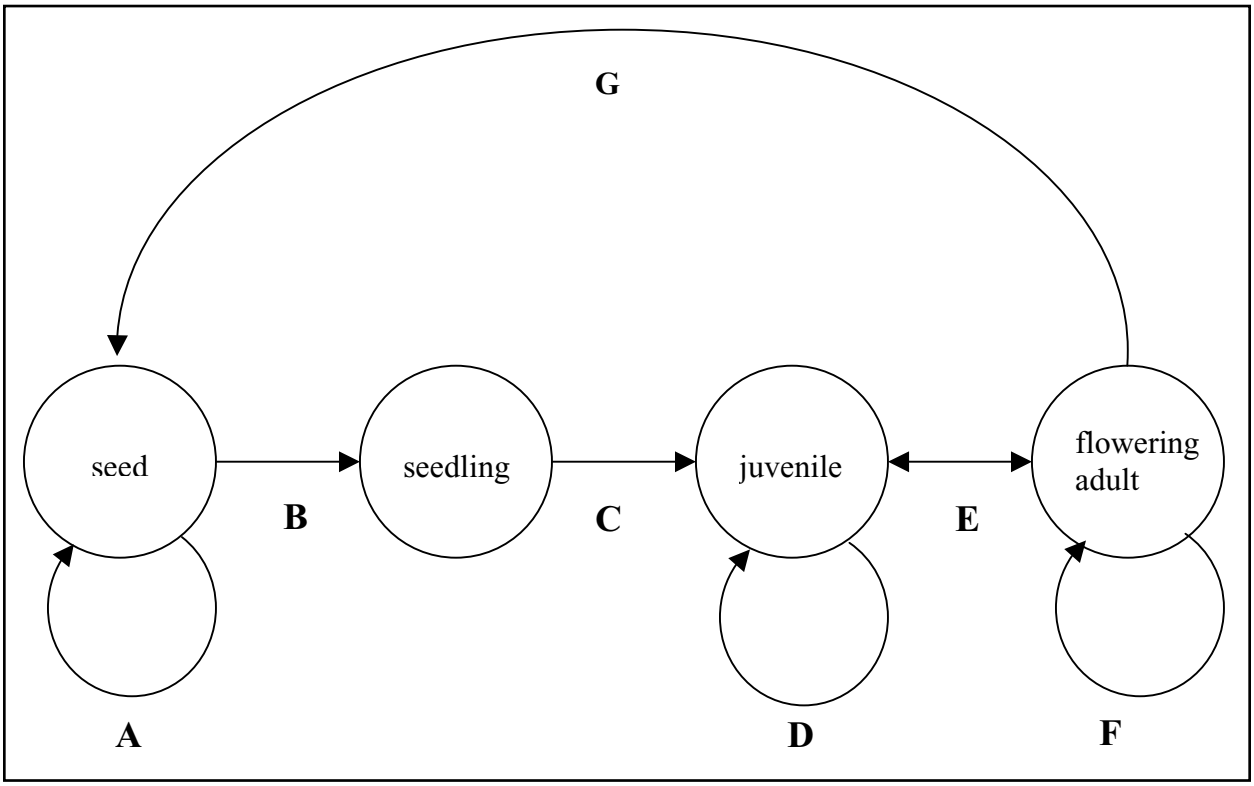

Figure 13. Hypothetical life cycle graph (after Caswell 2001) for *Festuca campestris*. Much of this is speculative because there has been no monitoring where individuals were tracked through their life history stages. The value of A is not known, although seeds are known to persist in the seed bank for a number of years. The duration of the juvenile stage is not known, but plants remain in the juvenile stage for multiple years before reaching reproductive maturity (D). *Festuca campestris* is clearly a polycarpic perennial (F). The lifespan of *F. campestris* is unknown, but may be in the vicinity of 20 years based on other species of *Festuca*.

greatly reduced the number of seeds of *F. campestris* in the seed bank. Johnston et al. (1969) noted a decline in basal area and in the number of viable soil-stored seeds in *F. campestris*.

Community ecology

Throughout its range, *Festuca campestris* is a dominant species in grassland, shrubland, and woodland plant associations (Aiken and Darbyshire 1990, NatureServe 2005). Many authors have studied and described the communities defined by *F. campestris* and its relatives, but in early studies there were no distinctions made among members of the *F. scabrella* complex. There have been many different interpretations of the communities in which these grasses dominate. Fescue grasslands are widespread in western North America, and they are most extensive in Saskatchewan, Alberta, interior British Columbia, and Montana (Gould and Shaw 1983, Romo 2003). Looman (1969) used phytosociological methods to describe the fescue grasslands of western Canada.

Festuca campestris and *F. hallii* are dominant species in vegetation communities in the northwestern Great Plains, in the northern Rockies on both sides of the Continental Divide, and eastern Washington and Oregon (**Table 5**). *Festuca campestris* is dominant in grass- and shrub-dominated associations, as well as in *Pinus ponderosa* (ponderosa pine) woodlands, open ponderosa pine forests, subalpine forest, and on grassy balds within forested areas (Pavlick and Looman 1984, NatureServe 2005). Tirmenstein (2000) lists ecosystems, BLM physiographic regions, Küchler plant associations, forest cover types, and Southern Rocky Mountain rangeland cover types containing *F. scabrella*, but does not distinguish among members of the *F. scabrella* complex in these lists.

Dasiphora floribunda (shrubby cinquefoil) is increasing in the grasslands of Alberta, where it is invading communities dominated by *Festuca campestris* (Scotter 1975). The increase in shrub cover is attributed to overgrazing by elk (*Cervus elaphus*) and horses (Scotter 1975). *Dasiphora floribunda* is also found at Cordova Pass with *F. hallii* (**Figure 14**; Elliott personal communication 2005). Fire suppression (Bailey and Anderson 1978) and nitrogen loading (Köchy and Wilson 2001) have been implicated in the spread of woody species into meadows and prairies. In parts of Montana, large areas of grasslands have been invaded by *Pseudotsuga menziesii* (Douglas-fir), causing reductions in *F. scabrella* dominance (Arno and Gruell 1986). "Brush" has invaded fescue grasslands in central Alberta (Bailey and Anderson 1980).

Herbivores

Festuca campestris and *F. hallii* are the dominant species in their respective grassland associations, and they are important sources of forage for native ungulates and cattle in western Canada (King et al. 1995). Because of their agronomic, economic, and ecological importance, there is a large body of literature dealing with the relationship of *F. campestris* and *F. hallii* with livestock and native wildlife. All three species in the *F. scabrella* complex are very productive and highly palatable to livestock and wildlife (Aiken and Darbyshire 1990).

Festuca campestris and *F. hallii* are prime winter forage because they cure well on the stalk and retain high nutrient levels during dormancy (USDA Forest Service 1937, Wilston and Johnston 1971, King et al. 1995). The nutritive value of these species is above average when compared with associated grassland species in southern Alberta (Bezeau and Johnston 1962). They are most nutritious in the spring prior to the inflorescence emerging (Bezeau and Johnston 1962). Their native status and agronomic potential have increased the demand for these species (King et al. 1995).

Festuca campestris and *F. hallii* are thought to have evolved under intermittent grazing pressures imposed by nomadic herds of bison (Moss and Campbell 1947). Of the relationship between *F. campestris*, *F. hallii*, and bison, Dormaar and Willms (1990) wrote, "The Rough Fescue Prairie historically has been the home of many animal species, the most conspicuous of which was the plains bison (*Bison bison bison* L.). It is believed that bison used this prairie for their wintering grounds by taking advantage of the relatively good quality grass and the presence of warm chinook winds that ensured access to it by eliminating snow cover. Although information is scarce, it appears that mankind's first attempt to manage the prairie resource involved burning the range to eliminate excess litter as a means of attracting bison into an area for hunting. This was likely done in the fall or spring, while plants were dormant and the herbage flammable." *Festuca campestris* and *F. hallii* are the primary food for contemporary bison herds wintering in the *Populus tremuloides* (quaking aspen) parklands of southern Canada (Johnson and Cosby 1966, Morgan 1980, Tirmenstein 2000).

Table 5. Summary of the associations and alliances in which *Festuca campestris* and *F. hallii* are dominant species (NatureServe 2005).

Alliance	Alliance Common Name	Association Scientific Name	G rank	Distribution
Evergreen woodland				
Pinus flexilis Woodland Alliance	Limber Pine Woodland Alliance	*Pinus flexilis / Festuca campestris* Woodland	G3	MT
Pinus ponderosa Woodland Alliance	Ponderosa Pine Woodland Alliance	*Pinus ponderosa / Festuca campestris* Woodland	G3G4	BC, ID, MT, WA
Pseudotsuga menziesii Woodland Alliance	Douglas-fir Woodland Alliance	*Pseudotsuga menziesii / Festuca campestris* Woodland	G4	MT, UT
Evergreen dwarf-shrubland				
Arctostaphylos uva-ursi Dwarf-shrubland Alliance	Kinikinnick Dwarf-shrubland Alliance	*Arctostaphylos uva-ursi / Festuca campestris - Festuca idahoensis* Dwarf-shrubland	G3G4	AB, MT
Perennial graminoid vegetation				
Artemisia tridentata ssp. *vaseyana* Shrub Herbaceous Alliance	Mountain Big Sagebrush Shrub Herbaceous Alliance	*Artemisia tridentata* ssp. *vaseyana / Festuca campestris* Shrub Herbaceous Vegetation	G3Q	AB, BC, MT, WA
Artemisia tripartita ssp. *tripartita* Shrub Herbaceous Alliance	Threetip Sagebrush Shrub Herbaceous Alliance	*Artemisia tripartita* ssp. *tripartita / Festuca campestris* Shrub Herbaceous Vegetation	G2?	BC, MT, WA
Dasiphora fruticosa ssp. *floribunda* Shrub Herbaceous Alliance	Shrubby-cinquefoil Shrub Herbaceous Alliance	*Dasiphora fruticosa* ssp. *floribunda / Festuca campestris* Shrub Herbaceous Vegetation	G4	AB, SK, MT
Festuca campestris Herbaceous Alliance	Prairie Fescue Herbaceous Alliance	*Festuca campestris - Festuca idahoensis* Herbaceous Vegetation	G3	AB, ID, MT, OR, WA
Not assigned	Not assigned	*Festuca campestris - Pseudoroegneria spicata* Herbaceous Vegetation	G4	AB, MT, ND
Festuca idahoensis Alpine Herbaceous Alliance	Idaho Fescue Alpine Herbaceous Alliance	*Festuca idahoensis* - (*Festuca campestris*) / *Potentilla diversifolia* Herbaceous Vegetation		AB, ID, MT
Festuca idahoensis Herbaceous Alliance	Idaho Fescue Herbaceous Alliance	*Festuca campestris* - (*Festuca idahoensis*) - *Achnatherum richardsonii* Herbaceous Vegetation	G2G3?	ID, MT, OR, WA
Not assigned	Not assigned	*Festuca campestris - Festuca idahoensis - Geranium viscosissimum* Herbaceous Vegetation	G3?	AB, MT, OR, WA
Purshia tridentata Shrub Herbaceous Alliance	Bitterbrush Shrub Herbaceous Alliance	*Purshia tridentata / Festuca campestris* Shrub Herbaceous Vegetation	G2?	MT

Figure 14. Habitat at Cordova Pass. Foreground vegetation includes *Lomatium* sp., *Fragaria virginiana*, *Trifolium attenuatum*, and *Achillea lanulosa*. Some *Dasiphora floribunda* (visible at lower right) is also present. Weber (1979) also reported *Festuca arizonica* in this vicinity. Surrounding forests are dominated by *Picea engelmannii* and *Pinus aristata*. Photograph provided by Brian Elliott, used with permission.

Festuca campestris and *F. hallii* are important elements of the diets of native ungulates including bighorn sheep (*Ovis canadensis*), mule deer (*Odocoileus hemionus*), and elk (Tirmenstein 2000). *Festuca campestris* comprises (8 percent) of the annual diet of bighorn sheep in British Columbia (Wikeem and Pitt 1992), and it is the largest component of their diet in July. This species is heavily used by elk on winter ranges, where it can be their primary forage (Jourdonnais and Bedunah 1986, Willms et al. 1996). Elk consumption of *F. campestris* may also be high in other seasons (Singer 1979, Peck and Peek 1991, Kingery et al. 1996). In Alberta, elk and cattle favor *F. campestris* grasslands for forage (Bailey 1986, Tirmenstein 2000). Mule deer (Stelfox 1976) and white-tailed deer (*O. virginianus*; Singer 1979) consume small amounts of *F. scabrella*.

Weber (1979) and Elliott (personal communication 2005) documented burrowing rodent activity in the meadows at Cordova Pass (**Figure 15**). The species present at this site is probably the northern pocket gopher (*Thomomys talpoides*), which produce the "eskers" seen in **Figure 15** (Siemers personal communication 2005). In Colorado, this animal is widespread from shortgrass prairie habitats to the alpine (Vaughan 1967). The population at Cordova Pass is near the upper end of its elevation range. The fossorial and subnival activities of northern pocket gophers can result in significant disturbance of the soil in glades and heavy snow pack areas (Ward and Keith 1962).

Northern pocket gophers collect large quantities of plant material during the winter. Some of these materials are consumed, and others are used to construct nests either below the soil surface or within the snow mantle (Bleak 1970). On high elevation grasslands (between 9,000 and 10,500 ft.) on Black Mesa, Colorado, northern pocket gophers favored *Festuca idahoensis* over other grasses for forage, but grasses were probably eaten incidentally because forbs constituted 93 percent of the diet (Ward and Keith 1962). Thus, it is possible that the presence of large numbers of pocket gophers may help shift the competitive balance in subalpine meadows in favor of grasses.

Figure 15. Habitat at Cordova Pass, showing soil disturbance by northern pocket gopher (*Thomomys talpoides*). This animal has been described as an "ecosystem engineer," having considerable effects on vegetation composition and structure. Photograph provided by Brian Elliott, used with permission.

Willms and Johnson (1990) observed two species of grasshopper using *Festuca scabrella*. *Camnula pellucida* (clear winged grasshopper) showed no forage preferences, but *Melanoplus sanguinipes* (migratory grasshopper) showed a preference for *F. scabrella*. The impact of these species on *F. scabrella* was proportional to their percent utilization. The authors suggest that grasshoppers, particularly M. sanguinipes, have the potential to shift species composition and to reduce the dominance of *F. scabrella*.

Livestock grazing

There has been extensive study of the effects of livestock grazing on *Festuca campestris* and *F. hallii*, and much research has been devoted to developing sustainable grazing practices on grasslands dominated by these species. Livestock prefer both of these species (USDA Forest Service 1937).

Festuca campestris and *F. hallii* are sensitive to summer grazing, and they will decline when grazed heavily during the growing season (Johnston 1961, McLean and Wikeem 1985a, King et al. 1998, Willms and Fraser 1992). *Festuca campestris* showed steep declines in top growth and root mass with 20 percent defoliation (Johnston 1961, Willms and Fraser 1992). Basal area is a good indicator of grazing history on most sites. Light season-long grazing reduces basal area (McLean and Wikeem 1985b). Following heavy grazing, large, robust bunches are typically reduced to small, inconspicuous shoots (Tirmenstein 2000). Two to five summers of heavy grazing can effectively eliminate *F. campestris* and *F. hallii* from rangelands (Johnston and MacDonald 1967, Willms et al. 1988). The erect growth form of *F. campestris* permits livestock to remove most of the photosynthetic material (Tirmenstein 2000). In clipping experiments, cutting frequency had a greater effect on plant yield than cutting height (Willms 1991). The negative impact of cutting was greatest when the plants were cut weekly to a height of 5 cm in May and June and least when plants were harvested before June (McLean and Wikeem 1985b).

Fescue grasslands are easily damaged by defoliation during the growing season (Willms and

Johnson 1990). It may require 20 to 40 years for overgrazed ranges of *Festuca campestris* and *F. hallii* to recover to excellent range condition (McLean and Tisdale 1972, Willms et al. 1985, Willms and Johnson 1990). In western Montana, *F. scabrella* is one of the first species to decline after grazing (Chaffee and Morriss 1982). Grazing may result in increased dominance by less desirable species of grasses, woody plants, and exotic species. Even under light summer grazing, *Danthonia parryi*, which is more tolerant of grazing, replaces *F. scabrella* as the dominant species in fescue grasslands (Johnston 1961, Willms 1991). Other species that commonly increase with livestock grazing of fescue grasslands include *F. idahoensis* (Idaho fescue), *Stipa* spp. (needlegrass), *Koeleria macrantha* (Junegrass), *Carex filifolia* (threadleaf sedge), *Agropyron* spp. (wheatgrass) *Artemisia frigida* (fringed sage), *Oxytropis campestris* (field locoweed), *Antennaria* spp. (pussytoes), *Taraxacum officinale* (dandelion), and *Chrysothamnus nauseosus* (rubber rabbitbrush) (Johnson 1961, Wilston and Johnston 1971, Dormaar and Willms 1990). In disturbed situations, *F. scabrella* may be reduced to minor importance or may be completely removed from the community (Gould and Shaw 1983). *Festuca scabrella* remained stable in lightly grazed plots but declined in more heavily grazed plots at Pine Butte Swamp Preserve in Montana. It was less sensitive to livestock grazing than *Agropyron spicatum* (Lesica and Hanna 2002). A single grazing event after a fire did not appear to exacerbate impacts on *F. campestris*, but because of its low forage value immediately following a fire, there is little to justify the increased risk to *F. campestris* by grazing it after fire (Bogen et al. 2003).

Both *Festuca campestris* and *F. hallii* tolerate winter grazing (USDA Forest Service 1937, Johnston and MacDonald 1967, Willms et al. 1996). Experiments with cutting frequency and cutting height confirm that fall or winter grazing is the most sustainable use of *F. campestris* grasslands (Willms 1991). Jourdonnais and Bedunah (1986) reported that 80 percent utilization of *F. campestris* can occur during dormancy without any appreciable loss of summer vigor. Grazing during dormancy may enhance plant vigor by stimulating tillering (Willms et al. 1986). In Alberta, production potential of *F. campestris* was not affected when plants were harvested once at the end of August in three consecutive years (Willms and Fraser 1992).

Parasites and disease

There have been no reports of parasites or disease among the observations of *Festuca scabrella* and *F. hallii* in Region 2. Aiken and Darbyshire (1990) report that 67 species of pathogenic or decay fungi have been identified from at least nine *Festuca* species in Canada. Ergot (*Claviceps purpurea*) epidemics often occur locally, to which grasses and sedges are susceptible. Members of the fungal tribe Balansiae are systemic endophytes that are closely related to ergot and produce toxic alkaloids. These can actually benefit their hosts by providing protection from herbivory, but can present a serious problem to grazing livestock (Aiken and Darbyshire 1990).

CONSERVATION

Threats

Current information indicates that *Festuca campestris* is not present in Region 2. If this is true, human activities in Region 2 do not threaten its viability. At Cordova Pass, where *F. campestris* was thought to occur, there are several possible threats that are pertinent to the habitat at this site and that could threaten *F. hallii* at this location. Similar threats pertain to other locations in Colorado where *F. scabrella* was documented; these are discussed in this section. Because there has been no report of *F. campestris* in Wyoming, threats dealing specifically with *F. hallii* in that state are not described explicitly here; instead, they are addressed in a Technical Conservation Assessment for that species (Anderson 2006).

Threats to fescue plants and habitat at Cordova Pass and elsewhere in Colorado include grazing, fire and fire suppression, invasion by exotic species, residential development, recreation, effects of small population size, pollution, handling, and global climate change. These threats and the hierarchy ascribed to them are based primarily on studies of members of the *Festuca scabrella* complex outside of Region 2. Grazing, disturbance, agriculture, and nitrogen pollution have all been shown to decrease habitat quality for *F. campestris* outside of Region 2 (USDA Forest Service 1937, Looman 1969, Dormaar and Willms 1998, Köchy and Wilson 2001).

Grazing

The effects of livestock grazing on *Festuca campestris* are well documented (e.g., Willms and Fraser 1992, Dormaar and Willms 1998, see also the Herbivores section). Most of this research was done in the heart of the range of *F. campestris*. There has been no research on the effects of grazing on the *F. scabrella* complex in Region 2 from which to make inferences.

Cattle grazing of *F. hallii* appeared light in Wyoming (Fertig 2002).

Studies in Canada concluded that heavy grazing (above 2.4 AUM per hectare) jeopardizes fescue grassland ecosystem sustainability by reducing fertility and water-holding capacity. Even light grazing (1.2 AUM per hectare) during the summer causes *Festuca campestris* and *F. hallii* to decline (Dormaar and Willms 1998).

In Colorado, 400 head of cattle graze the West Creek cattle and horse allotment at Cordova Pass. This allotment is shared by two permittees, one of whom has an on/off permit (Elliott personal communication 2005, Olson personal communication 2005, Vallejos personal communication 2005). An on/off permit is issued if National Forest System land is a small portion of the total grazed area. Cattle do not frequent the portion of the allotment where *Festuca hallii* occurs, and grazing impacts to this location appear minimal (Elliott personal communication 2005). Elliott (personal communication 2005) did not see a single cow fecal pat at Cordova Pass in 2004. Cattle are not encouraged to visit this location because of potential conflicts with recreationists. This location also receives limited livestock use because it is difficult for cattle to reach (Vallejos personal communication 2005). Because this is an on/off permit, it is not possible to quantify grazing intensity in AUMs per hectare. The use of temporary corrals in the meadows at Cordova Pass or elsewhere could have serious impacts on *F. hallii* (Elliott personal communication 2005).

All allotments in the Wet Mountains of Custer County are active, except for the Beulah Allotment, which is vacant. There are proposals to use portions of the Beulah Allotment with the Ophir Allotment to give more flexibility in grazing management (Vallejos personal communication 2005). Because the location of *Festuca scabrella* in Custer County is uncertain, the impacts resulting from grazing in these allotments cannot be assessed.

The Shipman Park allotment (where Wasser documented *Festuca scabrella* in 1954) is vacant and has been recommended for closure (La Fontaine personal communication 2005). This area receives heavy but localized horse grazing during the hunting season. The horses are often hobbled in the meadows where they tend to migrate towards riparian areas (Popovich personal communication 2005). Riding and pack stock (horses and mules) associated with outfitter and guide operations and with other recreationists use the Upper Laramie and Shipman Park allotments (LaFontaine personal communication 2005). Outfitter and guide stock graze an estimated 8 head months (1 horse for 1 month's use), nearly all during the big game hunting seasons (September through December) when *F. scabrella* is likely to be dormant. No estimates of recreation stock grazing intensity are available. Pack stock grazing is confined, and many outfitters and hunters feed their stock pellets (LaFontaine personal communication 2005). Allotment status for all occurrences on National Forest System lands is summarized in **Table 6**.

The negative effects of grazing on fescue grasslands are greatly exacerbated if pocket gophers are present. Soil displacement by gophers was three times greater in a very heavily grazed (4.8 AUMs per hectare) field and seven times greater in a lightly grazed (1.2 AUMs per hectare) field (Shantz 1967). These observations suggest that the meadows at Cordova Pass are more sensitive to livestock grazing than might otherwise be expected due to the presence of northern pocket gophers at this location.

Current grazing intensities are much lower now than they were historically where *Festuca campestris*, *F. hallii*, and *F. scabrella* were documented in Colorado and Wyoming. Grazing intensities in South Park were very high between the 1920s and 1950s. Sheep grazing was more common in *F. hallii* habitats in South Park in the 1800s and early 1900s (Lamb personal communication 2005). Both cattle and sheep have been grazed throughout the Rawah Mountains of western Larimer County, Colorado. Grazing was much more intense in these areas until the 1970s than it is now (LaFontaine personal communication 2005, Popovich personal communication 2005). Historic grazing practices on the Shoshone and Bighorn national forests of Wyoming have probably reduced and degraded *F. campestris* habitats (Tweit and Houston 1980, Fertig 2002).

In the Cordova Pass area, only 5 percent of Donald Park is within the Pike National Forest; the rest is privately owned and is grazed (Elliott personal communication 2006). This situation is common elsewhere in Colorado because productive montane grasslands were homesteaded prior to the creation of the USFS.

Altered fire regime

Fire suppression has led to the encroachment of shrubs and trees in the fescue grasslands of Canada.

Table 6. Allotment status for all reports of *Festuca scabrella*, *F. campestris*, and *F. hallii* on National Forest System land in Colorado.

Allotment	County	Occurrence	Allotment status
Shipman Park	Larimer	Wasser (1954)	Recommended for closure in 1997 forest plan/ currently vacant, last grazed in 1990
Upper Laramie	Larimer	CO EO #1; *Weber and Pickford 9694*	Currently vacant, not grazed since 1994
Allotments in Wet Mountains	Custer	*Harrington (1954)*	All are currently active except Beulah, which is vacant
Allotments in Northern South Park	Park	*Hall and Harbour 621*; Weber (2001)	Active, vacant, and closed
West Creek	Huerfano/ Las Animas	CO EO #1; *Weber and Wingate 15442*	Cattle and horse, shared by 2 permittees with an on/off permit. 400 head of cattle (217 AUMs) are currently grazed on this allotment between June 15 and October 15. Difficult to determine AUMs/hectare because of the nature of this permit. Cattle do not often visit the portion of the allotment near the occurrence
North Fork, East Peak	Huerfano/ Las Animas	Possibly *Swallen 1302*	Vacant
Lakes and Indian Creek	Huerfano/ Las Animas	Possibly *Swallen 1302*	Active

Populus tremuloides has encroached in many fescue grasslands but annual burning stopped invasion of *P. tremuloides* in *Festuca hallii* grasslands (Gerling et al. 1995, Tirmenstein 2000). However, burning, in either the spring or the fall, decreased the cover of *F. scabrella* for at least three years near Edmonton, Alberta (Gerling et al. 1995). The response of *F. scabrella* to fire is complex, and fire cannot be considered purely beneficial or detrimental to grasslands dominated by these taxa (Bailey and Anderson 1978, Romo 2003, Rice and Harrington 2005). The current character of most remnant fescue grasslands is the result of altered fire regimes (Romo 2003).

Residential development

Residential development, primarily second home construction, threatens suitable *Festuca hallii* habitat at Cordova Pass (Elliott personal communication 2006). Because the montane grasslands in the Spanish Peaks area are highly productive, many of these have been in private hands for many years and have not been searched for rare plants. There has been considerable subdivision and construction in this area during the past ten years. Urban growth rates are faster in the Colorado Front Range than anywhere else in the United States. Low and medium density development, which is common along the Colorado Front Range, fragments large areas of natural habitat (Knight et al. 2002). The proliferation of roads and construction are likely to encourage the spread of noxious weeds into developed areas. Forman and Alexander (1998) reviewed the ecological impacts of roads and road construction, including fragmentation.

Recreation

Recreational use of the Cordova Pass area poses a threat to the *Festuca hallii* occurrence there (Elliott personal communication 2005). A large trailhead at Cordova Pass receives heavy use because it is the primary access point to the summits of the Spanish Peaks. A wide trail passes through the occurrence and a USFS campground has been constructed at the edge of the occurrence (Elliott personal communication 2005). The campground's placement is unfortunate, but it may benefit the occurrence of *F. hallii* by concentrating recreational impacts and discouraging visitors from establishing informal campsites. Recreational use of livestock also threatens *F. hallii* (discussed in the Grazing section). Pack stock are usually either tethered or kept inside an electric fence. Weed free forage rules are in effect around Cordova Pass, but seeds of smooth brome (*Bromus inermis*) are not prohibited in weed-free hay, and other weed seed contaminants are likely to be present in manure (Elliott personal communication 2006).

Pollution

Atmospheric nitrogen deposition has become one of the most important agents of vegetation change in densely populated regions (Köchy and Wilson 2001). Nitrogen deposition appears to accelerate the expansion of forest into temperate grasslands; Köchy and Wilson (2001) observed a strong positive relationship between forest expansion into fescue grasslands and nitrogen deposition in six Canadian national parks.

Nitrogen loading and vegetation change is greatest near large metropolitan areas (Schwartz and Brigham 2003). Measurable impacts from nitrogen pollution might be expected in all locations where members of the *Festuca scabrella* complex have been reported in Colorado. Nitrogen enrichment experiments show universally that nitrogen is limited (Gross et al. 2000). While nitrogen enrichment is likely to cause a few species to increase in abundance, many others decline (Schwartz and Brigham 2003). The degree to which nitrogen pollution has resulted in the encroachment of woody species into the habitats of *F. hallii* (and possibly *F. campestris*) in Region 2 is unknown.

Climate change

Global climate change is likely to have wide-ranging effects in the near future for all habitats, but the direction of projected trends is yet to be determined, and predictions vary based on environmental parameters used in predictive models. The prevailing scientific opinion, based on numerous studies, is that global temperatures are increasing and will continue to increase through the next century, due in part to anthropogenically elevated levels of atmospheric CO_2 (Reiners 2003). The upper limit of global temperature increase over the next century is estimated to be 6 °C (Reiners 2003). Climate change scenarios for the Rocky Mountains offer different predictions of precipitation quantity and pattern. Some scenarios indicate that annual precipitation over the next 100 years will increase, but growing season precipitation will decrease (Giorgi et al. 1998). Other scenarios indicate that parts of the Rocky Mountains are likely to become drier. Any of these scenarios is likely to have significant effects on the distribution of montane grasslands in Region 2. Temperature increase could cause vegetation zones to climb 350 ft. in elevation for every degree Fahrenheit of warming (U.S. Environmental Protection Agency 1997), and this is likely to result in net drying due to increased potential evapotranspiration (Reiners 2003). This type of change is likely to result in a decline in habitat quality or availability that may extirpate *Festuca campestris* locally. Changes in precipitation patterns could also result in habitat loss. In experimental manipulations of winter snow pack on *F. idahoensis* meadows, increased snow depth caused decline in aerial cover of *F. idahoensis* (Weaver and Collins 1977). The effects of landscape-level vegetation change on potential *F. campestris* habitats cannot be assessed within the confines of Region 2 since this species is not known to occur there.

Interaction of the species with exotic species

Grasslands dominated by *Festuca campestris* and *F. hallii* are susceptible to weed invasion (Tirmenstein 2000). In Montana, the lower montane zone is particularly susceptible (Forcella and Harvey 1983). Noxious weed species such as leafy spurge (*Euphorbia esula*), Dalmatian toadflax (*Linaria dalmatica*), St. Johnswort (*Hypericum perforatum*), and spotted knapweed (*Centaurea stoebe* ssp. *micranthos*) have invaded *F. campestris* grasslands in Montana (Rice and Harrington 2005). Fescue grasslands in the Bob Marshall Wilderness and in Glacier National Park have also been invaded by leafy spurge (Bedunah 1992). In Montana, fescue grasslands have been described as "fairly resistant" to invasion by spotted knapweed, but this species is highly invasive and has invaded grasslands dominated by *F. idahoensis* (Olson et al. 1997) and *F. campestris* (Rice and Harrington 2005). Sheep grazing reduces the abundance of spotted knapweed in *F. idahoensis* grasslands, but causes Kentucky bluegrass (*Poa pratensis*) cover to increase (Olson et al. 1997). Grazing increased the germination of seed and the vegetative expansion of Kentucky bluegrass in *F. campestris* grassland (Willms and Quinton 1995). Smooth brome is invading fescue grasslands in Saskatchewan (Grilz and Romo 1995). Cheatgrass (*Bromus tectorum*) has invaded many *F. idahoensis* and *F. campestris* stands (Goodwin et al. 1999, Rice and Harrington 2005).

Threats from over-utilization

In collecting *Festuca campestris* and *F. hallii* for scientific purposes, collectors should take care not to remove entire plants from small populations (Wagner 1991, Pavlovic et al. 1992). Leaf handling by researchers has been shown to increase insect herbivory significantly in *F. campestris* (Hik et al. 2003). Collection and leaf handling present a minor risk overall for populations of *F. campestris* or *F. hallii* in Region 2, but impacts are possible if research is conducted that requires collection or contact with a significant portion of a population.

Conservation Status of Festuca campestris in Region 2

Research has shown that *Festuca campestris* is vulnerable to any grazing that occurs during the growing season, altered fire regimes, and nitrogen pollution. *Festuca campestris* and *F. hallii* are climax species that recover slowly from disturbance. If *F. campestris* is present in Region 2, then it is disjunct and genetically isolated from the center of its range. Hypothetical populations in Region 2 are at risk where heavy grazing of high elevation grasslands occurs. Where the natural fire regime has been suppressed or altered, occurrences of *F. campestris* would be threatened by the invasion of trees, shrubs, and exotic species.

Management of Festuca campestris in Region 2

Implications and potential conservation elements

Festuca campestris was long thought to be present in Region 2 due to confusing taxonomy, historic reports under a variety of names, a lack of proper diagnostics in local floras and keys, misidentifications, and lack of inventory. The implications of the findings presented in this assessment are threefold. First, current information suggests that *F. campestris* is not present in Region 2 and therefore does not warrant USFS sensitive species status in Region 2. Second, new surveys, ideally supported by deductive and inductive approaches for identifying probable habitats, are needed because there is a chance that undiscovered occurrences of *F. campestris* are present in Region 2. Third, opportunities for the management and conservation of members of the *F. scabrella* complex in Region 2 are limited to *F. hallii*.

Research outside of Region 2 suggests that undiscovered occurrences of *Festuca campestris* may be affected by activities that are taking place on National Forest System land in Region 2, especially summer grazing by livestock and pack stock. Historic grazing practices may have caused declines in members of the *F. scabrella* complex in Region 2, as they have elsewhere. An altered fire regime may also be affecting habitats of these species in Region 2.

Tools and practices

Species and habitat inventory

Targeted inventories are needed to relocate populations of members of the *Festuca scabrella* complex documented historically in Colorado. Potential habitat for *F. hallii* and possibly *F. campestris* is spread widely across Colorado and Wyoming. The highest priority areas for inventory are near reported occurrences. There are many meadows on Cuchara Pass, Cordova Pass, and along Forest Road 46 that appear to be potential habitat for *F. hallii* (Elliott personal communication 2005). Inventories are needed in northern Wyoming, where the range of *F. campestris* may extend from Montana onto the Shoshone National Forest. However, this area has already received considerable attention in recent botanical surveys (Fertig 1995, Mills and Fertig 1996, Fertig 1998), suggesting that it is less likely that *F. campestris* will be found there. Tweit and Houston (1980) noted that the niche occupied by *F. scabrella* on the Shoshone National Forest is very different from the one it occupies in Montana.

Hill et al. (1997) used deductive (knowledge-based) and inductive techniques to model the distribution of *Festuca altaica*, *F. campestris*, and *F. hallii* in Alberta, Canada. The authors selected ecologically relevant geospatial datasets of critical thresholds under controlled climatic and edaphic environments (King et al. 1995). Using monthly mean climate data (i.e., evapotranspiration ratio, monthly mean maximum temperature), the authors constructed a logical model that predicted the distribution of the target species fairly accurately. Differences in the modeled zones of *F. campestris* and *F. hallii* were best resolved by the May evapotranspiration ratio; for *F. campestris*, P/E in May must be relatively high. Similar datasets are available for Region 2, creating the opportunity to employ similar methods to model the distribution of *F. hallii* and *F. campestris* here.

Fertig (2002) used envelope models and Classification and Regression Tree (CART) techniques to model the potential distribution of *Festuca hallii* on the Bighorn National Forest of Wyoming. Combining CART with envelope models such as DOMAIN, BIOCLIM, or MaxEnt can help to refine a potential

distribution map by adding inference on the likelihood of the presence of *F. campestris* (Thuiller et al. 2003, Beauvais et al. 2004). CART has been used to model the distribution of other sensitive plant species in Wyoming (e.g., Fertig and Thurston 2003). Species distribution modeling is an effective means of determining the extent of suitable habitat on National Forest System land. Techniques for predicting species distributions are reviewed extensively by Scott et al. (2002).

A problem with the models described above is that they do not account for ecologically relevant past events. Historic grazing practices may have removed occurrences of *Festuca hallii* or *F. campestris*, in Region 2. However, without a geospatially explicit dataset of historic grazing intensity, this possibility cannot be accounted for in the model.

Population monitoring

Because *Festuca campestris* appears to be absent from Region 2, there is no need at present to monitor this species. However, if this species is found in Region 2, it is likely that population monitoring will be needed. Population monitoring would involve censusing entire populations (if feasible) or counting a subset of a population within permanent plots. This would be repeated each year at as many occurrences as possible to measure population trend. Ideally, a monitoring program for *F. campestris* would include a system for documenting impacts from known threats and other ecologically relevant information. This could include cover estimates of potential competitors such as exotic species or encroaching woody species.

Lesica and Hanna (2002) describe a method for monitoring the composition of foothills grasslands using the frequency of indicator species. In this study, macroplots were paired at three locations within pastures. One set of macroplots received less than average grazing intensity, while another received average or above average grazing intensity. The third set served as a control. Within each macroplot, 100 microplots of varying size were sampled. Change in frequency of the selected indicator species within each macroplot was the metric used to infer the effects of grazing on these species.

Demographic monitoring

As a non-rhizomatous bunchgrass that reproduces entirely by seed, the methods described by Lesica (1987) would be suitable for demographic monitoring of *Festuca campestris*. Monitoring methods generally employ the use of randomly arrayed systematic sampling units (quadrats). Demographic monitoring involves marking each plant within a quadrat. During annual visits, data are gathered for each marked plant. Ideally, this would include a measure of size (for *F. campestris*, a measurement of basal area would be appropriate; number of culms may also provide valuable information), life history stage, fecundity (the number of fruits or some other measure of reproductive output), and mortality. Recruitment within each quadrat is quantified by counting seedlings. To reduce the chance of missing seedlings, a subdivided quadrat frame can help observers to search each quadrat systematically and objectively. Elzinga et al. (1998) offers additional suggestions regarding this method. Seed viability and longevity can be estimated using small, buried bags containing known numbers of live seeds that are collected and tested periodically using tetrazolium chloride and germination trials on subsets of each bag.

Data from several years of demographic monitoring could provide insight into the rates of change among the life history stages and could be used to determine transition probabilities. These data would also yield insight into the longevity, fecundity, seed bank dynamics, annual growth rate, and recruitment rate of *Festuca campestris*, and would permit the use of modeling in which critical life history stages, minimum viable population size, and probability of long-term persistence could be determined.

Beneficial management actions

Research conducted outside Region 2 suggests that grazing during the dormant season is least detrimental to *Festuca campestris*. For optimum economic return, grazing should occur during the fall or winter because the plant will have a higher nutritional value than other grasses and because it tolerates dormant season grazing (Willms 1991). Deferred-rotation and rest-rotation systems of grazing are recommended for fescue grasslands in Montana (Mueggler and Stewart 1980).

Stocking rates below 1.2 AUM per hectare do not affect range condition of *Festuca campestris*. Stocking rates of 1.6 AUM per hectare led to a marked decline in range condition, including declines in basal area of *F. campestris*. At 2.4 AUM per hectare, *F. campestris* was nearly eliminated and replaced by *Danthonia parryi* (Willms et al. 1985). Dormaar and Willms (1990) discuss considerations for sustainable production on fescue grasslands in Canada that are relevant in Region 2.

Habitat monitoring is not needed unless it is determined that *Festuca campestris* is present in Region 2. Grilz and Romo (1995) recommend monitoring ranges regularly for smooth brome invasion, which has become problematic in the fescue grasslands of Saskatchewan.

Maintaining a natural fire regime is an important consideration in managing for *Festuca campestris*. A fire return interval of 5 to 10 years was most beneficial to *F. scabrella* grasslands in Montana (Antos et al. 1983). Prescribed fire may be needed to prevent the encroachment of woody species into their habitats. Spring burning had no effect on weed abundance in experimental test plots within *F. campestris* populations (Rice and Harrington 2005). To minimize harmful effects to *F. campestris* and *F. hallii*, fire should be avoided during extended dry periods (Wright 1974).

Application of herbicide effectively suppressed some noxious weed species (e.g., leafy spurge, Dalmatian toadflax, St. Johnswort, spotted knapweed) in test plots dominated by *Festuca campestris*. In this experiment, the canopy cover of native bunchgrasses, including *F. campestris*, responded positively to reduced competition from weeds (Rice and Harrington 2005). This research suggests that herbicides may be a valuable tool for restoring weed-infested *F. campestris* grasslands.

Seed banking and propagation

No seeds or genetic material are currently in storage for *Festuca campestris* at the National Center for Genetic Resource Preservation (Miller personal communication 2004). It is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Center for Plant Conservation 2004). Collection of seeds for long-term storage will be useful if restoration is ever necessary. *Festuca scabrella* is valuable for the rehabilitation of disturbed sites because it forms an extensive, fibrous root system (Stickney 1961, Tirmenstein 2000). It has been used for roadside revegetation outside of Region 2 (Tirmenstein 2000).

Festuca campestris seed has been produced at the Bridger Plant Materials Center (Majerus 2005). Baskin and Baskin (2002) outline protocols for the propagation of *F. campestris*. This species is included in restoration seed mixes in Glacier National Park (Majerus 2005). While *F. campestris* can be readily propagated, seed collection is difficult. Seed production averages 150 kg per ha, but difficulties associated with harvest may reduce seed yields to 12 kg per ha (Johnston and MacDonald 1967). Seeds of *F. campestris* should be sown on mesic sites (Tirmenstein 2000).

Information Needs

Although available data suggest that *Festuca campestris* is not present in Region 2, these data are sparse. However, there is sufficient evidence to conclude that conservation action is not appropriate for this species. The distribution in Region 2 of *F. hallii* is better known but also remains poorly understood. Awareness of *F. campestris* by agency botanists and others is needed so that it can be recognized if populations are found in Region 2. This appears most likely in northwestern Wyoming on the Shoshone National Forest; however, only *F. hallii* has been found there to date.

Festuca campestris habitats outside of Region 2 have been the topic of much research, and are thus relatively well understood. Knowledge of *F. campestris* habitats is sufficient to develop distribution models and to identify areas where this species may be present in Region 2.

Additional research and data resources

Stephen Darbyshire is preparing the treatment of *Festuca* for the Flora of North America series (Volume 24, part one of Poaceae). The treatment of *F. campestris* has not yet been completed. This species is included in the Checklist of the Grasses of North America (Barkworth et al. 2005), which will be used as the taxonomic standard for Volume 24.

Festuca hallii is present at the location where *F. campestris* was thought to occur in Colorado. This assessment focuses on presenting information, where relevant, for *F. campestris*. Because of uncertainty regarding the identity of much of the material in Colorado known only as "*Festuca scabrella*," credence was also given to these records since there remains a chance that at least some of these are *F. campestris*. A Technical Conservation Assessment is available for *F. hallii* (Anderson 2006) in which that species is treated in greater detail.

Definitions

Anemophilous – wind-pollinated; producing windborne pollen (Harris and Harris 1999).

Animal Unit Month (AUM) – the amount of forage needed by an "animal unit" (AU) grazing for one month; an animal unit is defined as one mature 1,000 pound cow and her suckling calf (Serafinchon 2001).

Chamaephyte – a low-growing perennial plant whose dormant overwintering buds are borne at or just above the surface of the ground (Barbour et al. 1987).

Competitive/Stress-tolerant/Ruderal (CSR) model – a model developed by J.P. Grime in 1977 in which plants are characterized as competitive, stress-tolerant, or ruderal, based on their allocation of resources; competitive species allocate resources primarily to growth, stress-tolerant species allocate resources primarily to maintenance, and ruderal species allocate resources primarily to reproduction; a suite of other adaptive patterns also characterize species under this model; some species show characteristics of more than one strategy (Barbour et al. 1987).

Deferred-rotation grazing – this system defers grazing on several pasture units in a planned rotation; in year one, a paddock is grazed early until a predetermined Proper Use Factor is reached; during year two, grazing is deferred until seed ripening to allow maximum carbohydrate storage and trampling of seed into the ground; in year three, grazing is deferred to allow new seedling establishment (Saskatchewan Agriculture and Food 2000).

Evapotranspiration ratio – this ratio is expressed as P/E, where P is precipitation at a given site and E is evapotranspiration; if the evapotranspiration ratio is high, then aridity (dryness) is low (Sankarasubramanian and Vogel 2002).

Floret – the basic unit of the grass inflorescence; consists of two bracts (the lemma and palea) that usually enclose a flower (Harrington 1977).

Glume – one of two bracts that subtend one or more florets on a grass spikelet (Harrington 1977).

Grass bald – natural treeless communities located on well-drained high-elevation sites below the climatic tree-line (Toti et al. 2000).

Lemma – the lower bract of a floret (Harrington 1977); it is often highly modified, and therefore is often useful in distinguishing grass taxa.

Palea – the inner bract of a floret (Harrington 1977); the palea is often very reduced, and it is not often useful in distinguishing grass taxa.

Rest-rotation grazing – similar to deferred-rotation grazing but it has the addition of a yearlong rest period once during a three year grazing cycle; this yearly rest period ensures establishment of new grass seedlings and allows for buildup of carbohydrate reserves (Saskatchewan Agriculture and Food 2000).

Scabrous – rough to the touch (Harris and Harris 1999).

Spikelet – a unit consisting of two empty bracts (glumes) at the base, subtending one or more florets (Harrington 1977).

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