Festuca hallii (Vasey) Piper (Hall's fescue): A Technical Conservation Assessment

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Author's Biography

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Cover Photo Credit

Festuca hallii (Hall's fescue). Photographs by Jennifer Whipple (left) and Brian Elliott (right), used with permission.

List of Errata

What happens here in mankind
is matched by what happens out there
in the history of grass and wheat…

—R.W. Emerson

Summary of Key Components for Conservation of *Festuca hallii*

Status

The center of the range of *Festuca hallii* (Hall's fescue) is at the northern edge of the Great Plains in Alberta, Saskatchewan, Manitoba, Montana, and North Dakota. Disjunct occurrences are known from Ontario, Washington, Wyoming, and Colorado. The species has declined range-wide due to human land use practices, including livestock grazing, agricultural conversion, and fire suppression. In Region 2, *F. hallii* is known from 12 occurrences in Wyoming and five in Colorado. There is a great deal of uncertainty regarding its status in Region 2 because only six of the 17 known occurrences have been assessed within the last 20 years.

Most of the documented occurrences of *Festuca hallii* in Region 2 are on or near the Shoshone National Forest in Park County, Wyoming. One robust population is known from the Medicine Bow National Forest in Albany County, Wyoming. *Festuca hallii* was first documented in Wyoming on the Bighorn National Forest, but it has not been seen there since 1898 and is probably extirpated at this location. In Colorado, *F. hallii* has been seen at only one location within the last 20 years, at Cordova Pass on the San Isabel National Forest. Two other occurrences are known from the Roosevelt National Forest, but these have not been seen since the 1950s. Two other vague records report *F. hallii* from Custer and Park counties.

Although the global NatureServe rank for *Festuca hallii* is G4, apparently secure, USDA Forest Service Region 2 considers it a sensitive species because of threats from grazing, its rarity and limited distribution, and the lack of information on population size. There is very little information on the abundance of *F. hallii* in Region 2, and population size is difficult to quantify for this species because of its rhizomatous habit.

Primary Threats

Research outside of Region 2 suggests that *Festuca hallii* may be affected by activities that are taking place on National Forest System land in Region 2. In order of decreasing priority, threats to *F. hallii* in Region 2 include grazing, fire and fire suppression, invasion by exotic species, residential development, recreation, effects of small population size, pollution, handling, and global climate change. Historic grazing practices may have reduced the distribution of *F. hallii* in Region 2 significantly, as they have elsewhere. Summer grazing by livestock and pack stock likely affects occurrences and their habitat, particularly on the Shoshone National Forest where summer pastures include five *F. hallii* occurrences.

These threats and the hierarchy ascribed to them are speculative since they are based largely on research conducted with members of the *Festuca scabrella* complex outside of Region 2. Also, the magnitude of specific threats differs at each occurrence.

Primary Conservation Elements

The documented decline of *Festuca hallii* in the northern Great Plains increases the potential significance of occurrences in Region 2. However, there has been no conservation management of this species in Region 2. Additional information is needed to clarify its status and to determine the effects of management practices

The establishment of protected areas managed for the conservation of *Festuca hallii* would be a good conservation strategy for this species. Since the majority of the occurrences of this species in Region 2 are on National Forest System land, inclusion of *F. hallii* occurrences in Special Interest Areas and Research Natural Areas could help to ensure its viability in Region 2.

Surveys are needed to relocate the 11 historic occurrences in Region 2 and to search for undiscovered occurrences. Five occurrences in Wyoming have been discovered or revisited since 1994, but seven have not been assessed in more than 20 years. One Wyoming occurrence has not been seen since 1898, and efforts to find this

occurrence suggest that it may have been extirpated. In Colorado, only the Cordova Pass location has been visited within the last 20 years. Surveys for this species have been minimal. All other locations in Colorado for which dates are known were discovered between 1862 (when the type specimen of *Festuca 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 in Colorado are imprecise, and targeted surveys will be required before it can be determined whether these occurrences remain extant. Species distribution modeling techniques have been used to identify likely habitats 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. hallii* in Region 2 and elsewhere.

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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 hallii* is the focus of an assessment because it is 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 its 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 hallii* 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 the 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 backgrounds 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 hallii* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although a majority of the literature on this species originates 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 the reproductive behavior, population dynamics, and other characteristics of *F. hallii* 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, peer-reviewed literature, non-refereed publications, research reports, and data accumulated by resource management agencies and other investigators were analyzed. Experts on this species were consulted during its synthesis. The University of Colorado Herbarium (COLO), Colorado State University 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), US National Herbarium (US), and the Arnold Arboretum (A) were searched for specimens. All available specimens of members of the *Festuca scabrella* complex in Region 2 were viewed to verify their identity and to record 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 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, however, because of the diversity of persons and methods used in collection.

Treatment of Uncertainty in Assessment

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. 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, and models must be relied on to guide our understanding of ecological relations.

Confronting uncertainty, then, is not prescriptive. 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 for *Festuca scabrella* published prior to the 1980s when it was split into three distinct taxa (*F. altaica*, *F. hallii*, and *F. campestris*). In some cases, it can be determined which of the three taxa is being treated, but in many others it cannot. When it is not clear with which species a source is dealing, the information is discussed in the context of *F. scabrella*, or as the "*F. scabrella* complex," in this assessment. Literature dealing specifically with *F. hallii* is given priority whenever possible, but information relating to *F. campestris* and *F. altaica* is presented where relevant because these taxa are all closely related. See the Classification and description section for details regarding the taxonomy of *F. hallii* and of the *F. scabrella* complex.

Treatment of This Document as a Web Publication

To facilitate the 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 Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, Web publication will facilitate the revision of the assessments, which 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 their release on the Web. This assessment was reviewed through a process administered by the Society for Conservation Biology, which employed two recognized experts on this or related taxa. Peer review was designed to improve the quality of writing and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

USDA Forest Service Region 2 placed *Festuca hallii* on its sensitive species list in 1993 (USDA Forest Service 1993). Its status as a sensitive species were re-evaluated in 2002 (Handley and Laursen 2002, Proctor and Austin no date), and it remained on the revised Region 2 sensitive species list (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; evidence indicates it could be proposed for listing as threatened or endangered under the federal Endangered Species Act if the downward trend is not reversed or stopped

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

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

It was determined that *F. hallii* warrants sensitive species status due to threats from grazing, its rarity and limited distribution, and lack of information on population size (Proctor and Austin no date).

Inclusion on the Region 2 sensitive species list affords some protection for *Festuca hallii* on National Forest System land. Because it is designated sensitive in Region 2, the Regional Forester must give consideration to this species in order to maintain its habitat and occurrences (see Forest Service Manual 2670). Issues regarding sensitive species must be addressed for projects planned within potential sensitive species 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 give consideration to *F. hallii* on a discretionary basis. Biological evaluations are conducted when applications for permits for various land uses are considered and provide a means by which impacts to sensitive species can be mitigated.

Festuca hallii is not included on the Bureau of Land Management (BLM) sensitive species

lists for Colorado (Bureau of Land Management 2000) or Wyoming (Wyoming Natural Diversity Database 2005).

The global NatureServe rank for *Festuca hallii* is G4 (Colorado Natural Heritage Program 2005, NatureServe 2005). The global conservation status (G) rank is based on the status of a taxon throughout its range. A rank of G4 is ascribed to taxa that are apparently secure, but for which there is some cause for long-term concern due to declines or other factors (NatureServe 2005). These species may be uncommon or rare in portions of their range.

The subnational (S) rank is based on the status of a taxon within a state or province, using the same criteria used to determine the global rank. In Colorado, *Festuca hallii* had a subnational rank of SH until 2005 (Colorado Natural Heritage Program 2005). This rank is applied to taxa that have not been observed within the state or province in more than 20 years, and that may be extirpated. Plants identified as *F. hallii* were found at Cordova Pass in 2004, 2005, and 2006, (Elliott personal communication 2005), proving that this species is still extant in Colorado. The subnational rank for Colorado is now S1, reflecting the extreme rarity of this species in the state. In Wyoming, *F. hallii* is ranked S2, which is applied to taxa that are considered imperiled.

Festuca hallii is not listed as threatened or endangered under the federal Endangered Species Act. *Festuca hallii* was once thought to be limited to Colorado. The U.S. Fish and Wildlife Service (USFWS) designated it a Category 2 species prior to the realization that it ranged widely across the northern Great Plains (O'Kane 1988). Category 2 taxa were those for which information available to the USFWS indicated that proposing to list the taxa as endangered or threatened might be appropriate, but for which substantial data on biological vulnerability and threat(s) were lacking (Hassinger 2002). O'Kane (1988) recommended downgrading *F. hallii* to Category 3C, reflecting the evidence that it was more abundant and widespread than was previously believed (Hassinger 2002). *Festuca hallii* is not listed as endangered or vulnerable by the International Union for Conservation of Nature and Natural Resources (Ayensu and DeFilipps 1978).

Most occurrences of *Festuca hallii* in the states of Region 2 are on National Forest System land (**Table 1**), so the continued viability of this species in Region 2 is contingent largely on USFS management. Two occurrences (WY EO #4 and 5) are located within the North Absaroka Wilderness on the Shoshone National Forest in Wyoming, where they are protected from most potential threats (Jones and Fertig 1999). However, these occurrences are both within active grazing allotments where they are exposed to domestic livestock grazing. Another occurrence, not seen since 1985, was documented within the Pat O'Hara Potential Research Natural Area on the Shoshone National Forest, but this area currently does not have any special status (Jones and Fertig 1999). One occurrence is included within the Cinnabar Park Special Interest Area on the Medicine Bow National Forest in Wyoming.

Table 1. Land ownership status of the 17 occurrences of *Festuca hallii* in Colorado and Wyoming. The numbers in parentheses are the record for Custer County, Colorado, which could be on the San Isabel National Forest, but for which insufficient information is available to make a determination. Because of this imprecise historic record, the total is less than the sum of the rows in the table. See **Table 4** for ownership of specific occurrences.

Ownership	Total	Subtotal
USDA Forest Service Region 2	**13 (1)**	
Shoshone National Forest		8
North Absaroka Wilderness		*2*
Bighorn National Forest		1
Medicine Bow National Forest		1
Roosevelt National Forest		2
San Isabel National Forest		1 (1)
Bureau of Land Management	**1**	
State of Wyoming	**1**	
Unknown (Imprecise Historic Records)	**1 (1)**	
TOTAL	**17**	

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Adequacy of current laws and regulations

There are no federal or state laws that explicitly protect *Festuca hallii* in Region 2. On privately owned lands, current laws and regulations may be inadequate to prevent damage or destruction of 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. hallii*.

Adequacy of current enforcement of laws and regulations

There have been no documented cases in which an occurrence of *Festuca hallii* was extirpated due to human activities or the failure to enforce existing regulations in Region 2. However, this does not necessarily indicate that current regulations or their enforcement are adequate for its protection. Outside Region 2, *F. hallii* has been extirpated throughout much of its former range by overgrazing and conversion of habitat to agriculture, but this was not the result of inadequate enforcement of laws and regulations. Tweit and Houston (1980) note that grazing resulted in the decline of this species in Wyoming. Our knowledge of the historical distribution and abundance of *F. hallii* is insufficient to determine the degree to which this species has declined in the states of Region 2. Loss of peripheral and disjunct populations could reduce the genetic diversity of the species as a whole, as well as depress its resilience in the face of genetic, demographic, and environmental stochasticity.

Biology and Ecology

Classification and description

Festuca hallii is known most commonly as Hall's fescue or plains rough fescue (Aiken et al. 1996, Tirmenstein 2000). *Festuca hallii* is in the family Poaceae (Gramineae), which is a large and diverse family that includes all grasses. The genus *Festuca* contains approximately 450 species worldwide, 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). Although a few species are considered weeds, most are regarded as beneficial. Members of *Festuca* (and other members of the tribe Poeae that includes *Festuca*) 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. hallii* and the members of the *F. scabrella* complex are included in subgenus Leucopoa (Grisebach) Hackel (Aiken and Darbyshire 1990, Aiken et al. 1996).

Early species concepts within the genus *Festuca* were very broad (Aiken and Darbyshire 1990). *Festuca scabrella* (often referred to as rough fescue) is a case in point. What was formerly called *F. scabrella* is now recognized as 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." In some papers they are referred to as "the *Festuca altaica* complex." 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 et al. 1969) and did not distinguish among these taxa. Because of this practice, there are many papers in which it is not obvious what 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 level of species, subspecies, variety, and subvariety (**Table 2**). 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 full species within what was formerly called *Festuca scabrella*, and 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 their seed proteins (Aiken and Gardiner 1991).

History of knowledge

It took many years to sort out the taxonomy of the *Festuca scabrella* complex. The extensive synonymy within this group is a litany of taxonomic confusion that continues to this day. Most authors lumped *F. hallii* with

Table 2. Synonyms for *Festuca hallii*. Sources cited include the original source. The currently accepted nomenclature of USDA Natural Resources Conservation Service (2005) is in bold type.

Name	Source
Daluca hallii (Vasey) Lunell	Lunell 1915
Festuca altaica ssp. *arizonica* subvar. *hallii* (Vasey) St.-Yves	St.-Yves 1925
Festuca altaica ssp. *hallii* (Vasey) Harms	Harms 1985
Festuca confinis ssp. *rabiosa* Piper	Piper 1906, Hitchcock and Chase 1950
***Festuca hallii* (Vasey) Piper**	**Piper 1906**
Festuca kingii var. *rabiosa* (Piper) Hitchcock	Hitchcock 1934, Hitchcock and Chase 1950
Festuca scabrella ssp. *hallii* (Vasey) W.A. Weber	Weber 1961
Festuca scabrella Torrey ex Hook (pro parte)	Torrey 1840, Hitchcock et al. 1969
Hesperochloa kingii var. *rabiosa*	Swallen 1941, Hitchcock and Chase 1950
Melica hallii Vasey	Vasey 1881

F. campestris and *F. altaica* under the name *F. scabrella* from the early 1900s until 1984. John Torrey described *F. scabrella* in 1840 (Torrey 1840). Harms (1985) provided an interesting version of the story of the collection of the type collection 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, there has been uncertainty which member of the *F. scabrella* complex he actually collected. By retracing Drummond's probable location 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.

Festuca hallii was first recognized as a distinct species by George Vasey, who described it as *Melica hallii* in 1881 (Vasey 1881). The type specimen of *F. hallii* used by Vasey was collected by Elihu Hall and J.P. Harbour in 1862 on a collecting foray through the mountains of central Colorado. Hall and Harbour collected the type specimens of numerous species on this trip (Ewan and Ewan 1981), including *F. hallii*. Weber (1961) retraced their route and determined that the type specimen of *F. hallii* was probably collected near the north end of South Park in Park County, Colorado.

Vasey initially included *Festuca hallii* in the genus *Melica* because of its large glumes, which bear some resemblances to those of *Melica*, and a general form that is atypical of the genus *Festuca*. Hall and Harbour's type specimens (housed at US) are heavily annotated. On one sheet, an annotation reads, "This is exactly my *#406* from Montana 1883, distributed as *Festuca scabrella*- It is no *Melica*- F.L.S." Another reads "An ambiguous and undetermined grass between *Melica* and *Festuca*" and "probably an alpine form of *Festuca scabrella*."

In describing *Melica hallii*, Vasey recognized that the plant collected by Hall and Harbour was the same as plants known to him from Canada. He wrote "This I have received from Mr. J. Macoun, collected three different seasons on the Great Plains of British America. It is also the No. *621* of Hall and Harbour's Colorado collection" (Vasey 1881 p. 297).

In 1889, George Vasey included *Festuca scabrella* in his book The Agricultural Grasses and Forage Plants of the United States; and Such Foreign Kinds as Have Been Introduced. Vasey's treatment of *F. scabrella* in this book does not include *F. hallii* as a synonym, and deals with what is now considered *F. campestris*. However, an illustration is included that is a fairly good depiction of *F. hallii*, at least with respect to some characters (**Figure 1**).

Charles Piper first applied the name *Festuca hallii* in 1906. Piper's circumscription of *F. hallii* was also based on the Hall and Harbour specimen (*621*) used by Vasey (1881), but it was much broader than the current concept of this species. Piper himself noted that his circumscription seemed imperfect, as exemplified by his statement that "The species as thus delimited includes rather diverse-looking material, but in the light of the specimens at hand we can suggest no better disposition. There are good reasons, indeed, for considering it a mere subspecies of *F. altaica*." Piper included specimens from the Yukon that have since been determined to be *F. altaica*. He also lumped *F. scabrella* var. *major* (now recognized as *F. campestris* Rydberg sensu Pavlick and Looman 1984) into *F. hallii*. Of *F. scabrella* var. *major*, Piper (1906) wrote, "This is a much larger plant than the type of *Melica hallii*, with

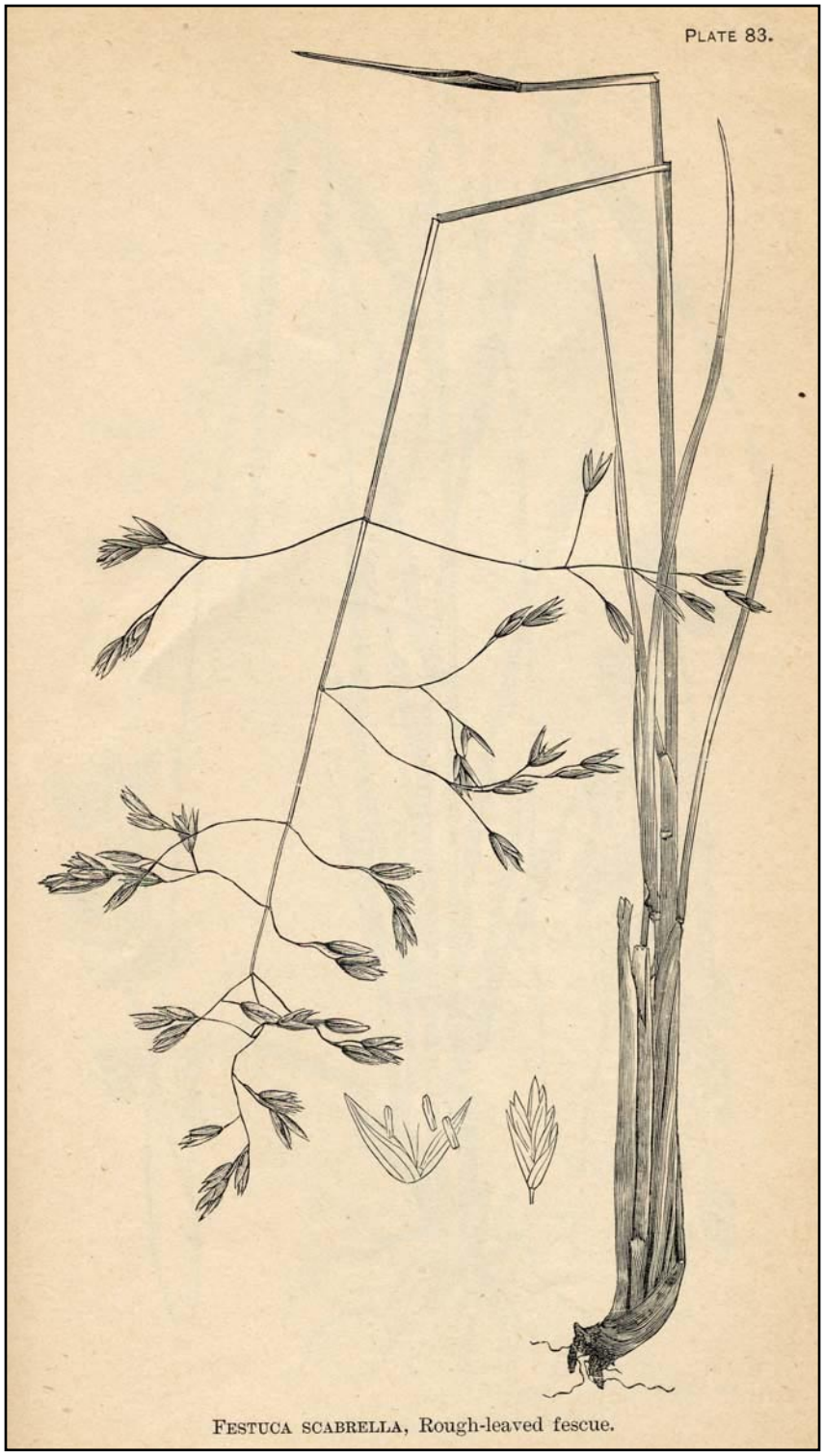

Figure 1. Illustration of *Festuca scabrella* from Vasey (1889). This illustration depicts a plant with spikelets characteristic of *F. hallii*, but with atypically long panicle branches. The small inset diagrams of spikelets are those of *F. campestris*.

a larger and looser panicle. Most of the United States material is quite intermediate between the two."

Other taxonomic treatments from the early 1900s resulted in further promulgation of synonymy among the three rough fescue taxa. Lunell (1915) renamed *Festuca hallii* as *Daluca hallii*. In a monograph of the North American members of *Festuca* (in French), Saint Yves (1925) included *F. hallii* as a subvariety of *F. altaica* ssp. *arizonica*. These taxa are now synonymized under *F. hallii* (Pavlick and Looman 1984).

Festuca hallii was first collected in Wyoming in 1898 at Crazy Woman Creek in Johnson County (WY EO #6) by T. Williams (*25*) with D. Griffiths (specimen housed at US). This was first thought to be a smaller variety of *F. confinis*, which is now recognized most often as *Leucopoa kingii*. Porter (1964) also noted the similarity of these species. The Williams and Griffiths specimen became the type for *F. confinis* ssp. *rabiosa*, described by Charles Piper in the same monograph in which *F. hallii* was circumscribed (Piper 1906). Other authors (Hitchcock 1934, Swallen 1941) renamed this taxon, but it was brought into synonymy with *F. scabrella* by Hitchcock and Chase (1950). The Williams and Griffiths specimen was annotated to *F. hallii* by Susan Aiken in 1990.

In 1984, Pavlick and Looman published a revision of the taxonomy of the *Festuca scabrella* complex that finally provided clarity on the distinctions among these taxa. In the same paper, Pavlick and Looman mapped the distributions of *F. altaica*, *F. campestris*, and *F. hallii*. Prior to this paper, it appeared that Vasey's original insights about *F. hallii* (i.e., the Colorado material was conspecific with material from the northern Great Plains) had been forgotten.

Members of the genus *Festuca* have long been of great economic importance. They are extremely important as forage for livestock and wildlife, as they are highly nutritious and productive. Grasslands dominated by *F. hallii* and *F. campestris* are some of the most productive grasslands in Canada, where they have been studied extensively 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. *Festuca scabrella* is the official grass emblem for the province of Alberta (Travel Alberta 2003).

Technical description (from Aiken et al. 1996)

Habit. Plants bluish gray green ("culms glabrous, often lustrous...blades mostly gray-green" [Looman and Best 1979 p. 129]), (18) 20 to 65 (85) cm high, densely tufted (but less so than in *Festuca altaica*; "somewhat rhizomatous and mat forming" [Harms 1985]), tiller bases stiffly erect, bases purplish (usually), horizontal rooting stems present (more or less well developed).

Vegetative morphology. Vegetative shoots arising from within existing sheaths. Sheaths glabrous (or minutely scaberulous at 40×), 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 1 to 2 cm long with scabrous or scaberulous trichomes on the veins, occur among the sheaths). Collars glabrous. Auricles represented by distinct, erect, swellings (usually). Auricular cilia absent. Ligules 0.3 to 0.6 mm long, ciliate. Leaf blades 10 to 35 cm long, erect, stiffish. Adaxial blade surfaces with trichomes, abaxial blade surfaces with trichomes (illustrated by Aiken and Lefkovitch 1985, p. 1868 and image library). Leaf blades plicate; 0.4 to 0.78 to 1 mm wide, 0.7 to 0.98 to 1.25 mm deep. Veins 5 to 10. Adaxial to abaxial sclerenchyma strands present. Abaxial sclerenchyma well developed, in broad bands or continuous (often narrow). Ribs 5 to 8. Uppermost culm leaf sheaths not inflated. Flag leaf blades 1.5 to 3 (5) cm long. Culm nodes never exposed; internodes scabrous-hirsute (minutely scaberulous).

Floral morphology and chromosome number. Inflorescence 6 to 16 cm long. Inflorescence branches at the lowest node 1 to 2, appressed after anthesis ("open to contracted at anthesis" [Looman and Best 1979 p. 129]), 2 to 4 (7) cm long. Rachis rounded in cross section or angular in cross section, trichomes over the entire surface. Spikelets aggregated towards the ends of the branches (with relatively few spikelets); 2 to 8 on the longest branches; 7 to 9.5 mm long (mostly green), 2 to 3.5 mm wide. Proliferating spikelets absent. Florets 2 to 3 (fertile, upper florets 0 to 2 sterile or with anthers only). Glumes subequal, glabrous, margins ciliate (boarder not conspicuously translucent). First glume (5) 6.5 to 8 (9.5) mm long, veins 1. Second glume as long as the first lemma, or almost as long (often longer than the first lemma), (6.2) 7 to 8.5 (9.5) mm long, veins 1 to 3. Rachilla internodes antrorsely scabrous. Lemma callus not elongated. Lemma 5.5 to 7(9) mm long, nerveless in dorsal view or sometimes with only the center vein

distinct, with trichomes, trichomes over the entire surface; apex entire (illustrated by Pavlick and Looman 1984, p. 1741). Lemma awn 0.5 to 1.3 mm long. Palea 5 to 6.5 (8.5) mm long (almost as long or longer than the lemma), distinctly pubescent between the keels. Lodicules with marginal teeth or without marginal teeth, glabrous or ciliate, 0.9 to 1.1 mm long. Anthers 4 to 6 mm long. Ovary apex pubescent. Caryopsis 2.5 to 3.5 mm long. 2n = 28.

Non-technical description

Festuca hallii is bluish gray-green, somewhat cespitose, and is typically rhizomatous (**Figure 2**; Pavlick and Looman 1984, Harms 1985). It usually forms small bunches typically containing three to five erect culms, which may vary in height (Pavlick and Looman 1984, Aiken and Darbyshire 1990, Aiken et al. 1996). Plants from Sunlight Basin on the Shoshone National Forest (WY EO #8) scarcely exceed 8 cm in height (**Figure 3**) while others from Rattlesnake Mountain, also on the Shoshone National Forest (WY EO #3) are approximately 50 cm high with numerous culms in robust bunches (**Figure 4**). Culms may approach 85 cm in height in *F. hallii* (Aiken et al. 1996). *Festuca hallii* is tetraploid (2n = 4x = 28) (Aiken and Fedak 1991, Aiken et al. 1996).

The presence of rhizomes in *Festuca hallii* is a valuable diagnostic character (**Figure 5**). Elliott (personal communication 2005) noted that they are quite brittle and require excavation since they will not stay with the plant if it is pulled from the ground. Rhizomes are often missing from specimens. In Alberta, short rhizomes connect bunches to form a large, loosely consolidated crown. Rhizomes emerge either laterally or from underneath the crown and radiate in all directions. Sprouts then arise within approximately 0.8 inch (2 cm) of the parent plant. Maximum root depth is 6 inches (15 cm). Maximum rhizome lengths are approximately 23 inches (60 cm) (Romo et al. 1991, Tirmenstein 2000).

The characteristics of the inflorescences, discussed below, are valuable in diagnosing this species and distinguishing it in Region 2. The spikelets of *Festuca* species, including *F. hallii*, disarticulate above the glumes (Aiken and Darbyshire 1990).

In Region 2, *Festuca hallii* is 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 leaving the adjacent lemmas exposed, whereas *F. hallii* has relatively long glumes. *Festuca hallii* plants collected in Colorado have extremely long glumes and a slightly longer rachilla than Canadian material, which led Vasey to describe this species erroneously as *Melica hallii* (Curto personal communication 2006). *Festuca hallii* has no more than four florets per spikelet, while *F. campestris* typically has 4 to 5 (7) florets per spikelet. The awns of *F. idahoensis* are usually considerably longer than those of *F. campestris* or *F. hallii* are, while those of *F. arizonica* 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*. *Festuca thurberi* can be distinguished from *F. hallii* and *F. campestris* by its extremely long ligules, which can reach 9 mm in length (Porter 1964, Aiken et al. 1996).

Festuca campestris has been reported from Colorado, but this report is apparently erroneous (Anderson 2006). However, it will be important to verify that material collected in Region 2 is not *F. campestris*. The fact that *F. campestris* and *F. hallii* were long considered the same species illustrates the challenges of distinguishing these taxa. *Festuca hallii* and *F. campestris* were known for more than a century before the differences between them were clearly recognized, and overlapping characteristics can make definitive identification difficult even now. These taxa are delimited from one another by a set of consistent morphological characters that, once recognized, greatly facilitates their identification.

In general, *Festuca campestris* tends to be more robust than *F. hallii* (Piper 1906, Aiken personal communication 2005). *Festuca hallii* typically has long rhizomes (**Figure 5**) and a much less bunchy habit than *F. campestris*, which may form bunches up to 50 cm in diameter (Moss and Campbell 1947). Leaf cross sections (**Figure 6** and **Figure 7**), the number of florets, and relative glume length (**Figure 8**) are the most useful characteristics for distinguishing *F. campestris* from *F. hallii* (Aiken personal communication 2005). Leaf cross sections are relatively unambiguous (Aiken and Consaul 1995). They can be readily made with a razor or scalpel. Soaking a leaf section of a dried specimen in water with a small amount of detergent or Pohl's solution will permit diagnosis. *Festuca hallii* has the most consistently pubescent leaf sheaths of members of the *F. scabrella* complex (Harms 1985). Aiken (personal communication 2005) noted that if the tops are 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,

Figure 2. *Festuca hallii* at Cordova Pass. Photograph by Brian Elliott, used with permission.

Figure 3. *Festuca hallii* from Sunlight Basin, Absaroka Mountains, Shoshone National Forest (WY EO #8). These plants were collected at an elevation of 6,800 ft. by Stephanie Mills (collection *#30a*, RM).

when plants are also less robust (Aiken et al. 1996). However, in these cases the floral characteristics remain consistent. **Table 3** summarizes the most useful diagnostic characteristics for *F. campestris*, *F. hallii*, and *F. idahoensis*.

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 not useful in resolving species identification among members of this complex.

Descriptions, photographs, keys, and illustrations

Because *Festuca hallii* is an important rangeland species, there are numerous sources of descriptions, photographs, keys, and illustrations. However, many pertain to *F. scabrella* without distinguishing *F. hallii*. Many sources of illustrations of *F. scabrella* actually depict *F. campestris* and are not very helpful in diagnosing *F. hallii*. The illustrations in USDA Forest Service (1937), Hitchcock et al. (1969), Cronquist et al. (1977), Lackschewitz (1991), and Stubbendieck et al. (1994) are labeled *F. scabrella*, but they actually show *F. campestris*. Houston et al. (2001) include the illustration by Jeanne R. Janish from Hitchcock et al. (1969) in their description of *F. hallii*, but it actually depicts *F. campestris*. The illustration of *F. hallii* in Spackman et al. (1997) is good and is available in online and print versions (**Figure 9**).

In describing *Festuca hallii*, Piper (1906) did not include an illustration but referred to the illustration in Vasey (1889). This illustration (**Figure 1**) includes inset diagrams of spikelets that depict *F. campestris*. The plant, however, is a fairly good depiction of *F. hallii* although the panicle branches are longer than is typical.

Recent sources are generally better for distinguishing *Festuca hallii* and *F. campestris*. Unfortunately, the keys in Wingate (1994) and Weber and Wittmann (2001), which are excellent for identifying most Colorado grasses, do not include critical diagnostic features regarding spikelets and leaf morphology, so they cannot be used to distinguish *F.*

Figure 4. *Festuca hallii* from Rattlesnake Mountain, Shoshone National Forest (WY EO #3). Specimens were collected at 8,409 ft. by Tweit and Houston (*s.n.*, RM).

hallii and *F. campestris*. However, Pavlick and Looman (1984), Aiken and Darbyshire (1990), and Aiken et al. (1996) are good sources for reliably distinguishing *F. hallii* and *F. campestris*. The taxonomic treatment of Pavlick and Looman (1984) includes a range map (which does not include Wyoming or Colorado), a key of 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; somewhat revised from that of Aiken and Darbyshire (1990) and more detailed), useful characters for distinguishing *F. hallii* and *F. campestris*, and photographs of *F. hallii* and its habitat. Cory (2005) includes good photographs and descriptions of *F. campestris* and *F. hallii*. Fertig et al. (1994) include a description and photographs of plants and habitat in Wyoming. Dorn (2001) and Porter (1964) provide keys that are useful for identifying *F. hallii* in Wyoming.

Figure 5. Close-up of the root system of *Festuca hallii* from a plant excavated at Cordova Pass, Colorado. Note the rhizome at right is giving rise to a shoot. *Festuca hallii* does not perennate vegetatively. The rhizomes are very brittle, so they are not often included with herbarium specimens. Photograph by Brian Elliott, used with permission.

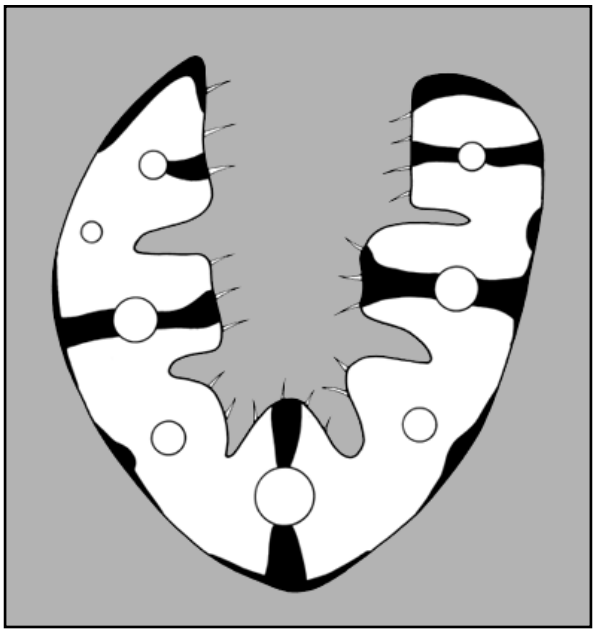

Figure 6. Diagram of the cross section of a leaf of *Festuca campestris*. Note the five major vascular bundles with sclerenchymatous strands adjacent to them, and the loosely involute blade. Illustration from Aiken and Darbyshire (1990). Used with permission of Susan Aiken.

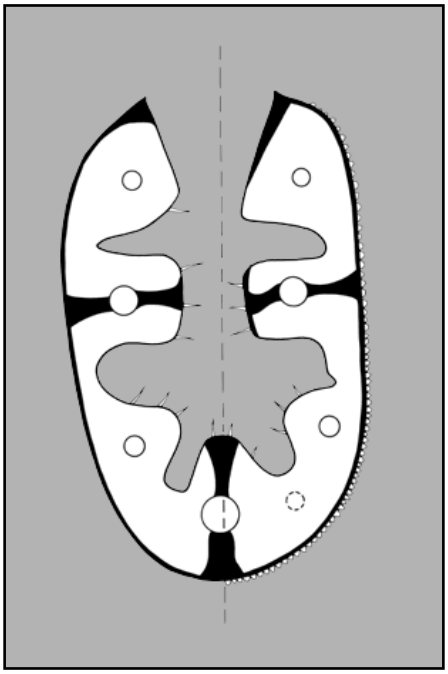

Figure 7. Diagram of the cross section of a leaf of *Festuca hallii*. Note the three major vascular bundles with sclerenchymatous strands, and the tightly involute blade. Illustration from Aiken and Darbyshire (1990). Used with permission of Susan Aiken.

Figure 8. Close-up of the florets of *Festuca hallii* (*Weber and Wingate 15442* at COLO). Increments below are 1 mm. 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 are diagnostic features of *F. hallii*.

Table 3. 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

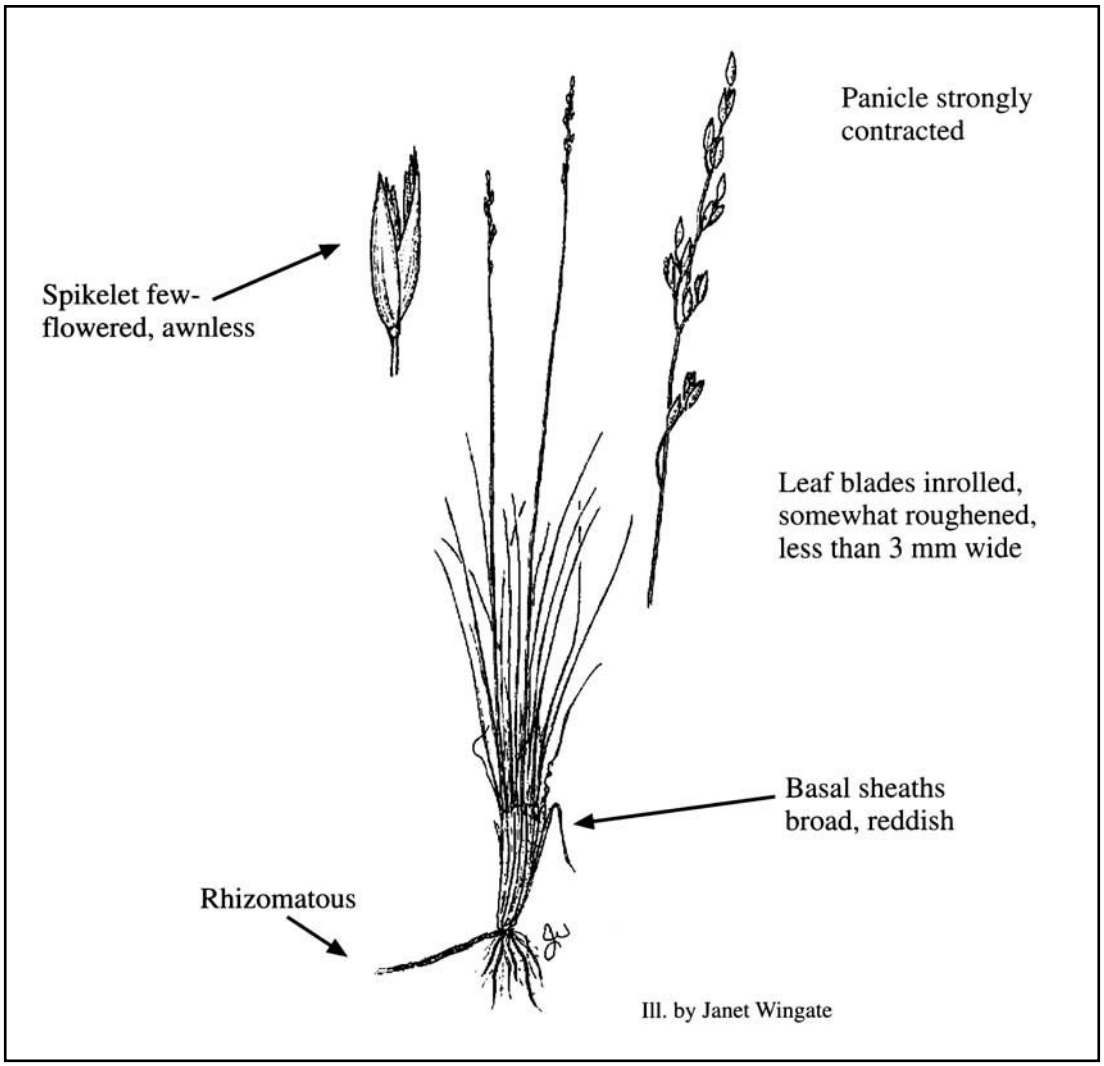

Figure 9. *Festuca hallii*, illustrating diagnostic characteristics. Illustration by Janet Wingate (From Spackman et al. 1997).

Distribution and abundance

Distribution within Region 2

Within Region 2, *Festuca hallii* is known from 17 occurrences in Wyoming and Colorado. **Figure 10** shows the distribution of reported locations of *F. scabrella*, *F. hallii*, and *F. campestris* in these two states in relation to National Forest System land. Twelve occurrences are known from Wyoming, ten of which are in or near the Shoshone National Forest in Park County. Recent surveys have discovered several new occurrences of *F. hallii* in Wyoming (Fertig 2002).

Five occurrences of *Festuca hallii* are known from Colorado. Data for *F. hallii* in Colorado are sparse, and most occurrences are known only from old and vague records. The known locations of *F. hallii* in Region 2 are discussed in detail below.

USDA Forest Service (1937) reported that old records of *Festuca scabrella* from Colorado have mostly been determined to be *F. thurberi*. All records discussed here are based on recently annotated herbarium specimens and are probably not *F. thurberi*. In Colorado, some uncertainty remains regarding the identity of the plants from two occurrences, which were reported as *F. scabrella* but for which no specimen is known.

The presence of *Festuca hallii* in Wyoming and Colorado is probably relictual (Tweit and Houston 1980). The southward migration of vegetation zones during the Pleistocene probably resulted in fescue

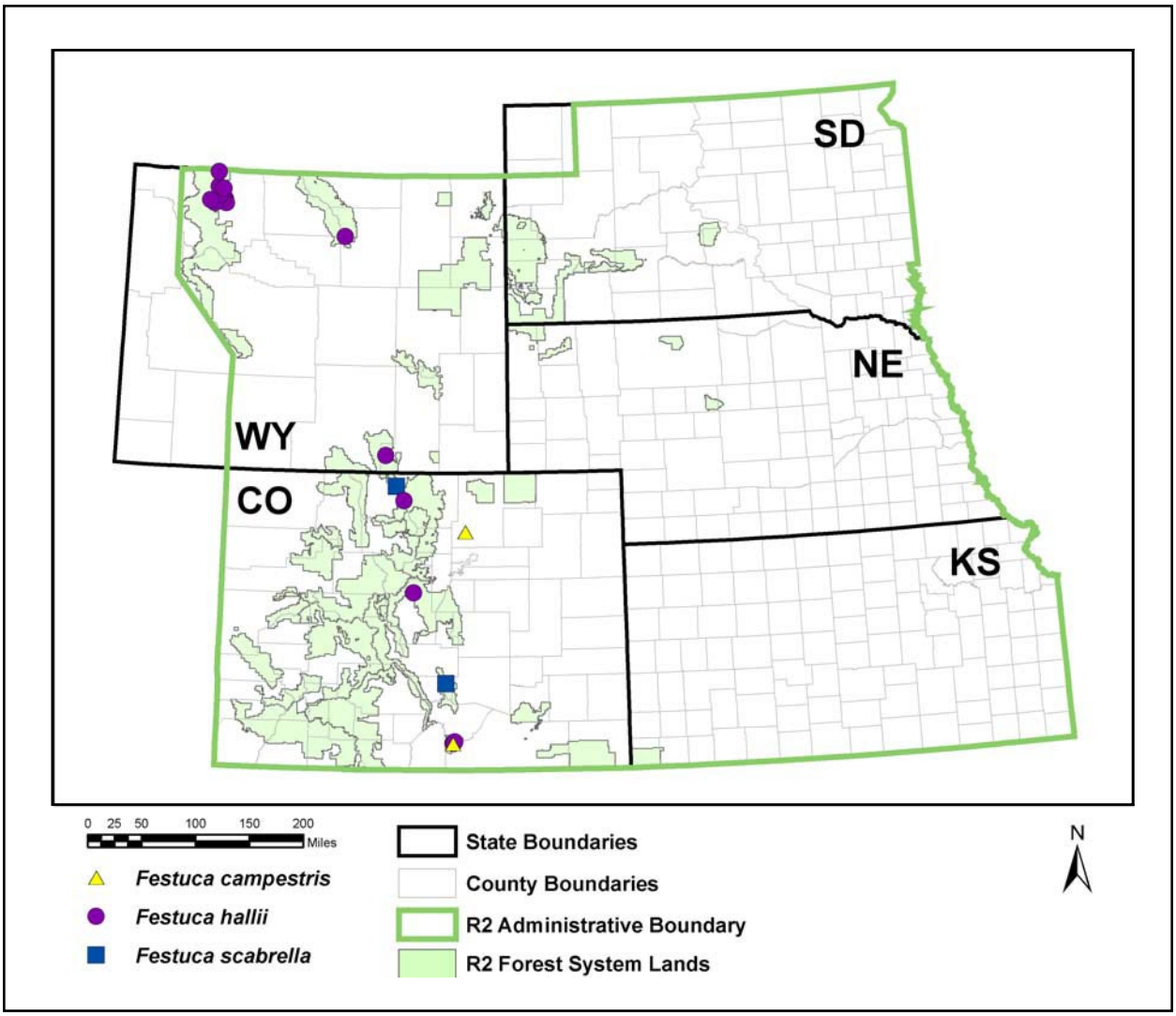

Figure 10. The distribution of reports of members of the *Festuca scabrella* complex in the states of Region 2. Both reports of *F. campestris* in Colorado are probably erroneous.

grasslands developing at lower latitudes. Warmer conditions following glacial retreat 10,000 years ago caused vegetation zones to move north again but left remnant populations in patches of suitable habitat (Johnston 1958).

A picture is starting to emerge that suggests that occurrences of *Festuca hallii* are more continuous through Colorado and Wyoming than was previously believed. It is possible that some of the historic Colorado occurrences discussed below remain extant, and that others remain to be discovered. Tools that could be applied to identify areas likely to support *F. hallii* are discussed in the Species inventory section. The difficulty in identifying grasses in general, and members of *Festuca* in particular, may have caused occurrences of *F. hallii* to be overlooked. It is possible that the intensive grazing practices of the late 1800s and early 1900s led to the extirpation of some occurrences of *F. hallii*.

Park County, Colorado

Weber (1961) retraced the 1862 route of Elihu Hall and J.P. Harbour through the mountains of central Colorado. The type specimen of *Festuca hallii* collected by Hall and Harbour (*621* at US) is labeled simply, "Rocky Mountains, lat. 39°-41°." However, it is likely that this specimen was collected in or 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

Weber and Weber and Pickford (*9694*) collected *Festuca hallii* on August 25, 1956 on the north and east sides of Cameron Mountain at approximately 11,600 ft. on the Roosevelt National Forest (CO EO #1). A specimen from this collection 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 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 [Harrington 1954] of its distribution- "Prairies, hillsides and open woods" (page 49) is incorrect."

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

Another record of a member of the *Festuca scabrella* complex was found among the archived notes of H.D. Harrington, author of the Manual of the Plants of Colorado (1954). Harrington's notes, which are remarkably well organized, are housed at the COLO. Among Harrington's papers is a memo (dated September 20, 1954) from Clinton H. Wasser, who was a professor in the Forestry Department at Colorado State University. The memo, regarding a *F. scabrella* specimen, reads,

> "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 for this assessment. 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 *Festuca scabrella* and has not been seen since 1954 or earlier, the identity of this record remains uncertain.

Huerfano and Las Animas counties, Colorado

Festuca hallii has been collected at least five times near Cordova Pass on the San Isabel National Forest (**Table 4**). This is the only occurrence of this species in Colorado that has been revisited within the last 20 years.

Festuca hallii has long been known from this area. Three specimens of *F. scabrella* that were collected in this area are housed at the U.S. National Herbarium. These 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 of the United States* is based (Hitchcock and Chase 1950). Susan Aiken annotated two of these specimens (*Swallen 1302* and *Van Schaak 2499*) as *F. hallii*. The Chase specimen (*5359*) was not annotated by Aiken, but it was annotated by P.F. Stickney in 1965 in agreement with Chase's identification. This specimen also appears to be *F. hallii* (Soreng personal communication 2005).

Table 4. Summary of information for the known reports of *Festuca scabrella sensu lato* (from old records), and *F. hallii* in Region 2. Source ID is the Colorado Natural Heritage Program and Wyoming Natural Diversity Database element occurrence number unless otherwise noted. Lands within the National Forest System are in bold. Shaded records represent a single occurrence at Cordova Pass.

Source ID[1]	Species ID	County/ State	Location	Owner	Date last observed	Abundance	Elevation (ft.)	Habitat and notes
WY EO #1	*F. hallii*	Park/ WY	Absaroka Mountains, Headwaters of Trail Creek	State of Wyoming	01-Aug-1980	not reported	8,000	meadow at edge of *Pinus contorta-Picea engelmannii* forest, on deep soil derived from the red Chugwater Formation; observed in flower and fruit; occurs with *Festuca idahoensis*, *Danthonia intermedia*, *Trisetum*, *Lupinus wyethii*, *Geum triflorum*, *Zigadenus elegans*, *Potentilla fruticosa*, and *Artemisia tridentata*
WY EO #2	*F. hallii*	Park/ WY	Absaroka Mountains, southwest side of Rattlesnake Mountain	Bureau of Land Management (BLM) Cody Field Office	11-Aug-1994	"locally common"	8,600- 9,000	meadow of *Festuca idahoensis* and *F. hallii* on gravelly limestone soil with pockets of open gravel on knoll above forest of lodgepole pine and scattered subalpine fir; known from 2 colonies; plants mostly past fruiting on August 11 (many culms with empty glumes); occurs with *Pyrrocoma carthamoides*, *Helictotrichon hookeri*, *Bupleurum americanum*, *Koeleria macrantha*, *Gentiana affinis*, *Minuartia obtusiloba*, and *Delphinium*
WY EO #3	*F. hallii*	Park/ WY	Absaroka Mountains, Rattlesnake Mountain	**USDA Forest Service (USFS) Shoshone National Forest Wapiti Ranger District**	20-Jul-1979	"frequent"	8,480	open meadow of limestone composed soils; *Festuca idahoensis/Elymus trachycaulus* habitat type; occurs with *Penstemon*, *lupinus*, and *Poa*; in flower and fruit
WY EO #4	*F. hallii*	Park/ WY	Absaroka Mountains, Head of East Fork Big Creek	**USFS Shoshone National Forest Wapiti Ranger District North Absaroka Wilderness**	02-Aug-1983	not reported	10,000-11,000	tundra; observed in flower and fruit
WY EO #5	*F. hallii*	Park/ WY	Northern Absaroka Mountains, Pat O'Hara Peak	**USFS Shoshone National Forest Clarks Fork Ranger DistrictNorth Absaroka Wilderness**	23-Aug-1985	not reported	9,000-9,600	open grassy slopes with limestone outcrops and spruce woodland margins; observed in fruit

Table 4 (cont.).

Source ID[1]	Species ID	County/ State	Location	Owner	Date last observed	Abundance	Elevation (ft.)	Habitat and notes
WY EO #6	*F. hallii* (annotated by Aiken)	Johnson/ WY	Bighorn Mountains, a branch of Crazy Woman Creek	**USFS Bighorn National Forest Powder River Ranger District**	03-Jul-1898	not reported	8,800	with *Stipa minor*
WY EO #7	*F. hallii*	Albany/ WY	Medicine Bow Mountains, Cinnabar Park	**USFS Medicine Bow National Forest Laramie Ranger District Cinnabar Park Special Interest Area**	29-Sep-1998	probably locally abundant and widespread	9,600	edge of erosional channel exposing quartzite rocks in a montane meadow dominated by *Koeleria macrantha*, *Danthonia*, *Poa secunda*, and *Antennaria*; soils rocky mollisols; observed in post-flowering condition on 29-Sept.
WY EO #8	*F. hallii*	Park/ WY	Northern Absaroka Mountains, Sunlight Basin	**USFS Shoshone National Forest Clarks Fork Ranger District**	19-Aug-1995	>500	6,800	mesic, limestone-derived soils in *Artemisia frigida/Festuca* meadow in full sunlight; occurs with *F. idahoensis*, *Poa* spp., *Pyrrocoma carthamoides* var. *subsquarrosa*, *Erigeron caespitosus*, *E. compositus*, *Astragalus miser*, and *Arenaria hookeri*; in fruit and vegetative
WY EO #9	*F. hallii*	Park/ WY	Eastern Absaroka Range, Bald Ridge/ Dead Indian Hill	**USFS Shoshone National Forest Clarks Fork RD**	15-Jul-1996	600-1000 plants; plants may be locally dominant in small patches up to 50 square meters, but otherwise are widely scattered	7,600-7,690	*Festuca idahoensis-F. hallii-Poa secunda* community on gentle east and west-facing slopes on dry to semi-moist, deep, rocky, limestone-humus soil with sparse limestone gravel on surface; may also occur in stands locally dominated by *Swertia radiate*; typically found in microsites with deeper soils and little to no sagebrush; plants may be locally dominant in small patches up to 50 square meters, but otherwise are widely scattered; occurs with *Pyrrocoma carthamoides* var. *subsquarrosa*, *Campanula rotundifolia*, *Castilleja longispica*, *Polygonum bistortoides*, *Gaillardia aristata*, and *Lupinus argenteus*; observed in flower and fruit

Table 4 (cont.).

Source ID[1]	Species ID	County/ State	Location	Owner	Date last observed	Abundance	Elevation (ft.)	Habitat and notes
WY EO #10	*F. hallii*	Park/ WY	Absaroka Range, Headwaters of Big Creek	**USFS Shoshone National Forest Wapiti Ranger District North Absaroka Wilderness**	24-Aug-1985	not reported	10,000-10,800	alpine basin, mostly tundra-turf community; observed in fruit
WY EO #11	*F. hallii*	Park/ WY	Beartooth Range north of Gardner Lake	**USFS Shoshone National Forest Clarks Fork Ranger District**	23-Aug-1999	<50 in 3 m2	10,400	gentle, northeast-exposed slope with 75 percent vegetation cover in *Geum rossii* community; occurs with *G. rossii*, *Polygonum bistortoides*, *Carex elynoides*, *Artemisia scopulorum*, *Phlox pulvinata*, *Arenaria obtusiloba*, and *Erigeron simplex*
A. Taylor (9022) with K. Taylor and K. Houston (RM)	*F. hallii*	Park/ WY	Logan Mountain	**USFS Shoshone National Forest Clarks Fork Ranger District**	23-Jun-2004	10 to 20	7,900	montane grassland and cushion community on calcareous soils with scattered limber pine; associated with *Shoshonea pulvinata*, *Leucopoa kingii*, *Carex filifolia*, *Pyrrocoma carthamoides* var. *subsquarrosa*, and *Castilleja nivea*
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
Wasser (1954)	*F. scabrella*	Larimer/ CO	Shipman Park	**USFS Roosevelt National Forest**	Before 20-Sep-1954	not reported	9,500	not known

Table 4 (cont.).

Source ID[1]	Species ID	County/ State	Location	Owner	Date last observed	Abundance	Elevation (ft.)	Habitat and notes
W.A. Weber and J. Wingate 15442 (COLO, RM); *Elliott 13597*, *13609* (RM, COLO, CS), *Sherman 61* (CS)	*F. campestris/ F. hallii* (annotated by Aiken; *F. campestris* is probably an erroneous report)	Huerfano/ CO	Cordova Pass and Donald Park	**USFS San Isabel National Forest**	24-Aug-2006	infrequent and scattered, probably spread over many acres but full extent is not known; hundreds of ramets were observed, but observers estimate thousands of ramets	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 *Festuca 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; often on or around disturbed gopher gardens; *Bromus inermis* is established and invading the area; a trailhead and campground are located on the edge of the occurrence
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
J.R. Swallen 1302 (US)	*F. hallii* (annotated by Aiken)	Unknown/ CO	Spanish Peaks	**unknown; probably USFS San Isabel National Forest**	28-Jul-1928	not reported	not reported	small grassy area above timberline
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

Table 4 (concluded).

Source ID[1]	Species ID	County/ State	Location	Owner	Date last observed	Abundance	Elevation (ft.)	Habitat and notes
Harrington 1954	*F. scabrella* (possibly referring to *F. campestris*, but probably *F. hallii*)	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

[1]Herbarium abbreviation:

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

On July 6, 1978, William A. Weber and Janet Wingate made a collection (*15442*) on Apishapa Pass (now known as Cordova Pass) west of West Spanish Peak on the boundary between Huerfano and Las Animas counties, on the San Isabel National Forest. Weber et al. (1979) identified this specimen as *Festuca campestris*, but there is now considerable evidence that this is an erroneous report (reviewed in detail in Anderson 2006). The Weber and Wingate collection (*15442*) has been annotated, and careful re-examination of it using the contemporary circumscriptions of these taxa strongly suggests that it is *F. hallii* and that *F. campestris* is not present in Region 2. Nonetheless, numerous sources indicate the presence of *F. campestris* in Colorado (e.g., NatureServe 2005, USDA Natural Resources Conservation Service 2005) or in Huerfano County, Colorado (e.g., Barkworth and Long 2005) that are likely based on this specimen and Weber et al. (1979). It is important to note that a clear circumscription of the *F. scabrella* complex was not available until 1984. *Festuca hallii* was collected on Cordova Pass by Brian Elliott in 2004, 2005, and 2006 and by Emily Sherman in 2006 (Elliott personal communication 2005, 2006). These specimens have been verified (Curto personal communication 2006, Shaw personal communication 2006).

Custer County, Colorado

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* from Custer County, Colorado (Kittridge personal communication 2005). The specimen on which Harrington based his notes 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 11**). He noted that this location is at 8,500 ft. in elevation. Using Harrington's notes and the 8,500 ft. contour line in eastern Custer County, some of the locational uncertainty of this report can be resolved (**Figure 12**), but an exact location of *F. scabrella* remains unknown. This occurrence may be on the San Isabel National Forest.

Park County, Wyoming

The densest aggregation of *Festuca hallii* within Region 2 is on the Shoshone National Forest and adjacent state and BLM lands in Park County, Wyoming, in the Absaroka and Beartooth Mountains (Handley and Laursen 2002, Wyoming Natural Diversity Database 2005). In Park County, Wyoming, there are eight occurrences on Shoshone National Forest, one on State of Wyoming land, and one on public lands managed by the Cody Field Office of the BLM (**Table 1**, **Table 4**).

Johnson County, Wyoming

T. Williams (*25*) and D. Griffiths made the first collection of *Festuca hallii* in Wyoming in 1898 at "Branch of Crazy Woman Creek." Details of this specimen are discussed in the History of knowledge section. The collection site is known to be located on the eastern slope of the Bighorn Range on the Bighorn National Forest (Porter 1964, Fertig 2002), but it has not been relocated. Fertig (2002) used element distribution modeling to identify likely places for *F. hallii* on the Bighorn National Forest, and then surveyed the locations indicated by the model. These surveys were unsuccessful. It is possible that intensive land use practices over the past century extirpated this occurrence (Fertig 2002), or that the model was flawed.

Albany County, Wyoming

Festuca hallii was known from the Medicine Bow National Forest only from an unconfirmed record until it was rediscovered by Walt Fertig on September 29, 1998 (Fertig 1997, Fertig 1998, Fertig 1999, Fertig 2002, Wyoming Natural Diversity Database 2005). This occurrence is in the Cinnabar Park Special Interest Area on the Laramie Ranger District, Medicine Bow National Forest.

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 locations in Michigan and eastern Canada (Rydberg 1922, Aiken et al. 1996). It is not known from Region 2. The range of *F. campestris* centers in the prairies of the Pacific Northwest and northern Rocky Mountains in Oregon, Washington, Idaho, Montana, British Columbia, and Alberta (Anderson and Franzen 1983, Pavlick and Looman 1984, Aiken et al. 1996, NatureServe 2005). *Festuca hallii* ranges from eastern British Columbia east to Manitoba and south to Montana and North Dakota (**Figure 13**, **Figure 14**). Disjunct populations occur in Ontario, Wyoming, and Colorado (Argus 1984, Pavlick and Looman 1984, Aiken et al. 1996, Tirmenstein 2000). There is some overlap of the ranges of the three

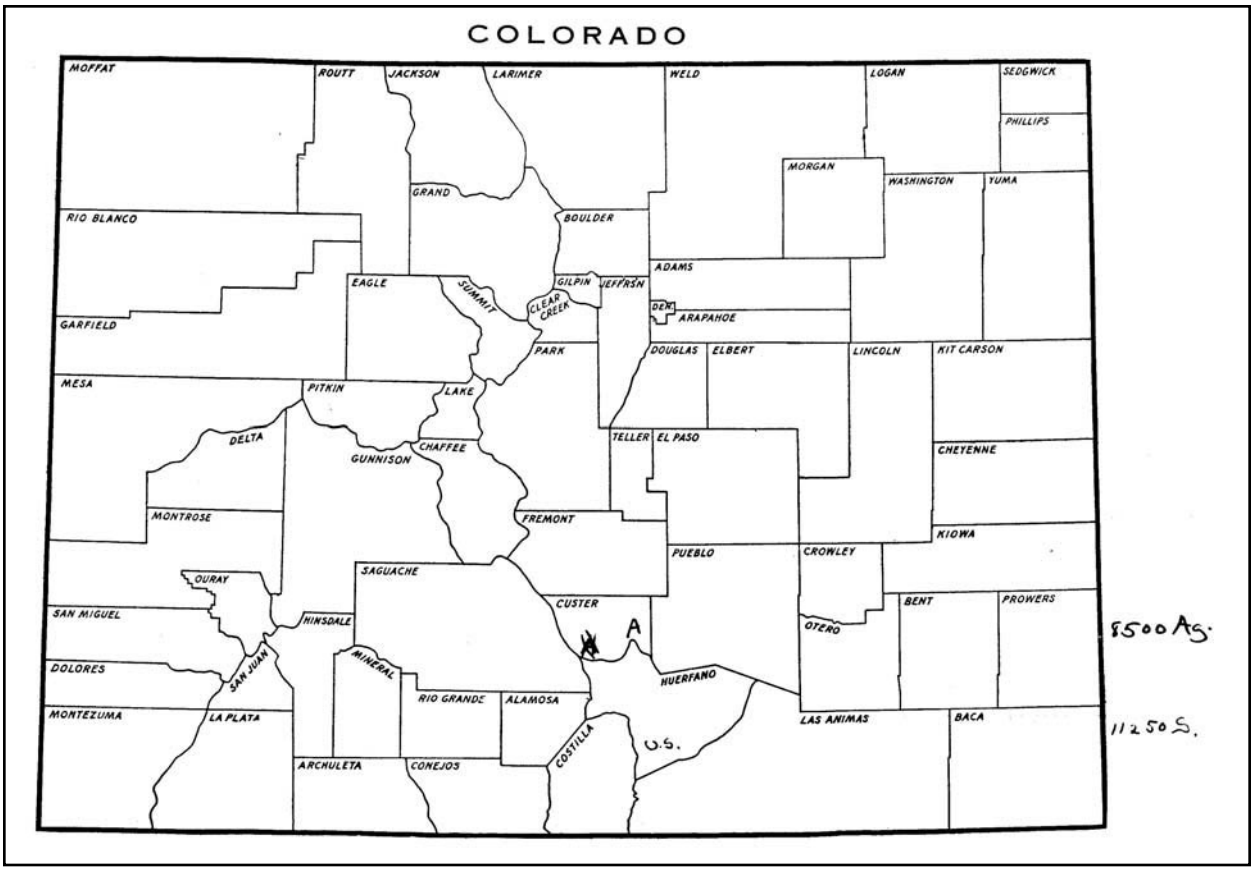

Figure 11. Map of the distribution of *Festuca scabrella* in Colorado from H.D. Harrington's notes. Letters denote locations and the institution housing the specimen at that location. A = Arnold Arboretum, US = US National Herbarium. Specimens at US have all been annotated to *F. hallii*. There are no specimens of any *Festuca* species from Custer County, Colorado currently housed at A.

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).

Abundance

Festuca hallii is not common anywhere in Region 2 (Handley and Laursen 2002). Because of its rhizomatous habit, it is difficult to quantify the number of individuals (or even the number of ramets) within a population. Likewise, most reports of *F. hallii* in Region 2 are not specific regarding population size, density, or occupied area, and there has been no attempt to use quantitative methods to determine these variables at any occurrence of *F. hallii* in Region 2.

There is limited information on which to base estimates of population size of *Festuca hallii* in Colorado. Elliott (personal communication 2005) reported that *F. hallii* at Cordova Pass is scattered and not in dense patches, and that the full extent of the occurrence is not known. Hundreds or thousands of ramets are distributed patchily among the three locations noted on Cordova Pass, where there is probably 100 to 200 acres of potential habitat on the San Isabel National Forest and adjacent private land. One large patch on Cordova Pass occupies approximately 5 acres. Recent surveys suggest that *F. hallii* is fairly common in open sites on Cordova Pass. The density of *F. hallii* on Cordova Pass is highest in gopher gardens and lower in densely vegetated meadows (Elliott personal communication 2005). *Festuca hallii* is described as being the dominant species at the Cameron Mountain location in Larimer County.

Reported estimates of population size range widely among occurrences in Wyoming. Very small populations were documented at Logan Mountain (*A. Taylor 9022*, 10 to 20 individuals) and in the Beartooth Range North of Gardener Lake (WY EO #11, fewer than 50 in 3 m^2), and there may be reason for concern regarding the viability of these occurrences

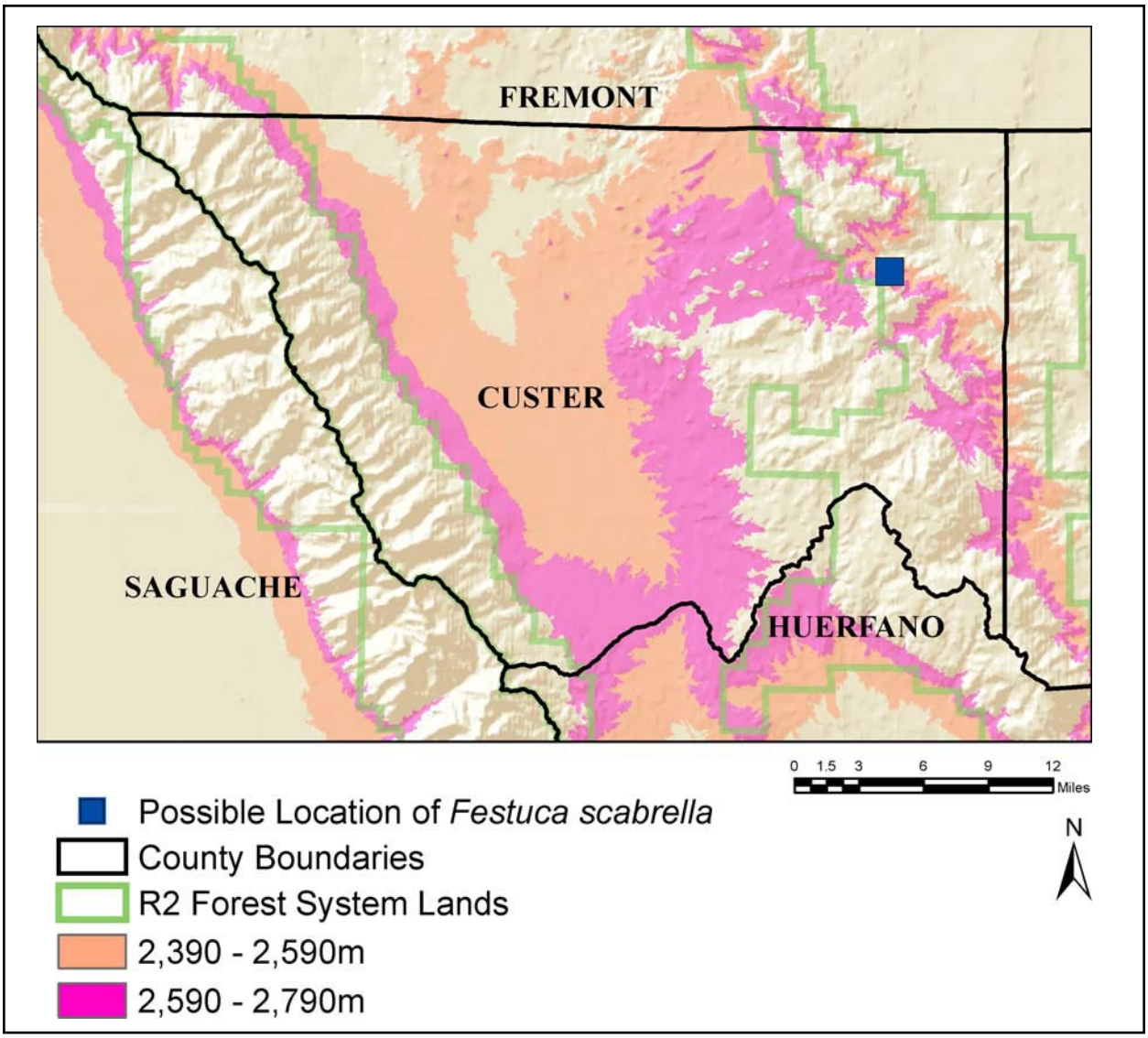

Figure 12. Map of Custer County, Colorado. A possible location of *Festuca scabrella* (based on Harrington's notes) is included, based on the elevation reported by Harrington (see **Figure 11**). The elevation surfaces shown are 200 meters below and 200 meters above that reported by Harrington. The most likely locations for this report are in eastern Custer County where these two surfaces meet.

due to small population size. However, estimates for five other occurrences in Wyoming (WY EO #2, 3, 7, 8, and 9) suggest more robust populations. The two occurrences in Wyoming that include numeric estimates are in the Absaroka Mountains where there are "over 500" (WY EO #8) and "600 to 1000 plants" (WY EO #9), respectively. *Festuca hallii* is "probably locally abundant and widespread" at the occurrence in Albany County (WY EO #7). Tweit and Houston (1980) report the presence of extensive areas dominated solely by the *F. scabrella* phase of the *F. idahoensis*/*Agropyron caninum* habitat type at two exceptional locations in Park County, Wyoming. *Festuca scabrella* is co-dominant with *F. idahoensis* at these locations.

Population trend

The extent of grasslands dominated by *Festuca hallii* has declined range-wide because of human activities, primarily agricultural conversion, intensive grazing, and fire suppression. Because of the economic and ecological importance of these grasslands, there is a large body of literature from outside Region 2 discussing how human activities affect them. USDA Forest Service (1937) noted that "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 montane grasslands and intermountain valleys in

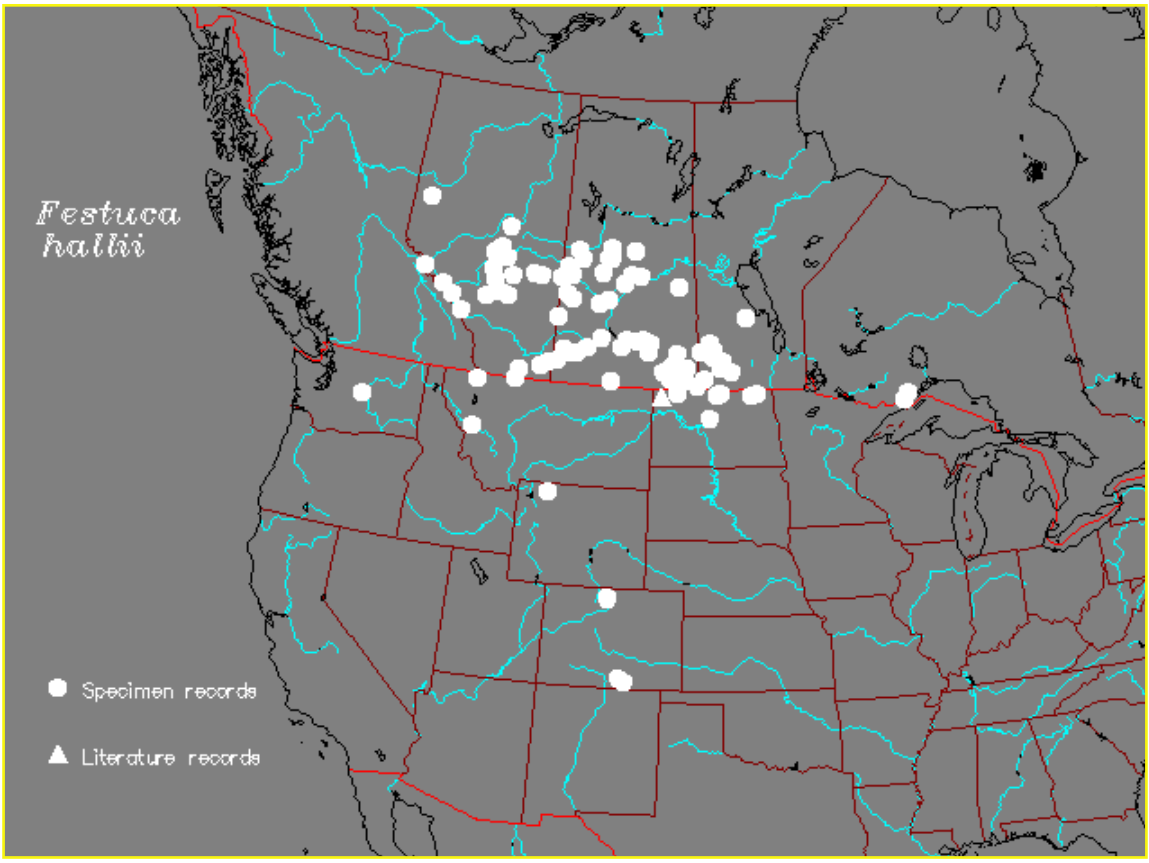

Figure 13. Global distribution of *Festuca hallii* from Aiken et al. (1996). Used with permission of Susan Aiken.

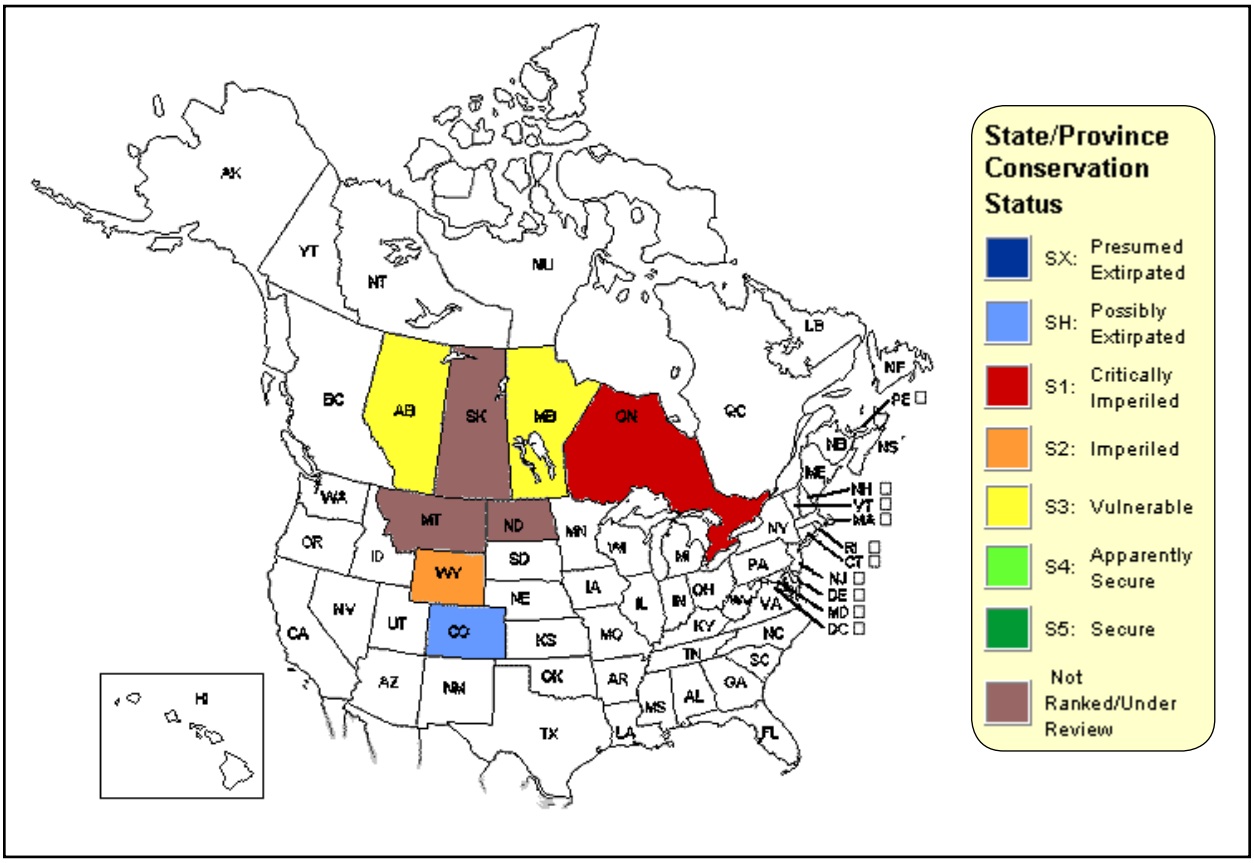

Figure 14. State (U.S.) and provincial (Canada) conservation status ranks given *Festuca hallii* by NatureServe member programs throughout the species' range (NatureServe Explorer 2005). The global conservation status rank of *F. hallii* is G4. *Festuca hallii* is now ranked S1 in Colorado.

northwestern and north-central Montana before grazing and agriculture largely eliminated it (Stickney 1961, Antos et al. 1983). Holcroft Weerstra (2003) mapped community types dominated by *F. hallii* in Alberta, and she wrote that "the mapping exercise highlights how few remaining areas of native grassland exist" in her study area. Looman (1969) wrote, "Already an estimated 90 percent of the fescue grassland has 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."

There is evidence to suggest that *Festuca hallii* has also declined within Region 2. Despite efforts to relocate historic occurrences (e.g., Fertig 2002), this species has not been seen at some locations in many years, and it is suspected that the species is in moderate decline (Wyoming Natural Diversity Database 2005). Six of the 12 occurrences in Wyoming and four of the five occurrences in Colorado have not been seen in more than 20 years. Two occurrences, one in Wyoming (WY EO #6) and one in Colorado (*Hall and Harbour 621*), have not been seen in more than 100 years and are likely to have been extirpated by intensive land use.

Habitat

Habitats range-wide

In the heart of its range, *Festuca hallii* occupies native prairies (**Figure 15**; Aiken et al. 1996) in the northern extremes of the North American Great Plains (Trottier 1986). The species' habitat has been characterized as dry prairie and sandhills in southern Manitoba (Scoggan 1957) and as parklands in Saskatchewan and Alberta (Cory 2005). It is found in the foothills and in montane grasslands of the Rocky Mountains in Montana, Wyoming, and Colorado (Romo et al. 1991, Tirmenstein 2000).

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* typically occurs in open forests, grass balds, and glades in montane forests, and also in the subalpine zone, while *F. hallii* occupies plains habitats (Pavlick and Looman 1984). Where these species overlap geographically in Alberta, *F. campestris* occurs at higher elevations than *F. hallii*.

Region 2 habitats

In Region 2, *Festuca hallii* grows in habitats that vary considerably in elevation and in associated biota. Handley and Laursen (2002) report *F. hallii* in Wyoming from interrupted habitats in montane meadows and in edges between open meadows and *Pinus contorta-Picea engelmannii* forests, and in tundra. Tweit and Houston (1980) documented *F. hallii* on gentle slopes (0 to 15 percent) on the Shoshone National Forest. Jones and Fertig (1999) noted the species' affinity for meadows, slopes, and open woods in Wyoming. In Colorado, a description of the Cordova Pass occurrence (Weber et al. 1979) reads, "It occurs sparsely on a grassy saddle along the trail from the pass toward West Spanish Peak. The saddle is dominated by *Trifolium attenuatum* and *F. 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." Cordova Pass supports a mosaic of montane meadows surrounded by forests and woodlands dominated by *Pinus aristata* and *Picea engelmannii* (**Figure 16**; Elliott personal communication 2005). Elliott (personal communication 2005) observed the prevalence of gopher activity at Cordova Pass also described by Weber et al. (1979), and noted the tendency of *F. hallii* to occur on or around disturbed gopher gardens (**Figure 17**). See the Herbivores section for more information on the relationship among herbivores, *F. hallii*, and its habitat.

Festuca hallii is found in tundra at one known location on Cameron Mountain in Colorado (Weber 1961). This occurrence was documented on mature tundra, where it was co-dominant with *Kobresia myosuroides*.

All reports of *Festuca hallii* and *F. scabrella* in Region 2 for which habitat data are available are from open sites. These include sites above tree line and meadows in the subalpine zone. Meadows are defined as treeless areas dominated by various species of grasses, sedges, and forbs that are scattered throughout forests of the Rocky Mountains (Peet 2000). There is little agreement on what ecological processes are responsible for the creation and maintenance of meadows; in Rocky Mountain National Park, they are maintained by a combination of saturated, fine-textured soils, high snow accumulation, and cold air drainage (Peet 2000). The unforested areas on Cordova Pass may be glades that are maintained by snow drifts, but fire may also play a role in the maintenance of these openings.

Figure 15. *Festuca hallii* at Kernen Prairie, near the town of Saskatoon, Saskatchewan. This site is a five-acre prairie remnant that has never been plowed. One of the dominant native grasses is *F. hallii*. Photograph by E. Hendrycks, Canadian Museum of Nature, from Aiken et al. (1996). Used with permission of Susan Aiken.

Figure 16. 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 by Brian Elliott, used with permission.

Figure 17. Habitat at Cordova Pass, showing soil disturbance by northern pocket gopher (*Thomomys talpoides*). The pocket gopher been described as an "ecosystem engineer," having significant effects on vegetation composition and structure. Photograph by Brian Elliott, used with permission.

Grassland and shrubland habitat types on the Shoshone National Forest are restricted to sites that are too arid to support tree growth (Tweit and Houston 1980). Characteristics such as elevation, annual precipitation, and regional weather pattern, and more site-specific factors including soil depth, landform, topographic position, and available nutrients may be responsible for causing these conditions. Grassland and shrubland habitat types on the Shoshone National Forest dominate the foothill zone where low elevation climates and a lack of precipitation combine to make moisture stress severe (Tweit and Houston 1980).

Table 4 summarizes all available habitat information for members of the *Festuca scabrella* complex in Region 2.

Climate

Festuca hallii is a cool-season grass that is adapted to a short growing season. The effects of temperature and moisture on its performance 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 a similar climate. Mean temperatures in the coldest month vary between –3 and –10 °C, mean temperatures in the warmest month vary between 14 and 18 °C, and daily temperature varies about 18 °C. The growing season includes two to four months with fewer than six frost days, and evapotranspiration exceeds precipitation on fewer than 60 days (Weaver 1979). *Festuca scabrella* is associated with mesic grassland sites with more than 14 inches of annual precipitation and a short, cool growing season (Weaver 1979). *Festuca campestris* occurs on cooler, more mesic sites than *F. hallii* or *F. altaica* (Aiken and Darbyshire 1990).

Weaver (1979) noted that the climate of fescue grasslands is similar to that 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. Gould and Shaw

(1983) noted climatological distinctions between fescue grasslands and mixed-grass prairie. Fescue grasslands occur in regions of greater moisture efficiency than in mixed-prairie communities. Lower temperatures, lower evaporation rates, and slightly higher precipitation enhance the availability of moisture in fescue grasslands. A short growing season is also associated with the lower temperatures in fescue grasslands. *Festuca scabrella* is found in more mesic 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 had similar temperatures 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 for mean daily maximum) and worse at warmer temperatures (approximately 17 °C for mean daily maximum), where *F. altaica* and *F. hallii* performed best. *Festuca hallii* is adapted to growth through the summer, leaving it dependent on the availability of summer precipitation (King et al. 1995, Hill et al. 1997). In three locations in Colorado (Cordova Pass, Shipman Park, and Cameron Mountain), average annual precipitation is approximately 25 to 30 inches per year (Bureau of Land Management 1998). Monsoonal rains in July through September ameliorate summer drought conditions in most years at these locations. All Wyoming stations occur in areas where average annual precipitation exceeds 16 inches per year (Daly 1998).

Soils and geology

Throughout Region 2, *Festuca hallii* is known from areas characterized by either calcareous sedimentary rocks (sometimes influenced by intrusive igneous rocks) or Precambrian granite or gneiss. *Festuca hallii* is usually found in areas underlain by limestone or other calcareous sedimentary rocks. Most occurrences in northwestern Wyoming fall into this category (Jones and Fertig 1999), as does the occurrence at Cordova Pass in Colorado. In northwestern Wyoming, *F. hallii* occurs on Madison limestone and members of the Chugwater, Dinwoody, and Gros Ventre formations; it may also occur on the Three Forks, Jefferson, and Beartooth Butte Formations (U.S. Geological Survey 1994). In Cinnabar Park on the Medicine Bow National Forest (WY EO #7), *F. hallii* grows on upper Miocene sedimentary rocks (U.S. Geological Survey 1994). In Colorado, *F. hallii* occurs on an outcrop of the Huerfano Formation at Cordova Pass, which consists of highly fossiliferous shale and sandstone (Tweto 1979). On the Shoshone National Forest, this species appears to be restricted to glacial till soils derived mainly from limestone substrates (Tweit and Houston 1980).

While most occurrences are found on calcareous sedimentary rocks in Region 2, at least four are known from exposures of granite, gneiss, or other rocks. This includes both occurrences in Larimer County, Colorado. The occurrence at Cameron Mountain (CO EO #1) is underlain by Precambrian granite, and Shipman Park is underlain by Triassic and Permian rocks. Much of eastern Custer County, Colorado at suitable elevations for *Festuca hallii* is underlain by felsic and hornblendic gneiss derived mostly from volcanic rocks. The geology of the Crazy Woman Creek area (where *F. hallii* has not been seen since it was first collected in 1898) consists of the Oldest Gneiss Complex (U.S. Geological Survey 1994).

At some sites in Wyoming and Colorado, intrusive igneous rocks are evident, but the intrusions are in beds of calcareous sedimentary rock. In northwestern Wyoming, the sedimentary rocks include the Washburn Group (Sepulcher, Lamar River, and Cathedral Bluffs Formations) and the Sunlight Group (Wapiti Formation and Trout Peak Andesite). In Colorado, the occurrence at Cordova Pass is adjacent to dikes and massive intrusions associated with the extinct Spanish Peaks volcano.

Festuca scabrella grows on several soil types, including loam and silty loam (Koterba and Habeck 1971). *Festuca scabrella* is dominant on deep mollisols of western Canada (Willms 1988). In Wyoming, *F. hallii* is usually found on soils derived from calcareous parent materials (Handley and Laursen 2002), but it is also reported from soils derived from volcanic materials (Evert 1991). 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 develop on moderate to steep slopes.

Elevation

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

outside Region 2, in Oregon. In Colorado, *F. hallii* has been reported at elevations between 8,500 ft. in Custer County and 11,248 ft. at Cordova Pass. Of the type specimen probably collected in Park County, Colorado, Piper (1906) wrote that it was "evidently from high altitudes." In Wyoming, *F. hallii* is known from elevations ranging from 6,800 to 11,000 ft. (Handley and Laursen 2002).

Succession

Festuca hallii is characterized as a climax species of fescue grasslands, but it also occurs in seral and late-successional fescue prairie communities (Tirmenstein 2000). *Festuca scabrella* is a component of early seral communities following fire because of residual plant survival (Moss and Campbell 1947). Stands of *F. hallii* typically take three to four years to develop. Initial establishment is enhanced on sites that are protected from grazing. The establishment of *F. hallii* is likely to be highest where competition is reduced (Grilz et al. 1994).

Fire

Tirmenstein (2000) provided a thorough review of the extensive literature on the effects of fire on *Festuca hallii*. *Festuca campestris* and *F. altaica* are more susceptible to fire damage than the rhizomatous *F. hallii* due to their bunchy habit, which may burn longer and result in damage to the root crown (Tirmenstein 2000).

Antos et al. (1983) suggested that the historical fire return interval of five to 10 years probably benefited *Festuca scabrella* in Montana most. 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 excessive fuel buildup. In Saskatchewan, biomass returned to that of unburned plots in two to three years in experimentally burned plots dominated by *F. hallii* (Redmann et al. 1993).

Fire initially reduces *Festuca hallii* regardless of the season of burning, and it may reduce productivity for one to three years (Redmann et al. 1993, Cory 2005). Reduction in primary production is due to injury to the plant and decreased soil water potential on burned sites (Willms 1988).

Light burning during dormancy does not harm *Festuca scabrella* (Anderson and Franzen 1983), but when burning occurs during the growing season, it can severely reduce this species (Bailey and Anderson 1978). In aspen parkland 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 a fall burn. Biomass in *F. hallii* grasslands was reduced by up to 84 percent following a spring burn in Saskatchewan (Redmann 1991). Defoliation from burning or mowing in the early spring had little effect on standing crop that year (Gerling et al. 1995). Increased tiller density apparently compensated for the reduction in tiller length. Despite high burn temperatures, *F. scabrella* can 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 aspen and to remove litter accumulations.

Fire probably plays a natural role in the ecosystems where *Festuca hallii* occurs in Region 2. The estimated mean fire return interval for forests dominated by *Pinus aristata* on the Pike National Forest ranges from 16 to 55 years, which is an order of magnitude shorter than the mean fire return interval typical of *Picea engelmannii/Abies lasiocarpa* forests in Colorado and Wyoming (Donnegan et al. 2001). The Cordova Pass occurrence is in meadows among *Pinus aristata* forest stands. Fire may help to maintain these meadows.

Festuca hallii responds to fire by increasing tiller production (Tirmenstein 2000), with greatest increases following early spring fires (Gerling et al. 1995). Burned swards are shorter and denser than unburned swards. The further into the growing season the burning occurs, the greater the detrimental effect. Grilz and Romo (1994) reported reduced tillering of *F. hallii* following spring or fall burns. Sinton (1980) observed a nearly linear negative relationship between herbage production, leaf blade length, and tiller density following burning one week, four weeks, and eight weeks after snowmelt.

Reproductive biology and autecology

Grasses, such as *Festuca hallii*, that are community dominants in productive ecosystems fit well into the competitive category in the Competitive/Stress-Tolerant/Ruderal (CSR) model of Grime (2001). *Festuca hallii* is capable of rapid primary growth during the growing season. *Festuca scabrella* can produce more than 2,000 kg per ha of forage (Willms et al. 1986). The poor response of *F. hallii* to disturbance (caused by fire, soil movement, or grazing) is also typical of competitive strategists in the CSR model. *Festuca hallii* is sensitive to defoliation, and its competitiveness declines when

it is grazed during the growing season (Looman 1969). Disturbance by livestock grazing reduced the dominance of *F. hallii* (Vujnovic et al. 2002).

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 hallii* can be regarded as a *K*-selected species in the classification scheme of MacArthur and Wilson (1967). In the Raunkiaer Life Form classification system (Raunkiaer 1934), *F. hallii* is a chamaephyte, with overwintering buds at or near the ground (Tirmenstein 2000).

Reproduction

Festuca hallii reproduces primarily by seed (Pavlick and Looman 1984, Aiken et al. 1996, USDA Natural Resources Conservation Service 2005). *Festuca hallii* and *F. campestris* produce seed very erratically, and several years may elapse without appreciable seed set (Johnston and MacDonald 1967, Tirmenstein 2000). In southern Alberta, Johnston and MacDonald (1967) reported high seed production in *F. campestris* in 1902, 1952, 1964, and 1966. Flowering was prolific for *F. hallii* in 1987 at Kernen Prairie in Saskatchewan, with a mean of 224 inflorescences per m^2 (Toynbee 1987). These observations suggest that climate controls reproductive effort, with mild winters and warm springs enhancing reproduction. Growth of floral primordia begins in late August to early September, so it is possible that mild winters result in lower attrition of these structures to frost damage (Toynbee 1987). Wind and animals disperse the seeds of most *Festuca* species (Johnston 2002), and seeds germinate over a wide range of temperatures (Tirmenstein 2000).

Festuca hallii spreads vegetatively via rhizomes, which distinguishes it from *F. campestris* and *F. altaica* (Aiken et al. 1996). See the Non-technical description section of this assessment for more information on this mode of reproduction in *F. hallii*.

Virtually all fescues, and many other grasses, are capable of producing leafy bulbils or plantlets instead of floral bracts. This is most common in stressed plants, where it is initiated by the disruption of hormonal regulation. Although this is sometimes called "vivipary," 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 of 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 up to 155 m away (Rognli et al. 2000). This suggests a significant degree of genetic isolation among the occurrences in Region 2.

Phenology

In Manitoba, *Festuca hallii* begins growth between mid-April and early May. Plants reach reproductive maturity in late May through mid-June, depending on environmental conditions (Trottier 1986). *Festuca hallii* flowers two to three weeks earlier than *F. campestris*, but the seeds of *F. hallii* mature later.

Festuca hallii typically initiates growth immediately following snowmelt, completes growth before the onset of summer drought, and is dormant by October. Soil temperature, rather than soil moisture or air temperature, appears to control the onset of growth in the spring (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, with final seed head maturation occurring the next summer (Stout et al. 1981, Tirmenstein 2000). Rapid culm elongation occurs during May and early June (Tirmenstein 2000). Fall regrowth of *F. hallii* has been observed occasionally in Manitoba (Trottier 1986).

Fertility and propagule viability

The seed germination rate 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 spring burns do not affect floral initiation, but by May the greater height of reproductive growing points leaves them susceptible to fire damage. Fall burning did not affect subsequent seed head development. USDA Natural Resources Conservation Service (2005) described seedling vigor as "medium." Toynbee (1987) reported that unburned

F. hallii had the greatest reproductive output, which declined in plots that were burned the previous fall, and was very low in plots that were burned in early or late spring of the same year. However, Gerling et al. (1995) reported that inflorescence density increased following burning between 8 April and 1 June in parklands in central Alberta.

Water stress, not temperature, primarily controls germination in *Festuca hallii*. (Grilz et al. 1994). *Festuca hallii* germinates over a wide range of temperatures, but germination is highest at constant temperatures of 59 and 68 °F (15 and 20 °C) (Romo et al. 1991). Exposure to moist conditions at low temperatures reduces germination of *F. hallii*. (Grilz et al. 1994).

Mycorrhizae

Aiken and Fedak (1992) describe collecting two live plants of *Festuca campestris* in Alberta that were growing close together but were conspicuously different in size and morphology. They found the arbuscular mycorrhizal fungus *Glomus fasiculatus* in the roots of the larger individual. The response of *F. campestris* to infection with mycorrhizal fungi may include larger size or the production of wide, flat leaves. While there appear to be no such reports of a response for *F. hallii*, it is possible that mycorrhizal symbionts may elicit similar morphological responses in that species.

Marler et al. (1998) reported that arbuscular mycorrhizal fungi had a strong indirect effect on the outcome of competitive interactions between *Festuca idahoensis* and the noxious weed *Centaurea maculosa* in greenhouse experiments. In this study, non-mycorrhizal *F. idahoensis* plants were 171 percent larger than mycorrhizal individuals when grown with *C. maculosa*, suggesting that AM fungi mediate the competitive interactions between these species and give a competitive advantage to *C. maculosa*. These results suggest that arbuscular mycorrhizal fungi increase the susceptibility of fescue grasslands to invasion by *C. maculosa*.

Hybridization

Members of the *Festuca scabrella* complex are among the fescues that commonly hybridize (Aiken and Darbyshire 1990). Because *F. campestris* has twice the number of chromosomes of *F. hallii* and *F. altaica*, it is possible that *F. campestris* arose from a hybridization event involving these or other taxa. *Festuca campestris* is not an autopolyploid 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 inconclusive. There are no other reports of possible hybrids involving *F. hallii*.

Demography

While there has been a considerable amount of research on other aspects of *Festuca hallii*, there have been few studies dealing with its demography. Most demographic research involving *F. hallii* 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. hallii*, and its population genetic characteristics have not been investigated directly. No population viability analysis (PVA) has been performed for *F. hallii*.

Festuca rubra and *F. trachyphylla* have been the subject of demographic studies, from which very general inferences can be made regarding the life history characteristics of *F. hallii*. Like *F. hallii*, *F. rubra* spreads vegetatively via rhizomes, while *F. trachyphylla* is a nonrhizomatous bunchgrass that reproduces only by seed (Winkler and Klotz 1997). Winkler and Klotz (1997) determined that *F. trachyphylla* becomes reproductive after 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). In *F. rubra*, shoots are least likely to survive the first year, but after the first year, the fate of shoots varies independently of their age (Hara and Herben 1997).

Most fescues are obligate outcrossers (Johnston 2002), which means that small populations may be vulnerable to inbreeding depression. Genetic variability within and among populations has not been measured directly in *Festuca hallii* or *F. campestris*. May et al. (2003) observed phenotypic 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 created genotypes that are more winter-hardy.

Festuca hallii flowers multiple times throughout its lifespan (iteroparous). The recruitment rate and periodicity of recruitment events are not known for

F. hallii or its relatives. *Festuca hallii* produces seed infrequently (Johnston and MacDonald 1967, Romo et al. 1991). Very little is known about the character of the seed bank, and the longevity of seeds in the seed bank is not known. Grilz et al. (1994) report that the viability of rough fescue seed in the soil is low. Romo (1996) observed that seed germinability declined linearly over a period of 91 months under controlled conditions; at 91 months, almost no germination occurred. This study suggests that *F. hallii* seed banks are relatively short-lived. Willms and Quinton (1995) observed the effects of various grazing intensities on the seed bank of *F. campestris*. In this study, grazing 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*. No such study has been conducted for *F. hallii*, but the inferential value of this study is high because these species are closely related. **Figure 18** is a life cycle graph of *F. hallii* (after Caswell 2001).

Community ecology

Festuca hallii is a dominant species in numerous grassland, shrubland, and woodland plant associations (Aiken and Darbyshire 1990, NatureServe 2005). The communities defined by *F. hallii* and its relatives have been studied and described by many authors, but in earlier studies, no distinctions were 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 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.

Either *Festuca hallii* or *F. campestris* is a dominant species in 12 plant associations in the northern Great Plains, in the northern Rocky Mountains on both sides

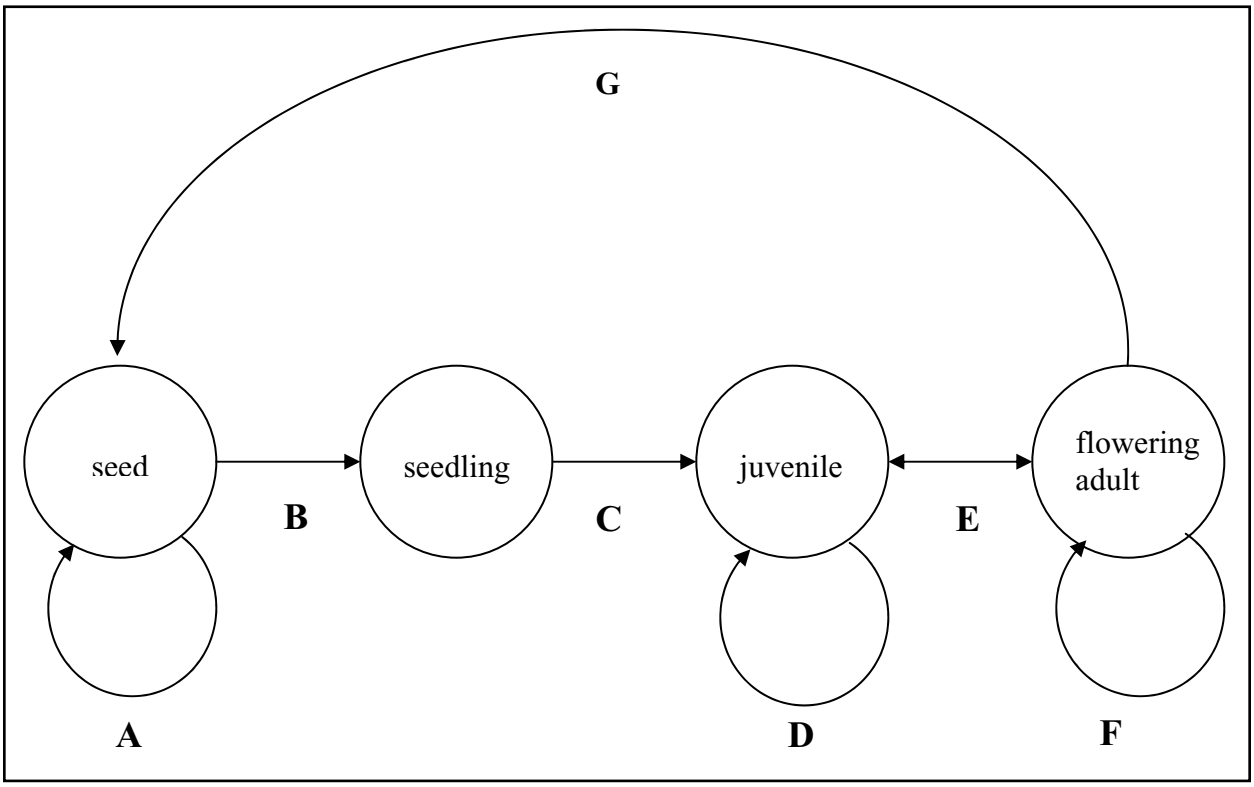

Figure 18. Hypothetical life cycle graph (after Caswell 2001) for *Festuca hallii*. Much of this is somewhat speculative because there has been no demographic monitoring where individuals were tracked through their life history stages. The value of **A** is not known, although seeds are known to persist in the seedbank 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 hallii* is clearly a polycarpic perennial (**F**). The lifespan of *F. hallii* is unknown, but may be in the vicinity of 20 years based on other species of *Festuca*. Unlike its close relative *F. campestris*, *F. hallii* is rhizomatous and is capable of clonal spread.

of the Continental Divide, and in eastern Washington and Oregon. Weerstra and Holcroft Weerstra (1998) described eight community types within the Plains Rough Fescue Herbaceous Alliance, and these community types have been mapped in Alberta (Holcroft Weerstra 2003). Moss and Campbell (1947) described communities dominated by *F. hallii* in southern Alberta, Crosby (1965) in North Dakota, Blood (1966) in southern Manitoba, and Carbyn (1971) in Prince Albert National Park, Saskatchewan. Tirmenstein (2000) listed ecosystems, BLM physiographic regions, Küchler plant associations, USFS forest cover types, and southern Rocky Mountain rangeland cover types, but did not distinguish among members of the *F. scabrella* complex in these lists.

In describing communities on the Shoshone National Forest, Tweit and Houston (1980) described a *Festuca scabrella* phase of the *F. idahoensis-Agropyron caninum* habitat type: "The *Festuca scabrella* phase is dominated by *F. scabrella* with canopy cover ranging from 5 to 25 percent. *Festuca idahoensis* is the co-dominant with coverages sometimes exceeding that of *F. scabrella*. Total graminoid cover ranges from 25 to 60 percent, forb cover ranges from 20 to 50 percent." Their description is similar to that of Mueggler and Stewart (1980), who described *F. scabrella-A. spicatum* and *F. scabrella-F. idahoensis* habitat types in Montana. Tweit and Houston (1980) list species associated with the *F. idahoensis-A. caninum* Habitat Type, but these are not specific to the *F. scabrella* phase of this habitat type. **Table 5** is a list of all species documented with *F. hallii* in Region 2.

Festuca hallii is infrequently reported with shrubs. Elliott (personal communication 2005) reported

Table 5. Vascular plant species documented with *Festuca hallii* in Colorado and Wyoming.

Growth form	Species	WY	CO	Growth form	Species	WY	CO
Tree	*Picea engelmannii*	X	X	Forb	*Bupleurum americanum*	X	
Tree	*Pinus aristata*		X	Forb	*Campanula rotundifolia*	X	
Tree	*Pinus contorta*	X		Forb	*Castilleja longispica*	X	
Shrub	*Artemisia frigida*	X		Forb	*Castilleja nivea*	X	
Shrub	*Artemisia tridentata*	X		Forb	*Delphinium* sp.	X	
Shrub	*Dasiphora fruticosa*	X	X	Forb	*Erigeron caespitosus*	X	
Graminoid	*Carex elynoides*	X		Forb	*Erigeron compositus*	X	
Graminoid	*Carex filifolia*	X		Forb	*Erigeron simplex*	X	
Graminoid	*Carex* sp.		X	Forb	*Fragaria virginiana*		X
Graminoid	*Danthonia intermedia*	X		Forb	*Gaillardia aristata*	X	
Graminoid	*Elymus trachycaulus*	X		Forb	*Gentiana affinis*	X	
Graminoid	*Festuca arizonica*		X	Forb	*Geum rossii* var. *turbinatum*	X	
Graminoid	*Festuca idahoensis*	X		Forb	*Geum triflorum*	X	
Graminoid	*Helictotrichon hookeri*	X		Forb	*Lomatium* sp.		X
Graminoid	*Kobresia myosuroides*		X	Forb	*Lupinus argenteus*	X	
Graminoid	*Koeleria macrantha*	X		Forb	*Lupinus wyethii*	X	
Graminoid	*Leucopoa kingii*	X		Forb	*Minuartia obtusiloba*	X	
Graminoid	*Poa secunda*	X		Forb	*Penstemon* sp.	X	
Graminoid	*Poa* spp.	X		Forb	*Phlox pulvinata*	X	
Graminoid	*Stipa minor*	X		Forb	*Polygonum bistortoides*	X	
Graminoid	*Trisetum* sp.	X		Forb	*Pyrrocoma carthamoides* var. *subsquarrosa*	X	
Forb	*Achillea lanulosa*		X	Forb	*Shoshonea pulvinata*	X	
Forb	*Antennaria* sp.	X		Forb	*Swertia radiata*	X	
Forb	*Arenaria hookeri*	X		Forb	*Trifolium attenuatum*		X
Forb	*Artemisia scopulorum*	X		Forb	*Zigadenus elegans*	X	
Forb	*Astragalus miser*	X					

one shrub species, *Dasiphora floribunda*, with *F. hallii* (**Figure 16**). Because of overgrazing by elk and horses, *D. floribunda* is invading areas dominated by *F. campestris* in Alberta (Scotter 1975). Fire suppression (Bailey and Anderson 1978) and nitrogen loading (Köchy and Wilson 2001) have also been implicated in accelerating the spread of woody species into meadows and prairies. In parts of Montana, Douglas-fir (*Pseudotsuga menziesii*) has invaded large areas of *F. scabrella* grasslands (Arno and Gruell 1986). "Brush" has invaded fescue grasslands in central Alberta (Bailey and Anderson 1980). *Populus tremuloides* (aspen) has encroached in many fescue grasslands (Carbyn 1971, Jourdonnais and Bedunah 1990, Redmann et al. 1993, Gerling et al. 1995).

Herbivores

Festuca hallii and *F. campestris* are the dominant species in their respective grassland associations, and they are important sources of forage for native ungulates and domestic livestock 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. hallii* and *F. campestris* to livestock and native wildlife. All the species in the *F. scabrella* complex are productive and highly palatable to livestock and wildlife, and they are important native forage grasses in Canada (Aiken and Darbyshire 1990).

Festuca hallii and *F. campestris* are prime winter forage because plants cure well on the stalk and retain high nutrient levels during dormancy (USDA Forest Service 1937, Wilson 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 vegetative stage prior the inflorescence emerges (Bezeau and Johnston 1962). Their native status and agronomic potential have increased the demand for these species (King et al. 1995).

Festuca hallii and *F. campestris* probably evolved with intermittent grazing pressure imposed by herds of nomadic bison herd (Moss and Campbell 1947). Of the relationship between *F. hallii*, *F. campestris*, 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 hallii* and *F. campestris* are the primary forage species for bison wintering in quaking aspen parklands of southern Canada (Johnson and Cosby 1966, Morgan 1980, Tirmenstein 2000).

Festuca hallii and *F. campestris* are important dietary components for native ungulates, including bighorn sheep, mule deer, and elk (Bailey 1986, Jourdonnais and Bedunah 1986, Peck and Peek 1991, Wikeem and Pitt 1992, Kingery et al. 1996, Tirmenstein 2000). Mule deer (Stelfox 1976) and white tailed deer (Singer 1979) consume lesser amounts of *F. scabrella*.

Gopher activity in meadow habitats at Cordova Pass is well documented (**Figure 17**; Weber et al. 1979, Elliott personal communication 2005). The animal using this site is probably the northern pocket gopher (*Thomomys talpoides*), which build characteristic "eskers" seen in **Figure 17** (Siemers personal communication 2005). In Colorado, this species is widespread in shortgrass prairie habitats up to the alpine (Vaughan 1967). The population at Cordova Pass is near the upper end of their elevation range. The fossorial and subnival activities of northern pocket gophers can result in considerable soil disturbance in glades and areas of heavy snow pack (Ward and Keith 1962). However, the level of disturbance is considered relatively low at Cordova Pass, where about 10 percent of the surface shows evidence of gophers (Elliott personal communication 2006).

Northern pocket gophers use 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). In grasslands between 9,000 and 10,500 ft. on Black Mesa, Colorado, northern pocket gophers favored *Festuca idahoensis* over other grasses for forage, but forbs constituted 93 percent of the diet (Ward and Keith 1962). It is possible that the presence of large numbers of pocket gophers may help to shift the competitive balance in favor of grasses.

Willms and Johnson (1990) observed utilization of *Festuca scabrella* by two species of grasshopper. *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 the percent utilization. The authors suggest that grasshoppers, particularly *M. sanguinipes*, could alter species composition and reduce the dominance of *F. scabrella*.

Livestock grazing

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

Two to five summers of heavy grazing can effectively eliminate *Festuca hallii* and *F. campestris* from rangelands (Johnston 1961, Johnston and MacDonald 1967, McLean and Wikeem 1985a, Willms et al. 1988, King et al. 1998). *Festuca hallii* and *F. campestris* are sensitive to defoliation, and their competitiveness declines when grazed during the growing season (Willms and Fraser 1992). Under 20 percent defoliation, steep declines in top growth and root mass were observed in *F. campestris* (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). Heavy grazing typically reduces large, robust bunches to small, inconspicuous shoots (Tirmenstein 2000). Light to moderate grazing may reduce *F. hallii* during the growing season in Alberta (Willms and Fraser 1992). Heavy grazing may reduce vegetative regeneration via rhizomes in *F. hallii* (Romo et al. 1991).

Livestock grazing affects community composition in fescue grasslands. Fescue grasslands are easily damaged by defoliation during the growing season (Willms and Johnson 1990). Overgrazed ranges of *Festuca campestris* and *F. hallii* may require 20 to 40 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 in response to grazing (Chaffee and Morriss 1982).

Grazing may result in increased dominance of less palatable grasses, woody plants, and exotic species. Even under light summer grazing, *Danthonia parryi*, which is more tolerant of grazing, replaces *Festuca scabrella* as the dominant species in fescue grasslands (Johnston 1961, Willms 1991). Other species that increase with livestock grazing include *F. idahoensis*, *Stipa* spp., *Koeleria macrantha*, *Carex filifolia*, *Agropyron* spp., *Artemisia frigida*, *Oxytropis campestris*, *Antennaria* spp., *Taraxacum officinale, and Chrysothamnus nauseosus* (Johnston 1961, Wilson and Johnston 1971, Dormaar and Willms 1990). In disturbed situations, *F. scabrella* may be reduced or 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).

Festuca hallii tolerates winter grazing (USDA Forest Service 1937, Johnston and MacDonald 1967, Willms et al. 1996). Experiments with cutting height and frequency 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. This may be the case for *F. hallii* as well. 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 *Festuca hallii* occurrences 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. Grasses and sedges are susceptible to local ergot (*Claviceps purpurea*) epidemics. 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 they can create a serious problem for grazing livestock (Aiken and Darbyshire 1990).

CONSERVATION

Threats

In order of decreasing priority, threats to *Festuca hallii* in Region 2 include grazing, fire and fire suppression, invasion by exotic species, residential development, recreation, effects of small population size, pollution, over-utilization, and global climate change. These threats and the hierarchy ascribed to them are

speculative and based largely on research conducted on members of the *F. scabrella* complex outside of Region 2. The magnitude of specific threats also differs at each occurrence. Fertig (2000) included grazing, competition from exotics, and habitat disturbance as possible threats to Wyoming occurrences of *F. hallii*. Grazing, disturbance, agriculture, and nitrogen pollution have all been shown to decrease habitat quality for *F. hallii* or *F. campestris* outside of Region 2 (USDA Forest Service 1937, Looman 1969, Dormaar and Willms 1998, Köchy and Wilson 2001). The following sections describe these threats to individual plants and to habitat. Assessment of threats to this species will be an important component of future inventories and monitoring studies.

Grazing

The effects of livestock grazing on *Festuca hallii* and *F. campestris* are well documented (see Herbivores section of this assessment). However, this research was done in the center of the range of *F. hallii*; there has been no research on the effects of grazing on *F. hallii* in Region 2. Use of *F. hallii* by cattle appeared light in grazed areas in Wyoming (Fertig 2002).

Canadian studies have reported that heavy grazing (above 2.4 AUMs per ha) jeopardizes ecosystem sustainability in fescue grasslands by reducing fertility and water-holding capacity, and even light grazing (1.2 AUMs per hectare) during the summer causes the decline of *Festuca campestris* and *F. hallii* (Dormaar and Willms 1998).

In Colorado, 400 head of cattle are grazed on the West Creek cattle and horse allotment at Cordova Pass on the San Isabel National Forest. 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). Cattle do not frequent the portion of the allotment where *Festuca hallii* is found, and grazing impacts in this location are minimal (Elliott personal communication 2005). Elliott (personal communication 2005) did not see a single cow fecal pat within the Cordova Pass occurrence in 2004. This location is in the far corner of the West Creek allotment, has no developed water source and receives limited livestock use because it is difficult for cattle to reach (Vallejos personal communication 2005). Cattle are also not encouraged to visit this location because of potential conflicts with recreational users. The current grazing regime has existed at this site for at least 50 years, and *F. hallii* is still present. Because this is an on/off permit, it is not possible to quantify the grazing intensity in AUM per ha. The establishment of a temporary corral in the Cordova Pass meadows 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 vacant Beulah Allotment. Proposals exist 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 grazing allotment (where *Festuca scabrella* was documented by Wasser in 1954) is currently vacant, and it has been recommended for closure (La Fontaine personal communication 2005). This area receives heavy but localized grazing by horses during the hunting season. Riding and pack stock (horses and mules) use the Upper Laramie and Shipman Park allotments (LaFontaine personal communication 2005). Outfitter and guide operations graze an estimated 8 head months (1 horse for 1 month), concentrated during the big game hunting seasons when *F. hallii* is dormant. No estimates of recreation stock grazing intensity are available. Pack stock grazing is confined, and many of the users bring pellets to feed their stock (LaFontaine personal communication 2005).

Available information suggests that there is cause for concern regarding current grazing practices at six occurrences in Wyoming, where *Festuca hallii* is found in allotments that are grazed during the growing season. Summer use is occurring at WY EO #3, 5, 8, 9, and 10 on the Shoshone National Forest, and at Crazy Woman Creek (WY EO #6) on the Bighorn National Forest. *Festuca hallii* has not been seen at Crazy Woman Creek since 1898, and since the exact location where it was collected is not known, conservation management actions will be difficult to implement at this site. Allotment status of all locations on National Forest System land is summarized in **Table 6**.

Impacts of grazing in fescue grassland are greatly exacerbated where pocket gophers occur. Soil displacement (by both gophers and livestock) was three times greater in a very heavily grazed (4.8 AUM per ha) field and seven times greater in a lightly grazed (1.2 AUM per ha) 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 large population of northern pocket gophers at this location.

Table 6. Allotment status for all reports of *Festuca hallii* and *F. scabrella* in Region 2 on National Forest System land.

Occurrence	County/State	Allotment	Allotment status
Wasser (1954)	Larimer/CO	Shipman Park (Routt National Forest)	Recommended for closure in 1997 forest plan; currently vacant, last grazed in 1990.
CO EO#1, *Weber and Pickford 9694*	Larimer/CO	Upper Laramie (Routt National Forest)	Currently vacant, not grazed since 1994.
Harrington (1954)	Custer/CO	Allotments in Wet Mountains (San Isabel National Forest)	All are currently active except Beulah, which is vacant.
Hall and Harbour 621, Weber (2001)	Park/CO	Allotments in Northern South Park (Pike National Forest)	Active, vacant, and closed.
CO EO#1, *Weber and Wingate 15442*	Huerfano, Las Animas/CO	West Creek (San Isabel National Forest)	Cattle and horse, shared by two permitees, one 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.
Possibly *Swallen 1302*	Huerfano, Las Animas/CO	North Fork, East Peak (San Isabel National ForestF)	Vacant
Possibly *Swallen 130*2	Huerfano, Las Animas/CO	Lakes and Indian Creek (San Isabel National Forest)	Active
WY EO#11	Park/WY	Beartooth Highway, Line Creek West (Shoshone National Forest)	Closed
WY EO#8	Park/WY	Basin (Shoshone National Forest)	Four permittees share this allotment. 1: 17 cow/calf pairs from June 16 to October 31. 2: 25 cow/calf pairs and 40 horses from June 16 to October 30. 3: 239 cow/calf pairs and 12 horses from June 16 to October 31. 4: 54 cow/calf pairs from June 16 to October 30. Total: 335 cow/calf pairs and 40 horses.
WY EO#5, WY EO#9	Park/WY	Bald Ridge (Shoshone National Forest)	588 cow/calf pairs from June 21 to September 30, shared between two permittees.
WY EO#3	Park/WY	Pearson (Shoshone National Forest)	Managed as a pasture along with five other allotments; 650 cow/calf pairs permitted on the five allotments together; approximately 45 days of use during the summer.
WY EO#4	Park/WY	Jim Mountain (Shoshone National Forest)	Part of an allotment managed as a wildlife winter range; only livestock present when needed for vegetation management; no permit is issued.
WY EO#10	Park/WY	Big Creek (Shoshone National Forest)	17 horses from June 16 to October 15.
WY EO#6	Johnson/WY	Crazy Woman S&G (Bighorn National Forest)	Vacant but currently some limited informal use; the lower portion is grazed by cattle, and the upper end is grazed by sheep.
WY EO#7	Albany/WY	Cinnabar Park (Medicine Bow National Forest)	Not active

Current grazing intensities are much lower now than they were historically where *Festuca campestris*, *F. hallii*, and *F. scabrella* have been reported in Region 2. 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 grazed throughout the Rawah Mountains of western Larimer County, Colorado. Grazing was much more intense in this area 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 reduced the range of *F. hallii* (Tweit and Houston 1980, Fertig 2002).

Altered fire regime

The current character of most remnant fescue grasslands is the result of altered fire regimes (Romo 2003). Fire suppression has led to the encroachment of shrubs and trees in the fescue grasslands of Canada. *Populus tremuloides* has encroached in many fescue grasslands (Gerling et al. 1995). Annual burning stopped invasion of *P. tremuloides* in *Festuca hallii* grasslands (Gerling et al. 1995, Tirmenstein 2000). However, burning, either in the spring or fall, decreased the coverage of *F. scabrella* for at least three years near Edmonton, Alberta. 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).

Exotic species

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

Exotic species are absent at most occurrences of *Festuca hallii* in Region 2. However, exotic species represent a threat to the viability of any occurrence if they become established in or near a population. Exotic *Cirsium* species, including bull thistle (*C. vulgare*), are invading fescue grasslands in Wyoming (Tweit and Houston 1980).

At Cordova Pass, Elliott (personal communication 2005) noted that smooth brome was apparently seeded when the campground and trailhead were constructed, and it is spreading into the undisturbed meadow that contains *Festuca hallii*. As noted above, research outside Region 2 has determined that smooth brome threatens the viability of *F. hallii* and is known to invade *F. hallii* grasslands. Elliott (personal communication 2005) considers the invasion of smooth brome to be the greatest threat to *F. hallii* at Cordova Pass, along with the pasturing of recreational livestock at this site.

Residential development

Most occurrences of *Festuca hallii* in Region 2 are on National Forest System land. However, it is likely that occurrences remain to be found on private land in the Cordova Pass area, where residential development threatens suitable habitat (Elliott personal communication 2006). Because the montane grasslands in the Spanish Peaks area are highly productive, many of these have been in private ownership for many years and have not been surveyed. Ninety-five percent of Donald Park is privately owned and is grazed (Elliott personal communication 2006). There has been considerable subdivision and development of this area over the last 10 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-related disturbance are likely to encourage the spread of noxious weeds into *F. hallii* habitat. Forman and Alexander (1998) reviewed the ecological impacts of roads and road construction, including fragmentation.

Recreation

Recreational use threatens the *Festuca hallii* occurrence in the Cordova Pass area (Elliott personal communication 2005). The trailhead at Cordova Pass leading to the summit of West Spanish Peak receives heavy use, and a wide trail passes through the *F. hallii* occurrence in this area (Elliott personal communication 2005). A USFS campground has been constructed at the edge of the occurrence (Elliott personal communication 2005). The placement of this campground is unfortunate, but it may eventually benefit the occurrence of *F. hallii* by concentrating recreational impacts and discouraging the establishment of informal campsites. If horses are pastured at Cordova Pass for recreation, they could damage the *F. hallii* occurrence. Horses are usually either tethered or kept within a temporary corral. Weed-free hay rules are in effect in this area, but seeds of smooth brome are allowed in weed-free hay, and weed seeds are likely to be present in manure (Elliott personal communication 2006). Limited impacts from recreation may be occurring at other occurrences in Wyoming and Colorado.

Effects of small population size

Demographic stochasticity is the variation over time in vital rates such as recruitment and survival, and it is generally only a concern for very small populations. Because there are few abundance data for Region 2, the degree to which the effects of demographic stochasticity threaten populations is unknown. Reported numbers of individuals at two occurrences of *Festuca hallii* fall below the generally accepted minimum effective population size of 50 individuals (after Soulé 1980) needed to buffer against the probability that a fluctuation in vital rates will take the population to the extinction threshold. However, small populations of a rhizomatous species such as *F. hallii* may be able to persist for long periods of time through clonal perennation.

Environmental stochasticity generally refers to variation over time in the physical and biological environment. For a single population, this includes natural events happening at random intervals that cause the deaths of a large proportion of the population. Such events may occur very rarely, yet still have a large effect on population persistence (Menges 1991). Maintaining multiple populations can mitigate the effects of environmental stochasticity. However, studies of other species of *Festuca* suggest that there is little connectivity among the occurrences of *F. hallii* in Region 2. These occurrences are vulnerable to extirpation by catastrophic local disturbances and events such as fire, landslides, and disease.

Pollution

Atmospheric nitrogen deposition has become an important agent of vegetation change in densely populated regions (Köchy and Wilson 2001). Nitrogen deposition appears to accelerate the expansion of forests 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 have been observed to be greatest near large metropolitan areas (Schwartz and Brigham 2003). Measurable impacts from nitrogen pollution can be expected in many *Festuca hallii* locations in Region 2, especially in northern Colorado. Nitrogen enrichment experiments show universally that nitrogen is limited (Gross et al. 2000). Nitrogen enrichment is likely to cause a few species to increase in abundance while 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* in Region 2 is unknown.

Over-utilization

In collecting *Festuca hallii* for scientific purposes, collectors should take care not to remove 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. hallii* in Region 2, but impacts are possible if research is conducted that requires collection or contact with a significant portion of a population.

Climate change

Global climate change is likely to have wide-ranging effects in the near future in all habitats, although the direction of projected trends is yet to be determined. Predictions vary based on environmental parameters used in predictive models. The prevailing scientific opinion is that global temperatures are increasing and will continue to rise through the next century, due in part to anthropogenically increased 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. 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.

The impacts of landscape level vegetation change on *Festuca hallii* within Region 2 are difficult to assess, especially given the uncertainties involved. 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 is likely to result in net drying due to increased evapotranspiration (Reiners 2003). This type of change may degrade habitat quality or availability that may extirpate *F. hallii* locally. Changes in precipitation patterns would also result in habitat loss. In experimental manipulations of winter snow pack in *F. idahoensis* meadows, increased snow depth caused a decline in aerial cover of *F. idahoensis* (Weaver and Collins 1977). Because of the disjunct nature of *F. hallii* occurrences in the southern part of its range, and the fact that these populations may be unable to retreat to more suitable conditions nearby, this threat is pertinent to all occurrences in Region 2.

Conservation Status of Festuca hallii in Region 2

Research has shown that *Festuca hallii* is vulnerable to grazing during the growing season, altered fire regimes, and nitrogen pollution. *Festuca hallii* is a climax species that recovers slowly from disturbance. Occurrences 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. hallii* are threatened by the invasion of trees, shrubs, and exotic species.

Management of Festuca hallii in Region 2

Implications and potential conservation elements

There is no documentation of the consequences of historic, ongoing, or proposed management activities on the abundance and distribution of *Festuca hallii* at any occurrence in Region 2. However, research outside of Region 2 suggests that activities that are taking place on National Forest System land within Region 2 may be affecting *F. hallii*. It is possible that summer grazing by livestock and pack stock affect occurrences and habitat, particularly on the Shoshone National Forest, where summer grazing is ongoing within five occurrences of *F. hallii*. Recreation may also negatively affect occurrences of this species. Historic grazing practices may have reduced the distribution of *F. hallii* in Region 2, as they have elsewhere. An altered fire regime may also be affecting the habitats for *F. hallii* in Region 2. There has been no conservation management of *F. hallii* in Region 2. Additional information is needed to clarify the status of *F. hallii* and to determine the impacts of management practices.

The documented decline of *F. hallii* in the northern Great Plains increases the potential significance of the populations in Region 2. Disjunct and peripheral populations are of interest to conservationists even when the survival of the species does not depend directly on these populations. *Festuca hallii* is a Pleistocene relict in Region 2; its presence provides information about the Quaternary natural history of North America. Peripheral populations may be important as genetic reserves since outlying populations sometimes contain atypical genetic variation in response to more difficult environmental conditions at the edge of the species' ecological range (Lesica and Elmendorf 1995, Curto personal communication 2006). Peripheral and disjunct populations also provide an important resource for research in biogeography, met population dynamics, population genetics, and other topics.

Desired environmental conditions for *Festuca hallii* include natural grazing and fire regimes. Ideal conditions for this species are more likely to be realized where livestock grazing is excluded. Studies outside Region 2 suggest that *F. hallii* can tolerate very light grazing (1.2 AUM per ha or less) especially if grazing takes place during the dormant season (October through March). Livestock grazing must be carefully managed if this species is to persist in grazed grasslands. Exotic species, especially smooth brome, are absent under ideal circumstances. Habitat connectivity should be sufficient to allow natural processes and species migration to occur.

Tools and practices

Species and habitat inventory

Potential habitat for *Festuca hallii* is spread widely across Colorado and Wyoming. Recent discoveries of the species in Wyoming suggest that other occurrences remain to be found. Targeted surveys

in areas of suitable habitat remain a high priority for this species in Region 2, but constraining the search area is difficult. The most effective means of beginning this process will be to relocate historical occurrences. High-priority survey areas include the potential Pat O'Hara Mountain Research Natural Area in the Shoshone National Forest, with its extensive limestone grasslands (Jones and Fertig 1999). On the Bighorn National Forest, Fertig (2002) indicated that surveys for *F. hallii* are needed in the Canyon Park area south of Powder River Pass, the Hazelton and Billy Creek-Arch Creek areas (on private and BLM lands south of the Bighorn National Forest boundary), Penrose Park, and Dry Fork Ridge. Additional unsurveyed habitat on private and National Forest System land exists in the Cordova Pass area on the San Isabel National Forest in Colorado, and near Cuchara Pass off Forest Road 46 (Elliott personal communication 2005, 2006).

Aerial photography, topographic maps, soil maps, and geology maps can be used to fine-tune surveys of large areas, and these tools could be highly effective for refining survey areas for *Festuca hallii*. Their use is most effective for species for which we have basic knowledge of its substrate and habitat specificity such as *F. hallii*, and from which distribution patterns and potential search areas can be deduced.

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. To model these species, the authors selected ecologically relevant geospatial datasets of critical thresholds in the climatic and edaphic environment. These were determined under controlled conditions (King et al. 1995). Using monthly mean evapotranspiration ratio and mean maximum temperature, the authors constructed a 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, while climates in which *F. altaica* and *F. hallii* occur have a lower P/E in May. Similar datasets are available for Region 2, creating the opportunity to employ similar methods to model the distribution of *F. hallii*.

Fertig (2002) used envelope models and Classification and Regression Tree (CART) techniques to model the potential distribution of *Festuca hallii* in Wyoming. Field inventories were then conducted on the Bighorn National Forest to attempt to find the species within its administrative boundary, where it has not been seen since 1898. Although *F. hallii* was not found at the survey locations, this model is a valuable tool for identifying areas to target in future surveys for this species in 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 potential for *Festuca hallii* to be present (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. Scott et al. (2002) reviewed techniques for predicting species distributions.

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

Population monitoring

Monitoring that tracks population trends can be an important tool for the conservation of *Festuca hallii*. Combining monitoring with research on the biology and demography of *F. hallii* would provide information to support management decisions for this species. Lesica and Hanna (2002) describe a method for monitoring the composition of foothills grasslands that would be suitable for *F. hallii*. In this study, paired macroplots were established at three locations within pastures: one received less than average grazing intensity and the other received average or above average grazing intensity. A third pair of macroplots provided a control. Within each macroplot, 100 microplots of varying sizes were sampled. Changes in the frequency of selected indicator species within each macroplot were used to infer the impacts of grazing on these species. Grazing impacts can also be determined for *F. hallii* by measuring the basal area of clumps or by counting the number of culms in a clump. Other studies have employed the use of destructive sampling to determine yield under various grazing intensities, but these methods are unsuitable for the small populations in Region 2.

Beneficial management actions

Research conducted outside Region 2 suggests that grazing is least detrimental to *Festuca hallii* during

the dormant season. *Festuca hallii* and *F. campestris* remain relatively nutritious to livestock and wildlife while dormant, but many occurrences of *F. hallii* in Region 2 are inaccessible to livestock in the winter. A single late August harvest at a cut height of 15 cm produced yields that were similar to undisturbed plants, and produced the maximum sustainable forage yield (Willms and Fraser 1992). 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 it tolerates dormant-season grazing (Willms 1991). Deferred-rotation and rest-rotation grazing systems are recommended for fescue grasslands in Montana (Mueggler and Stewart 1980).

Maintaining stocking rates below 1.2 AUM per ha apparently has minimal impacts on the range condition of *Festuca hallii*. Stocking rates of 1.6 AUM per ha led to a marked decline in range condition, resulting in declines in basal area of *F. campestris*. At 2.4 AUM per ha, *F. campestris* was nearly eliminated and was replaced by *Danthonia parryi* (Willms et al. 1985). Because *F. campestris* and *F. hallii* show similar responses to grazing, these data are also relevant to *F. hallii*. Dormaar and Willms (1990) discuss considerations for sustainable production on fescue grasslands in Canada that are relevant in Region 2.

Surveys are needed to relocate occurrences of *Festuca hallii* in Colorado and Wyoming. Of the 17 known occurrences in Region 2, only six have been assessed within the last 20 years. Surveys are also needed to search suitable habitat for new occurrences of *F. hallii*.

Habitat monitoring may benefit undiscovered populations and serve other management goals by providing feedback regarding management protocols. Grilz and Romo (1995) recommend monitoring ranges regularly for smooth brome invasion, which has become problematic in fescue grasslands in Saskatchewan. Monitoring grazing intensities on cattle and horse summer ranges can alert managers to overgrazing that would negatively affect *Festuca hallii* (Tirmenstein 2000). All occurrences of *F. hallii* that are subject to summer grazing need to be monitored in order to determine whether these grazing regimes are compatible with the species' persistence.

Maintaining a natural fire regime is an important consideration in managing for *Festuca hallii*. These grasslands tolerate fire and can be maintained with prescribed burns (Tirmenstein 2000). Romo (2003) wrote, "The current character of most Fescue Prairie remnants is the result of altered fire regimes." A fire return interval of 5 to 10 years appears to be most beneficial to *F. scabrella* grasslands in Montana (Antos et al. 1983). Jourdonnais and Bedunah (1990) and Redmann et al. (1993) recommend periodic burning of *F. scabrella* to reduce invasion of woody species, such as *Populus tremuloides*, and to reduce litter accumulations. Encroachment by *P. tremuloides* is common in *F. hallii* grasslands (Carbyn 1971, Weerstra and Holcroft Weerstra 1998). Gerling et al. (1995) noted that annual burning of *F. hallii* grasslands stopped the encroachment of *P. tremuloides*. Romo (2003) determined that the reintroduction of fire is needed to conserve the fescue grasslands of the northern Great Plains. However, fire produces variable effects in fescue grasslands. Gerling et al. (1995) observed that spring burns were the least detrimental to *F. hallii*, resulting in the smallest decreases in tiller length and standing herbage while resulting in higher densities of inflorescences compared to sites burned in the summer. To minimize harmful effects to *F. hallii*, fire should not be used for habitat management during extended dry periods (Wright 1974).

Although there is evidence to suggest that fire is a natural and important part of *Festuca hallii* ecology, the role of fire in maintaining populations of *F. hallii* in Region 2 has not been investigated. The habitats where *F. hallii* occurs in Region 2 are different from those in the northern Great Plains. Careful consideration is needed before fire is employed as a management tool for *F. hallii* in Region 2. Although fire appears to be necessary to prevent the encroachment of woody perennials in Canada, at least one study suggests that burns during the growing season result in lasting negative effects (Pylypec and Romo 2003). Elliott (personal communication 2005) is considering cutting encroaching trees rather than using fire for ecosystem management at Cordova Pass.

Management that reduces or eliminates smooth brome and other exotic species threatening populations of *Festuca hallii* will help to ensure their viability. Efforts are currently underway to eradicate smooth brome on Cordova Pass (Elliott personal communication 2005, 2006). It is important to proceed cautiously with attempts to improve habitats for *F. hallii* by eradicating exotic species. Given the known impacts of smooth brome on *F. hallii*, it is prudent to avoid using smooth brome in restoration and reclamation projects near *F. hallii* and its habitat. In grasslands dominated by *F. campestris* in Montana, *F. campestris* canopy cover increased following herbicide treatments of exotic species due to competitive release (Rice and Harrington

2005). In this study, early spring burning had no effect on noxious weed abundance.

The establishment of protected areas managed for the conservation of *Festuca hallii* is a useful conservation strategy. Since the USFS manages the majority of the occurrences of this species in Region 2, designation of special interest areas or research natural areas could help to protect this species. The available information for *F. hallii* in Region 2 suggests that the occurrences of highest conservation priority are WY EO #8 and 9 on the Shoshone National Forest, and the occurrence at Cordova Pass on the San Isabel National Forest. These occurrences support relatively large and evidently viable populations, but they are managed for multiple use. Further surveys would be helpful in creating an accurate picture of the conservation priorities for *F. hallii* in Region 2.

Seed banking and propagation

No seeds or genetic materials of *Festuca hallii* are currently in storage 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 hallii* plants in Region 2 may harbor unique alleles that could be useful in the development of germplasm for agronomic use or restoration. *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 plantings outside of Region 2 (Tirmenstein 2000). *Festuca campestris* seed has been successfully produced at the Bridger Plant Materials Center (Majerus 2005). Baskin and Baskin (2002) outline protocols for the propagation of *F. campestris* that are probably relevant for *F. hallii* as well. While *F. hallii* can be propagated readily, seed collection is difficult. Estimated 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. hallii* should be sown on mesic sites (Tirmenstein 2000).

Information Needs

The distribution of *Festuca hallii* remains poorly understood in Region 2, especially in Colorado where surveys have been limited. Increasing the awareness of *F. hallii* among agency botanists and others is needed so that the species can be recognized during general fieldwork. Surveys of private land in the Cordova Pass area, and in suitable habitats elsewhere, are also needed. While the morphological character states of members of the *F. scabrella* complex are now well understood, there has been limited genetic research on these species. The development of a "bar code" technique for identifying these taxa would help to evaluate quickly and confidently the identity of populations range-wide.

Festuca hallii habitats outside of Region 2 have been the topic of much research and are relatively well understood. However, this species occupies very different habitats in Region 2, and its habitat requirements are not well understood. Other factors that are understood outside of Region 2 (i.e., threats, response to fire and grazing) have not been investigated within Region 2. Studies of this species within Region 2 will be valuable for developing best management practices for its conservation.

Fertig (2002) indicated that the identity of the specimen collected in 1898 by William and Griffiths on the Bighorn National Forest needed to be verified. This specimen, housed at the U.S. National Herbarium, was annotated as *Festuca hallii* by Susan Aiken, verifying its identity and confirming the presence of this species on the Bighorn National Forest.

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. hallii* has not yet been completed. *Festuca hallii* is included on the Checklist of the Grasses of North America (Barkworth et al. 2005), which will be the taxonomic standard for Volume 24.

To remain compliant with the National Environmental Policy Act, the Pike-San Isabel National Forest evaluates all livestock grazing allotments on a periodic basis. The allotments in question are scheduled for a NEPA-based analysis and decision by 2008 (Quimby personal communication 2006). Because of this analysis, changes may be made to the management or boundaries of these allotments, and these changes would remain in effect for at least 10 years (Elliott personal communication 2006). Most forests in Region 2 are moving to an adaptive management model, in which monitoring data will be used to adjust management of the allotments (Quimby personal communication 2006).

Definitions

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

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

Conservation Status Rank – the Global (G) Conservation Status (Rank) of a species or ecological community is based on the *range-wide* status of that species or community. The rank is regularly reviewed and updated by experts, and takes into account such factors as number and quality/condition of occurrences, population size, range of distribution, population trends, protection status, and fragility. A subnational (S) rank is determined based on the same criteria applied within a subnation (state or province). The definitions of these ranks, which are not to be interpreted as legal designations, are as follows:

- **GX** **Presumed Extinct**: Not located despite intensive searches and virtually no likelihood of rediscovery
- **GH** **Possibly Extinct**: Missing; known only from historical occurrences but still some hope of rediscovery
- **G1** **Critically Imperiled**: At high risk of extinction due to extreme rarity (often 5 or fewer occurrences), very steep declines, or other factors.
- **G2** **Imperiled**: At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.
- **G3** **Vulnerable**: At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.
- **G4** **Apparently Secure**: Uncommon but not rare; some cause for long-term concern due to declines or other factors.
- **G5** **Secure**: Common; widespread and abundant.

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).

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

Glume – one of two bracts that subtend and often enclose 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); often highly modified, and therefore useful in distinguishing grass taxa.

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

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

Spikelet – a unit consisting of two glumes subtending or enclosing one or more florets (Harrington 1977).

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LIST OF ERRATA

11/30/06 Page 11: Replaced "Another occurrence, not seen since 1985, was documented within the Pat O'Hara Potential Research Natural Area on the Shoshone National Forest, but this area currently does have any special status (Jones and Fertig 1999)" with "Another occurrence, not seen since 1985, was documented within the Pat O'Hara Potential Research Natural Area on the Shoshone National Forest, but this area currently does not have any special status (Jones and Fertig 1999)". (The word "not" appeared to be missing.)

Page 53. Replaced "To remain compliant with the National Environmental Policy Act, the Pike San Isabel National Forest will re-evaluate all grazing allotments by 2008 (Quimby personal communication 2006)" with "To remain compliant with the National Environmental Policy Act, the Pike-San Isabel National Forest evaluates all livestock grazing allotments on a periodic basis. The allotments in question are scheduled for a NEPA-based analysis and decision by 2008 (Quimby personal communication 2006)".

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