Field Survey and Modeling of

Hall’s Fescue

(*Festuca hallii*)

on Bighorn National Forest

Potential distribution of *Festuca hallii* in the central Bighorn Range

Prepared for Bighorn National Forest
and the Wyoming Natural Diversity Database,
University of Wyoming

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Abstract

Hall's fescue (*Festuca hallii*) is uncommon to rare in Wyoming and Colorado and has been listed as Sensitive by US Forest Service Region 2 since 1993. In Wyoming's Bighorn Range, this species has not been observed since 1898 and may be extirpated due to impacts from past heavy grazing, changes in fire frequency, or competition from invasive weeds. In 2001, Bighorn National Forest contracted with the Wyoming Natural Diversity Database of the University of Wyoming to identify and survey potential Hall's fescue habitat in the Bighorn Range. Using GIS and statistical modeling, two potential habitat models were developed using correlations between the known distribution of Hall's fescue in Wyoming and Colorado and selected environmental variables (mean monthly precipitation, mean monthly temperature, elevation, GAP land cover, bedrock geology, and soils). The simpler "range" model was based on intersecting in GIS the range of values for each environmental variable at known *F. hallii* sites. A more complex "classification tree" model employed a geostatistical program to identify correlations between environmental variables at known present sites and inferred absent locations of Hall's fescue. Both models were tested with independent validation data and resulting maps compared with known trends in distribution of the species elsewhere in Wyoming. Of the two, the range model produced a map that had better validation success and identified more plausible habitat in the Bighorn Range. Survey sites were selected from both models for field validation in June and July 2001. Although over 20 areas of seemingly appropriate habitat were identified, no populations of *F. hallii* were discovered or relocated during the survey. More remote locations were not surveyed in 2001, and the possibility remains that this species could still be present in the Bighorn Range. Lingering questions about the identification of the original collection of *F. hallii* from the Bighorn Mountains need to be resolved and surveys are needed of other populations in US Forest Service Region 2 before changes in Sensitive status are considered.

Acknowledgements

I would like to thank Rob Thurston of the University of Wyoming for his pivotal role in the development and refinement of the modeling procedures used in this study and for creating the maps I used for field surveys. Field assistance was provided by Bernie Bornong, Tucker Galloway, and Meaghan Smith of Bighorn National Forest and by Max Welp. Financial assistance for field surveys was provided by Bighorn National Forest and the Wyoming Natural Diversity Database. Additional funding for model construction was provided by the National Gap Analysis Program of the US Geological Survey Biological Resources Division and the National Aeronautics and Space Administration.
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INTRODUCTION

Hall's fescue was first collected in Wyoming by Thomas A. Williams and David Griffiths along a "Branch [of] Crazy Woman's Creek" in the Bighorn Range on 3 July 1898 (Porter 1964). In 1906 Charles Piper selected the Williams and Griffiths specimen as the holotype for a new variety of King spike fescue that he named *Festuca confinis* var. *rabiosa*. This taxon was transferred to *Festuca kingii* var. *rabiosa* by Albert Hitchcock in 1934 and *Hesperochloa kingii* var. *rabiosa* by Jason Swallen in 1941 (Hitchcock et al. 1969). Agnes Chase believed the type of var. *rabiosa* actually represented Rough fescue and synonymized the earlier names under *Festuca scabrella* in 1950 (Hitchcock 1950). Rough fescue is a taxonomically complex species that has subsequently been subdivided into at least three taxa, with Wyoming material corresponding to *Festuca hallii* or *F. altaica* var. *hallii* (Harms 1985; Pavlick and Looman 1984).

Hall's fescue ranges widely from northern Alberta to Ontario and south to Montana, North Dakota, northern and southeastern Wyoming, and northern Colorado (Fertig et al. 1994; Pavlick and Looman 1984). The species is extremely rare to uncommon at the southern edge of its range in Colorado and Wyoming (O'Kane 1988; Spackman et al. 1997) and potentially at high risk from local extirpation from grazing and habitat alteration (Marriott et al. 1990). In 1993, *Festuca hallii* was officially designated as Sensitive in US Forest Service Region 2 (Estill 1993).

Bighorn National Forest contracted with the Wyoming Natural Diversity Database (WYNDD) of the University of Wyoming in 2001 to survey potential habitat for *Festuca hallii* on Forest Service lands in the Bighorn Mountains. Potential survey sites were selected using a computerized habitat modeling program developed by WYNDD and the University of Wyoming Department of Botany for the National Gap Program (Fertig 1999 a). The following report contains the results of the survey and modeling efforts, as well as additional information on the current status of Hall's fescue in Wyoming (Appendix A).

METHODS

Areas for field survey on Bighorn National Forest were selected using two different potential *Festuca hallii* distribution models created for the entire state of Wyoming. Both models were based on the intersection in GIS of selected environmental datasets (monthly mean temperature and precipitation, elevation, land cover, bedrock geology, and soil order and suborder) that characterize the known habitat of this species. The simpler "range" model was developed using the range of values for each selected environmental variable at all known locations of *F. hallii* in the state. The more complex "classification tree" model used a computerized statistical program to identify correlations between the values of environmental variables at sites where *F. hallii* is known to be present and sites where it is presumed to be absent. The methodology for each of these models is discussed in more detail in the following sections.

Field surveys were conducted from 22-25 June and 28-31 July 2001 and targeted a stratified subset of the areas identified in the range and classification tree models. Due to time and budget constraints, sites that were too inaccessible were not surveyed. USGS 7.5 minute quad maps and
USFS land status maps were used to identify and locate areas of potential habitat selected by each model. Ground survey entailed hiking through potential habitat, collecting vouchers of possible *F. hallii* specimens, and photographing and categorizing vegetation of each site. Sampling locations were mapped in the field and digitized on base maps in GIS (Figures 6-13).

**Range Model** The range model incorporated data from 14 known locations of *Festuca hallii* in Wyoming and Colorado using records from WYNDD, the Colorado Natural Heritage Program, and the Rocky Mountain Herbarium digital specimen database (Figure 1). The only known location not used in the model was the historical collection by Williams and Griffiths from the Bighorn Range which was considered too imprecise. All points were scrutinized to eliminate duplicate specimens or collection sites and locations that were too close (within 2400 m) to each other. Four of the present points from Wyoming were randomly withdrawn from the model-building dataset for use in validating the finished model.

Environmental attributes for each known location of Hall's fescue were derived from digital statewide or regional coverages in ArcView version 3.1. Coverages included all of Wyoming and a 2 degree buffer zone in adjoining states. Elevation was determined from 60 m Digital Elevation Model (DEM) coverages resampled to 30 m (US Geological Survey 1993). Mean monthly temperature and precipitation data for January, April, July, and October were derived.

*Figure 1. Locations of Festuca hallii in Wyoming and Colorado used for model-building and validation.*
from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) for the period 1961-1990 (Daly et al. 1994, 1997). These data were resampled to 60 meters and the grid cell size reduced to create a coverage with smoother boundaries. Land cover was derived from the Wyoming Gap Analysis Project (Merrill et al. 1996) and comparable coverages for adjacent states (Edwards et al. 1995; Fisher et al. 1998; Thompson et al. 1996, US Geological Survey 1986). These datasets were reprojected into the Lambert conformal conic projection and converted to grids. Land cover types were reclassified into a common system of 31 main types. Bedrock geology was derived from digital statewide and regional coverages (Conservation and Survey Division 1996; Hintze 1980; Johnson and Raines 1996; King and Beikman 1974; Love and Christensen 1985; Raines & Johnson 1996; Tweto 1976). Geologic formations were reclassified by age and major rock type into 29 categories, approximating the classification used in regional maps prepared by the American Association of Petroleum Geologists (1967). Dominant soil order and suborder were derived from the State Soil Geographic (STATSGO) database (US Department of Agriculture 1994) based on the dominant soil type present by map unit.

For continuous environmental variables (climate and elevation), the minimum and maximum values were identified using the field/statistics option in ArcView. To improve the predictive ability of the model, the minimum value was decreased by 5% and the maximum value increased by 5% (Table 1). The values of categorical variables (landcover, bedrock geology, and soils) were determined using the field/summarize function in ArcView (Table 1). In ArcInfo, new environmental coverages were created based on the values identified for the continuous and categorical variables. These coverages were then intersected to identify all areas within Wyoming with the combination of environmental conditions found at known *Festuca hallii* locations.

**Classification Tree Model** The classification tree model was developed using the same known present and absent location points as in the range model (Figure 1). Unlike the range model, however, the classification tree model utilized absence data in model construction. Since absence data are not routinely collected for plant species, the Rocky Mountain Herbarium's database of over 9000 sampling points in Wyoming was used to identify locations where *Festuca hallii* was not collected, and thus presumed to be absent* (Fertig 1999a). From an initial pool of 1087 putative absent locations, 943 were selected for modeling (144 were rejected because they were from environments where *F. hallii* was not likely to occur). Of these 943 locations, 878 were selected randomly for model construction and 75 reserved for model validation (Table 2). As in the range model, the points selected for the classification tree model were intersected with environmental coverages of mean monthly precipitation, temperature, elevation, land cover, bedrock geology, and soils (Table 2).

* Rocky Mountain Herbarium researchers have systematically established collection sites across the state for the purpose of documenting all plant taxa present in the immediate area. Collection sites were chosen for this study if sampling had been adequate (over 50 specimens) and if locations were at least 2400 km apart.
Table 1. Values of variables used in construction of range model of Festuca hallii in Wyoming. See text for data sources.

Ranges of Continuous Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Minimum (decreased by 5% from actual values)</th>
<th>Maximum (increased 5% from actual values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>2265 m</td>
<td>3696 m</td>
</tr>
<tr>
<td>January Mean Precipitation</td>
<td>20.1 mm</td>
<td>122.9 mm</td>
</tr>
<tr>
<td>April Mean Precipitation</td>
<td>50.4 mm</td>
<td>129.6 mm</td>
</tr>
<tr>
<td>July Mean Precipitation</td>
<td>33.3 mm</td>
<td>83.4 mm</td>
</tr>
<tr>
<td>October Mean Precipitation</td>
<td>28.4 mm</td>
<td>79.2 mm</td>
</tr>
<tr>
<td>January Mean Temperature</td>
<td>14.9º F</td>
<td>25.9º F</td>
</tr>
<tr>
<td>April Mean Temperature</td>
<td>28.7º F</td>
<td>41.5º F</td>
</tr>
<tr>
<td>July Mean Temperature</td>
<td>49.6º F</td>
<td>63.7º F</td>
</tr>
<tr>
<td>October Mean Temperature</td>
<td>34.3º F</td>
<td>47.8º F</td>
</tr>
</tbody>
</table>

Values of Categorical Variables

**Land Cover**: Alpine Tundra (AlpTn), Mountain big sagebrush (MtSge), Subalpine meadow (SbAlp), Spruce-fir (SpFir)

**Bedrock Geology**: Eocene volcanic extrusive (Eex), Miocene/Pliocene ash (MiPl), Precambrian felsic (PCf), Permian/Triassic/Jurassic (PTJ), Early Paleozoic (Pze)

**Soil Dominant Order**: Alfisols, Inceptisols, Mollisols, Rock

**Soil Dominant Suborder**: Cryalfs, Crypets, Cryolls, Rock

The environmental data from present and absent locations were then imported into the statistical software program S-Plus (version 1.1) for classification tree analysis. Classification trees are derived using a recursive partitioning algorithm that identifies which values of continuous or categorical variables best explain the differences in known present and absent locations of the target species (Breiman et al. 1984). From the initial data pool (or "root" node in classification tree terminology), the data set is continually subdivided into pairs of smaller subsets based on the single variable that accounts for the greatest difference between known presence and absence. This splitting continues along each branch of the tree (using different variables and values at each split, or node) until the dataset reaches a predetermined minimum size threshold (Figure 2). By experimentation, the optimal size for the minimum splitting threshold was found to be 1/10 of the number of present points used for construction of the model. If the node size is too small, the model becomes overly complex, while if too large the models are too simplistic and interesting trends can be obscured.

When a branch of the classification tree can no longer be subdivided it is called the terminal node. By default, S-Plus assigns a value of "yes" (predicted present) for terminal nodes in which
Table 2. Location points and environmental variables used in the construction of a classification tree model for Festuca hallii in Wyoming.

<table>
<thead>
<tr>
<th></th>
<th>Model-Building</th>
<th>Validation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total (WY/Non-WY)</td>
<td>WY Only</td>
<td></td>
</tr>
<tr>
<td>Known Present</td>
<td>10 (9/1)</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>Known Absent</td>
<td>868 (868/0)</td>
<td>75</td>
<td>943</td>
</tr>
<tr>
<td>Total</td>
<td>878 (877/1)</td>
<td>79</td>
<td>857</td>
</tr>
</tbody>
</table>

Data Source (Records): Wyoming Natural Diversity Database (10), Rocky Mountain Herbarium (3), Colorado Natural Heritage Program (1)

Modeling Notes
Independent Variables: Elevation, January mean precipitation, April mean precipitation, July mean precipitation, October mean precipitation, January mean temperature, April mean temperature, July mean temperature, October mean temperature, June maximum temperature, July maximum temperature, August maximum temperature, April minimum temperature, May minimum temperature, June minimum temperature, major GAP land cover, bedrock geology, soil dominant order, and soil dominant suborder.
Minimum Number of Observations Before Split: 1
Minimum Node Size: 2
Minimum Node Deviance: 0.01
Minimum Percent for Pruning: 4
Biomes used for validation: Alpine, Foothills, Rocky Mountain Forest

the majority of points were from known Festuca hallii populations, or "no" (predicted absent) if the majority of points were from locations where F. hallii was inferred to be absent. To compensate for the low number of present points available for the model, the terminal nodes were reclassified based on a percentage system. As a result, terminal nodes were ranked "yes" if the percentage of all available present points at the node was greater than the percentage of all available absent points, and "no" if the percentage of all available absent points at the node was greater than the percentage of present points (Table 3).

The final step in preparation of the classification tree model was to simplify the tree by removing extraneous branches by "pruning". Unpruned models tend to overfit the data used in model construction, resulting in predicted distribution maps that strongly match present points, but which may perform poorly in predicting independent validation data. Pruning is done by eliminating all nodes in the S-Plus classification tree output (Table 3) in which the percentage of present or absent points falls below a selected threshold. In the case of the Hall's fescue model, pruning was done with cutoffs of 0, 1, 2, 4, and 8 percent. The pruned model that best resulted in
the lowest increase in false negatives and largest reduction in false positives (4%) was selected for final model construction (Tables 2, 3).

The final pruned output of S-plus consists of a dichotomously branched classification tree (Figure 2), and an associated table that defines cutoff values for the environmental variables selected at each node (Table 3). In the case of the *Festuca hallii* model, 3 nodes were selected with a 4% pruning. The original dataset of 878 points (868 absent and 10 present) was split into two groups at the first node based on values of major GAP land cover. All points representing Alpine tundra, Mountain big sagebrush, Subalpine meadow, or Spruce-fir were divided into one group at node # 2, while the remaining points from other land cover types were segregated into node # 3. The points in node # 2 were then further divided into two subgroups (node # 4 and # 5) based on minimum April temperature. Since there were no present points in node # 3, it was not subdivided, and the pathway was scored as "no", indicating that no areas of the state with these land cover types were predicted to have potential *F. hallii* habitat. Of the 6 points at node # 5, with a minimum April temperature greater than 29.3°F, 5 represented known present points of Hall's fescue. This node was not divided again because the number of absent points (1) fell below the minimum node size threshold that was set at 2 (Table 2). Since the percentage of present points at node # 5 outnumbered the percentage of absent points (50% to 1%), the node was scored as "yes", indicating that the branch going through nodes 5 and 2 represent potential areas of likely habitat for *F. hallii* (Table 4). Node # 4 (based on a minimum April temperature less than 29.3°F) was subdivided into nodes 8 and 9 using April precipitation. 73 points in node

**Figure 2.** Classification tree used in model construction for *Festuca hallii*. See Table 3 for cutoff values at each node and Table 4 for definitions of present ("Yes") pathways.
Table 3. Classification tree output. The root node (number 1) indicates the number of data points used in construction of this tree (878), the number of absent and present points (868 and 10, respectively), and the percentage of absent and present points represented at the node. Subsequent node numbers correspond with the branch numbers in Figure 2 and indicate the environmental variable selected at that node, the values or categories represented, the number of points at the node, percentage and raw number of absent and present points at the node, percentage of absent and present points at the node relative to the total available pool of present and absent points in the entire model, and whether the node is predicted to represent "presence" (yes) or "absence" (no) for the species. Nodes that end with an * are terminal nodes.

1) root 878  (868,10) (100,100)
2) LANDCOVMAJ (Land cover): Alpine tundra, Mountain big sagebrush, Subalpine meadow, Spruce-fir 101 (0.9010,0.09901) (91,10) (10.5,100) Yes
4) TMIN04 (minimum April temperature) <29.3°F: 95 (0.9474,0.05263) (90,5) (10.4,50) Yes
  8) PPT04 (mean April precipitation) <76.1 mm: 73 (1.0000,0.00000) (73,0) (8.4,0) No *
  9) PPT04 (mean April precipitation) >76.1 mm: 22 (0.7727,0.22730) (17,5) (2.5,0) Yes *
5) TMIN04 (minimum April temperature) >29.3°F: 6 (0.1667,0.83330) (1,5) (0.1,50) Yes *
3) LANDCOVMAJ (Land cover): Active sand dunes, Alpine bare rock & soil, Aspen forest, Black sagebrush steppe, Bur oak woodland, Basin bare rock & soil, Douglas-fir, Desert shrub, Forest-dominated riparian, Greasewood fans & flats, Graminoid-dominated riparian, Human disturbed, Juniper woodland, Limber pine woodland & scrub, Lodgepole pine, Mesic upland shrub grassland, Mixed grass prairie, Ponderosa pine, Unvegetated playa, Shortgrass prairie, Shrub-dominated riparian, Saltbush dunes & flats, Vegetated dunes, Open water, Whitebark pine, Wyoming big sagebrush, Xeric upland shrub: 777 (1.0000,0.00000) (777,0) (89.5,0) No *

Table 4. Path composition and likelihood for classification tree model of Festuca hallii. See Figure 2 and Table 3 for explanation of individual tree branches (node lists) and tree structure.

<table>
<thead>
<tr>
<th>Yes Path</th>
<th>Node List</th>
<th>% of Present Points</th>
<th>Likelihood Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>9, 4, 2</td>
<td>50</td>
<td>High</td>
</tr>
<tr>
<td>b</td>
<td>5, 2</td>
<td>50</td>
<td>High</td>
</tr>
</tbody>
</table>
# 8 had an April precipitation of less than 76.1 mm. Because all of these points were absent, the node was not subdivided further and was scored as "no". Node # 9 consisted of 17 absent points and 5 present points that all had an April precipitation value greater than 76.1 mm. The percentage of present points (50%) at this node greatly outnumbered the percentage of absent points (2%), giving the branch a score of "yes". Since the percentage of absent points fell below the 4% pruning cutoff, this node was not divided again, and the tree was completed.

Two pathways were utilized for final construction of a predicted range map (Table 4). Values from the environmental variables selected at each node of the two paths were entered into an Arc-Info program to generate new intersected grid coverages. The final map was created in ArcView based on the combined area of the two pathways. The probability of a given area on the map containing Hall's fescue was color-coded using a 3-part ranking system (low, medium, and high). Pathways were scored as low if they contained 10% or less of all available present points used in construction of the model, medium if they contained more than 10% and less than 50% of the present points, and high if they contained 50% or more of the present points. Since both pathways in the F. hallii model contained 50% of the available present points, each was coded as high probability.

Model Validation  Both the range and classification tree models were tested with an independent validation dataset of 4 randomly chosen present points and 75 inferred absent points. These points were overlaid on the final distribution maps to determine the number that were correctly identified. Rates of omission (false negatives) and commission (false positives) error were calculated for each map, as well as the total number of correctly identified points (Table 5).

RESULTS

Both the range and classification tree models for Festuca hallii had similarly high success rates for model-building points. Based on independent validation data, however, the range model outperformed the classification tree model in the total number of points correctly identified and in having a lower percentage of false negatives and false positives (Table 5). Omission error is generally considered the most costly type of error, as it can result in known populations of a species being overlooked in designing survey efforts or in conservation planning (Fertig and Reiners 2001, in ed.). Reduction of commission error is also valuable in reducing the likelihood of survey effort or conservation attention being wasted on lands that are unsuitable for the target species. Of the two models, the range model was superior in minimizing both types of error.

More importantly, the range model identified locations of potential habitat in the Bighorn Range that are more plausible than the classification tree model based on past experience with F. hallii in Wyoming (Figures 3-4). The range model (Figure 3, 5) primarily identified high montane and subalpine grasslands on calcareous substrates that are known to provide habitat for this species in many areas of the Absaroka Range (Fertig 1997, 1998). By contrast, the classification tree model focuses mostly on alpine areas of granite bedrock along the crest of the Bighorn Range (Figure
Table 5. **Classification error rates for range and classification tree models of Festuca hallii.** Points that are known to be present (but are predicted by the model as absent) are considered false negatives or omission errors, while points that are known to be absent (but are modeled as present) are false positives or commission errors.

### Range Model

<table>
<thead>
<tr>
<th>Model-Building Points</th>
<th>Model-Present</th>
<th>Model-Absent</th>
<th>Validation Points</th>
<th>Model-Present</th>
<th>Model-Absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Known Present</td>
<td>9/9 (100%)</td>
<td>0/9 (0%)</td>
<td>Known Present</td>
<td>2/4 (50%)</td>
<td>2/4 (50%)</td>
</tr>
<tr>
<td>Known Absent</td>
<td>7/868 (0.8%)</td>
<td>861/868 (99.2%)</td>
<td>Known Absent</td>
<td>1/75 (1.3%)</td>
<td>74/75 (98.7%)</td>
</tr>
</tbody>
</table>

Total Correct: 870/877 (99.2%)  
Total Incorrect: 7/877 (0.8%)  

### Classification Tree Model

<table>
<thead>
<tr>
<th>Model-Building Points</th>
<th>Model-Present</th>
<th>Model-Absent</th>
<th>Validation Points</th>
<th>Model-Present</th>
<th>Model-Absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Known Present</td>
<td>9/9 (100%)</td>
<td>0/9 (0%)</td>
<td>Known Present</td>
<td>1/4 (25%)</td>
<td>3/4 (75%)</td>
</tr>
<tr>
<td>Known Absent</td>
<td>18/868 (2.1%)</td>
<td>850/868 (97.9%)</td>
<td>Known Absent</td>
<td>7/75 (9.3%)</td>
<td>68/75 (90.7%)</td>
</tr>
</tbody>
</table>

Total Correct: 859/877 (97.9%)  
Total Incorrect: 18/877 (2.1%)  

4). Although known from such habitats in a few locations in the Beartooth and Absaroka ranges, this habitat type is much less typical for *F. hallii* in Wyoming than lower elevation calcareous meadows. For the purposes of this project, the range model produced the more plausible potential distribution map and was used for guiding most of the field survey effort.

The range model identified 70 polygons of potential habitat at the north and south ends of the Bighorn Range (Figures 3, 6-13). 18 of the selected polygons were located completely within densely forested areas (based on USGS 7.5 minute maps) and were rejected for ground survey, as were 6 polygons located outside of Bighorn National Forest. Of the remaining 46 polygons, 22 were surveyed in June and July 2001. An additional 8 polygons selected by the classification tree model (Figures 4, 6-13) were surveyed even though they were not identified by the range model.
Figure 3. Potential distribution of Festuca hallii in the Bighorn Range of north-central Wyoming based on range model. Note the predominance of subalpine habitat selected along the mid to lower slopes of the range (mostly on Paleozoic calcareous substrates). Inset boxes correspond to maps in Figures 6-13.

Figure 4. Potential distribution of Festuca hallii in the Bighorn Range of north-central Wyoming based on classification tree model. Note the predominance of alpine habitat selected along the crest of the range.
Figure 5. Potential distribution of Festuca hallii in Wyoming based on range modeling. Known present locations used for model building and validation are depicted as black dots. The total area of the state identified as potential habitat encompasses 2,631 km², or 1.0% of Wyoming.
Figure 6. Potential distribution of Festuca hallii (indicated in yellow) from the northwestern Bighorn Range, north of US Highway 14. Areas surveyed on 28-29 July 2001 are indicated in red. Compare with Figure 3 for approximate location within the Bighorn Range.
Figure 7. Potential distribution of Festuca hallii (indicated in yellow) from the north-central Bighorn Range, north of US Highway 14. Areas surveyed on 30 July 2001 are indicated in red. Compare with Figure 3 for approximate location within the Bighorn Range.
Figure 8. Potential distribution of Festuca hallii (indicated in yellow) from the northwest Bighorn Range, between US highways 14 and 14A. Areas surveyed on 29-31 July 2001 are indicated in red. Compare with Figure 3 for approximate location within the Bighorn Range.
Figure 9. Potential distribution of Festuca hallii (indicated in yellow) from the north-central Bighorn Range, south of US Highway 14. Compare with Figure 3 for approximate location within the Bighorn Range.
Figure 10. Potential distribution of Festuca hallii (indicated in yellow) from the eastern Bighorn Range in NW Johnson County. Areas surveyed on 25 June 2001 are indicated in blue. Compare with Figure 3 for approximate location within the Bighorn Range.
Figure 11. Potential distribution of Festuca hallii (indicated in yellow) from the eastern Bighorn Range in vicinity of US Highway 16. Areas surveyed on 22-25 June 2001 indicated in blue. Compare with Figure 3 for approximate location within the Bighorn Range.
Figure 12. Potential distribution of Festuca hallii (indicated in yellow) from the southern Bighorn Range, south of US Highway 16. Areas surveyed on 24-25 June 2001 are indicated in blue. Compare with Figure 3 for approximate location within the Bighorn Range.
Figure 13. Potential distribution of Festuca hallii (indicated in yellow) from the southern Bighorn Range, south of Bighorn NF boundary. Compare with Figure 3 for approximate location within the Bighorn Range.
Despite the presence of seemingly potential habitat in many of these locations, no new populations of Hall's fescue were discovered, and the historical locality of Williams and Griffiths could not be relocated. Several sites appeared to be extremely promising in the field (particularly at Elgin Park, High Park, Hunter Mesa, highlands above Cookstove Basin, Sunlight Mesa, and Freezeout Point), but were invariably occupied by other bunchgrass species, such as *Leucopoa kingii*, *Festuca idahoensis*, *Poa secunda*, and *P. junciformis*. In the process of surveying for Hall's fescue, several other Forest Sensitive plants were located, however, including new populations of *Arnica lonchophylla*, *Aster mollis* (*Symphyotrichum molle*), *Penstemon caryi*, and *Sullivantia hapemanii*.

**DISCUSSION**

Although the range model identified large areas of potential habitat for *Festuca hallii* in the Bighorn Range, no new populations could be located in 2001. Most areas of suitable subalpine or high montane calcareous or granitic grassland habitat were occupied by *Leucopoa kingii*, *Festuca idahoensis*, *Poa secunda*, and *P. junciformis*. Several potential areas remain unsurveyed, however, especially 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.

Several factors may account for the apparent absence of Hall's fescue on Bighorn National Forest. This species may be extremely rare on the Forest as a result of range contraction in the past century, possibly from grazing, wildfire, or other changes in land use. Studies in Montana, northwestern Wyoming, and southern Canada indicate that *Festuca hallii* and related "rough fescue" species are highly palatable and extremely vulnerable to heavy grazing pressure, especially in summer months (Mueggler and Stewart 1980; Tirmenstein 2000; Tweet and Houston 1980). Past grazing pressure on more accessible meadow areas on the north and east flanks of the Bighorn Mountains may have reduced or eliminated this species over much of its potential range. Other impacts, including changes in fire frequency, concentration of winter game range, or competition from invasive weed species may have resulted in local extirpation of Hall's fescue.

The possibility remains that the original collection of *Festuca hallii* from the Bighorns may have been misidentified. The specimen of Williams and Griffiths was initially described as a new variety of *Festuca confinis*, and later transferred to *F. kingii* and *Hesperochloa kingii*. Each of these names is a synonym of what is known today as *Leucopoa kingii*. The two taxa are very similar superficially, with *L. kingii* being quite abundant and widespread today throughout potential *F. hallii* habitat in the Bighorn Range. The original Williams and Griffiths specimen should be relocated at the US National Herbarium (Smithsonian) to determine which identification is correct. If the specimen were to be determined as *L. kingii* it is possible that Hall's fescue has never occurred in the Bighorns in the modern era.

Although its status in the Bighorn Range remains uncertain, surveys in the past decade have demonstrated that *Festuca hallii* is more widespread in Wyoming than initially suspected.
when it was listed as Sensitive by the US Forest Service in 1993. Several new populations have been documented in the Shoshone National Forest (including the first report of the species from the Beartooth Range in Wyoming), and a previously unconfirmed record from the Medicine Bow Range has been relocated (Fertig 1997, 1998, 1999b; Jones 1992; Mills and Fertig 1996a; Welp et al. 2000). Additional information is needed on threats to existing populations and the potential for restoration of the plant to former habitat before a decision is made on possibly removing the species from the regional Sensitive list.

LITERATURE CITED


Conservation and Survey Division. 1996. A digitized version of the bedrock geology of Nebraska. University of Nebraska – Lincoln, Lincoln, NE.


Fertig, W., C. Refsdal, and J. Whipple. 1994. Wyoming Rare Plant Field Guide. Wyoming Rare Plant Technical Committee, Cheyenne, WY.


Appendix A.

WYNDD Plant Species Abstract

*Festuca hallii*
(Hall's fescue)
Poaceae or Gramineae

**Status:**
US Fish & Wildlife Service: None.
Agency Status: USFS Region-2: Sensitive

Heritage Rank:
Global: G4 State: S1
WYNDD Plant List: Peripheral (Medium conservation priority)

**Description:** Hall's fescue is a tufted perennial with culms 20-80 cm tall and short rhizomes. Leaf blades are inrolled, somewhat roughened, and less than 3 mm wide. Fragments of old leaves persist at the base of the stem. The membranous ligules are higher at the sides than at the center and are less than 0.5 mm long. Spikelets are 2-3 flowered and arranged in a narrow panicle 7-12 cm long. Glumes are awnless and 5-8 mm long, while the lemmas are 5.5-7 mm long, sharp-pointed or awn-tipped, and minutely roughened (Hitchcock et al. 1969; Pavlick and Looman 1984; Dorn 1992; Fertig et al. 1994; Mills & Fertig 1996b).

**Synonyms:** *Festuca altaica* ssp. *hallii*; has been included in *Festuca scabrella* by some authors.

**Similar Species:** *Festuca arundinacea* and *F. pratensis* have broader, flattened leaves and ear-shaped (auriculate) sheaths. *F. thurberi* has pointed ligules over 2 mm long.

Above: *Festuca hallii* by Jennifer Whipple.

Other *Festuca* spp. have longer awns or lemmas shorter than 7mm (Fertig et al. 1994). *Leucopoa kingii* has broad, flat leaf blades and spikelets with 3-5 unawned florets. *Poa juncifolia* has blunt-tipped lemmas that are rounded on the back and 4-6 mm long, and ligules 1-2 mm long.
Flowering/Fruiting Period: May-July.

Distribution: Northern Alberta to Ontario, south to North Dakota and Colorado (Cronquist et al. 1977). In Wyoming it is known from the Absaroka, Beartooth, Bighorn, and Medicine Bow Mountains in Albany, Johnson, and Park counties.

Habitat: In Wyoming, Hall's fescue occurs in montane meadows, alpine tundra, and edges of open coniferous woods of Lodgepole pine and Engelmann spruce at 6800-11000 feet. It is usually found on soils derived from calcareous parent material, although it occasionally occurs on granitic, volcanic, or quartz-derived substrates. Common associates species include Potentilla fruticosa, Artemisia tridentata, Danthonia intermedia, Lupinus wyethii, Geum triflorum, Zigadenus elegans, and Penstemon spp. Hall's fescue may be locally dominant in some grasslands (Tweit and Houston 1980), or be codominant with Festuca idahoensis or Elymus spicatus (Mueggler and Stewart 1980).

Occurrences in Wyoming: Known from 10 confirmed records in Wyoming and one vague, historical record. Five populations have been discovered or relocated since 1994 (most recently in 1999). See Table 6 for known locations.

Abundance: Surveyed occurrences contain 500-1000 plants. Most populations, however, have never been censused.

Trends: Hall's fescue is highly palatable and is considered a decreaser under heavy grazing pressure (especially in summer) in Montana and Canada (Mueggler and Stewart 1980; Tweit and Houston 1980; King et al. 1998; Tirmenstein 2000). Populations in the Absaroka Range of Wyoming are considered vulnerable to heavy grazing (Tweit and Houston 1980; Fertig 1995). Rangewide, the extent of habitat dominated by Hall's fescue and other rough fescue species may have declined by 95% in the past 125 years (Grilz and Romo 1995).
Protection status: Three occurrences of Hall's fescue are protected within the North Absaroka Wilderness Area. Populations also occur in the potential Pat O'Hara Mountain and Line Creek/Twin Lakes Research Natural Areas and just south of the proposed Bald Ridge RNA (Jones and Fertig 1999). An occurrence is also present in the Cinnabar Park Special Management Area on Medicine Bow National Forest. All other populations are on state or public lands managed for multiple use. This species is listed as Sensitive in US Forest Service Region 2.

Threats: Threatened by heavy grazing by livestock and wild ungulates, competition from invasive weeds, and high fire frequency (Tirmenstein 2000).

Managed Areas: Found on lands managed by Shoshone National Forest (Clarks Fork and Wapiti RDs), Medicine Bow National Forest (Laramie RD), and the BLM Cody Field Office. An historical record may be from Bighorn National Forest (Welp et al. 2000).

Literature Cited: See citations on pages 25-29.

Author: Walter Fertig
Updated: 00-12-22

Derived from Wyoming Natural Diversity Database website, www.uwyo.edu/wyndd.

Table 6. Location information for known populations of Festuca hallii in Wyoming

<table>
<thead>
<tr>
<th>Occurrence #</th>
<th>County</th>
<th>Legal Description</th>
<th>Latitude (decimal degrees)</th>
<th>Longitude (decimal degrees)</th>
<th>Elevation (ft)</th>
<th>Location</th>
<th>Habitat</th>
<th>Ownership</th>
<th>Date Last Observed</th>
<th>Voucher</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>Park</td>
<td>T54N R103W S31</td>
<td>44.6153</td>
<td>-109.3064</td>
<td>8000</td>
<td>Absaroka Range, headwaters of Trail Creek on eastern slope of Rattlesnake Mountain.</td>
<td>Meadow at edge of Pinus contorta-Picea engelmannii forest, on deep soil derived from the red Chugwater Formation.</td>
<td>State of Wyoming</td>
<td>1 August 1980</td>
<td>D.L. Martin 1484 (RM)</td>
</tr>
<tr>
<td>002</td>
<td>Park</td>
<td>T53N R103W S17, 20, 27</td>
<td>44.5644</td>
<td>-109.2833</td>
<td>8600-9000</td>
<td>Absaroka Range, southwest side of Rattlesnake Mountain, 2 locations: (1) at end of BLM road that follows Trail Creek; (2) east side of Canyon Creek ca 1.25 miles northeast of Rattlesnake Creek and ca 3 miles north of Buffalo Bill Reservoir.</td>
<td>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.</td>
<td>BLM Cody Field Office</td>
<td>11 August 1994</td>
<td></td>
</tr>
</tbody>
</table>
Occurrence # 003
County: Park.
Legal Description: T54N R104W S35
Latitude (decimal degrees): 44.6208
Longitude (decimal degrees): -109.3528
Elevation: 8480 ft.
Location: Absaroka Range, Rattlesnake Mountain, Trough Springs.
Habitat: Open meadow of limestone composed soils. *Festuca idahoensis*/ *Elymus trachycaulus* habitat type.
Ownership: Shoshone NF.
Date Last Observed: 20 July 1979.
Voucher: R.W. Lichvar 2045 (RM); S. Tweit & K. Houston s.n. (RM).

Occurrence # 004
County: Park.
Legal Description: T53N R105W S21-22.
Latitude (decimal degrees): 44.5567
Longitude (decimal degrees): -109.5000
Elevation: 10,000-11,000 ft.
Location: Absaroka Range, North Fork Shoshone River drainage, in basin north of Jim Mountain at head of East Fork Big Creek.
Habitat: Alpine tundra.
Ownership: Shoshone NF (North Absaroka Wilderness)
Date Last Observed: 2 August 1983.
Voucher: E.F. Evert 5801 (RM).

Occurrence # 005
County: Park.
Legal Description: T54N R104W S16-17.
Latitude (decimal degrees): 44.6686
Longitude (decimal degrees): -109.4000
Elevation: 9000-9600 ft.
Location: Absaroka Range, 0.5-2 air miles west of summit of Pat O'Hara Peak.
Habitat: Open grassy slopes with limestone outcrops and spruce woodland margins.
Ownership: Shoshone NF (North Absaroka Wilderness)
Date Last Observed: 23 August 1985.

Occurrence # 006
County: Johnson
Legal Description: T49N R85W S35 (approximate)
Latitude (decimal degrees): 44.1703 (approximate)
Longitude (decimal degrees): -107.0389 (approximate)
Elevation: ca 8800 ft.
Location: Bighorn Range, a branch of Crazy Woman Creek [mapped on North Fork near headwaters around Sheep Mountain and Powder River Pass].
Habitat: Not reported.
Ownership: Bighorn NF?
Date Last Observed: 3 July 1898.
Voucher: Williams and Griffiths 25 (US holotype of *Festuca confinis* ssp. *rabiosa*).

Occurrence # 007
County: Albany.
Legal Description: T15N R79W S36
Latitude (decimal degrees): 41.2306
Longitude (decimal degrees): -106.2214
Elevation: 9600 ft.
Location: Medicine Bow Range, Cinnabar Park just northeast of Rob Roy Reservoir.
Habitat: Edge of erosional channel exposing quartzite rocks in a montane meadow dominated by *Koeleria macrantha*, *Danthonia*, *Poa secunda*, and *Antennaria*. Soils rocky mollisols.
Ownership: Medicine Bow NF
(Cinnabar Park Special Interest Area).
Date Last Observed: 29 September 1998.
Voucher: W. Fertig 18618 (RM).

Occurrence # 008
County: Park.
Legal Description: T56N R104W S30-31
Latitude (decimal degrees): 44.7797
Longitude (decimal degrees): -109.4389
Elevation: 6800 ft.
Location: Absaroka Range, Russell Creek drainage in the vicinity of Sunlight Basin, in the meadow below and to the southeast of Antelope Mountain.
Habitat: Mesic, limestone-derived soils in Artemisia frigida/Festuca meadow in full sunlight.
Ownership: Shoshone NF.
Date Last Observed: 19 August 1995.
Voucher: S. Mills 30a (RM).

Occurrence # 009
County: Park.
Legal Description: T55N R104W S10-12, 14-15
Latitude (decimal degrees): 44.7542
Longitude (decimal degrees): -109.3444
Elevation: 7600-7690 ft.
Location: Absaroka Range, Bald Ridge/Dead Indian Hill area. 2 main locations: (1) ridge paralleling the Bald Ridge Road at Point 7652, on east side of Dead Indian Gulch, ca 1.5 miles east of Dead Indian Hill. (2) ridge ca 1-2 miles north of the Chief Joseph Highway (WY Hwy 296) and Dead Indian Pass [on west side of Dead Indian Gulch].
Habitat: 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 radiata. Typically found in microsites with deeper soils and little to no sagebrush.
Ownership: Shoshone NF.
Date Last Observed: 15 July 1996.
Voucher: E.F. Evert 7883 (RM); W. Fertig 16847 (RM).

Occurrence # 010
County: Park.
Legal Description: T53N R106W S11-12
Latitude (decimal degrees): 44.5925
Longitude (decimal degrees): -109.5858
Elevation: 10,000-10,800 ft.
Location: Absaroka Range, North Fork Shoshone River drainage, headwaters of Big Creek, ca 1-2 miles northeast of Big Creek Falls, ca 10-12 miles north of US Highway 14/16/20.
Habitat: Alpine basin, mostly tundra-turf community.
Ownership: Shoshone NF (North Absaroka Wilderness).
Date Last Observed: 24 August 1985.
Voucher: E.F. Evert 9644, 9656 (RM).

Occurrence # 011
County: Park.
Legal Description: T58N R104W S29
Latitude (decimal degrees): 44.9775
Longitude (decimal degrees): -109.4503
Elevation: 10,400 ft.
Location: Beartooth Range, just east of old gravel quarry ca 0.8 miles north of US highway 212 and 0.6 miles north of Gardner Lake.
Habitat: Gentle, northeast-exposed slope with 75% vegetation cover in Geum rossii community.
Ownership: Shoshone NF.
Date Last Observed: 23 August 1999.
Voucher: S. Mellmann-Brown 1200 (RM).