Survey and Mapping of Black Hills Montane Grasslands in the Black Hills in Wyoming

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Introduction

Black Hills montane grasslands, or *Sporobolus heterolepis - Achnatherum richardsonii - Danthonia intermedia* Herbaceous Vegetation, are endemic to the Black Hills of western South Dakota and northeastern Wyoming. The type is ranked G1 by NatureServe (Marriott 2012) -- endangered due to restricted global range, significant habitat loss in the past, continued habitat loss, and low level of protection afforded remaining stands.

Black Hills montane grasslands occur at higher elevations, generally above 6000 feet, on the Limestone Plateau of the western Black Hills. Grasses dominate, but forb species are common and diverse. These meadows were showy enough to be noticed and described by Lt. Col. G.A. Custer during his expedition to the Hills in 1875:

> "Every step of our march that day was amid flowers of the most exquisite colors and perfume ... it was a strange sight to glance back at the advancing columns of cavalry, and behold the men with beautiful bouquets in their hands, while the head-gear of the horses was decorated with wreaths of flowers fit to crown a queen of May. Deeming it a most fitting appellation, I named this Floral Valley."

The first botanists to formally describe the mountain meadows were Hayward (1928) and McIntosh (1930, 1931), both of whom also noted the spectacular shows of wildflowers. After this early work, high elevation grasslands were largely ignored by botanists and ecologists until the early 1990s. A survey of riparian vegetation on Black Hills National Forest included higher-elevation grasslands (Girard ca. 1991), but none of the stands sampled matched the meadows described by Hayward and McIntosh, and data analysis yielded no grassland types restricted to higher elevations. There was concern that native mountain meadows were gone from the Black Hills.

The Black Hills Community Inventory was a three-year effort (1996-1998) to develop a vegetation classification for the Black Hills, and to identify sites with high-quality stands of native vegetation (Marriott et al. 1999). Reconnaissance surveys for Black Hills montane grasslands were done during the final field season. A few high-elevation meadows with montane grassland species were found, but most were dominated by non-natives, mainly timothy and smooth brome[1]. More extensive survey was carried out in the South Dakota portion of the Black Hills in 1999. Only 26 stands were found with enough native montane grassland to warrant survey; of these, only seven were considered high-quality, i.e. largely native (Marriott 2000).

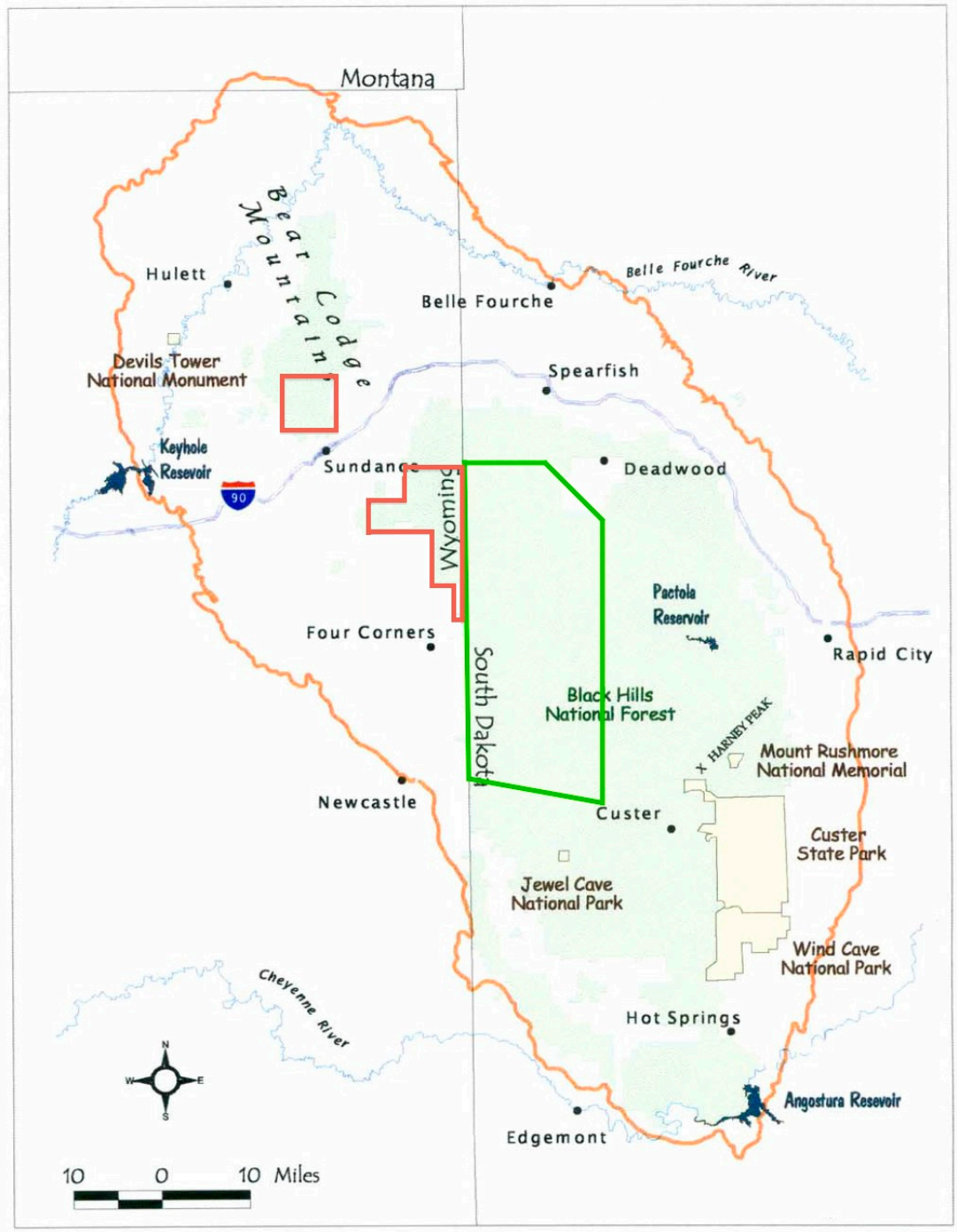
In 2011, a comprehensive survey of montane grasslands was completed in the South Dakota part of the Black Hills (Marriott 2012; Figure 1). Of 78 montane grasslands

[1] In this report, common names are used for plants in most cases (USDA NRCS 2012). For scientific names, see Appendix A.

assessed, only eight were found to be largely native in composition, representing less than 12% by area.

In 2012, Black Hills National Forest provided funding for montane grassland survey in the Wyoming part of the Black Hills. This is the final report for that project.

Figure 1. The Black Hills in western South Dakota and northeastern Wyoming; 2011 Black Hills montane grassland study area in South Dakota outlined in green, 2012 study area in Wyoming in red (modified from Marriott et al. 1999).

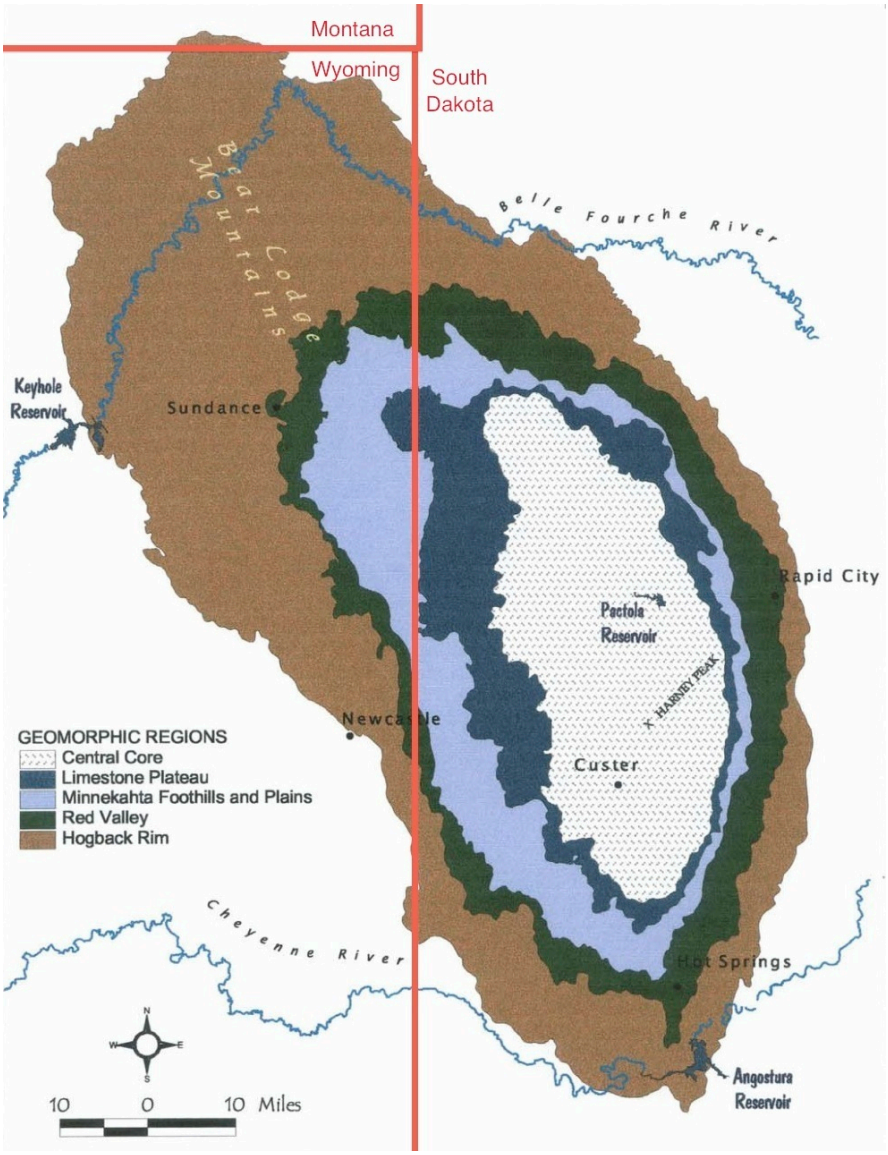


Methods

Study Area

The Black Hills are a small isolated mountain range on the Great Plains in western South Dakota and northeastern Wyoming, roughly 120 miles in length and 40 to 50 miles across. They were uplifted 75-35 million years ago during the Laramide Orogeny, the mountain building episode that created the Rocky Mountains (Bird 1998). The Hills are similar to many ranges in the Rockies, with a broad crest and relatively-steep flanks. Erosion has exposed Precambrian igneous and metamorphic rocks at highest elevations. These are surrounded by progressively-younger sedimentary strata underlying plateaus, hogbacks and valleys (Figure 2).

Figure 2. Geomorphic regions of the Black Hills (modified from Marriott et al. 1999, after Froiland 1990).



Much of the Black Hills is forested with ponderosa pine, and they appear as a black hummocky ridge above the surrounding plains, hence their name. Grasslands are a significant component of the vegetation as well (Marriott et al. 1999). At lower elevations, these are dominated by Great Plains species, including little bluestem, needle and thread, blue grama, western wheatgrass and green needlegrass.

High-elevation grasslands are best developed on the Limestone Plateau where broad dry drainage bottoms are occupied by Black Hills montane grasslands composed of prairie dropseed, Richardson's needlegrass, timber oatgrass and many forbs.

There also are several very large high-elevation grasslands near Deerfield Lake, on sites underlain by schist and slate. These are mosaics of lower-elevation grassland types and patches of Black Hills montane grassland species.

Another type of high-elevation grassland is found in the Wyoming part of the Black Hills, at Cement Ridge south of Beulah, and on Warren Peaks on the crest of the Bear Lodge Mountains, a small uplift superimposed on the northwest Black Hills (Figures 1 and 2). Reconnaissance surveys in 1998 described these large grasslands as similar to Black Hills montane grasslands of the Limestone Plateau, but with some differences in species composition.

The study area for this project included the northwestern Limestone Plateau in the Wyoming portion of the Black Hills, Cement Ridge, and the Warren Peaks area at the crest of the Bear Lodge Mountains (Figure 1). Delineation of the study area was based in part on earlier work, which documented location and elevational limits of montane grassland habitat (Marriott 2000, 2012).

Survey Site Selection

We selected 24 candidate survey sites, including grasslands identified in prior surveys, new sites identified with online aerial photography (ESRI ArcGIS Online 2012; Google Earth; USGS National Map Viewer 2012), and sites recommended by Black Hills National Forest staff. Most were above 5500 ft elevation. Grasslands smaller than 5 ha (12 ac) were not considered, as small patches lack variability, are subject to conversion to adjacent community types, and are susceptible to invasion from any adjacent weedy edges (Marriott et al. 1999). We did not survey burned slopes with grassy vegetation seral to ponderosa pine, nor wet meadows.

Highest priority for survey were stands identified as high- or medium-quality in earlier work, stands where condition was unclear in earlier visits, and new sites. Stands previously ranked D (<50% native cover) were lowest priority for survey.

Ecological Integrity Assessment

In earlier surveys (Marriott et al. 1999, Marriott 2000), Black Hills montane grasslands were evaluated using the EORANK (element occurrence rank) methodology of the Natural Heritage Program network, a mix of qualitative and semi-quantitative criteria. Each was assigned ranks for condition, size, landscape context and overall quality. During montane grassland surveys in 2011 (Marriott 2012) and during this project, stands were assessed using a system of metrics and criteria developed specifically for Black Hills montane grasslands, following the ecological integrity assessment (EIA) framework of NatureServe (Faber-Langendoen et al. 2009). Six metrics -- size, landscape context and four condition metrics -- were assessed (Table 1); ranks for each ranged from A (highest) to D (Tables 2 and 3).

Table 1. Ecological integrity (EIA) metrics for Black Hills montane grasslands.

CONDITION		**Assessment level**
Relative cover native species	% overall cover contributed by native plants	Level 2 (field)
Cover exotic invasive species	% cover of non-natives considered invasive	Level 2 (field)
Native increaser species	native species in concentrations beyond natural range of variation	Level 2 (field)
Soil surface condition	% area with bare soil or old disturbances visible as altered vegetation; due to human activities, including livestock	Level 2 (field)
SIZE		
Absolute size	current size (area) of the occurrence or stand	Level 1 (aerial photos in GIS)
LANDSCAPE CONTEXT		
Landscape connectivity	percent unaltered (natural) habitat within specified landscape area (1000 ha, 2471 ac)	Level 1 (aerial photos in GIS), some Level 2 (field)

Table 2. Ranks and criteria for Size and Landscape Context metrics for Black Hills montane grasslands.

Metric	A	B	C	D
Absolute Size	> 100 ha (247 ac)	25-100 ha (62-247 ac)	5 - 24 ha (12-59 ac)	< 5 ha (12 ac)
Landscape Connectivity (across 1000 ha, 2471 ac)	> 90% of assessment area is intact	60 - 90% of assessment area is intact.	20 - 59% of assessment area is intact.	< 20% of assessment area is intact.

Table 3. Ranks and criteria for Condition metrics for Black Hills montane grasslands.

Metric	A	A-	B	C	D
Relative Cover Native Species	Native spp >99% relative cover.	Native spp 95-99% relative cover.	Native spp 85-94% relative cover.	Native spp 50-84% relative cover.	Native spp <50% relative cover.
Cover Exotic Invasive Species	Exotic invasive spp <1% absolute cover.		Exotic invasive spp 1-2% absolute cover.	Exotic invasive spp 2-10% absolute cover.	Exotic invasive spp >10% absolute cover.
Native Increaser Species	Concentrations of increasers absent or <10% of stand area		Concentrations of increasers occupy 10%-25% of stand area.	Concentrations of increasers occupy 25-50% of stand area.	Concentrations of increasers occupy >50% of stand area.
Soil Surface Condition [Natural disturbances at natural densities not included in total.]	<1 % of area with bare soil or old disturbances visible as altered vegetation; due to human activities, including livestock.		1-10 % of area with bare soil or old disturbances visible as altered vegetation; due to human activities, including livestock.	10-25 % of area with bare soil or old disturbances visible as altered vegetation; due to human activities, including livestock.	>25 % of area with bare soil or old disturbances visible as altered vegetation; due to human activities, including livestock.

NOTE: Kentucky bluegrass, *Poa pratensis*, widely-naturalized in western North America, was *not* treated as non-native in EIA, and was considered a native increaser species in some situations.

Size was measured in ArcGIS 9.3.1 Desktop. In ranking size, we assumed bigger is better. Larger stands are better buffered from adjacent disturbance, and more likely to maintain species composition and natural processes if some part were disturbed.

Landscape connectivity also was ranked using GIS, by assessing the 1000 ha (2471 ac) surrounding a grassland. Common down-ranking factors were roads, livestock facilities and hay fields. Categories for landscape connectivity are broad and easy to apply in the Black Hills, where the much of the landscape is intact but utilized to some extent.

The four condition metrics (Table 3) were assessed in the field. We also assigned a tentative overall condition rank to incorporate professional judgement. After the field season, condition ranks were combined using a point-based formula to produce overall condition rank for a grassland (Table 4). Native cover was heavily weighted, as native stands are rare. Grasslands ranked D for native cover received an overall rank of D automatically.

Table 4. Formulas for calculating overall EIA ranks from individual metric ranks.
Points for ranks: A 5; A- 4.375; B 3.75; C 2.5; D 1.25
Scores for overall ranks: A = 4.4 – 5, B = 3.1 – 4.3, C = 1.9 – 3.1, D < 1.9

Overall Condition	(8*native cover + exotic invasives + native increasers + soil surface condit.)/11
Example -- Gillette Canyon, Upper (SD)	Native cover A, exotic invasives A, native increasers A, soil surface condition B. ((8 x 5) + 5 + 5 + 3.75)/11 = 4.89, for an overall condition rank of A.
Overall Rank	(8*overall condition + absolute size + landscape connectivity)/10
Example -- Smith Draw South (SD)	Overall condition A, absolute size B, landscape connectivity B. ((8 x 5) + 3.75 + 3.75)/10 = 4.75, for an overall rank of A.

Ranks for absolute size, landscape connectivity and overall condition were combined using a point-based system to produce an overall rank for each grassland (Table 4 above). Condition rank was heavily weighted due to rarity of native stands, and overall rank reflects the condition rank of a grassland in most cases.

Ecological integrity assessment of Black Hills montane grasslands is described in more detail in Marriott (2012).

Black Hills Montane Grassland Scorecard

Black Hills National Forest staff requested a scorecard for identifying Black Hills montane grasslands in the field (Appendix B). During the 2011 field season, a draft was tested on montane grasslands representing a range of conditions. It worked well in all Black Hills montane grassland stands, but received only limited testing outside the type. We continued trials during fieldwork in 2012.

Field Survey

Surveys were done July 12 through August 16, 2012, to be consistent with earlier projects. Though the 2012 season was ahead of schedule, this worked well for the most part. Grasses generally were identifiable, but the forb component was difficult to characterize at some locations. All surveys were on Black Hills National Forest. Some private lands were observed in passing from public roads and lands.

Information collected included site location and description, montane grassland description and condition, human use, and boundary information for mapping. The 2012 field crew also did the surveys in South Dakota in 2011; we worked together the first week to "calibrate" grassland characterization and assessment, and to test condition metrics, a very useful and recommended step (Marriott 2012).

We evaluated condition metrics at all sites visited. Stands obviously ranked D for native cover (<50%) were not surveyed further. Other stands were walked until all condition metrics could be assessed. High-quality stands (>85% native cover) were to be walked in their entirety for mapping purposes. Observations, at points documented with GPS, were noted. We took photos of representative areas in higher-quality grasslands, and in some lower-quality stands.

Information Management

After the field season, information from field forms was entered into a project database. Exported records and hard copies of field forms have been provided to the Wyoming Natural Diversity Database. A digital map of high-elevation grasslands in the Wyoming part of the Black Hills was created in ArcGIS 9.3.1 Desktop. Grassland boundaries were heads-up digitized from 2006 NAIP imagery at a scale of 1:7500. A photo points layer was constructed as well.

Quantitative Analyses

High-quality montane grasslands, ranked A or B, were to be sampled for quantitative analyses, using methods of previous projects (Marriott et al. 1999, Marriott 2012). In those projects, data were collected using 100 sq m plots placed at representative points within stands, and away from stand boundaries. Habitat data collected included slope, aspect, elevation, and some soils information, and any information on site disturbances and fire history. Vegetation data included lists and cover estimates of all plant species in the plot grouped by major strata, as well as cover class for each stratum.

Following the 2012 field season, montane grassland plot data from all projects were combined with shrubland and grassland data from the Black Hills Community Inventory (Marriott et al. 1999) for ordination and cluster analyses using the PC-ORD 6 package (McCune and Mefford 2011).

Results

Field Surveys

We visited 21 survey sites during the 2012 field season. Three sites surveyed in earlier projects were not revisited, but are included in the project database and digital map, for a total of 24 grasslands. Black Hills montane grassland was found at 14 sites. Others contained a mix of lower-elevation grassland species and non-natives (timothy and smooth brome). The large grasslands on the crest of the Bear Lodge Mountains and at Cement Ridge differ sufficiently in composition from Black Hills montane grasslands to be considered a different type, described in detail in **Results** below.

Quantitative Analyses

No plot data were collected in 2012, as no new high-quality Black Hills montane grasslands were found. Four plots done during reconnaissance survey in Wyoming in 1998 were included in the dataset for analysis.

After the 2012 field season, all montane grassland plot data were combined with grassland and shrubland data from the Black Hills Community Inventory for analyses. We included only grassland and shrubland types for which sufficient plot data were available, i.e. at least three plots unless a type might potentially be combined with another, or have other plots better reassigned to it. We excluded several plots done in sites too small to be representative of types at the scale of 0.5 ha or more. The final dataset consisted of 81 plots with 284 species. Two analyses were run: a flexible beta linkage cluster analysis, and a non-metric multi-dimensional scaling (NMS) ordination.

Plots from montane grasslands segregated clearly from other types in both analyses. Two montane types were recognized: Black Hills montane grasslands as described by Hayward (1928) and McIntosh (1930), and Northwest Black Hills fescue montane grasslands (provisional name), a type not previously recognized (see description in **Results** below).

Quantitative analysis is described in more detail in Appendix C.

Ecological Integrity Assessment

We found no high-quality montane grasslands, ranked A or B, during survey in 2012. All stands had less than 85% relative cover of native species. In fact, we found only two C-ranked stands (50-85% native cover). The others were ranked D, with less than 50% native cover. This is consistent with results of survey in South Dakota, which showed that Black Hills montane grassland habitat in the northern Black Hills is largely dominated by timothy and smooth brome (Marriott 2012).

Figure 3. Timothy dominates many grasslands in the northern Black Hills, such as this one in the Guidinger Spring drainage. All photos by author unless otherwise noted.

The two partially-native (C-ranked) montane grasslands found in 2012 are consistent in composition and structure with Black Hills montane grasslands in South Dakota. They are graminoid-dominated but forb-rich; common grasses include montane grassland species such as timber oatgrass, Richardson's needlegrass and green needlegrass, as well as non-natives, especially timothy. Kentucky bluegrass is sometimes locally common. For detailed range-wide information about Black Hills montane grassland vegetation, see Marriott (2012).

Survey in 2012 confirmed that native high-quality Black Hills montane grasslands are rare, especially in the northern Black Hills. Less than 11% of montane grasslands by area are ranked A or B. Table 5 summarizes ecological integrity assessment of Black Hills montane grasslands in South Dakota and Wyoming.

Table 5. Numbers, areas of Black Hills montane grasslands, by overall quality rank (South Dakota and Wyoming).

Overall Rank	# Sites	Area, ha (ac)	% of total montane grassland area
A	5	289.5 (715.4)	5.5
B	3	259.3 (640.7)	4.9
C	22	1370.6 (3386.8)	26.1
D	65	3332.4 (8234.5)	63.5
totals	95	5251.8 (12,977.4)	

Some lower-ranked Black Hills montane grasslands have more native cover locally within the site, and may be candidates for experimental management to improve condition. Six C-ranked sites in the South Dakota Black Hills were recommended for consideration (Marriott 2012). Two sites surveyed in Wyoming in 2012 also would be candidates for such management (Table 6; Figures 4 and 5).

Table 6. C-ranked Black Hills montane grasslands found in 2012.

Site	Point within site	Comments
Riflepit Canyon, lower	572300E, 4906117N (NAD83)	Similar to downstream end of Riflepit site surveyed in 1999 in SD -- with relic patches of montane grassland species on lower slopes occasionally; more natives than in most meadows in area.
Melquist Gulch	569815E, 4896951N (WGS 84)	Montane grassland species found on slopes, mixed with non-natives. Bottom is largely non-native. Most other meadows surveyed in this area lack montane grassland species.

Figure 4. Black Hills montane grassland in Melquist Gulch. Slopes in foreground and across road in distance are largely native. Other areas are dominated by non-native grasses.

Figure 5. Montane grassland in lower Riflepit Canyon. This site has relic patches of montane grassland species, and more native species than most meadows in the area. Photo by H.M. McGranahan.

Northwest Black Hills fescue montane grasslands (provisional)

Reconnaissance survey in 1998 suggested that the large grasslands on Warren Peaks in the Bear Lodge Mountains, and at Cement Ridge (also called Sand Creek Headwaters) were similar to Black Hills montane grasslands of the Limestone Plateau, mainly in being forb-rich. However significant differences were noted. Of the Black Hills montane grassland indicator grasses, only timber oatgrass was common in these stands, and Rocky Mountain fescue was one of the most common grasses.

With extensive range-wide surveys completed, the Black Hills montane grassland type now is well-characterized. During survey in 2012, surveyors felt that grasslands in the Warren Peaks area and at Cement Ridge were too different to include in that type, verified by low values on the Black Hills Montane Grassland Scorecard (Appendix B). In addition, plots from these stands segregated from other types in quantitative analyses (Appendix C).

We investigated the possibility that these grasslands are a type known outside the Black Hills, by querying regional ecologists and NatureServe's national database (NatureServe Explorer), but found no candidate types. For now, they are being treated as a new type, provisionally called Northwest Black Hills fescue montane grassland.

Habitat

In contrast with the Black Hills montane grasslands of Hayward (1928) and McIntosh (1930), which occupy drainage bottoms and lower slopes underlain by limestone, the fescue montane grasslands occupy ridge crests and slopes below, on several types of igneous rock. Cement Ridge is underlain by Tertiary trachytic intrusive rocks. The bedrock at Warren Peaks is a huge Archean granite block uplifted by a Tertiary intrusion (DeWitt et al. 1989).

Vegetation structure and composition

The position of these grasslands on ridge crests and slopes means variable habitat, and variable vegetation structure and composition as a result (Figures 6, 7 and 8). At one extreme are dry rocky areas with less cover and generally more forbs. Mesic aspects and other areas with good soil development have heavy grass cover and less forb cover; stands of low shrubs are common. Vegetation intermediate between these two extremes covers large areas as well.

Figure 6. Very large grassland on Warren Peaks, crest of Bear Lodge Mountains; viewed from southwest.

Species commonly observed in drier parts of these mosaics include Rocky Mountain fescue, prairie Junegrass, sun sedge, lesser spikemoss, hairy false goldenaster, field chickweed, prairie smoke and many other forbs. In areas surveyed, cover ranged from 50 to 100%. On more mesic sites, grasses have greater cover (generally 100%) and are taller. Common species include Kentucky bluegrass, green needlegrass and timber oatgrass. Forbs contribute less relative cover; common species include wild bergamot, lupine, northern bedstraw, white sagebrush (mugwort) and sticky purple geranium. Stands of low shrubs are common, including snowberry, chokecherry, Saskatoon serviceberry (June berry), creeping barberry (Oregon grape) and snowbrush ceanothus.

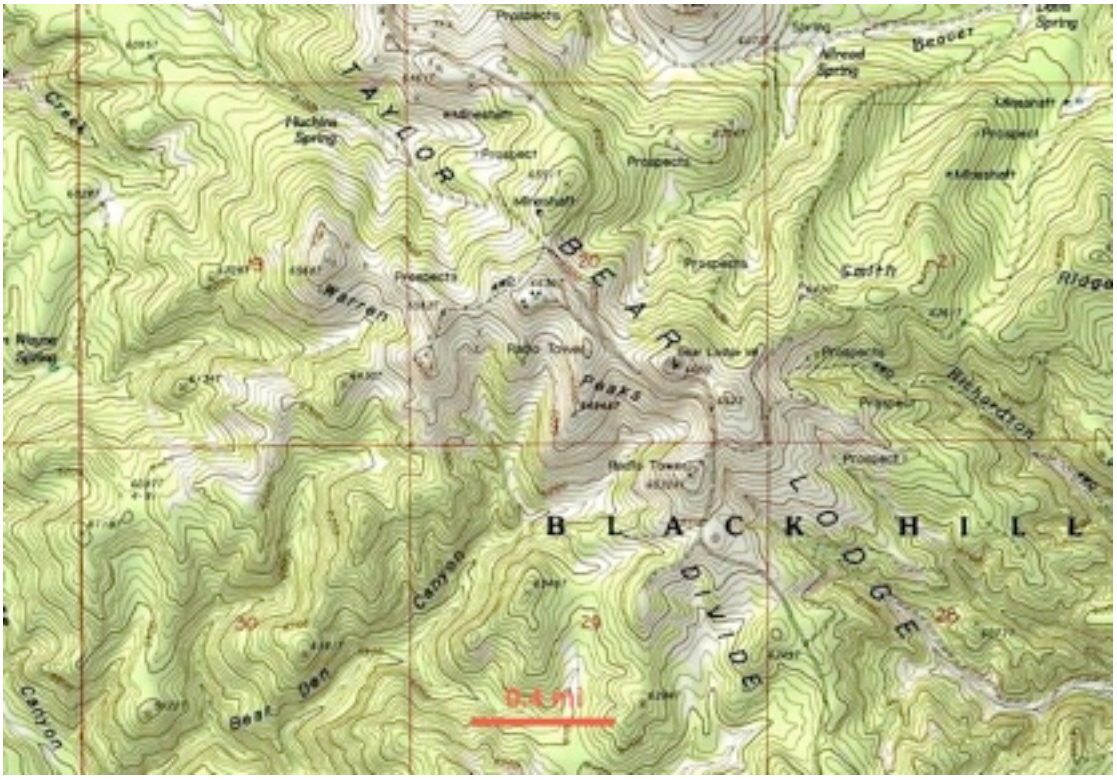
This description does not include all variation present, especially on Warren Peaks where the grassland is over 200 ha in extent, and includes habitat with widely variable aspect, slope and rockiness (Figure 10). Additional survey is needed for complete descriptions of these grasslands.

Figure 7. Grassland mosaic on Warren Peaks; xeric habitat on crest, greener slopes below are more mesic.

Figure 8. Mesic grassland on Warren Peaks north of fire lookout.

Figure 9. Northwest Black Hills fescue montane grassland on Cement Ridge.

Figure 10. Map of Warren Peaks area, Bear Lodge Mountains, showing extent of grasslands (white) and habitat variability (slope and aspect). US Geological Survey and ESRI ArcGIS Online (2012).



Summary

Black Hills montane grassland survey in Wyoming in 2012 resulted in virtually no change to the concept of the type nor to its conservation status. The type of high-elevation grasslands of the Bear Lodge Mountains and Cement Ridge was clarified. These now are considered distinct from the montane grasslands of the Limestone Plateau to the south. They have been provisionally named Black Hills fescue montane grassland; their relationship to similar types outside the Black Hills needs to be determined.

No high-quality Black Hills montane grasslands were found during the 2012 field season, and the type remains rare both globally (endemic to the Black Hills) and locally. While there is extensive montane grassland habitat on the Limestone Plateau in South Dakota and Wyoming, most stands are partially or largely non-native. Only eight of the 95 Black Hills montane grasslands surveyed in all projects are dominated largely by native grasses.

Due to limited global distribution and rarity of native stands, Black Hills montane grassland vegetation is ranked G1S1 in South Dakota and Wyoming, "critically imperiled" on a global and local basis (Marriott 2012). Given the rarity of native Black Hills montane grasslands, all high-quality stands should be considered conservation targets. At least eight lower-ranking montane grasslands, including two in Wyoming, have sufficient native vegetation to be candidates for experimental management to improve condition.

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Appendix A. Plant names used in report.

Nomenclature follows USDA NRCS PLANTS Database (2012).

Common Name	Scientific Name
blue grama	*Bouteloua gracilis*
chokecherry	*Prunus virginiana*
creeping barberry (Oregon grape)	*Mahonia repens*
field chickweed	*Cerastium arvense*
green needlegrass	*Nassella viridula*
Kentucky bluegrass	*Poa pratensis*
little bluestem	*Schizachyrium scoparium*
lupine	*Lupinus* sp.
needle and thread	*Hesperostipa comata*
ponderosa pine	*Pinus ponderosa*
prairie smoke	*Geum triflorum*
prairie dropseed	*Sporobolus heterolepis*
Richardson's needlegrass	*Achnatherum richardsonii*
Rocky Mountain fescue	*Festuca saximontana*
Saskatoon serviceberry (June berry)	*Amelanchier alnifolia*
smooth brome	*Bromus inermis*
snowberry	*Symphoricarpos* sp.
snowbrush ceanothus	*Ceanothus velutinus*
sticky purple geranium	*Geranium viscosissimum*
timber oatgrass	*Danthonia intermedia*
timothy	*Phleum pratense*
western wheatgrass	*Pascopyrum smithii*
white sagebrush (mugwort)	*Artemisia ludoviciana*
wild bergamot	*Monarda fistulosa*

Appendix B. Black Hills montane grassland scorecard.

Black Hills Montane Grassland Project 2012 -- Wyoming

Type Verification Scorecard

This scorecard can be used mid-July through early September in a typical season. Good plant id skills are required. Assess as large an area as possible, dominated by native species.

1. Estimated tree cover _____% Estimated shrub cover _____ %

   Tree, shrub species _____

2. Indicate which are present. Scores: Grasses _____ Forbs _____

   2.a. Grasses (4 points each, minimum 8 points)
   _____ Elymus trachycaulus ssp. subsecundus
   _____ Sporobolus heterolepis
   _____ Danthonia intermedia
   _____ Achnatherum richardsonii

   2.b. Forbs (1 point each, minimum 5 points)
   _____ Achillea millefolium
   _____ Agoseris glauca
   _____ Allium cernuum
   _____ Anemone cylindrica, A. multifida
   _____ Campanula rotundifolia
   _____ Cerastium arvense
   _____ Dodecatheon pulchellum
   _____ Erigeron subtrinervis
   _____ Galium boreale
   _____ Gaillardia aristata
   _____ Geranium viscosissimum
   _____ Gentianella amarella
   _____ Geum triflorum
   _____ Heterotheca villosa
   _____ Heuchera richardsonii
   _____ Iris missouriensis
   _____ Orthocarpus luteus
   _____ Pulsatilla patens
   _____ Sisyrinchium montanum
   _____ Thalictrum dasycarpum
   _____ Vicia americana

If you feel that contrary to the above scores the stand *is* or *is not* a montane grassland, explain: _____

_____

Other comments _____

_____

Appendix C. Quantitative analyses of Black Hills grassland and shrubland plot data.

Relationship of Black Hills montane grasslands to other grassland and shrubland types in the Black Hills; results of quantitative analyses.

by Don Faber-Langendoen, Senior Ecologist, NatureServe, Arlington VA; Jim Drake, Regional Vegetation Ecologist, NatureServe, Minneapolis MN; and Hollis Marriott, Botanist/Ecologist, Poorperson's Enterprises, Laramie WY.

Methods

Quantitative data collected from montane grasslands in the Black Hills in 1998, 1999 and 2011 were combined with grassland and shrubland data from the Black Hills Community Inventory (BHCI) for analysis. The BHCI was a three-year effort (1996-1998) to develop a plant association-level vegetation classification for the Black Hills, and to identify sites with high-quality stands of native vegetation (Marriott et al. 1999, Marriott and Faber-Langendoen 2000). Quantitative data were collected from at least three high-quality examples of most vegetation types, and were analyzed during the final year of the project.

Prior to the BHCI, it was thought that the mountain meadow vegetation of the Black Hills described by Hayward (1928) and McIntosh (1930) had been extirpated. However, a week of reconnaissance during the final field season identified several candidate Black Hills montane grasslands. Plots were done in some of these stands, but too late to add to the BHCI dataset for quantitative analysis. However, a description and stand summary table for the type were included in the final report (Marriott and Faber-Langendoen 2000). Several grasslands on the crest of the Bear Lodge Mountains and at Cement Ridge, both in Wyoming, were included in the description and stand summary table. Based on results of subsequent surveys, these grasslands have been moved to a separate type provisionally called Northwest Black Hills fescue montane grasslands.

During montane grassland surveys in 1999 and 2011 in the South Dakota part of the Black Hills, quantitative data were collected in higher-quality stands following the methodology of the BHCI (Marriott 2000, 2012). Survey in the Wyoming part of the Black Hills in 2012 produced no montane grasslands of sufficient quality for quantitative sampling.

In the BHCI and subsequent montane grassland surveys, data were collected using 100 sq m plots placed at representative points within stands and away from stand boundaries. Locations were recorded on topographic maps in 1998 and 1999, and with GPS units in later studies. Habitat data collected included slope, aspect, elevation, and some soils information, and information on site disturbances and fire history if available. Vegetation data included lists and cover estimates for all species in the plot grouped by major strata (tree canopy, subcanopy, tall shrub (2-5 m), short shrub (0.5-2 m), dwarf-shrub (< 0.5 m), herbaceous, and non-vascular). Cover class also was estimated for each stratum as well. The cover scale used was similar to the Braun-Blanquet scale: trace, 0-1, 1-5, 5-25, 25-50, 50-75, and 75-100% cover.

After the 2012 field season, montane grassland plot data were combined with grassland and shrubland data from the BHCI for analysis. We included only types for which sufficient plot data were available, i.e. at least three plots unless a type might potentially be combined with another, or might have additional plots assigned to it during analysis. We excluded several plots from sites that were too small to be representative at the scale of 0.5 ha or more. The final dataset contained 81 plots, with 284 species.

We performed two analyses using the PC-ORD 6 package (McCune and Mefford 2011). First, we used the flexible beta linkage cluster method, with Sørensen distance (Bray and Curtis 1957 in McCune and Mefford 2011). No transformations were done. Species with just one occurrence in the entire data set were removed before partitioning the data set. We also ran a non-metric multi-dimensional scaling (NMS) ordination, again deleting species with just one occurrence. Relative Sørensen distance was used in the ordination.

We determined diagnostic species for types based on phi coefficient of association, to accommodate unequal and small sample sizes (Chytrý et al. 2002). We also applied the method of Dufrêne and Legendre (1997), which incorporates abundance but is sensitive to unequal sample sizes. Both methods gave similar results, producing 80-100% of the same diagnostic species. For our data set, we used a threshold of phi ≥ 35% (Willner et al. 2009, Kusbach et al. 2012), p value < 0.1 and constancy ≥ 40%.

Results and Discussion

Analyses resulted in 11 vegetation types (Table C-1). Types were fairly well discriminated in both cluster analysis and ordination. There were few changes to the original BHCI classification; we changed plot assignments in only a few cases.

Plots from montane grasslands segregated clearly in both analyses (Figures C-1 and C-2). Two montane types were recognized: Black Hills montane grasslands as described by Hayward (1928) and McIntosh (1930), and Northwest Black Hills fescue montane grasslands (provisional name), a type not previously recognized.

Both types had large numbers of statistically-significant diagnostic species, 20 and 16 respectively. Some, especially forb species, need further evaluation to determine ecological significance. For the Black Hills montane grassland type, all grass species considered diagnostic based on qualitative surveys ranked highly in analysis: *Sporobolus heterolepis, Danthonia intermedia, Achnatherum richardsonii* and *Elymus trachycaulus* ssp. *subsecundus*.

Results suggested there are two phases of the Black Hills montane grassland type, a more common dry-mesic phase and a mesic phase (these are relative terms; all montane grasslands grow on drier habitat away from streams and standing water). Most plots were placed in locations considered typical of Black Hills montane grasslands based the description of McIntosh (1930), and with mostly native species. However, many of the stands sampled also had areas of more mesic habitat where cover was greater, with

more grasses and fewer forbs, and often with significant cover of *Poa pratensis* and sometimes *Phleum pratense*. A few plots were done in these areas to show range of variation across stands. This "phase" is more common outside of the higher-quality grasslands sampled, especially in the northern Black Hills where much montane grassland habitat is now dominated by non-natives.

Table C-1. Codes and vegetation types for cluster analysis and ordination diagrams (Figures C-1 and C-2).

Code	Vegetation Type
3	*Andropogon gerardii - Schizachyrium scoparium* Northern Plains Herbaceous Vegetation
9	*Cercocarpus montanus / Bouteloua curtipendula* Shrubland
16	*Pascopyrum smithii - Nassella viridula* Herbaceous Vegetation
17	*Pascopyrum smithii - Stipa comata* Central Mixedgrass Herbaceous Vegetation
18	*Stipa comata - Bouteloua gracilis - Carex filifolia* Herbaceous Vegetation
19	*Rhus trilobota / Pseudoroegneria spicata* Shrubland
51	*Schizachyrium scoparium - Bouteloua (curtipendula, gracilis) / Carex filifolia* Herbaceous Vegetation
56	*Symphoricarpos occidentalis* Shrubland
60	*Sporobolus heterolepis - Achnatherum richardsonii - Danthonia intermidia* Herbaceous Vegetation
61	Northwest Black Hills fescue montane grassland (provisional; *Festuca saximontana*)
75	*Rhus trilobota / Carex filifolia* Shrubland

Figure C-1. Results of flexible beta linkage cluster analysis, PC-ORD 6.

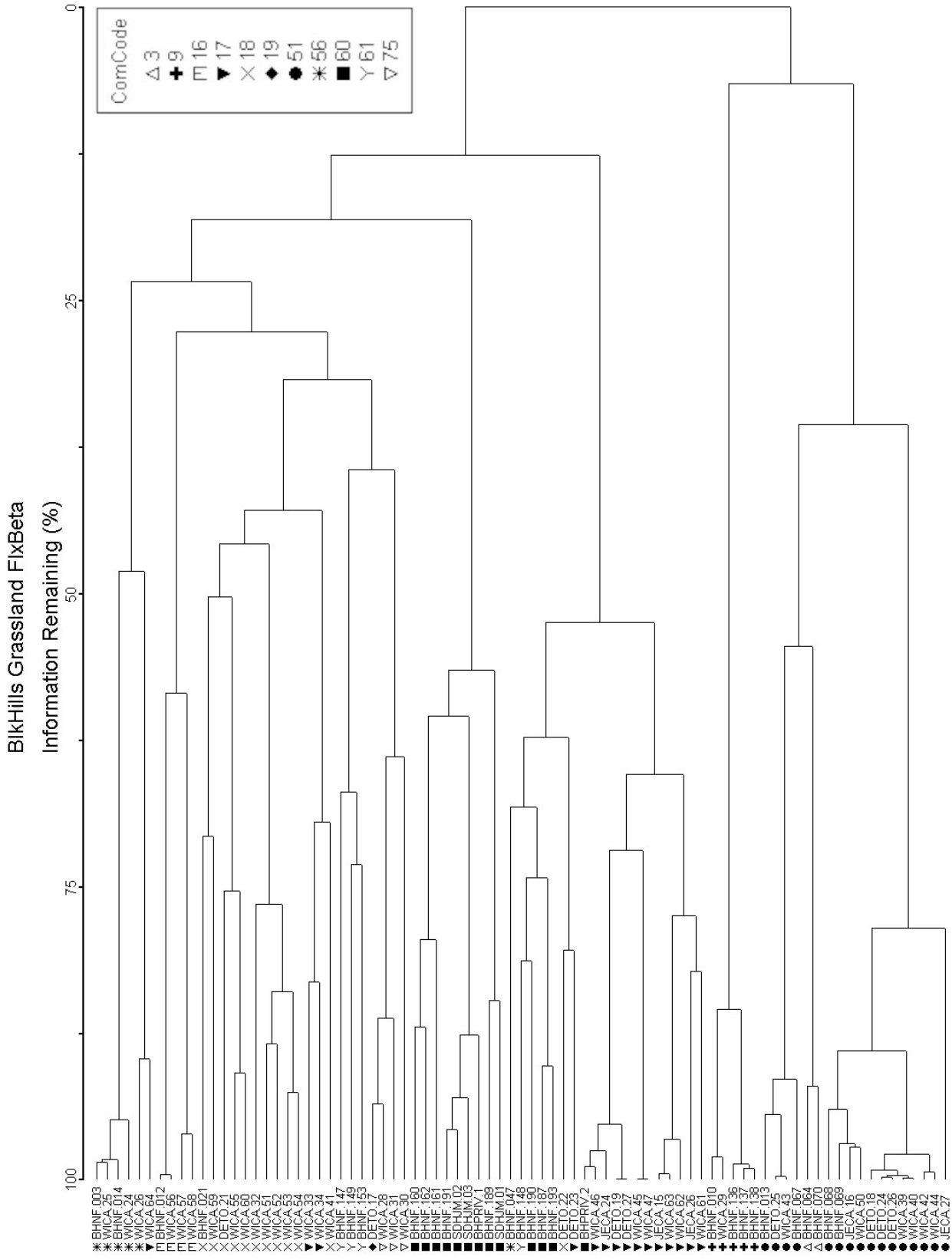
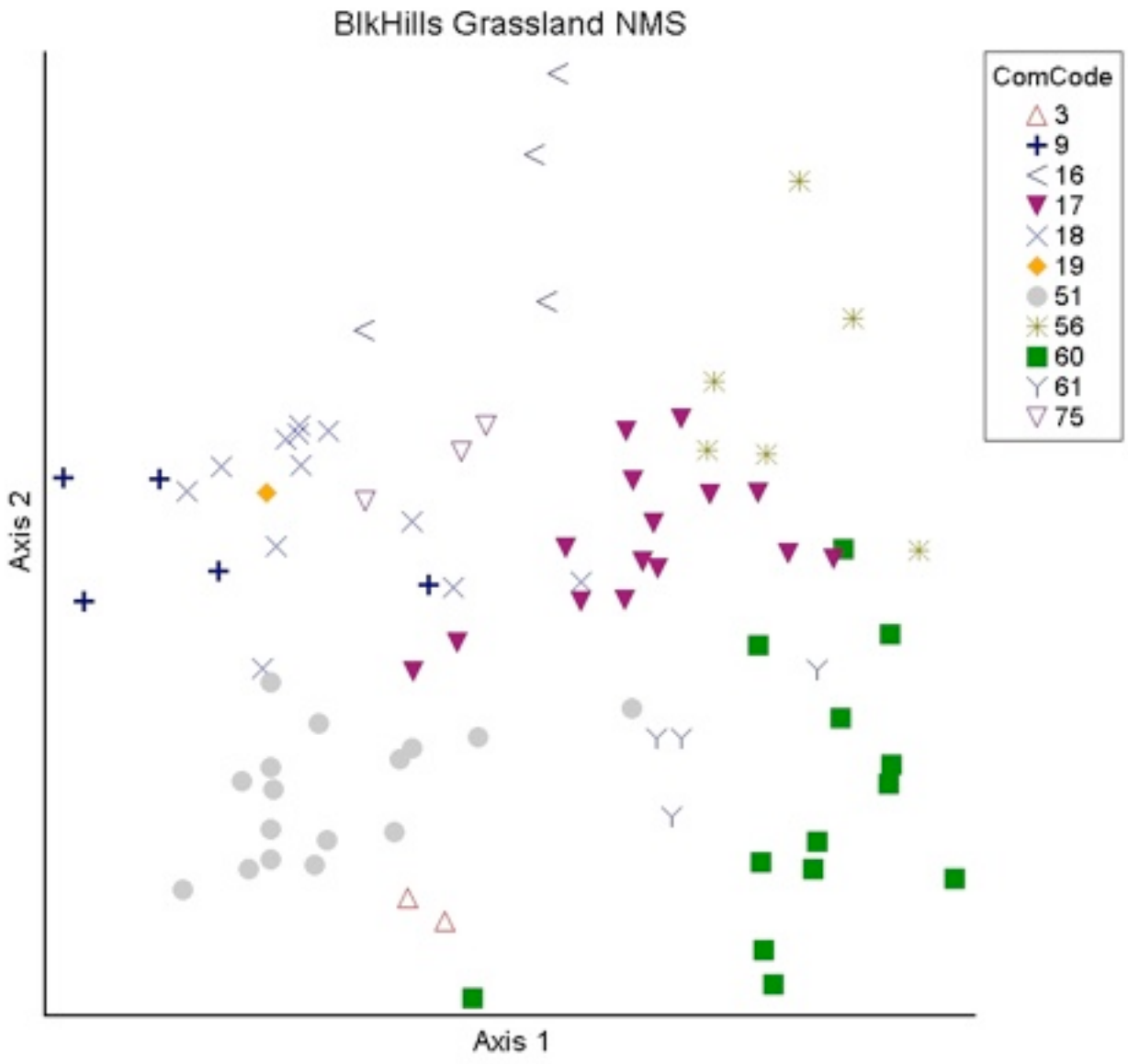


Figure C-2. Results of non-metric multi-dimensional scaling (NMS) ordination, PC-ORD 6.



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