Botanical and Ecological Characteristics of Fens in the Medicine Bow Mountains, Medicine Bow National Forest

Albany and Carbon Counties, Wyoming

Prepared for:
Medicine Bow-Routt National Forest

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ABSTRACT

A three-year, three-phase investigation has documented the botanical and ecological characteristics of montane peatlands in the Medicine Bow Mountains portion of the Medicine Bow-Routt National Forest. Before this investigation, only one peatland site was widely-recognized by botanists in the Medicine Bow Mountains, along Sand Lake Road. Today, we know that peatlands cover significant parts of the land area of the Medicine Bow Mountains, comprising over 1% of the land area in portions of the Medicine Bow Mountains, including 138 peatland sites that have been ground-truthed and mapped.

Despite the extensiveness of fen habitat, only 17 occurrences of ten Wyoming plant species of concern have been documented. All 17 occurrences are restricted to five sites that have unusual fen plant community types or composition. This potentially places a premium on identifying and buffering the rarest fen types. Two additional species once considered Wyoming plant species of concern proved widespread at 85 sites in extensive inventory.

Results from this investigation document that most Medicine Bow Mountains peatlands are fen systems associated with drainage courses as settings of flow-through hydrology. A smaller number of fens occupy glacial kettle settings that have outlets but otherwise function like closed-basins.

Twelve study sites were selected as representative of montane Medicine Bow Mountain fens. Five plant community types were identified at the 12 study sites. The two main plant communities include graminoid fens dominated by *Eleocharis quinqueflora* (fewflower spikerush) that predominate in most of the Middle Fork Study Area, and graminoid fens dominated by *Carex aquatilis* (water sedge) with major components of *Salix planifolia* (plane-leaf willow) or less often, *Betula glandulosa* (resin birch), that predominate in the North Fork Study Area. *Carex aquatilis* fens with major *Betula glandulosa* components were the only fen plant communities found in the Sheep Mountain Study Area. Vegetation plots in the two prevailing fen plant community types had an average moss canopy over 60%. Three uncommon fen types were found only in the North Fork Study Area. One is dominated by *Betula glandulosa* with a unique composition found at the lowest elevation site. Two others, dominated by *Carex limosa* (mud sedge) and *C. vesicaria* (blister sedge), were minor components in a fen complex otherwise dominated by *Carex aquatilis* types.

A vascular flora of 162 species that includes five Forest Service sensitive species and five additional Wyoming species of concern was documented at the 12 study sites. The vascular flora represents over 5% of the state flora and over 2% of Wyoming's plant species of special concern, including five species of concern that had not previously been known from southern Wyoming. The documented bryophyte flora included 74 bryophyte species, and six liverwort species, representing over 20% of the state bryophyte flora.

The results provide an overview of Medicine Bow Mountain peatlands, detailed documentation of the 12 study sites, and the context for understanding the 126 additional field-verified sites. It also contributes baseline information to an understanding of peatlands in Wyoming and in the Rocky Mountains.

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Without the help of three bryologists, we would have learned almost nothing about the mosses and liverworts in the Medicine Bow Mountains. Dr. Elena Kosovich-Anderson sampled the bryophyte flora at four of the twelve study sites, prepared a set of portable samples for reference in the field and produced annotated checklists for the four sites based on her collections. Robin Jones made determinations for all bryophyte specimens collected by the authors during vegetation sampling. Judith Harpel identified moss samples collected at one site in the Medicine Bow Mountain in addition to one site in the Laramie Range by WYNDD in 2002.

This report draws on the results from two earlier phases of the project, which involved Wyoming Natural Diversity Database staff members. The 2002 pilot study benefited from the help of Scott Laursen. Geographic Information Systems preparations for the extensive peatland inventory were coordinated by Rob Thurston, who later helped conduct the inventory. In addition, this report benefited by the editorial assistance of Gary Beauvais and Joy Handley.

Peat and water samples were analyzed by Ramona Belden at the University of Wyoming Soils Testing Laboratory. Larry Munn, professor in the UW Department of Renewable Resources, loaned us a peat coring tool and also steered us to the Hecht Creek Fen. The digitized soils mapping on the Medicine Bow National Forest done under his direction proved invaluable.

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INTRODUCTION

In 2002, the USDA Forest Service and the University of Wyoming entered into a cooperative agreement in which biologists of the University's Wyoming Natural Diversity Database initiated a three-phase study of peatlands in part of the Medicine Bow-Routt National Forest in southeastern Wyoming. The ultimate goal of this project was to document the botanical resources and the extent of the peatlands in the montane zone of the Medicine Bow Mountains. The first phase of the project was a pilot study at several sites in 2002. Results were reported by Heidel and Laursen (2003). The second phase, conducted in 2003, was an extensive inventory to document the distribution of peatlands in three study areas. Results of that inventory were reported by Heidel and Thurston (2004). The third phase of the project was intensive floristic inventory and vegetation sampling in 2004 at 12 sampling sites within the peatlands delineated in 2003. This document reports the results of the third phase of the project.

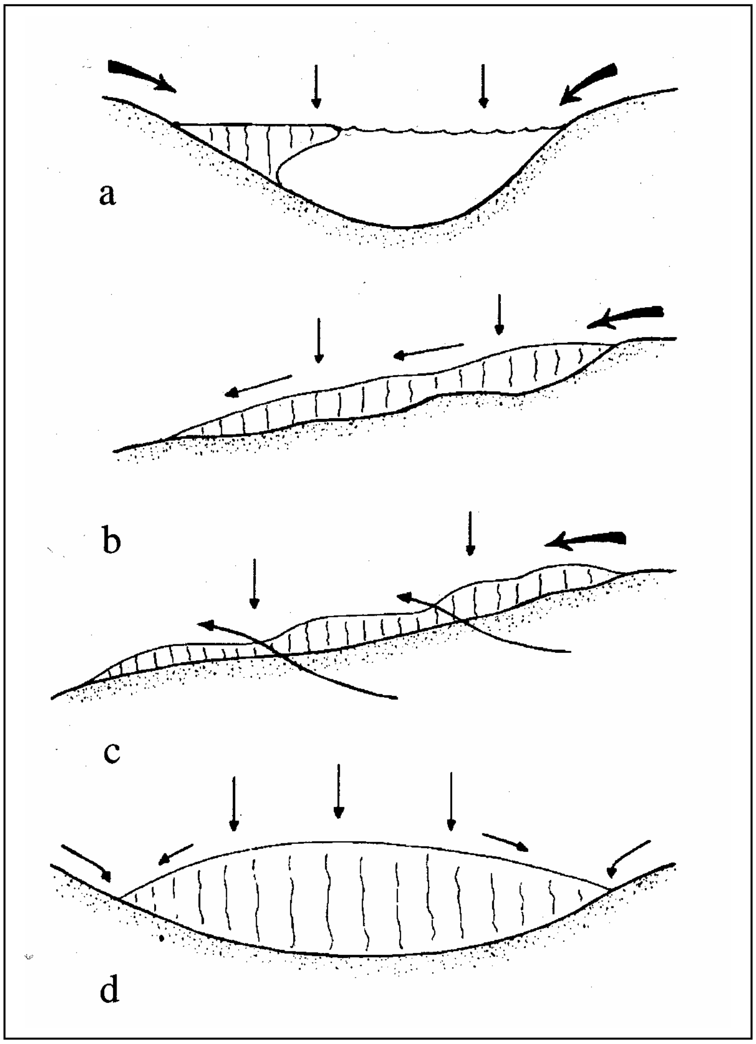
Definition and Types of Peatlands

Peat is partly decayed organic matter that accumulates in wetlands where cool, stable anaerobic conditions allow the rate of organic matter accumulation to exceed the rate of decay (Gorham 1957, Heinselman 1963, Richardson and Vepraskas 2001). Due to their water-holding capacity, peatlands are exceptionally stable and may persist for centuries, conferring a self-perpetuation of plant communities (Chadde et al. 1998). A minimum thickness of peat is necessary for a wetland to be considered a peatland. For example, the U.S. Fish and Wildlife Service has used a 20-cm minimum in its policy for the Rocky Mountain Region (USDI Fish and Wildlife Service 1998, and 1999 amendments), while 40 cm of peat is required in most circumstances for a soil to qualify as a peat soil in the U.S. soil classification (USDI Soil Conservation Service 1992, Richardson and Vepraskas 2001). In this report, we use the term "peatland" to refer to any wetland where peat accumulates.

Peatlands have been classified in various ways. A widely used classification divides them into fens and bogs. Fens are dominated by graminoids or shrubs, have relatively high pH, and are richer in nutrients than bogs because water reaches them after flowing through the soil (from which it absorbs nutrients). These peatlands also are known as groundwater peatlands, or flow-through peatlands. They form in either basin or sloping settings, also referred to as topogenous or soligeneous settings, respectively (Figure 5). Bogs are dominated specifically by ericaceous shrubs, sedges, and mosses; are very acidic; and are poor in nutrients because water reaches directly from precipitation, without flowing through the soil, also referred to as ombrogeneous peatlands.

Windell et al. (1986) provide a general overview of Rocky Mountain peatlands. More detailed reviews of peatlands are provided by Chadde *et al.* (1998) for northwestern Montana and adjoining Idaho and by Rocchio (2006) for Colorado. In most of the Rocky Mountains, the climate is unsuitable for the formation of bogs, and the peatlands are fens.

Figure 1. Major peatland types of the Rocky Mountains (from: Chadde et al. 1998)



a. Basin fen; also topogeneous; fed by groundwater

b. Flow-through fen; also soligeneous fen; fed by groundwater

c. Patterned peatland (a type of flow-through fen; also soligeneous fen; fed by groundwater

d. Bog; fed by precipitation only

Significance

Although peatlands are concentrated at high latitudes, they are among the most widespread wetlands in the world, representing 50-70% of global wetlands (Chapman et al. 2003). Peatlands are known for their biological, geochemical, and hydrological characteristics, and for their role in preserving the paleoenvironmental record (Bedford and Godwin 2003, Chapman et al. 2003, Barber 1982). On national forest lands in the USDA Forest Service – Rocky Mountain Region, peatlands are thought to occupy a limited part of the landscape,and research their ecosystem values also has been limited (Austin 2005). Research in the Medicine Bow-Routt National Forest indicates that they may serve as ground water reservoirs and stream flow regulators (Fleming 1966, Sturges 1968a) even though they have higher rates of evaporation than open water (Sturges 1968b). They also retain heavy metals and radionuclides (Sturges and Sundin 1968). The reader is directed to reviews of peatland significance that have been prepared for agencies (Austin 2005, Roche 2004, Weddell 2005, Rocchio 2006) and in the literature (Bedford and Godwin 2003, Chapman et al. 2003) for more complete background.

A 2002 comparison of the Wyoming plant species of concern list to regional peatland floras was reported in Heidel and Laursen (2003) and it indicated that peatlands harbor over 10% of the Wyoming plant species of concern (52 of 487 species). Of the 14 species currently considered sensitive by the Medicine Bow National Forest (USDA Forest Service 2004), at least five and possibly seven are peatland species. They have boreal centers of distribution and are peatland obligates as they occur in the Rocky Mountains at southern ends of their distributions.

Management Context

In recent years, peatlands have been recognized under the Clean Water Act (USDI Fish and Wildlife Service – Region 6, 1998, 1999) as wetlands that cannot be protected through mitigation, because peat accumulates slowly (at rates of centimeters per century; Richardson and Vepraskas, 2001). In one fen in the Medicine Bow Mountains, the rate of peat accumulation is estimated at 0.036-0.084 cm/year (Fleming 1966). Some European management initiatives aim for sustainable peat extraction through peatland restoration (Chapman *et al.* 2003), but evidence to date suggests that this is impractical for cordilleran peatlands such as those found in the Rocky Mountains. Studies in montane settings indicate that peatlands are extremely difficult, if not impossible, to restore at montane elevations due to slow rates of accumulation and restoration (e.g., Cooper 1990, Cooper 1993, Cooper et al. 1998, Cooper and MacDonald 2000).

The Forest Service Rocky Mountain Region has promulgated a policy on management of fens (USDA Forest Service. 2002), and a review of the Region's fen resource and their significance has been drafted (Austin 2005). Regulations have been compiled for use on the Medicine Bow-Routt National Forest (Roche 2004). Given the interest in peatlands exhibited by the U.S. Forest Service Rocky Mountain Region, this report on peatlands in the Medicine Bow Mountains is timely.

STUDY AREA

The Medicine Bow Mountains of southeastern Wyoming and north-central Colorado measure approximately 90 miles (145 km) from north to south and 32 miles (51 km) from east to west at their widest. The Wyoming segment is almost 60 miles (97 km) long. The Medicine Bow-Routt National Forest encompasses most of the Wyoming portion of the Medicine Bow Mountains. For the sake of brevity, the Medicine Bow-Routt National Forest is referred to in this report as Medicine Bow National Forest (MBNF).

This project was conducted in three study areas (the North Fork, Middle Fork, and Sheep Mountain Study Areas), all in the Medicine Bow Mountains within the Wyoming portion of the Medicine Bow National Forest (Figure 2). The areas encompass large portions of major watersheds of the Medicine Bow Mountains. The North Fork Study Area lies in the watersheds of the North Fork of the Little Laramie River and of Rock Creek. The Middle

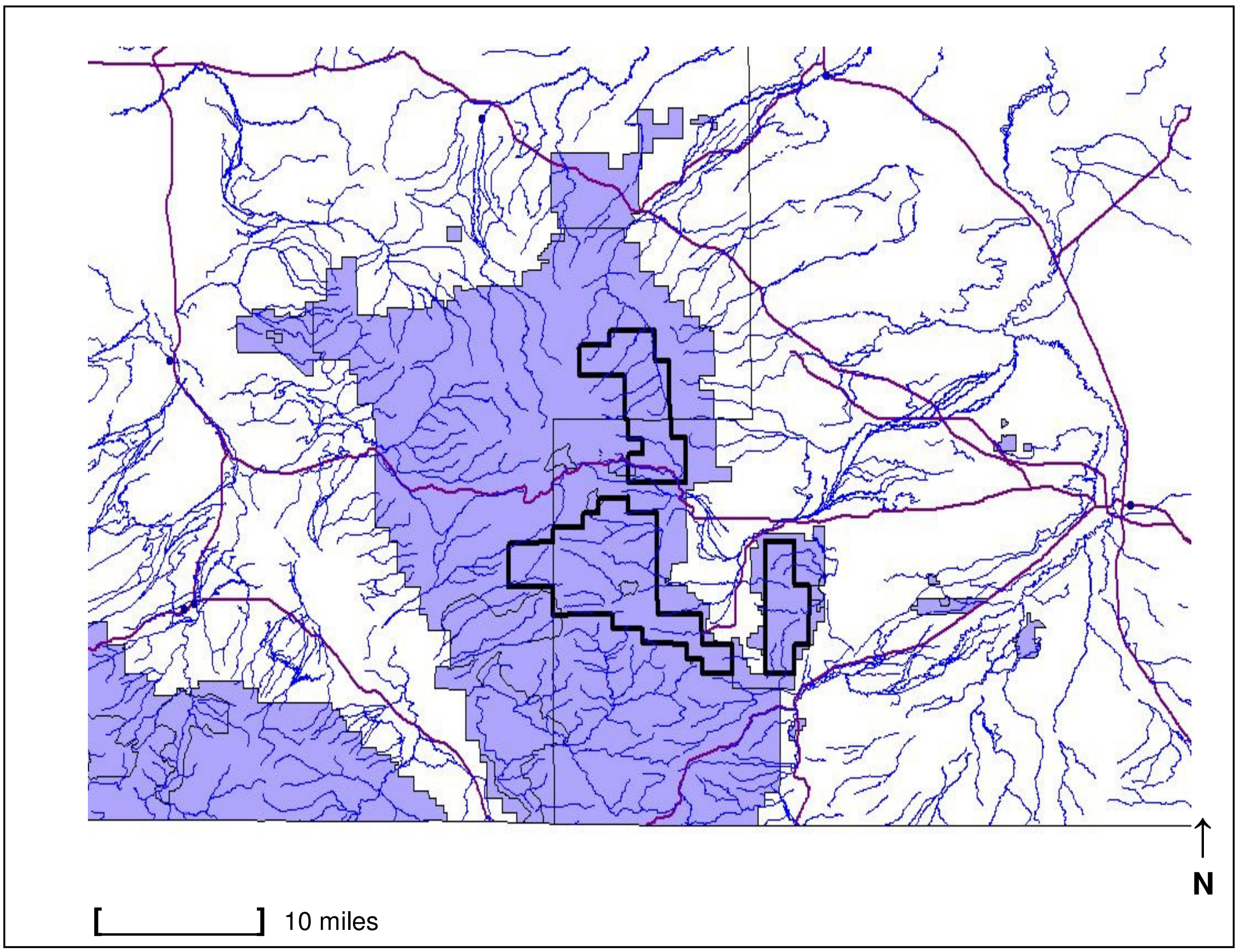
Fork Study Area lies in the watersheds of the Middle and South Forks of the Little Laramie River and of Douglas Creek. The Sheep Mountain Study Area lies in the watersheds of the South Fork of the Little Laramie River and the Laramie River.

The three study areas represent over 10% of Medicine Bow National Forest lands on the mountain range (Table 1 and Figure 2).

Table 1. Medicine Bow Mountains study areas, MBNF

Study area name	FS Ranger District	Size in acres (sq km)	Elevation in ft (m)
Middle Fork	Laramie, Brush Creek-Hayden	46,265 (187.2)	8,500-10,000 (2,590-3,050)
North Fork	Laramie, Brush Creek-Hayden	26,324 (106.5)	8,800-10,670 (2,680-3,250)
Sheep Mountain	Laramie	13,660 (55.3)	7,960-9,585 (2,425-2,920)
TOTAL	2 ranger districts	86,249 (349.0)	7,960-10,670 (2,425-3,250)

Figure 2. Medicine Bow Mountains study areas, MBNF
(Study areas are outlined in black, including North Fork, Middle Fork, and to the lower right, Sheep Mountain)



Geology

The Medicine Bow Mountains are a Laramide uplift with a core of various types of Precambrian rock. The North Fork Study Area is formed of Archean metamorphosed igneous rock (> 2.5 billion years), and has a discontinuous mantle of Pleistocene glacial deposits. The Middle Fork Study Area, farther south, is formed of Archean metamorphosed marine sediment (>1.8 billion years) and has no glacial deposits. The Sheep Mountain Study Area lies on a north-south trending ridge of Sherman Granite, an Archean crystalline rock (> 1.4 billion years). It is located east of the main body of the Medicine Bow Mountains and also has no glacial deposits.

Soils

Two histosol-containing soils units have been recognized in Medicine Bow National Forest soil classification and mapping (Table 2). These wetland soil units cover 3.5% of the three study areas. Prevailing upland soils in the surrounding landscape are Alfisols.

Table 2. Soils units of the Medicine Bow National Forest that include histosol components

Soil unit*	**Histosol components**	**Total extent (acres)**	**Total extent (%)**	**Map unit no.**
Argic Cryaquolls-Typic Cryohemist, euic association, 0 to 10% slope	Incl. 30% Typic Cryohemists, euic and 5% Histic cryaquoll	4,429	0.5	85
Typic Cryaquolls-Typic Cryohemists, euic association, 0 to 15% slope	Incl. 25% Typic Cryohemist, euic	27,970	3.0	92

*Soil units were originally described by Bauer *et al.* (1989) and were revised and mapped by Munn and Arneson (1999).

Climate

The montane elevations of the Medicine Bow Mountains receive 25-32 inches (63.5-81 cm) of mean annual precipitation and have a frost-free period of less than 20 days (Bauer et al. 1986). Evaporation often exceeds precipitation in the Rocky Mountains, so only peatlands that are supported by groundwater sources (exogenous water sources) are found. The years preceding our peatland study were dry ones, judging from the meteorological data collected at Centennial, Wyoming, at the eastern foot of the Medicine Bow Mountains at an elevation of 8,140 feet (2,480 m). Average annual precipitation at Centennial for the years 1971 - 2000 was 14.84 inches (37.7 cm), but total annual precipitation in the years 2000 and 2001 was only 8.56 inches and 7.52 inches (21.7 cm and 19.1 cm), respectively.

Terrestrial Flora and Vegetation

Across the Medicine Bow Mountains, *Pinus contorta* (lodgepole pine) dominates forests at lower elevations and on dry sites, comprising 66% of the forested land (Alexander et al. 1986). *Abies lasiocarpa* (subalpine fir) and *Picea engelmannii* (Engelmann spruce) dominate forests at higher elevations and on more mesic sites, covering 27% of the forests (Alexander et al. 1986, Dillon *et al.* 2005). Approximated 21% of the land area is nonforested. While all three study areas are montane, the North Fork study area has a mantle of glacial till in places with deeper soils and more extensive representation of *A. lasiocarpa* and *P. engelmannii* compared to the other study areas. The Middle Fork Study Area has generally shallow soils and the Sheep Mountain Study Area has both shallow soils and lower elevation. The latter two study areas are predominantly covered by *P. contorta*. A zone of *A. lasiocarpa* and *P. engelmannii* vegetation was present around the North Fork sampling sites, corresponding with the deeper soils that accompany glacial till. By contrast, there was, at best, only a broken line of *P. engelmannii* around Middle Fork sampling sites and a few trees of *P. engelmannii* bordering the Sheep Mountain sampling site, all of which were otherwise surrounded by *P. contorta*. Sporadic *Populus tremuloides* (quaking aspen) patches or bands border peatlands in all three areas. The transitions between peatland vegetation and upland vegetation are abrupt, often with sharp contrasts within one meter.

The terrestrial flora of the Medicine Bow Mountains is documented by Nelson (1984) and collections in the Rocky Mountain Herbarium. This information is the foundation for all work on the aquatic flora of the Medicine Bow Mountains as well.

<u>Wetland Flora and Vegetation</u>

A primary goal of this study is to document the fen flora and vegetation of the Medicine Bow Mountains. Three previous sets of studies conducted in three peatland sites provide a starting point and frame of reference for later peatland research.

Soils and their paleoecology have been documented in a forest-peatland continuum on glaciated terrain at a site referred to in this report as the Sand Lake Road Fen (Sanson 1972, Sanson and Reider 1974, Reider 1977, Reider 1983). In addition, peat cores have been collected from the site but the results not published (Mark Lyford personal communication to Walter Fertig). and this readily-accessible site is routinely used for various instructional purposes (e.g., Munn and Kinter 2002). Vegetation was characterized incidental to the soils studies, and dominants were said to include *Carex* spp. (sedges), *Juncus* spp. (rushes) and *Eleocharis* spp., (spikerushes), *Caltha leptosepala* (marsh marigold) and *Equisetum laevigatum* (smooth horsetail), with shrubs on hummocks including *Pentaphylloides floribunda* (shrubby cinquefoil), *Betula glandulosa* (resin birch), and *Salix* spp. (willows); (Reider 1983).

The hydrology of a montane peatland and the influence of climate on its paleoecology have been documented on unglaciated terrain at a site referred to in this report as the West Elk Creek Fen (called the "Elk Creek Bog" in Fleming 1966 and in Sturgis 1968a). Radiocarbon dates indicated that organic matter accumulation began 3,840 +/- 300 years, at maximum growth rates of ca 0.084 cm/year (Fleming 1966). The same site retains groundwater near the surface throughout the growing season, and slows the rate of water leaving the aquifer (Fleming 1966, Sturges 1967). Daily water movement rates directly below the surface may be only 0.0024 cm per day (Sturges 1968a), prolonging discharge and stream flows. Evapotranspiration losses are also major components of the water budget (Sturges 1968b).

The peat also retains radionucleotides, preventing or delaying their movement in the watershed (Sturges and Sundin 1968). The vegetation characterization conducted incidental to the hydrology study included documentation of the most common vascular and nonvascular plants at the site (Appendix A in Fleming 1966; and Sturgis 1968b). The site is dominated by *Eleocharis quinqueflora* (fewflower spikerush) and mosses. The Fleming thesis (1966) also included site photographs, and descriptions of microhabitat features (e.g., two pools and two springs) that are identifiable today.

Even earlier, alpine peatland patterning was documented at the base of Medicine Bow Peak (Billings and Mooney 1959). Researchers documented the cyclic process of peat hummock-frost scar-sorted polygon cycles formed under extreme environments of the alpine zone where there is no stable "climax" tundra. The dominant peatland species are both similar and dissimilar from the montane zone, reported to include *Carex aquatilis* (water sedge) and *Salix arctica* (arctic willow) in the peat-forming phase, and *Geum rossii* (Ross' avens) in the sod formation phase following-induced peat erosion.

METHODS

<u>Study Area Delimitation</u>

Montane habitat was made the priority for inventory because the pilot peatland study indicated that most rare species and species diversity were in this zone (Heidel and Laursen 2003). The elevation range of the defined study areas was within 2400-3300 m elevation. Montane habitat makes up most of the Medicine Bow National Forest, and most management activity takes place in the montane zone.

Our three study areas were originally delineated in 2003 around landscapes known to have peatland sites based on pilot surveys (Heidel and Laursen 2003), known to have extensive wetlands as indicated on aerial photos, and having documentation of peatland obligate species present as indicated by collection records at the Rocky Mountain Herbarium. Grazing allotment maps were overlain to help determine the shape and extent of the two largest study areas, the North Fork and Middle Fork Study Areas. The third and smallest study area spans all of Sheep Mountain, which is a discrete part of the Medicine Bow Mountains.

In 2003, peatland sites were identified in these three study areas by use of digitized soils data and photointerpretation (Heidel and Thurston 2003). Soils mapping was available as a GIS layer on file at the Medicine Bow National Forest. Alternate inventory methods were considered, as discussed in Heidel and Thurston (2003).

2003 Peatlands and 2004 Fen Study Sites in the Medicine Bow Mountains

Figure 3. Fen study sites in the North Fork Study Area

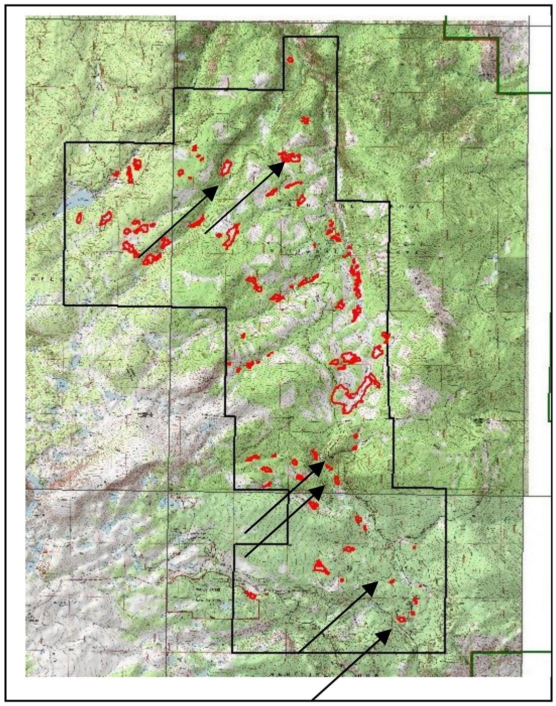


Figure 4. Fen study sites in the Middle Fork Study Area

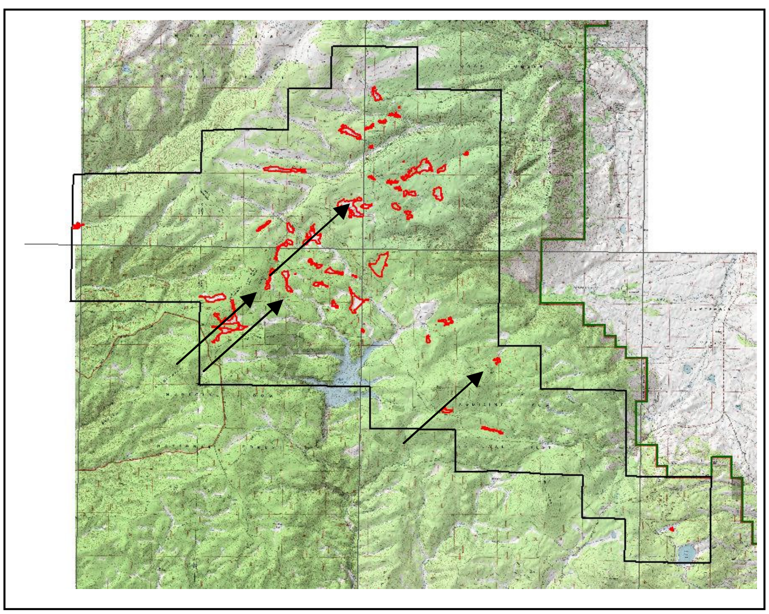


Figure 5. Fen study sites in the Sheep Mountain Study Area

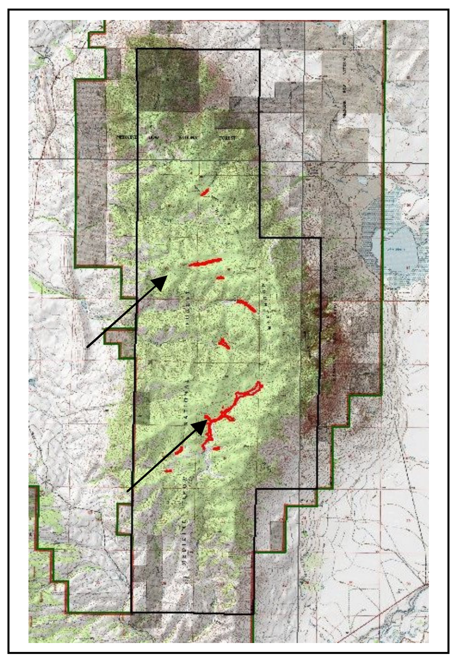


Table 3. Peatlands ground-truthed in the Medicine Bow Mountains (2003), MBNF

Study area	Study Area Extent in Acres (Hectares)	Peatland Extent in Acres (Hectares)	Peatland % of Landscape	Nos. of Peatlands
Middle Fork	46,265 (18,723)	302.3 (122.3)	1.69	50
North Fork	26,324 (10,653)	299.6 (121.2)	1.99	78
Sheep Mountain	13,660 (5,528)	41.2 (16.7)	0.43	10
TOTAL	86,249 (34,904)	643.1 (260.2)		138

Documenting Peatland Locations and Extent

The locations and extent of peatlands was documented in the 2003 extensive inventory: likely peatlands had been identified on aerial photographs, and a global positioning system receiver (Garmin eMap) was then used to record, in the field, the latitude and longitude (NAD 27) of points at the opposite ends of each peatland. The GPS receiver automatically incorporated on-site differential correction. The latitude and longitude coordinates were converted into a shapefile and projected into the UTM coordinate system (Zone 13 North, datum NAD83) and overlain onto digital orthophotos for mapping the peatland boundaries. These maps were used to select sites to be sampled in the intensive phase of the study.

It was common to find wetland basins that had 100% peat cover, but many basins had inclusions (shrub carr, open water, outcrops) particularly in the Middle Fork area. The mapping did not address inclusions, and coarse adjustments were made to produce conservative estimates of net peatland acreage in the study areas by putting each basin into a cover class estimate of peatland extent (+/- 25%) to produce a highly conservative estimate of peatland percentage. By this adjustment, only the North Fork Study Area had over 1% of net surface area covered by peat, though the Middle Fork Study Area also had over 1% of surface area covered by peat in unadjusted mapping and calculations (Table 3).

Sampling Site Selection

Twelve sampling sites were selected for intensive work (Table 4) from the 137 mapped peatlands in the Medicine Bow Mountains (Figures 3-5, and Appendix A in Heidel and Thurston 2004) by application of two required criteria and several additional screening criteria. A twelfth site was added in 2004 at Hecht Creek on Sheep Mountain. The sampling sites include the largest, most unaltered, and most unusual of peatlands in terms of their setting and vegetation structure, to show the range of features on fens in the study areas.

Required Criteria:

- Relatively unaltered conditions, as indicated by absence of grazing-induced hummocks that oxidize peat, or the inundation/desiccation associated with beaver dams
- Minimum size (large enough to accommodate 10 m x 25 m vegetation sampling plot in homogeneous vegetation)

Primary screening criteria:

- Large size of peatland site (net area, or length; indicating level of peat development)
- Vegetation structure (graminoid or shrub, w/o tree cover)
- Settings (upper drainage, mid drainage or basin; as an indication of hydrological conditions)

Secondary screening criteria:

- Unusual floristic characteristics (Wyoming plant species of concern; Heidel and Thurston 2003)
- Distribution of peatland sites within and between the three study areas
- Inclusion of sites that have previous peatland research (Elk Creek Fen West, Sand Lake Road Fen)
- Ease of access

Most of the high-priority sites identified in the extensive inventory (Table 5 in Heidel and Thurston 2004) are addressed in this study, and there is only one addition (Hecht Creek). The selection criteria drew from 26 information fields that had been recorded at each peatland during field investigation in that inventory (Heidel and Thurston 2004). The primary screening criteria and secondary screening criteria that qualified each sampling site for selection are shown in Table 4 (next page).

Vegetation: The two main vegetation structure classes are graminoid fens and shrub fens (with short shrubs less than 0.5 m tall). Sometimes both structures were well-represented in different parts of the same site. A few sites also had an open forest or sparse tree cover component, and a well-developed bryophyte layer. Sites with both graminoid and shrub structure types were favored for selection. In a final set of criteria, peatlands with unique dominants or co-dominants were favored in an effort to represent the spectrum of vegetation types.

Size: We sought to conduct the intensive study at the largest, unaltered peatlands. Only one large peatland site was rejected as having grazing-induced hummock formation such that vegetation and hydrology were altered. The intensive study sites ranged in size from 2.4-35.8 acres (1.0-14.5 ha). Small sites were not included unless they had unusual vegetation features that were well-developed and were not found at larger sites. Vegetation was presumed unaltered unless there was evidence of disturbance (hummock development that oxidized peat, stream channel down-cutting, pooling or desiccation adjoining roads, logging, etc.). There were usually only one or two well-developed vegetation types per site, but one site with the most open water habitat also had the highest number of different peatland vegetation types (North Fork of the Rock Creek Complex). Most glacial kettle peatland sites without an outlet connecting it to a watercourse were much smaller than 0.5 ha (Heidel and Thurston 2004). These sites did not have well-developed peatland profiles at this size, were only known from a small area of the North Fork Study Area, and did not have unique vegetation features compared to the peatlands in drainage settings.

Table 4. Twelve fen sampling sites selected on the Medicine Bow Mountains (2004)[1], MBNF

Study area	Sampling Site Name	Primary Screening Criteria	Secondary Screening Criteria
Middle Fork	Elk Creek Study Fens – west (original)*	Headwaters, typical graminoid dominants, large size	1 of the 2 intensively-studied sites in MBNF
Middle Fork	Elk Creek Study Fens – east (new)	Headwaters, typical graminoid dominants, large size; commonalities and contrasts with preceding	Proximity to preceding
Middle Fork	Fall Creek Fen	Headwaters, typical mosaic of shrub carr and graminoid dominants, very large size	Complicated by mosaic patterns, access time, beaver influence in part of area
Middle Fork	Strain Creek Fen	Mid drainage, shrub dominants (small size)	Small relict site within altered habitat; rare plants
North Fork	North Fork Little Laramie R. Headwater Fens – sphagnum site	Mid drainage, unique Sphagnum dominants, including an area of tree co-dominants	Rare plants
North Fork	North Fork Little Laramie R. Headwater Fens – upper site	Headwater, typical graminoid dominants, contrast with preceding	Proximity to preceding
North Fork	North Fork Little Laramie R. Fen test site (Also called "Paludella Fen" in bryology collection references)	Mid drainage, shrub dominants	Rare plants. Note: Sampling was completed at this test site in 2003
North Fork	North Fork Rock Creek Fen	Mid drainage, shrub and graminoid dominants	Relatively steep-sloping
North Fork	North Fork Rock Creek Fen complex	Headwaters and kettle, unique floating graminoid dominants and shrub dominants, large size; contrast with preceding	Diverse fen habitat requires multiple samples; rare plants
North Fork	Sand Lake Rd Fen*	Headwaters and kettle, shrub dominants	1 of the 2 intensively-studied sites in MBNF; rare plants
Sheep Mountain	Fence Creek Fen*	Headwaters, shrub and graminoid dominants, large size	Relatively time-consuming to access; rare plants
Sheep Mountain	Hecht Creek Fen	Headwaters, shrub and graminoid dominants, large size	Ground-truthed for the first time in 2004, time-consuming to access; not included in vegetation sampling; rare plants

Unaltered condition: The majority of peatland sites that were documented in extensive inventory (Heidel and Thurston 2004) were characterized as unaltered. A few have some degree of hydrological alteration. One sampling site (the North Fork Rock Creek Fen) is situated directly below a road, with a steep clearcut above the road, but does not have clear signs of disturbance (zones of pooling or desiccation below the road, changes in stream flow, plant communities of single-species composition in zones nearest disturbance). Another (the Strain Creek Fen) is located downstream from a railroad embankment built across a creek and its associated wetland habitat where the fen itself appears to be fed by lateral groundwater discharge (perpendicular to the valley) rather than by the creek. The lower end of one sampling site (Fence Creek Fen)is affected by an irrigation diversion and beaver, while the upper end is relatively unaltered. Parts of the Fall Creek sampling site are influenced by

[1] Those intensive inventory sites that were previously addressed in the pilot investigation in 2002 (Heidel and Laursen 2003) are indicated by an asterisk in the place names column.

beaver. Logging had taken place in the vicinity of many sampling sites, and may have accounted for the relatively dry *Carex limosa* (mud sedge) plot in the North Fork Rock Creek Complex. The study focused on those portions of the fens which appeared to have been least-altered and generally were farthest from areas where the habitat had been altered, as best as could be determined from aerial photographs and field observations.

Setting: Almost all peatlands encountered during the extensive inventory lie along drainage courses, though some in the North Fork Study Area are basins that appear to include glacial kettles with outlets. Many are located at the heads of the local catchments, but a few are in middle portions of drainages rather than at the heads. One of the twelve study sites (Elk Creek study fen) has been the subject of hydrological monitoring in the fen and across the surrounding catchment over the growing season (Fleming 1966). The setting, water source and water flow patterns are key in peatland classification (Figure 5).

A site was neither favored nor ruled out for being close to another sampling site, and three sampling sites (pair of Elk Creek sites, pair of sites at the headwaters of North Fork of the Little Laramie River, and pair of sites near the North Fork of Rock Creek) lie within a mile of one another.

There have been various systems developed for evaluating and prioritizing wetlands in general and peatlands in particular (e.g., Shelly and Chadde 1998, Bursik and Moseley 1995). One of the more elaborate is a system in Colorado in which montane fens are scored on tiered criteria regarding landscape context, biotic condition, abiotic conditions, and size (Roccio 2006).

<u>Overview of Field Sampling</u>

Field sampling included vegetation sampling; measurement of water and peat pH and temperature; peat coring to determine depth, and collection of peat samples for later classification. Survey for sensitive plant species, begun in the extensive inventory phase (Heidel and Thurston 2004), continued during the vegetation sampling. General floristic inventory also continued. The rare species, floristic and vegetation sampling was conducted at one site (North Fork Little Laramie River Fen test site) in August 2003, and at 10 additional sites between July 27 and September 3, 2004 (Table 5).

Vegetation was not sampled at the twelfth site, Hecht Creek Fen on Sheep Mountain. (This site was added to the set of sampling sites in 2004 because reconnaissance showed that it contains plant species of interest and provides a contrast to the other fen on Sheep Mountain.) Sampling for water and peat pH and temperature, and collection of peat samples, was completed at all 12 sites in 2004.

Table 5. Fen data collection at intensive study sites on the Medicine Bow Mountains, MBNF

Study area	Place Name(s)	Quad Name	Plot No.	Sampling Date	Added Moss Coll. Date (EKA)
Middle Fork	Elk Creek Study Fens – west (original)	Keystone	04MBP11	8-25-04	
Middle Fork	Elk Creek Study Fens – east (new)	Keystone	04MBP12	8-25-04	
Middle Fork	Fall Creek Fen	Centennial	04MBP10	8-24-04	
Middle Fork	Strain Creek Fen	Lake Owen	04MBP01	7-27-04	
North Fork	North Fork Little Laramie R. Headwater Fens – sphagnum site	Morgan	04MBP02 04MBP03	7-28-04,	5-23-04
North Fork	North Fork Little Laramie R. Headwater Fens – upper site	Morgan	04MBP15	9-2-04	
North Fork	North Fork Little Laramie R. Fen test site (Also called "Paludella Fen" in bryology collection references)	Centennial	03MBP01	8-4-03	5-23-04
North Fork	North Fork Rock Creek Fen	Morgan	04MBP04 04MBP05	7-29-04	
North Fork	North Fork Rock Creek Fen complex	Morgan	04MBP07 04MBP08 04MBP09	8-2-04	
North Fork	Sand Lake Rd Fen	Centennial	04MBP16	9-3-04	6-18-04
Sheep Mountain	Fence Creek Fen (Also called "Sheep Mt Fen" in bryology collection references)	Lake Owen	04MBP13 04MBP14	8-30-04	6-2-04
Sheep Mountain	Hecht Creek Fen	Lake Owen	None	8-31-04	

Sensitive Species Inventory

The location of each sensitive species encountered at the sampling sites was recorded with a GPS unit and mapped as points or polygons. The extent of the population was mapped, and the plants were counted or the population size estimated. Voucher specimens were collected for depositing at Rocky Mountain Herbarium and photographs were taken selectively of the species and its habitat.

Floristic Inventory

Lists of vascular plant species in peatlands were expanded with the data from the vegetation plots, and with collections and notes taken outside the plots in 2004 visits. The timing of vegetation sampling, in the latter half of the growing season, corresponded with the flowering or fruiting of most species. However, *Salix* spp. (willows) were not in fruit then, but these were collected during early summer site visits in 2004. In the dry years of 2002-2003, there were reduced levels of flowering and fruiting for many species, so the 2004 field season represented improved conditions for inventory.

References used for vascular plant identification in the field were Dorn (1996, 2001), Johnston (2001), and Hurd et al. (1998). Most peatland vascular species were collected at least once, but not from each site where they occur. Voucher specimens were collected for all species of concern at a site. Repeat collections were made in 2004 in cases when the prior voucher material was immature or otherwise unsuitable for verification. All vascular plant voucher specimens were deposited at the Rocky Mountain Herbarium.

Mosses had been collected at the sites of the 2002 pilot study by B. Heidel. Those specimens from one of the sites (the Sand Lake Road Fen) were identified by Judith Harpel. Mosses were collected again at this site, and at three additional sites, in greatly expanded inventory by Dr. Elena Kosovich-Anderson with Heidel in early 2004. Dr. Kosovich-Anderson produced an annotated checklist of collections at these four sites (using keys by Lawton [1977] and Vitt *et al.* [1988]), provided a reference set of moss specimens from these collections for use in later field sampling, and prepared a preliminary bryophyte checklist for the Forest.

The bryophyte list was augmented with the information from the vegetation sampling plots and from the areas near the vegetation plots. Specimens collected during this intensive study were identified by Robin Jones, following the taxonomic conventions of Weber and Wittmann (2000). The names of bryophytes used in this report are referenced to the Wyoming checklist by Eckel (1997) and the detailed Colorado checklist by Weber and Wittmann (2000).

<u>Vegetation and Environment Sampling</u>

At each study site, at least one sampling point was located subjectively in a stand of a plant community-type, that is, in an area that quick reconnaissance suggested was homogeneous in vascular plant species composition and vegetation structure. At each sampling point, data on plant canopy-cover and on ground-cover were collected in nested vegetation-sampling plots (modified-Whittaker plots, *sensu* Stohlgren *et al.* 1995). This plot design features a macroplot (in this case, measuring 10 m x 25 m) with 13 sub-plots inside it (Figure 6). The field crew placed the starting corner for the macroplot at the sampling point, and then used a GPS receiver to determine the UTM coordinates (NAD27, Zone 13 North) of the corner's actual location. UTM coordinates were recorded by hand. The azimuth of the macroplot's long axis was determined with a sighting compass.

Sampling began with the microplots: in each, the percentage of the microplot beneath the canopy of each plant species was estimated, and was recorded as the mid-point of the appropriate cover range (Table 6). The canopy cover of a plant was defined (following Daubenmire 1959) as the polygon described by a line drawn around the leaf tips of the undisturbed above-ground portion of the plant. After canopy cover of each vascular plant and bryophyte had been estimated in the 10 microplots, the two corner sub-plots were searched for species (vascular species and bryophyte species) that had not been recorded in the microplots, and their presence was noted. The center sub-plot was next searched for species that had not been recorded in the microplots or in the corner sub-plots, and finally, the area of the macroplot outside of the microplots and the corner and center sub-plots was searched for new species. With this procedure, canopy cover was recorded only for the plants in the microplots, and presence alone was recorded for species in the larger sub-plots and in the macroplot. Specimens of plants that could not be identified to species, or for which identification was uncertain, were collected and identified later.

Figure 6. Layout of the nested, modified-Whittaker sampling plots.

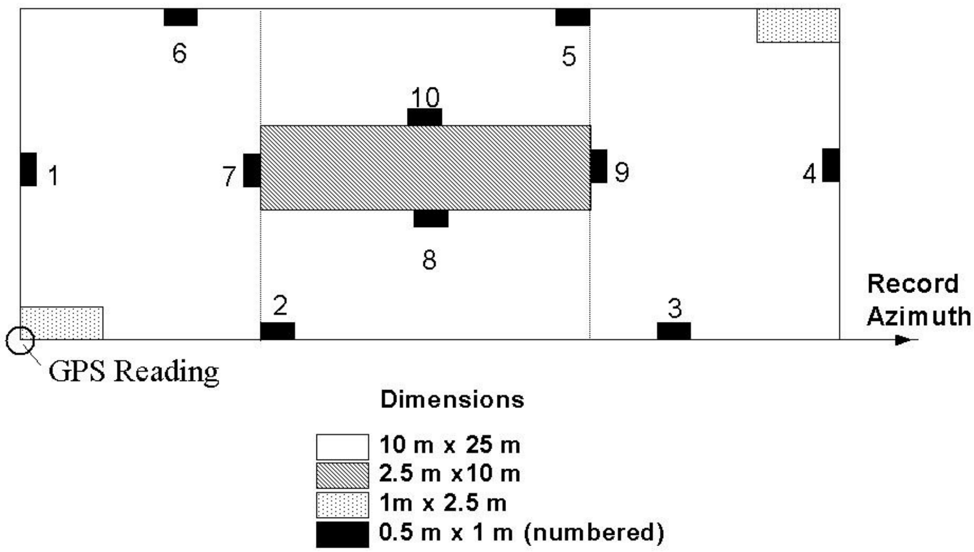


Table 6. Canopy cover ranges and mid-points used in vegetation sampling.

% cover	>1	1-5	5-15	15-25	25-35	35-45	45-55	55-65	65-75	75-85	85-95	95-99	>99
Mid-point (value recorded)	1	3	10	20	30	40	50	60	70	80	90	98	100

Most vascular plants were identified to species in the field. When this was impossible, the plants were give descriptive names on the field sampling forms. Efforts were made to identify bryophytes to genus in the field. Vouchers were collected for most bryophytes for later identification. Several of the vouchers were mixed collections of several species, and in most of these cases, the name of the most common species in the mixed voucher was assigned to the descriptive name on the data sheet. Two of the vouchers contained roughly equal amounts of different species. Sufficient material could not be found for vouchers of some mosses, and those were treated as unknown species.

The values for a species from the 10 microplots were averaged to give an estimate of the species' cover for the entire macroplot, and that estimate was converted to the mid-point of the appropriate cover range. For example, suppose that the 10 values for species A (each a mid-point value from a microplot) averaged 7.6, which average falls within the 5% - 15% cover range (Table 6). The value for species A for the macroplot then was given as 10, the mid-point of that range. Any species that was not found in a microplot but was found in one of the corner plots, or in the center plot, or in the macroplot, was assumed to have a canopy cover of less than 1% and was assigned a value of 1 for the macroplot. (If trees or large shrubs appeared to contribute more than 1% cover, then an estimate of their cover was recorded for the macroplot.) This method of estimating canopy cover allows one to say that the canopy cover for a given species in a macroplot falls within a range. It does not yield a precise, point estimate of canopy cover for the species.

The vegetation at the sampling point was briefly described and, at most plots, a photograph was taken of the macroplot. The percentage of the ground surface in the macroplot covered by each of 9 categories of material (Table 7) was estimated. Depth of the peat was estimated from one core sample in each macroplot, and the pH of the water in the core sampling hole was recorded. Water pH also was measured at other points in some sites. Steepness and aspect of the slope on which the macroplot lay were recorded.

Table 7. Categories of ground cover recorded in the sampling plots

Category	Description
Bare Soil	Particles < 2 mm across
Gravel	Particles 2 mm - 75 mm across
Cobble	Rocks 75 mm - 250 mm across
Boulder	Rocks > 250 mm across
Bedrock	Consolidated rock
Litter	Loose organic matter < 6 mm across
Wood	Loose organic matter > 6 mm across
Lichen	Fruticose lichens on soil surface
Moss*	Living mosses
Peat	Saturated organic matter with no other overlying plant material
Water	Standing water, with no other overlying plant material

* Canopy-cover of each moss species was recorded for the microplots, and those canopy-cover estimates, not this ground-cover estimate, were used in the data analysis.

The pH of the water and peat were also recorded in each macroplot. The pH was measured with a Hanna pH meter (Model HI 98129), calibrated daily with the closest pair of Oakton buffer solutions (pH solutions of 4.0, 7.0, or 10.0). At the only site sampled in 2003 (North Fork Laramie River test site), pH readings were taken at several spots and the values ranged from 6.89 to 7.77, depending on whether the reading were taken in standing surface water, in subsurface water lying in the hole where the peat core was taken, or in a subsurface locations among vegetation or mound and trough microtopography. In later sampling, for standardization, all pH readings were taken in surface water among mosses, unless there was no standing water. In these cases, the pH reading was taken in the subsurface water at the bottom of a peat core-hole (approximately 10 cm deep). The pH meter model adjusts for temperature, but temperature also was recorded for reference with each pH reading.

Peat depth was evaluated at the corner of each plot with a peat coring instrument. One sample of peat was taken from each vegetation plot for later textural classification. Each sample consisted of a plug approximately 10 cm long, taken with a steel trowel from the surface 15 cm of the peat layer within the most common vegetation in the macroplot. Samples were classified by the Soils Testing Laboratory at University of Wyoming. Electrical conductivity of the water retained in the peat core was measured in the Soils Testing Laboratory at University of Wyoming, for half of the samples.

Vegetation Data Summary and Analysis

The descriptive information from each sampling plot was summarized into a general characterization of the vegetation in and around the plot. Quantitative, canopy-cover data were used to examine patterns of similarity between plots, with an eye to identifying groups of similar plots that might represent plant community-types. Similarity between plots was examined with ordination, an analysis approach that arranges entities (in this case, sample plots) along axes of similarity. The results of an ordination analysis are displayed on graphs that place similar plots close together and dissimilar plots far apart. Ordination is particularly useful in revealing gradients of similarity between plots, in contrast to classification, which groups plots together but is less effective at showing the patterns of similarity.

Ordination was performed with nonmetric multidimensional scaling (NMS), a technique that is particularly well-suited for analyzing vegetation data, which usually are not normally distributed and contain a wide range in values (McCune and Grace 2002). NMS works by first calculating a matrix of similarity between every pair of plots, then constructing axes and arranging the plots along the axes in a manner that preserves, as much as possible, the pattern of similarity among all of the plots contained in the original matrix. NMS analysis was done with the PC-ORD software package (MjM Software Design, Gleneden Beach OR, USA), version 4.3, using the autopilot mode with medium thoroughness settings (McCune and Mefford 1999). The medium-thoroughness values for the NMS parameters are shown in Table 8. Similarity between plots was calculated with Sorensen's coefficient.

Before analysis, the original cover class values for each species were relativized by plot totals, by dividing the value for a species in a plot into the total canopy-cover for the plot, using the equation:

$$b_{ij} = x_{ij} / \Sigma_n (x_{ij})$$

where

b_{ij} = the relativized value for species *j* in plot *i*,
x_{ij} = the original cover-class value for species *j* in plot *i*, and
n = the number of species in plot *i*.

This relativization removes the effect on the analysis of differences between plots in the total amounts of vegetation present, so that the ordination looks for similarities and differences in the relative amounts of each species. Even though the data set contains many species that occurred in only one or two plots, all species were used in the analysis. Exploratory analyses on smaller data sets, from which rare species had been excluded, produced essentially the same results as did the full data set.

NMS ordination produced a three-dimensional ordination of the plot data. Various types of information about the vegetation, such as total cover and relative cover of different plant-growth forms, were displayed on the two-dimensional ordination graphs to show patterns of vegetation features.

Table 8. NMS ordination analysis - medium thoroughness settings for input parameters

Parameter	Value
Similarity measure	Sorensen
Starting configuration	Random, using time-of-day
Starting number of dimensions (axes)	4
Reduction in dimensionality at each cycle of each run	1
Maximum number of iterations in each run	200
Step length between each iteration	0.2
Instability criterion (standard deviation in stress over preceding 10 iterations)	0.0001
Number of runs with real data	15
Number of runs with randomized data for Monte Carlo test	30

RESULTS

Fen Sensitive Species

Twelve Wyoming vascular plant species of concern (Fertig and Heidel 2002, Keinath et al. 2003) have been documented in peatlands of the Medicine Bow Mountains (Table 9). Five of the twelve were designated as sensitive species in the Rocky Mountain Region of the Forest Service (USDA Forest Service 2003; Table 9), except that one of the five designated species, *Carex leptalea*, was dropped from the sensitive list in 2004, the most recent update.

Prior to the start of this work, only three Wyoming plant species of concern were known from the Medicine Bow Mountains associated with peatland. After the pilot investigation in 2002, three more species were documented. Extensive inventory in 2003 added another four species. Finally, intensive sampling in 2004 added two more species to the list, for a total of twelve species. However, two of the original twelve Wyoming plant species of concern, *Carex paupercula* (boreal bog sedge) and *Epilobium oregonense* (Oregon willowherb), have proven to be widespread on common fen types of the Medicine Bow Mountains, their state ranks have been changed and they have since been removed from the state tracking list (Keinath et al. 2003), though they are habitat specialists and wetland obligates.

Two other peatland species of concern were mentioned in Heidel and Laursen (2003) or Heidel and Thurston (2004) reports that are not in the Medicine Bow Mountains, though they are in the Laramie Range or the Sierra Madre Range (*Salix serissima*; autumn willow, and *Potamogeton epihydrous;* ribbonleaf pondweed, respectively.)

The ten current Forest Service sensitive and other Wyoming species of concern that occupy peatlands are represented by seventeen occurrences in the study areas and in the entire Medicine Bow Mountains. Complete occurrence records are provided in Appendix A. The majority of the occurrences (11 of 17) are located in the Sheep Mountain Study Area (Fence Creek and Hecht Creek Fens). The three other sites where Wyoming species of concern were found represent the extremes in rich and poor fens, including one other relatively high concentration of rare species in the North Fork of Rock Creek fen complex. These three sites are also large compared to the study sites with only one occurrence of a sensitive species.

Table 9. Fen species of concern, Medicine Bow Mountains, MBNF

Scientific name	Common name	Forest Service status / G&S ranks	Study area	First documentation in the MedBow Range	No. of new (and prior) study area records in MedBow Range
Carex diandra	lesser panicled sedge	Sensitive G5 S1S2	North Fork	2003	1 (1)
Carex leptalea	bristly-stalk sedge	Sensitive ; dropped in 2004 G5 S2	Sheep Mountain	2002	2 (0)
Carex limosa	mud sedge	G5 S2	North Fork (also Huston Park)	2003	1 (0)
Carex paupercula	bog sedge	G5 S1->S2	North Fork, Middle Fork	Pre-2002	32 (3)
Epilobium oregonense	Oregon willow-herb	G5 S1->S2S3	North Fork, Middle Fork (also Huston Park)	Pre-2002	53 (2)
Eriophorum gracile	slender cottongrass	Sensitive/ G5 S1->S2	Sheep Mountain	2002	2 (0)
Lomatogonium rotatum	marsh felwort	G5 S2	Sheep Mountain	2004	2 (0)
Muhlenbergia glomerata	marsh muhly	G5 S1->S2	Sheep Mountain	2004	1 (0)
Salix candida	hoary willow	Sensitive/ G5 S2	North Fork, Sheep Mountain	Pre-2002	2 (2)
Sparganium natans (Sparganium minimum)	small bur-reed	G5 S1	North Fork	2003	1 (0)
Trichophorum pumilum (Scirpus pumilus)	pygmy bulrush	G3Q S1	Sheep Mountain	2002	3 (0)
Utricularia minor	lesser bladderwort	Sensitive/ G5 S2	North Fork	2003	1 (0)

There is no formal Wyoming species of concern list for nonvascular plants, but the data collected in this study can serve as the foundation for such a list. It is premature to report on bryophyte results and rarity at this time because the results draw heavily from the work of others, and identified specimens do not have labels prepared yet for sumittal. It is noteworthy that moss species recognized as species of concern in Colorado and Montana were documented by Kosovich-Anderson (2005, 2006 a,b,c, and d) and in vegetation sampling plots.

Fen Flora

The vascular flora of Medicine Bow National Forest peatland sites includes at least 162 vascular plant species. The species that are most likely to be encountered are reflected in part by the number of vegetation sampling plots in which fen species appeared (Table 10). It represents concerted collecting but does not represent all ecotones and secondary habitats (e.g., streams, pond margins, thicket gradients). A complete list of the vascular fen flora, showing sampling site and collector is presented in AppendiX B. The revised vascular flora resembles the previously-reported tally of 160 species (Heidel and Laursen 2003), but is a significant editing to include only those that are in the Medicine Bow Mountains (excluding Laramie Range and Sierra Madre) and excluding those that are in meadow or forest perimeters. Appendix B also shows which vascular species are documented by vouchers deposited at the Rocky Mountain Herbarium. It might be compared with similar floristic lists for the northern Rockies (e.g., Bursik 1990, Chadde *et al*. 1998).

The floristic data has been reviewed in combination with published literature (Chadde et al. 1998), collection label data and data from Shoshone National Forest Service studies to produce a draft list of 63 rare obligate or facultative fen species of Wyoming (Heidel 2006). The expanded vegetation description in this study helped to refine descriptions of their habitat requirements.

The nonvascular flora of Medicine Bow National Forest fens (Appendix C) includes at least 73 species. Mosses collected in the course of vegetation sampling and species inventory at the 12 sampling sites represent at least 61 species. The total number represents over 20% of the statewide moss flora as known to date (Eckel 1996). These results are preliminary, and the collection of mosses in Medicine Bow National Forest peatland sites have yet to have labels prepared for depositing at Rocky Mountain Herbarium

<u>Peatland Types</u>

All of the peatlands recently documented in the Medicine Bow Mountains are fens (Heidel and Laursen 2002, Heidel and Thurston 2004, and this study)., as indicated by their locations along drainage courses, circumneutral pH values (Table 15), and dominant vascular plants (described below). All of the study site fens in the Medicine Bow Mountains have at least small outlets and so qualify as flow-through fens (also referred to as soligeneous fens or slope fens; Chadde *et al.* [1998], Roccio [2006]).. Two sites in the North Fork Study Area (Sand Creek Road and North Fork Rock Creek Complex), lie in glacial basins and might be classified as topogeneous fens, though they have small outlets.

Fen vegetation patterns are strongly related to three principal gradients (discussed in Cooper and Andrus 1994): the poor-rich gradient (Sjörs 1950), the gradient from peatland interior to margin, and the variations due to microtopography. These fen types also have characteristic suites of mosses (e.g., Slack et al. 1980) and of vascular plants, particularly in the *Carex* genus (Jeglum 1971, Gignac et al. 2004). The data at hand indicate that Medicine Bow Mountain fens include poor fens (low pH, *Sphagnum* spp. cover nearly continuous, vascular plants usually scattered), rich fens (pH slightly acid to alkaline, sedges and spikerushes or shrubs dominant, true mosses common but *Sphaghum* spp. rare or absent), and transitional fens (intermediate conditions). The extensive and intensive peatland survey data indicate that are none of the peatlands studied are true bogs (nutrient-poor peatlands with low pH, supported by precipitation and largely independent of soil water or ground water). *Sphagnum* spp. hummocks at the North Fork Little Laramie River Headwaters Fen – Sphagnum site, instead, represent a poor fen, and at least the floating mat part of the North

Fork Rock Creek Complex has poor fen characteristics. Our vegetation sampling protocol did not address within-site gradients, but observations indicate that peatland interior-exterior gradients are without discrete zonation. Our vegetation sampling did not address microtopography, but we did not find hydrology-driven patterned peatland as represented in Figure 5 (though it has been provisionally identified at higher elevations around Libby Flats; Heidel and Laursen 2003).

<u>Plant Community Composition</u>

In general, the fen plant communities sampled with the vegetation macroplots are moss- and graminoid-dominated communities, sometimes with a significant short shrub component of greater than 20% canopy cover (Figure 7). Tree cover approached 10% at only one plot (04MBP03) in part of the North Fork Little Laramie River Headwater Fens - Sphagnum site. Forb cover is usually highest where there are seep influences or standing water that favors generalist plants like *Caltha leptosepala* (marsh marigold).

One-hundred sixty-one plant species were recorded in the 17 sample plots, consisting of 105 vascular plants, 53 mosses, and three liverworts (Table 10, Appendix D). Outside of the plots, an additional 57 vascular species and 21 bryophyte species were identified, for a total of 162 vascular plants and 74 bryophytes. A complete listing of those species sampled and collected or observed at each of the sampling sites is presented in Appendix B. All of the vascular plants in the sampling plots were identified to species, but 23 mosses and one liverwort were not identified to species or vouchered. For the data analysis, these species were assumed to be different in each plot. Some of the undetermined mosses listed for different sample plots, though, may be the same as moss species already identified, and knowing their identities could well shorten the species list from the plots.

The contributions of different life-forms to species diversity strongly favored herbaceous species. Forb species were the most numerous in nine plots and were equal in number to graminoids in a 10^{th} plot (Figure 8). Graminoids species were the next-most diverse life-form, contributing the most species in six plots and equal numbers with forbs in a 7^{th} plot and with bryophytes in an 8^{th}. Bryophytes (nearly all mosses) were secondary to forbs and graminoids in most plots. Shrubs generally were present in lower numbers than bryophytes, and sub-shrubs and trees were incidental in numbers of species.

The data from the sample plots exhibit the common pattern of species occurrence: most species were found in just a few plots, and only a handful of species were widespread (Figure 9). One-hundred forty-five of the plant species (90%) were found in less than half of the plots, and 63 of the species (39%) were documented in only one plot. Just one plant, *Eleocharis quinqueflora*, was documented in all 17 sample plots (Figure 9, Table 13). Four additional vascular plants were found in at least 75% of the plots (that is, 13 plots): *Carex aquatilis*, *Carex utriculata* (beaked sedge), *Viola macloskeyi* (small white violet), and *Pedicularis groenlandica* (elephanthead lousewort). The most widespread moss was *Aulacomnium palustre* (aulacomnium moss), recorded from ten plots. One additional moss, *Drepanocladus aduncus* (drepanocladus moss), was found in half of the sample plots; the remaining 54 bryophytes were found in four plots or less. Knowing the identity of the large number of minor mosses no doubt would show that the mosses are at least somewhat more widespread than they appear, but how much more widespread is unknown.

Figure 7. Cover of different life-forms in each sample plot.

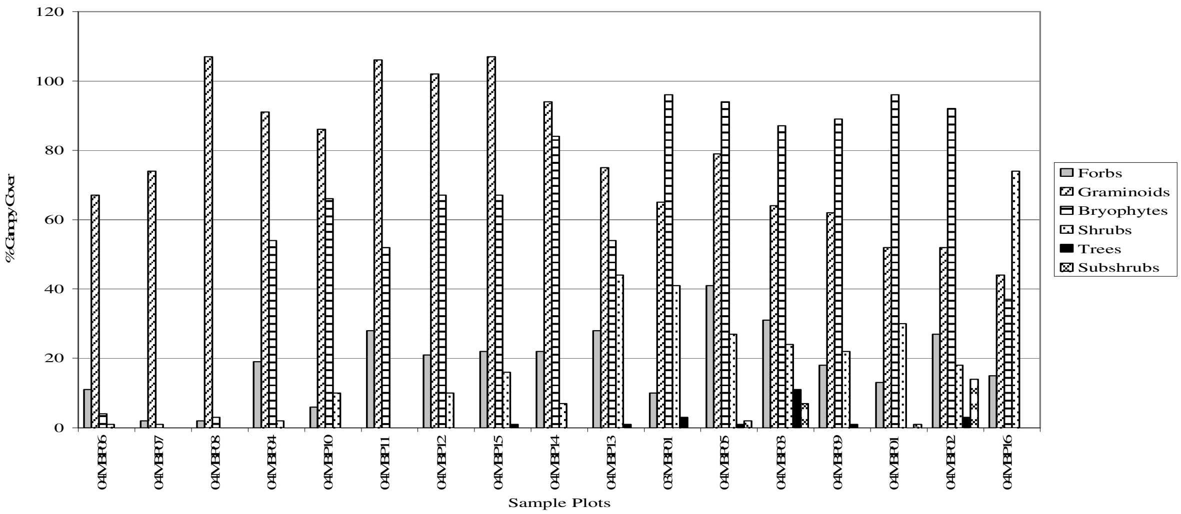
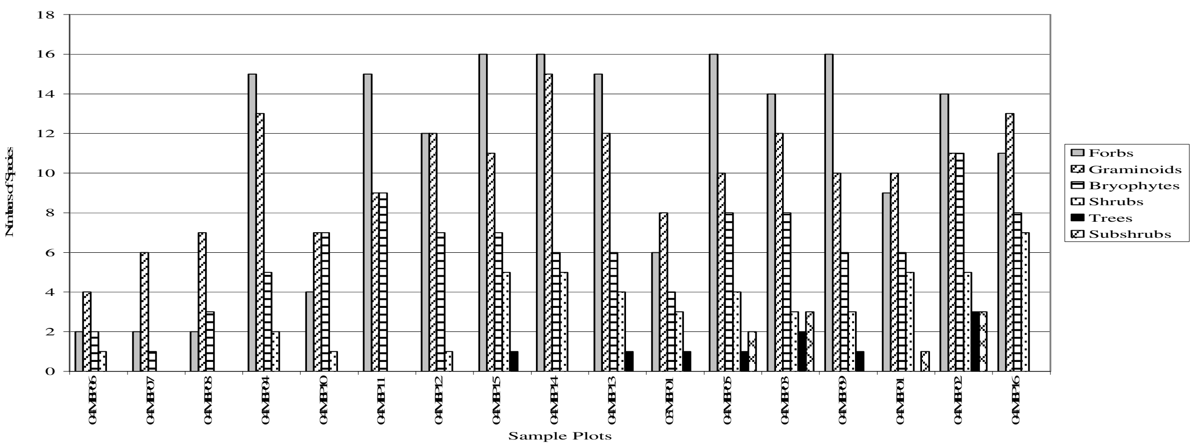
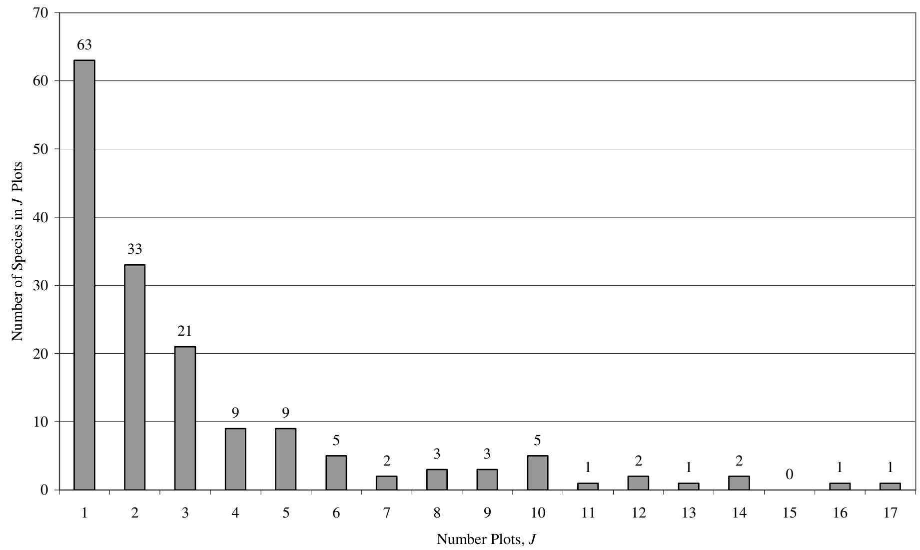


Figure 8. Numbers of species of different life-forms in each fen sample plot, MBNF



The contributions of different life-forms to canopy-cover showed a different pattern from their contribution to numbers of species (Figures 7 and 8). Graminoids contributed the most cover to ten plots, usually by a wide margin over other life-forms. Bryophytes were the largest single component of the plant cover in six plots, and they were substantially larger contributors than vascular plants in several of those plots. The three plots with moss cover less than 10% corresponded with extreme peat conditions, including a floating peat mat (04MBP07 at North Fork Rock Creek Complex) where it is possible that submerged brown moss was mistaken for dead moss or the floating mat condition in this setting precludes higher moss cover. Forbs, despite their large numbers, contributed relatively little cover to any plot. The few species of shrubs contributed more cover than did forbs in five plots, and shrubs were the major source of plant cover in one plot. Sub-shrubs and trees contributed very little cover.

Figure 9. Frequency of occurrence of 161 plant species in17 fen sample plots, MBNF



Plant Community-type Classification

Non-metric multidimensional scaling produced a three-dimensional ordination that accounted for 77.6% of the variation among plots (Table 11) and shows five groups of plots that are proposed here as representing five fen plant community-types. These groups can be seen on the graphs that show the relationships between sample plots on the three ordination axes (Figures 10-12). Plant canopy-cover in the plots of each group is shown in Appendix B.

One group consists of plots dominated by *Carex limosa* (04MBP06 and 04MBP07), which are consistently located close together and are distinct from the other plots. Both plots had relatively little plant canopy cover and only a trace of moss cover, and were strongly dominated by graminoids (Figure 7). Plot 04MBP06 was on a floating vegetation mat (Appendix A); *C. limosa* strongly dominated the vegetation and *Menyanthes trifoliata* (buckbean) was the only species of secondary importance (Table 13). Plot 04MBP07 was on anchored peat; *C. limosa* dominated there and *Carex utriculata* was sub-dominant.

One additional plot strongly dominated by graminoids and with only a trace of bryophyte cover (Figure 7; plot 04MBP08), also was separated from other plots by the ordination (Figure 11). *Carex vesicaria* (blister sedge) was the major species (Table 12), and *Carex aquatilis* was the only other graminoid species present in more than trace amounts (. This plot was on solid peat that apparently had been flooded earlier in the season (as suggested by the lack of moss on the surface) but had no water on the surface in the plot at the time of sampling, and it contained relatively few plant species (Figure 8) and relatively little total canopy cover (Figure 7). Both *Carex limosa* and *C. vesicaria* community-types had low pH values and low species diversity characteristic of poor fens.

Table 10. Vascular plant and bryophyte species in the fen vegetation plots, Medicine Bow Mountains, MBNF – sorted alphabetically
(One-hundred five vascular plants and 56 bryophytes documented in the 17 plots, in alphabetical order. Vascular species are listed first, followed by bryophytes. Of the bryophytes, 53 are mosses and three are liverworts.)

Species	NRCS Code	Number of Plots (n=17)
VASCULAR PLANTS		
Abies lasiocarpa, subalpine fir	abla	2
Agrostis exarata, spike bentgrass	agex	1
Agrostis scabra, rough bentgrass	agsc5	10
Agrostis thurberiana, Thurber's bentgrass	agth2	5
Antennaria corymbosa, flattop pussytoes	anco	1
Antennaria pulcherrima, showy pussytoes	anpu	4
Arctostaphylos uva-ursi, kinnikinnick	aruv	1
Arnica mollis, hairy arnica	armo4	1
Betula glandulosa, resin birch (bog birch)	begl	8
Bromus ciliatus, fringed brome	brci2	1
Calamagrostis canadensis, bluejoint	caca4	6
Calamagrostis inexpansa, northern reedgrass	cain	7
Caltha leptosepala, marsh marigold	cale4	10
Carex aquatilis, water sedge	caaq	16
Carex aurea, golden sedge	caau3	6
Carex canescens, silvery sedge	caca11	7
Carex capillaris, hairlike sedge	caca12	3
Carex disperma, softleaf sedge	cadi6	1
Carex gynocrates, northern bog sedge	cagy2	1
Carex interior, inland sedge	cain11	3
Carex jonesii, Jones' sedge	cajo	5
Carex leptalea, bristlystalked sedge	cale10	1
Carex limosa, mud sedge	cali7	2
Carex norvegica var. stevenii, Steven's sedge	canos2	1
Carex paupercula, boreal bog sedge	capa22	9
Carex simulata, analogue sedge	casi2	5
Carex utriculata, Northwest Territory sedge	caut	14
Carex vesicaria, blister sedge	cave6	2
Castilleja sulphurea, sulphur Indian paintbrush	casu12	1
Chamerion angustifolium, fireweed	chana2	2
Cicuta douglasii, western water hemlock	cido	1
Conioselinum scopulorum, Rocky Mountain hemlockparsley	cosc2	12
Danthonia intermedia, timber oatgrass	dain	1
Deschampsia caespitosa, tufted hairgrass	deca18	9
Dodecatheon pulchellum, darkthroat shootingstar	dopu	1
Eleocharis quinqueflora, fewflower spikerush	elqu2	17
Elymus trachycaulus, slender wheatgrass	eltr7	1
Epilobium ciliatum, hairy willowherb	epci	3

Table 10 (continued).

Species	NRCS Code	Number of Plots (n=17)
Epilobium oregonense, slimstem willowweed	epor2	10
Equisetum arvense, field horsetail	eqar	5
Erigeron peregrinus, subalpine fleabane	erpe3	3
Eriophorum angustifolium, tall cottongrass	eran6	3
Eriophorum gracile, slender cottongrass	ergr8	1
Fragaria vesca, woodland strawberry	frve	4
Fragaria virginiana, Virginia strawberry	frvi	2
Galium trifidum, threepetal bedstraw	gatr2	5
Gaultheria humifusa, alpine spicywintergreen	gahu	3
Gentiana aquatica, moss genian	geaq	1
Gentianopsis detonsa var. elegans, Rocky Mountain gentian	gedee2	11
Geranium richardsonii, Richardson's geranium	geri	1
Juncus balticus, Baltic rush	juba	1
Juncus ensifolius, swordleaf rush	juen	2
Juniperus communis, common juniper	juco6	2
Kalmia microphylla, alpine laurel	kami	2
Listera cordata, heartleaf twayblade	lico6	1
Lomatogonium rotatum, marsh felwort	loro	1
Lonicera involucrata, twinberry honeysuckle	loin5	3
Luzula parviflora, smallflowered woodrush	lupa4	6
Menyanthes trifoliata, buckbean	metr3	2
Mitella pentandra, fivestamen miterwort	mipe	1
Muhlenbergia filiformis, pullup muhly	mufi2	2
Orthilia secunda, sidebells wintergreen	orse	1
Oxypolis fendleri, Fendler's cowbane	oxfe	1
Parnassia palustris, northern grass of Parnassus	papa8	1
Pedicularis groenlandica, elephanthead lousewort	pegr2	13
Pentaphylloides floribunda, shrubby cinquefoil	pefl15	4
Phleum alpinum, alpine timothy	phal2	9
Picea engelmannii seedling, Engelmann spruce seedling	pien1	2
Picea engelmannii, Engelmann spruce	pien	5
Pinus contorta seedling, lodgepole pine seedling	pico1	2
Pinus contorta, lodgepole pine	pico	3
Platanthera dilatata, boreal bog orchid	pldi3	3
Platanthera huronensis, Huron green orchid	plhu2	3
Poa cusickii ssp. epilis, Cusick`s bluegrass	pocue2	1
Poa reflexa, nodding bluegrass	pore	2
Polygonum viviparum, alpine bistort	povi3	6
Potentilla diversifolia, varileaf cinquefoil	podi2	3
Primula incana, silvery primrose	prin	1
Pyrola asarifolia, liverleaf wintergreen	pyas	6
Salix bebbiana, Bebb willow	sabe2	1
Salix candida, sageleaf willow	saca4	3
Salix eriocephala var. watsonii, yellow willow	saerw	5
Salix eriocephala, Missouri River willow	saer	2

Table 10 (continued).

Species	NRCS Code	Number of Plots (n=17)
Salix planifolia, plane-leaf willow	sapl2	12
Salix wolfii, Wolf's willow	sawo	5
Saxifraga odontoloma, brook saxifrage	saod2	2
Sedum rhodanthum, redpod stonecrop	serh	10
Senecio crassulus, thickleaf groundsel	secr	4
Senecio streptanthifolius, cleftleaf groundsel	sest3	1
Senecio triangularis, arrowleaf groundsel	setr	4
Spiranthes romanzoffiana, hooded ladiestresses	spro	4
Stellaria longifolia, longleaf starwort	stlo	2
Swertia perennis, star gentian	swpe	8
Symphyotrichum boreale, northern bog aster	sybo2	3
Symphyotrichum laeve, smooth blue aster	syla3	2
Taraxacum officinale, common dandelion	taof	2
Thalictrum alpinum, alpine meadowrue	thal	1
Trichophorum pumilum, Roland's bulrush	trpu18	1
Triglochin palustre, marsh arrowgrass	trpa6	3
Trisetum wolfii, Wolf's trisetum	trwo3	5
Utricularia minor, lesser bladderwort	utmi	2
Vaccinium scoparium, grouse whortleberry	vasc	3
Valeriana edulis, edible valerian	vaed	2
Veronica wormskjoldii, American alpine speedwell	vewo2	3
Viola macloskeyi, small white violet	vima2	14
BRYOPHYTES		
Aulacomnium palustre, aulacomnium moss	aupa70	10
Brachythecium turgidum, turgid brachythecium moss	brtu70	1
Bryum argenteum, silvergreen bryum moss	brar71	1
Bryum caespiticium, dry calcareous bryum moss	brca71	2
Bryum capillare, bryum moss	brca25	1
Bryum pseudotriquetrum, common green bryum moss	brps70	2
Calliergon giganteum, giant calliergon moss	cagi70	4
Calliergon stramineum, calliergon moss	cast70	2
Calliergonella, calliergonella moss	calli11	2
Campylium hispidum, hispid campylium moss	cahi70	1
Campylium stellatum, star campylium moss	cast51	4
Cephaloziella hampeana, liverwort	ceha4	2
Climacium dendroides, tree climacium moss	clde70	2
Drepanocladus aduncus, drepanocladus moss	drad2	8
Hamatocaulis vernicosus, hamatocaulis moss	have70	2
Helodium blandowii, Blandow's helodium moss	hebl2	3
Liverwort 4mbp11	bryombp1	1
Lophozia incisa, liverwort	loin11	1
Marchantia polymorpha, liverwort	mapo16	1
Meesia uliginosa, meesia moss	meul70	1

Table 10 (continued).

Species	NRCS Code	Number of Plots (n=17)
Paludella squarrosa, angled paludella moss	pasq70	3
Philonotis americana, american philonotis moss	pham13	1
Plagiomnium drummondii, drummond's plagiomnium moss	pldr	4
Plagiomnium venustum, plagiomnium moss	plve	2
Polytrichum longisetum, polytrichum moss	polo18	1
Polytrichum strictum, polytrichum moss	post70	3
Pseudocalliergon angustifolium, pseudocalliergon moss	pseud38	2
Sarmenthypnum sarmentosum, sarmenthypnum moss	sasa19	1
Sphagnum fuscum, sphagnum	spfu70	2
Sphagnum russowii, sphagnum	spru6	2
Sphagnum warnstorfii, sphagnum	spwa70	3
Tomentophytum nitens, moss	toni1	2
Warnstorfia fluitans, warnstorfia moss	wafl2	2

A group of five plots -- 04MBP04, 04MBP10, 04MBP11, 04MBP12, and 04MBP15 -- remained together on all three ordination axes (Figures 10 - 12). Like the *Carex limosa* and *Carex vesicaria* plots, these five plots were dominated by graminoids, but they had greater bryophyte cover (Figure 7) and, consequently, greater total canopy cover. They also had more forb species than did the *C. limosa* and *C. vesicaria* plots (Figure 8). Shrubs were minor constituents of the vegetation, both in number of species and in canopy cover. In every plot, *Eleocharis quinqueflora* was, by far, the dominant vascular plant, and at least one moss species contributed as much cover as did the second most common vascular plant (Table 13). The plots did not share dominant mosses. Water was present on the peat surface in all five plots (Table 13). *Carex aquatilis* was usually present in significant amounts.

The largest group of plots, consisting of 03MBP01, 04MBP01, 04MBP02, 04MBP03, 04MBP05, 04MBP09, 04MBP13, and 04MBP14, (Figures 11 and 12) also had substantial amounts of bryophyte cover, and bryophytes contributed more cover than did other life-forms in six of these eight plots (Figure 7). In all eight plots, *Carex aquatilis* was the dominant or co-dominant vascular plant (Table 12). *Eleocharis quinqueflora* was present in all eight plots and contributed substantial cover to three. Otherwise, the vegetation was heterogeneous among plots. First, although bryophytes contributed much of the canopy cover, only two plots shared the same dominant moss species (Table 12). Second, in seven of the eight plots, shrubs contributed at least one-third of the vascular plant canopy cover. (The exception is plot 04MBP14, which is close to the *E. quinqueflora*-dominated plots in the ordination graphs (Figures 10-12) and in which *E. quinqueflora* and *Carex simulata* (analogue sedge) shared dominance with *C. aquatilis*.) In five of the plots, *Salix planifolia* (plane-leaf sedge) was the dominant, or a co-dominant, shrub; and in two plots, *Betula glandulosa* was the major shrub and *S. planifolia* was present in a trace amount or was absent. All of these plots were in meadow-like fens, although water was present on the peat surface in the microplots in only three of them (Table 12).

The final plot, 04MBP16, was separated from the other plots on the ordination axes (Figures 10-12), and was the only plot in which shrubs contributed most of the canopy cover (Figure 7). Graminoid and bryophyte cover both were substantial (Figure 7), and graminoids were the most common species (Figure 8). Total canopy cover was intermediate for the plots sampled. *Betula glandulosa* contributed the greatest amount of canopy cover of any vascular species or bryophyte (Table 12). Two other short shrubs, *Pentaphylloides floribunda* and *Salix wolfii* (Wolf's willow), contributed a substantial amount of cover, and three sedges, *Carex capillaris* (hairlike sedge), *C. simulata*, and *C. utriculata* were the most common herbaceous species. Three mosses, *Calliergon giganteum* (giant calliergon moss), *Campylium stellatum* (star campylium moss), and *Drepanocladus aduncus*, contributed most of the bryophyte cover. Water was present at the soil surface (Table 13).

At six of the sampling sites, only one community-type covered enough area to merit sampling in the judgement of the authors. At the remaining five sites, the vegetation was considered diverse enough that two or three vegetation plot samples were taken (Table 14B).

Table 11. Results of the NMS ordination of plot data.

Parameter	Value
Number of final dimensions	3
Final stress for 3-d result	8.00115
Final instability	0.00009
Number of iterations in final 3-d solution	70
Proportion of random runs with stress less than the stress from runs with real data (i.e., probability from Monte Carlo test)	0.0323
Proportion of variance in original distance matrix represented by axis 1 (increment, cumulative)	0.281, 0.281
Proportion of variance in original distance matrix represented by axis 2 (increment, cumulative)	0.306, 0.587
Proportion of variance in original distance matrix represented by axis 3 (increment, cumulative)	0.189, 0.776

Table 12. Distribution of plant community-types among fen sampling sites, MBNF
(At sites with more than one type, the type covering the most area is indicated by an asterisk.)

Study Area	**Sampling Site**	**Plant Community-type**	**Veg. Plot Number**
Middle Fork	Elk Creek Study Fens - west (original)	*Eleocharis quinqueflora*	04MBP11
	Elk Creek Study Fens - east (new)	*Eleocharis quinqueflora*	04MBP12
	Fall Creek Fen	*Eleocharis quinqueflora*	04MBP10
	Strain Creek Fen	*Carex aquatilis*	04MBP01
North Fork	North Fork Little Laramie R. Headwater Fens -- Sphagnum site	*Carex aquatilis* (with *Betula glandulosa*)	04MBP02
		Carex aquatili (with *Salix planifolia*)*	04MBP03
	North Fork Little Laramie R. Headwater Fens -- upper site	*Eleocharis quinqueflora*	04MBP15
	North Fork Little Laramie R. Fen test site (aka Paludella Fen in bryology collections)	*Carex aquatilis*	03MBP01
	North Fork Rock Cr. Fen	*Eleocharis quinqueflora*	04MBP04
		Carex aquatilis (with *Salix planifolia*)*	04MBP05*
	North Fork Rock Cr. Fen Complex	*Carex limosa*	04MBP07
		Carex vesicaria	04MBP08
		Carex aquatilis (with *Salix planifolia*)*	04MBP09*
	Sand Lake Road Fen	*Betula glandulosa*	04MBP16
Sheep Mountain	Fence Cr. Fen (aka Sheep Mt Fen in bryology collections)	*Carex aquatilis* (with *Salix planifolia*)*	04MBP13*
		Carex aquatilis	04MBP14
	Hecht Creek Fen	No data	None

Figure 10. Graph of results from NMS ordination of 17 peat plots – ordination axes 1 and 2. Triangles represent plots. Species names show the dominant plant species among the plots in different areas of the graphs. Black shading in triangles (▲) indicates substantial cover of *Salix planifolia* and gray shading (△) indicates substantial cover of *Betula glandulosa*. Plant canopy cover in the plots is shown in Appendix B.

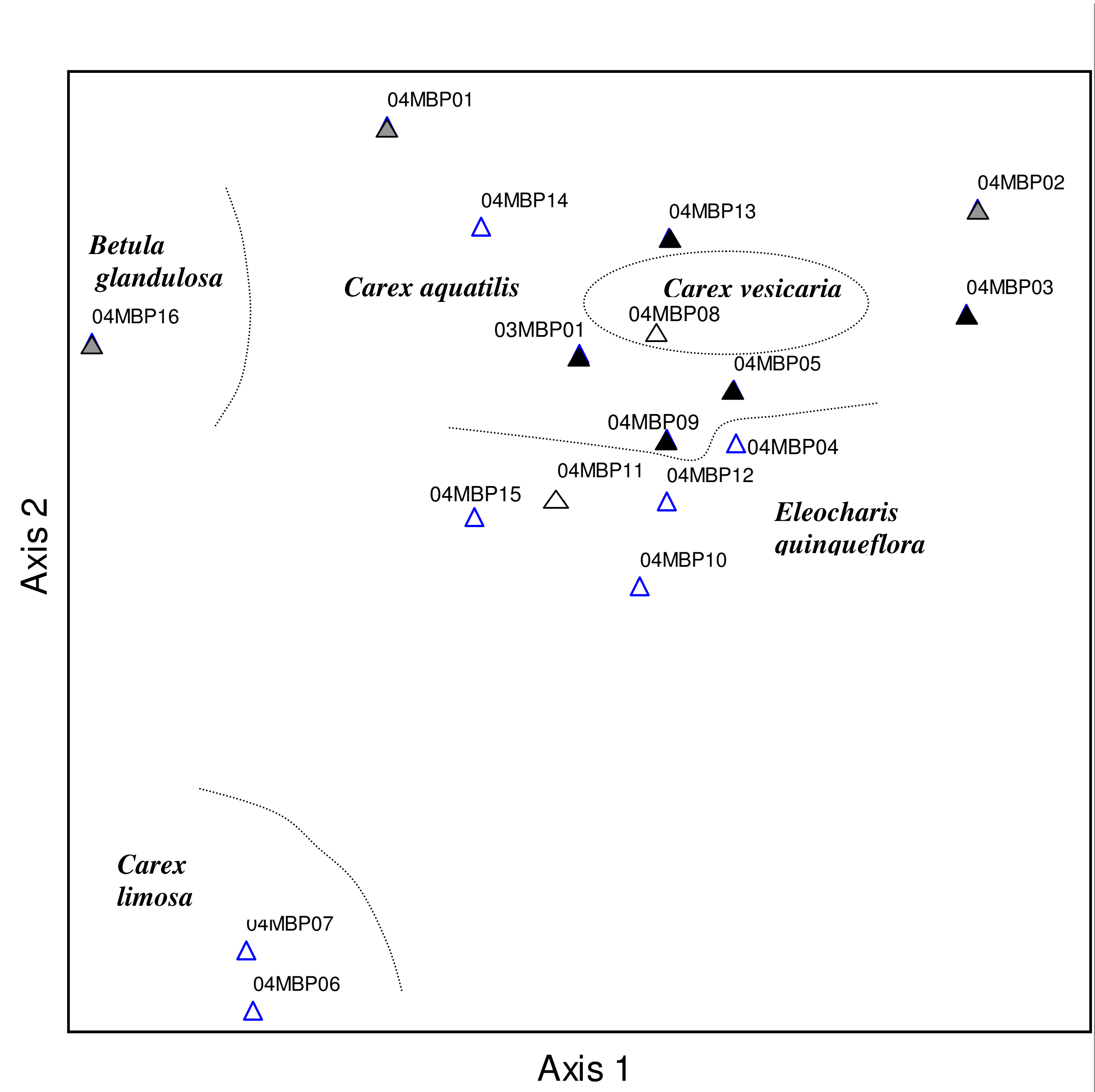


Figure 11. Graph of results from NMS ordination of 17 peat plots - ordination axes 1 and 3

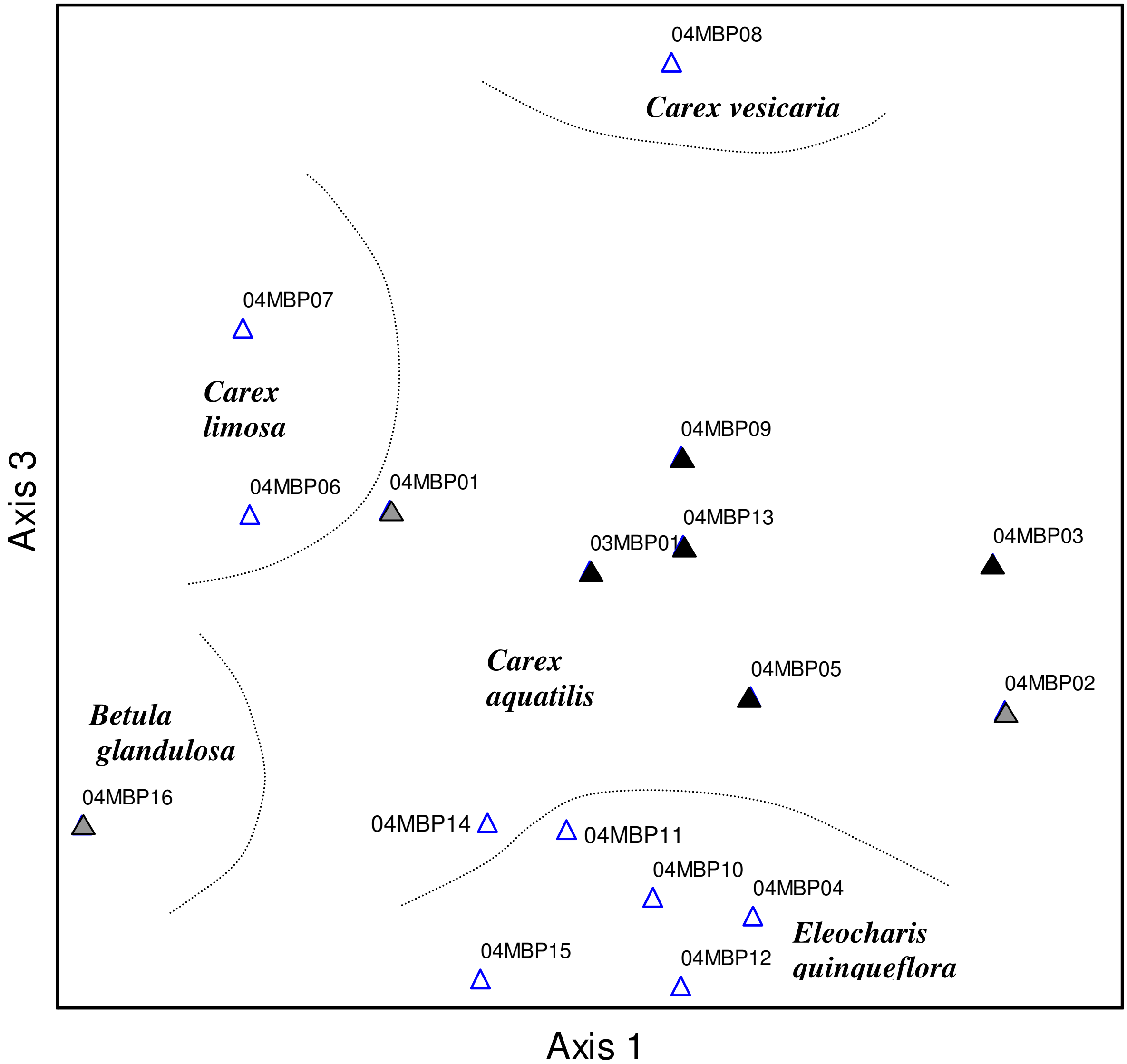


Figure 12. Graph of results from NMS ordination of 17 peat plots - ordination axes 2 and 3

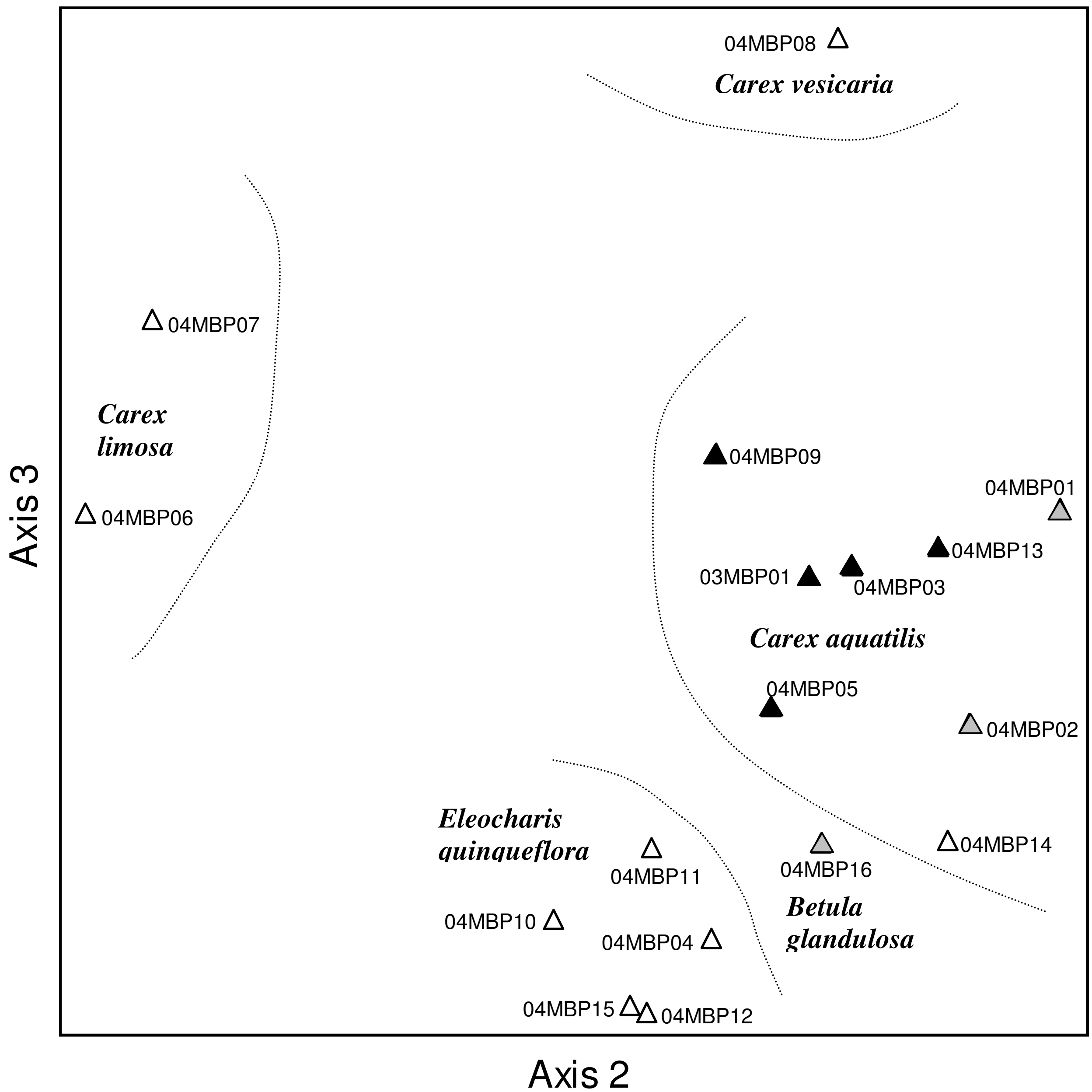


Table 13. Percent ground cover in different categories in fen sample plots, MBNF[2].

	Bedrock	Boulder	Clubmoss	Cobble	Cushion Plant	Dead Rooted Plant	Gravel	Lichen	Litter	Moss	Peat	Soil	Water	Wood
Carex limosa plots														
04MBP06	0	0	0	0	0	0	0	0	7	7	**83**	0	**15**	0
04MBP07	0	0	0	0	0	0	0	0	**13**	1	**87**	0	1	0
Carex vesicaria plot														
04MBP08	0	0	0	0	0	3	0	0	**99**	1	0	0	0	0
Eleocharis quinqueflora plots														
04MBP04	0	0	0	0	0	0	0	0	**23**	**65**	**26**	0	7	**10**
04MBP10	0	0	0	0	0	0	0	0	**18**	**68**	7	0	**15**	0
04MBP11	0	0	0	0	0	0	0	0	**10**	**42**	**22**	0	**26**	0
04MBP12	0	0	0	0	0	0	0	0	**21**	**57**	**14**	0	5	0
04MBP15	0	0	0	0	0	0	0	0	**23**	**65**	**12**	0	4	0
Carex aquatilis plots														
04MBP14	0	0	0	0	0	0	0	0	**11**	**83**	1	0	**14**	0
04MBP13	0	0	0	0	0	0	0	0	**40**	**57**	1	0	5	0
03MBP01	-	-	-	-	-	-	-	-	-	-	-	-	-	-
04MBP05	0	0	0	0	0	0	0	0	**19**	**77**	**12**	0	0	**20**
04MBP03	0	0	0	0	0	0	0	0	**50**	**89**	0	0	0	**10**
04MBP09	0	0	0	0	0	0	3	0	**15**	**88**	0	0	0	0
04MBP01	1	0	0	0	0	0	0	0	**12**	**94**	**35**	0	0	0
04MBP02	0	0	0	0	0	0	0	0	7	**85**	**11**	0	**14**	3
Betula glandulosa plot														
04MBP16	0	0	0	0	0	0	0	0	**77**	**21**	**20**	0	0	0

[2] All ground cover values of 10% or greater are bold-faced for ease of comparison.

Plant Community-types and the National Vegetation Classification

The vegetation types in the U.S. National Vegetation Classification (Maybury 1999) provide a framework into which vegetation data from studies such as the Medicine Bow peatland inventory can be placed. Table 14 shows the plant associations from the national classification that seem to be represented by the Medicine Bow peat stands sampled in this study. The descriptions of the *Carex limosa* plant association and the *Carex vesicaria* plant association in the national classification (NatureServe 2006) apply clearly to the *C. limosa* plots and the *C. vesicaria* plot, respectively, from this study. The description of the *Eleocharis quinqueflora* plant association from the national classification also seems to apply to the *E. quinqueflora*-dominated plots, except that mosses, which contribute much of the plant cover in the Medicine Bow plots, are not mentioned in the description of the association from the national classification.

Vegetation types in the national classification are defined partly by species composition but also in part by the amount of canopy cover from different plant life-forms (Maybury 1999). Consequently, most of the *Carex aquatilis*-dominated plots identified as a group in the ordination appear to fit into plant associations from the national classification that are recognized for the presence of a shrub stratum. Five plots with substantial amounts of *Salix planifolia* canopy cover seem to fit into the *Salix planifolia*/*Carex aquatilis* plant association of the national classification. The relationship of the two plots with substantial amounts of *Betula glandulosa* canopy to associations from the national classification, though, is unclear. They may represent the *Betula nana* (dwarf birch)/Mesic Forbs - Mesic Graminoids Shrubland association, but that type is described as having an herbaceous component rich in graminoids and forbs (NatureServe 2006), which does not apply to the Medicine Bow plots. The national classification contains a *Betula nana*/*Carex* spp. association that has been described only from northern Montana and southern Alberta and is poorly known (NatureServe 2006), and the Medicine Bow plots may be more similar to this association. Plot 04MBP14, which contained little shrub canopy-cover, seems to fit the description of the *Carex aquatilis* plant association from the national classification.

The description of the *Betula glandulosa*/Mesic Graminoids - Mesic Forbs association from the national classification (NatureServe 2006) seems to apply more clearly to the single plot (04MBP16) with a *B. glandulosa* shrub stratum and very little *Carex aquatilis*. The herbaceous component in this plot was dominated by *Carex* spp., as in the description from the national classification, but it also had a greater variety of other graminoids and forbs.

The major contribution of mosses to fen vegetation, as documented in the Medicine Bow sample plots (except for the *Carex limosa* and *Carex vesicaria* plots), seems to be largely unrecognized in the national classification. Only in the description for the *Betula nana*/*Carex* spp. association are mosses mentioned as sometimes contributing much canopy cover (NatureServe 2006). Mosses may go unmentioned in descriptions of the national classification types because stands of those types generally have little moss cover, in which case the Medicine Bow peat plots do not fit particularly well into the national-described types. But it seems plausible that mosses are rarely mentioned because identifying mosses is more difficult than identifying vascular plants, and they are simply treated as ground-cover.

le 14. Relationship of community-types identified from ordination of Medicine Bow Mountains fen sample plots to vegetation ts from the U.S. National Vegetation Classification.

ationships are based on the descriptions for types in the national classification found in NatureServe (2006).

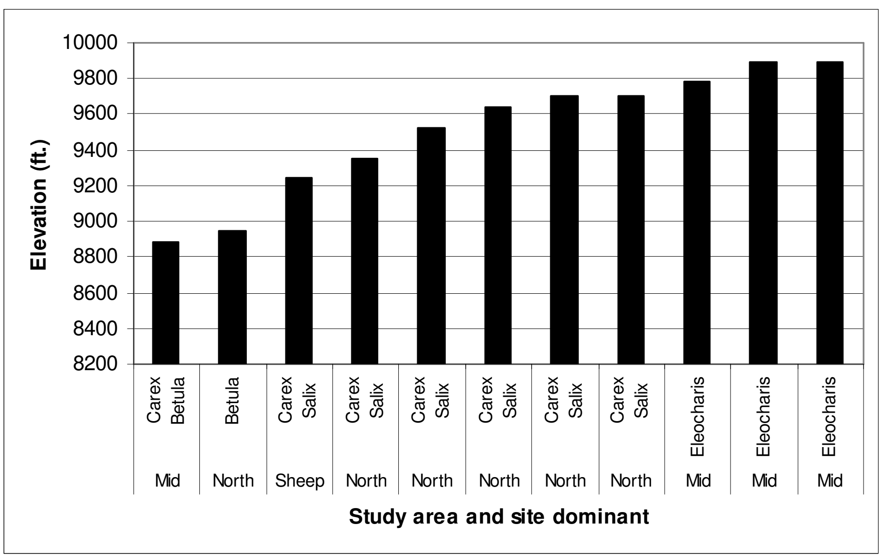
Medicine Bow National Forest			U.S. National Vegetation Classification				
ommunity-type		Sample Plots	Vegetation Unit	Code	Confidence in classification	Conservation Rank	Relatio
Carex aquatilis	little shrub cover	04MBP14	*Carex aquatilis* Herbaceous Vegetation	CEGL001802	Strong	G5 (Secure)	Medicine B appears to typ
	with *Salix planifolia*	04MBP13 03MBP01 04MBP05 04MBP03 04MBP09	*Salix planifolia/Carex aquatilis* Shrubland	CEGL001227	Strong	G5 (Secure)	Medicine appears to typ
	with *Betula glandulosa*	04MBP01 04MBP02	*Betula nana*/Mesic Forbs - Mesic Graminoids Shrubland	CEGL002653	Strong	G3G4 (vulnerable)	Medicir stands pro this t
			Betula nana/Carex spp. Shrubland	CEGL005887	Weak	Not yet ranked	Medicir stands ma typ
Carex limosa		04MBP06 04MBP07	*Carex limosa* Herbaceous Vegetation	CEGL001811	Strong	G2 (Imperiled)	Medicine fits NVC
arex vesicaria		04MBP08	*Carex vesicaria* Herbaceous Vegetation	CEGL002661	Moderate	G4Q (Apparently secure)	Medicine B fits NVC
Eleocharis quinqueflora		04MBP04 04MBP10 04MBP11 04MBP12 04MBP15	*Eleocharis quinqueflora* Herbaceous Vegetation	CEGL001836	Strong	G4 (Apparently secure)	Medicine appears to typ
tula glandulosa		04MBP16	*Betula nana*/Mesic Forbs - Mesic Graminoids Shrubland	CEGL002653	Strong	G3G4 (vulnerable)	Medicine B probably f typ

Four of the seven associations from the national vegetation classification that appear to be represented in the Medicine Bow peatlands are common enough that their status is considered secure or apparently secure. One association, the *Betula nana*/Mesic Forbs - Mesic Graminoids association, is considered vulnerable to loss or degradation throughout its range; and another, the *Carex limosa* association, is considered imperiled. Both of these rankings are based on the low numbers of stands of these association thought to exist throughout North America (NatureServe 2006), not (apparently) on known or suspected declines. The *Betula nana*/*Carex* spp. association is insufficiently known at present for a conservation status rank to be assigned.

<u>Plant Community-types and Elevation</u>

Five of the study sites had well-developed expressions of more than one fen plant community-type (Table 15). If only those plots representing the most extensive community-type at each site are considered, a graph of plant community-types against elevation indicates that there may be elevation sorting (Figure 13). The sites where the *Eleocharis quinqueflora* type predominate are at the highest elevation, sites with predominantly *Carex aquatilis* vegetation are at intermediate elevations, and sites with *Betula glandulosa* vegetation are at lower elevations.

Figure 13. Elevation of prevailing fen plant communities, Medicine Bow Mountains, MBNF



<u>Plant Community-types and pH</u>

The pH data collected at the sampling sites show a wide range of values (4.92-7.49) that potentially correspond with a range of poor to rich fens (Figure 14, Table 15). However, there is little consistent relationship apparent between pH measured in a vegetation plot and the community-type in that plot, except that sites with *Betula glandulosa* have relatively high pH readings.

Differences of up to 0.8 pH values were found between microhabitats at a single site. The vegetation plot pH readings were taken over the course of eight weeks, and it is unknown if values are stable over the growing season. In addition, the pH readings may have been affected by the accelerated oxidation of peat allowed by the drought conditions leading up to 2004. Classification of fen types requires confirmed pH readings, ideally with a full suite of electrical conductivity measurements.

Figure 14. Plot vegetation and pH in Medicine Bow Mountains fens, MBNF

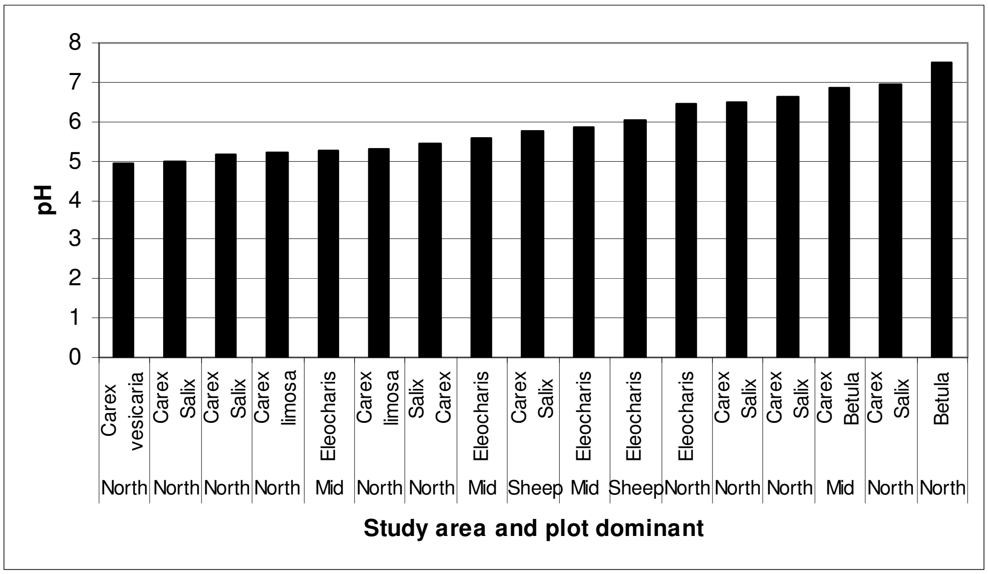


Table 15. Fen study site characteristics, Medicine Bow Mountains, MBNF

Study area	Sampling Site	pH reading	Temp. (℃)	Electrical conductivity (deciSiemens/ m)
Middle Fork	Elk Creek Study Fens – west (original)	5.24	18.7	0.040
Middle Fork	Elk Creek Study Fens – east	5.56	14.5	0.049
Middle Fork	Fall Creek Fen	5.85	11.0	0.031
Middle Fork	Strain Creek Fen	6.84	18.2	No data
North Fork	North Fork Little Laramie River Headwater Fens – sphagnum site	4.99 5.42	8.4 19.0	No data
North Fork	North Fork Little Laramie River Headwater Fens – upper	6.64	16.4	0.113
North Fork	North Fork Little Laramie River Fen test site	6.97	15.3	No data
North Fork	North Fork Rock Creek Fen	6.45 6.51	14.2	No data
North Fork	North Fork Rock Creek Fen complex	4.92 5.17 5.21 5.32	21.5 17.8 16.3 11.3	No data
North Fork	Sand Lake Road Fen	7.49	13.2	0.442
Sheep Mountain	Fence Creek Fen	5.77 6.03	15.2-17.5	0.087-0.125
Sheep Mountain	Hecht Creek Fen	No data	No data	No data

Each of the 17 vegetation plots had peat depth exceeded 0.5 m, and most exceeded the1 m length of the coring instrument. All of the 17 samples from peatland habitat were confirmed as fibrists. A Fibrist is a histosol that has the least degree of plant material decay of the three major kinds of histosols, having at least 40% intact fiber content or more by bulk weight. Electrical conductivity measurements were taken at less than half of the sites, and overall values were low, consistent with the non-sedimentary parent material. Values were highest at a glacially-influenced rich fen site, Sand Creek Road Fen

DISCUSSION

Fen Sensitive Species

All 17 known occurrences of the Forest Service sensitive species and the Wyoming species of concern are restricted to those five sampling sites that contain an unusual fen plant community-type (those dominated by *Carex limosa* or *Betula glandulosa*, or else the *Carex aquatilis* plant community-type with a major *Betula glandulosa* component). This distribution pattern suggests that identifying and locating the rarest and most diverse fen types may be a constructive step for managers to take in sensitive species programs.

The 17 occurrences also represent the only occurrences for those ten Forest Service sensitive species and Wyoming species of concern in the Medicine Bow Mountains. Nine of the ten fen species are fen obligates in Wyoming, and not known from other habitats (based on statewide habitat compilation). *Lomatogonium rotatum* (marsh felwort) is the one species documented in this study at Fence Creek and Hecht Creek Fens that is not restricted to fen habitats.

Five of the ten plant species were found for the first time in southern Wyoming during the project. One is *Carex leptalea* (bristlystalked sedge), which was removed from the sensitive species list of the Forest Service's Rocky Mountain Region in 2004 because new data around the Region showed that it is more common than previously thought. This species still is tracked by the Wyoming Natural Diversity Database as a species of concern. The other four species new to southern Wyoming are *Eriophorum gracilie* (slender cottongrass), *Muhlenbergia glomerata* (marsh muhly), *Sparganium natans* (small bur-reed), and *Trichophorum pumilum* (pygmy bulrush). Two additional plant species, *Carex paupercula* (boreal bog sedge) and *Epilobium oregonense* (Oregon willowherb), are now known to be frequent in widespread Medicine Bow Mountains fens, and consequently, they are no longer tracked as species of concern.

At least ten other vascular plant species present in Medicine Bow Mountains fens are of interest because they are habitat specialists. Most are boreal species near the southern limits of their geographic ranges. Some of these species were tracked in the past by the Wyoming Natural Diversity Database as species of concern but were removed from the list of tracked species prior to this peatland project. All are currently ranked S2, indicating that their rarity could cause them to be imperiled in Wyoming. These ten species are *Carex capillaris* (hair-like sedge), *Carex jonesii* (Jones' sedge), *Epilobium palustre* var. *palustre* (swamp willow-herb), *Listera cordata* (heartleaf twayblade), *Montia chamissoi* (Chamisso's candy-flower), *Oxypolis fendleri* (Fendler's cowbane), *Petasites sagittatus* (arrowleaf sweet coltsfoot), *Potentilla palustris* (red cinquefoil), *Symphyotrichum boreale* (bog aster), and *Thalictrum alpinum* (alpine meadow-rue).

In previous stages of the investigation, two Wyoming plant species of concern were documented at 85 sites and they were subsequently taken off the list of species of concern. Otherwise, only five of the 138 peatland sites visited during the extensive and intensive phases of this project contained Forest Service sensitive species or other Wyoming species of concern. Apparently, fens in the Medicine Bow Mountains are not consistently rich in rare vascular plant species, even though they may harbor a significant share of the wetland flora.

<u>Fen Flora</u>

A vascular fen flora of at least 162 species (including five Forest Service sensitive species and five additional Wyoming species of concern) has been documented in the Medicine Bow Mountains. The known flora represents a modest 5% of the statewide flora below the genus level in Wyoming (Dorn 2001) and over 2% of Wyoming's plant species of special concern, including five species that had not previously been known from southern Wyoming.

Three pairs of similar vascular plants could not be reliably distinguished in this study, and they should be noted in interpretation of both the flora and vegetation plot analysis. *Carex aquatilis* was usually found in vegetative condition. The similar-looking *C. scopulorum* (mountain sedge) has also been reported from at least one of the *C. aquatilis* sites (Elk Creek Fen West, by Fleming [1966]). We recorded all glaucous-leaved sedges of similar leaf width and stature as *C. aquatilis*, but some of the plants may have been *C. scopulorum*. Similarly, *Carex canescens* (silvery sedge) and *C. brunnescens* (brownish sedge) were frequently found in vegetative condition. We have vouchered *C. canescens* and both species are present in the study areas, but they were not consistently distinguished in site lists and plot data forms. Finally, the variety distinction was not consistently determined for *Salix eriocephala*, and we found vegetative material that exhibited a range of stem coloration on the same plant. Both *Salix eriocephala* var. *watsonii* (yellow willow) and *S. e.* var. *ligulifera* (strapleaf willow) were collected.

Bryology collections made in 2004 documented 61 bryophyte species, in addition to the 12 more fen species documented by bryology researcher, Dr. Elena Kosovich-Anderson The 73 species represent over 20% of the state's known bryophyte flora (Eckel 1997) and include 67 mosses and six liverworts. It is premature to report any new additions to the state bryophyte flora or to discuss species' rarity because the bryology results from this project draw heavily from the work of others, and is best pursued after labeled voucher specimens have been submitted.

Abundance of Plant Community-types in the Medicine Bow Mountains

The information from the 2003 extensive inventory of peatlands can be combined with the results from the intensive sampling to give a picture of the abundance of peatland community-types. In the North Fork Study Area, *Carex aquatilis*-dominated fens with substantial amounts of *Salix planifolia* outnumbered *Eleocharis quinqueflora*-dominated fens: at least 39 of 58 peatlands in that area were dominated by *Carex aquatilis*. Fens of Sheep Mountain were also mostly dominated by *Carex aquatilis*. In contrast, the Middle Fork Study Area had more *Eleocharis quinqueflora*-dominated fens (at least 27 of 49 fens) than *Carex aquatilis*-dominated fens.In cases where *Salix planifolia* cover was present in the Middle Fork, the shrubs were relatively tall and clumped, often forming tall thickets (shrub carrs) on muck soils rather than peat.

The three other plant community-types were represented by single sites and may represent rare habitats. The *Betula glandulosa* type is present in the lowest-elevation fen studied, and almost all sites where *B. glandulosa* is known from the extensive inventory to be common in the Medicine Bow Mountains were included in the 2004 sampling. The *Carex limosa* and *Carex vesicaria* plant community-types were not observed elsewhere in the Medicine Bow Mountains, although the latter species has been noted in a subalpine peatland (Heidel and Laursen 2003). *Carex limosa* vegetation has also been documented in a small Sierra Madre fen (Heidel and Thurston 2004). The only other prospective plant community types noted during extensive survey were dominated by *Carex utriculata* or *Salix geyeriana* (Geyer willow). Sites with these vegetation types often seemed to have been disturbed or to be transitional to mineral-soil habitats. They were not represented among the 2004 study sites.

Plant Community Diversity at Fen Sites

Several plant community-types of different structure and species composition may grow in different hydrological settings within a single fen. The site with the greatest documented fen plant community diversity is the North Fork of Rock Creek Fen Complex, where four fen plant communities were sampled (not including the open water communities). The two major fens on Sheep Mountain, the Fence Creek Fen and Hecht Creek Fen, also each support several plant community-types. These two fens also span the greatest topographic relief, even though they are not the steepest fens. The steepest fens are the Upper Headwaters Fen of the North Fork of the Little Laramie River, and the North Fork of Rock Creek Fen.

A review of the components often present in a fen mosaic in the northern U.S. Rocky Mountains is presented in Chadde *et al*. (1998). The fen mosaic components observed in the Medicine Bow Mountains (part of the central U.S. Rocky Mountains) represent a subset of those in the northern Rocky Mountains. No forested fens were prevalent at sites. Forests and woodlands bordering fens in the Medicine Bow Mountains typically stop abruptly at the edges of the fens, and the majority of our sampling sites had almost no ecotone between upland and wetland. The North Fork Study Area sites, though, had scattered *Abies lasiocarpa* and *Picea engelmannii*. These tree species, and *Pinus contorta*, were also widely scattered in the Fall Creek Fen mosaic of peatland and other wetland types in the Middle Fork Study Area. Other sites identified in the extensive peatland inventory in both the North Fork and Middle Fork

Study Areas had more tree cover, but even in those fens, the areas of dense tree cover were restricted.

Only one site (the North Fork of Rock Creek Fen Complex) in the inventoried Medicine Bow peatlands contained a floating mat of peat. This is also the only site in the Medicine Bow Mountains known to have vegetation dominated by *Carex limosa*(which composes the floating mat) and by *Carex vesicaria* (which dominates on solid peat). The associated submerged community was not sampled but supported several macrophytes not found elsewhere.

Several of the montane peatlands included open water in streams or rivulets, seeps, and pools. These small features often have vegetation that differs in structure and composition from the surrounding peatland and thereby contribute to the diversity of the fens. The vegetation sampling plots often failed to encompass these small features but some of the species growing in them were noted in the floristic inventory at the site.

Pools of open water are common in at least three different circumstances within peatlands. Discrete pools form at springs, sometimes in mounds built up above the rest of the peatland. Some resembled wells, with walls formed in spongey peat. Pools also form in peatland around rock outcrops and boulders, and the bottoms of some of these pools in the Medicine Bow Mountains peatlands are rocky. Finally, a number of peatlands had small spots where the dense moss cover had been torn up, resulting in bare patches that had filled with shallow water. The largest such area was noted in the North Fork of the Little Laramie River Headwaters Fen - Sphagnum sampling site, where the shallow pools occupied the portion of the fen with the densest *Sphagnum* cover. That disturbed area contained copious moose and elk droppings, strongly suggesting that the pools had developed in a wallow.

<u>Conclusions</u>

This project has contributed a body of knowledge about peatlands in the Medicine Bow Mountains, and that knowledge will be useful in at several areas of management and research. While we recognize that this project encompassed only a part of the Medicine Bow Mountains and did not touch on the other ranges of the Medicine Bow National Forest, still its results represent a large proportion of the montane zone administered by the Forest and can provide a frame of reference for several types of investigations.

First, this study shows that peatlands are widespread and relatively common features in the montane Medicine Bow Mountains landscape. According to the results from the extensive inventory phase of the project, over 1% of the land surface in the North Fork Study Area is covered by peat, and most of the montane peatlands are flow-through systems associated with streams in the in upper parts of drainages. Given the roles that peatlands in other areas are known to play in hydrology and biogeochemistry (Barber 1993, Bedford and Godwin 2003,Chapman *et al*. 2003), this information on distribution and abundance suggests that peatlands play a substantial role in ecosystem function in the Medicine Bow Mountains. For example, peatlands may store substantial amounts of water and release it for late-season flows in many montane streams. This may be a fruitful area of investigation for hydrologists and aquatic biologists on the Medicine Bow National Forest.

Second, we know that these peatlands of the Medicine Bow Mountains are fens. Bogs apparently are absent. This conclusion is based on the environment and types of vegetation documented during the extensive inventory and the intensive sampling, and also on the pH values measured at the sampling sites. The two prevalent plant community-types in these fens are dominated by *Eleocharis quinqueflora* and the other by *Carex aquatilis* with associated shrubs. Other vascular plant community-types are present but apparently are limited in their extent. Mosses are major components of the vegetation in most of the fens. Fen vegetation is an expression of both the botanical resources and the animal habitats of the Forest, so this new information should be of use to Forest planners and biologists.

Third, the results suggest that fens in the Medicine Bow Mountains support a number of plant species that are largely restricted to this habitat, and those species would be rare or absent from the Medicine Bow Mountains were it not for the presence of the fens. Consequently, fens contribute substantially to the biological diversity of the area. The fens also support a substantial number of the bryophytes known from the state. This information is of interest to botanists for what it tells us about botanical diversity, and also to managers for the guidance it might give them in planning for Forest uses. It may be possible to learn more about the contribution of peatlands to biological richness by comparing their flora and vegetation to those in mineral-soil wetlands nearby. We expect that mosses in particular are far more common in peatlands than other wetlands, and the same may be true for certain groups of vascular plants.

These conclusions also raise questions about applying results elsewhere. An exhaustive mapping of fens across all of the Medicine Bow Mountains may not be a priority, but the identification and documentation of the other large, unusual fen sites in the Medicine Bow Mountains would contribute directly to the sensitive species program. The elevation scope of this study could be broadened to determine if there are any foothills fens, the extent of subalpine fens, and their comparison with the botanical and ecological characteristics of montane fens in the Medicine Bow Mountains. There are also questions whether the conclusions drawn from this study also apply to the Sierra Madre, where the climate and topography would lead one to expect that peatlands are similarly common. Are peatlands in the Sierra Madre Range and other parts of the Medicine Bow Mountains, including foothills and subalpine settings, also flow-through fens located in the upper parts of drainages? Are they as common there as they are in the three Medicine Bow Mountains study areas? Do they harbor rare plants? Does the peatland vegetation in those areas also consist primarily of common community-types, with a few rare types in which are found the rare plant species? Are mosses similarly important in the fens of those areas?

Finally, this study provides a model for gauging and then documenting peatland significance and associated botanical and ecological characteristics over large landscapes. It provides botanical and ecological data for incorporating into emerging statewide and regional documentation of Wyoming fens and Rocky Mountain fens. It is intended as a contribution to ongoing dialogue and research by botanists and ecologists through the state and region.

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