Botanical and Ecological Inventory of Peatland Sites on the Shoshone National Forest

Prepared for Shoshone National Forest

By Bonnie Heidel and Scott Laursen
Wyoming Natural Diversity Database
University of Wyoming
P.O. Box 3381
Laramie, WY 82071

Challenge Cost-Share Agreement No. 02-CS-11021400-012

May 2003

ABSTRACT

Peatlands are specialized wetland habitats that harbor high concentrations of Wyoming plant species of special concern. Intensive botanical and ecological inventories were conducted at four select peatland sites on Shoshone National Forest to further document the vascular flora, update information on plant species of special concern, initiate documentation of the bryophyte flora composition, and to document the vegetation associations. This provides a preliminary summary of peatland botanical and ecological resources on Shoshone National Forest, data for comparison between sites, and both floristic and vegetation plot datasets for comparison between Shoshone National Forest and Medicine Bow National Forest where parallel studies were undertaken. It might be used for more intense botanical and ecological studies at these sites, more extensive systematic inventories of peatlands and their associated botanical and ecological attributes across the Clarks Fork District, or related efforts to evaluate watershed, wildlife, and other values associated with peatlands.

ACKNOWLEDGEMENTS

Kent Houston provided Forest Service coordination that made this project a reality. Joe Elliott made the moss species identifications for all moss specimens, and gratiously provided information on his unpublished inventory of the moss flora at Swamp Lake. George Jones provided review of this report that draws so heavily from the previous research that he conducted with Walter Fertig. Robert Booth and Jennifer Zygmunt shared their common interests in peatlands and provided pH data that they collected at two of the sites during the same time, also coordinating their fieldwork with this study at Little Moose Lake. Tessa Dutcher prepared the study area map and provided other GIS support. The interest and expertise of all is gratefully acknowledged.

This study was conducted as a challenge cost-share project supported by the Shoshone National Forest and the Wyoming Natural Diversity Database.

<u>Report citation:</u>

Heidel, B. and S. Laursen. 2003. Botanical and ecological inventory of peatland sites on the Shoshone National Forest. Report prepared for Shoshone National Forest by Wyoming Natural Diversity Database, Laramie, WY.

Cover page photo: Round-leaved orchis (*Amerorchis rotundifolia*) is at its southern limits on Shoshone National Forest peatlands relative to western North America and its boreal distribution. Photograph by Maria Mantas.

TABLE OF CONTENTS

Tables

Figures

Appendix

INTRODUCTION

The overall purpose of this project was to locate and inventory well-developed peatland sites on the Shoshone National Forest for their botanical and ecological features. It represents a phase of synthesizing past systematic inventory and analysis, adding or augmenting the vascular flora and bryophyte flora, updating and summarizing the rare plant species information, and analyzing the peatland vegetation associations present in the Shoshone Bow National Forest.

Peatlands are the focus of this study project because they have high biodiversity significance in Wyoming, harboring over 10% of the state plant species of special concern (52 of 487, as listed in Fertig and Heidel 2002). On the Shoshone National Forest, they harbor ca 26% of the state species of concern (27 of 105 species; from Fertig 1998), or 47% of the Sensitive species on the Forest (7 of 15 species, based on USDA Forest Service 1994). Many vascular and nonvascular plant species and plant communities of the Rocky Mountains are known only from peatlands, often comprising wetland communities that are compositionally unique in the region and species-rich (Chadde et al. 1996). Despite their biodiversity significance, and prospective diversity and uniqueness, peatlands have not been inventoried in the state apart from select site inventories and research natural area evaluations.

Peatlands have additional research and resource values that support the case for baseline inventory. They are "windows" into the geologic past, preserving pollen records and other microfossils, charcoal layers, and macrofossils as a faithful chronology of surrounding vegetation (e.g., Pennak 1963, Barber 1993). They perform important hydrological and water quality functions. For example, in the lab they have been shown to accumulate heavy metals such as uranium (Zielinski and Meier 1988, and Robbins et al. 1990, as cited in USDI FWS 1997) and in the field they appear to concentrate heavy metals such as iron (Sturges 1967). They also have extremely low rates of hydrologic conductivity (Sturges 1968), and streams emanating from groundwater-fed peatlands have lower total dissolved solids than the contributing groundwater (Sturges 1967), acting as hydrological buffers that stabilize downstream flows (Verry and Boelter 1978). There is also evidence that gross alpha and beta radiation present in snow and groundwater is filtered by the peatland (Sturges and Sundin 1968). In some landscapes, rare native cutthroat trout benefit from the water cleansing actions of fens in headwaters of streams (USDI FWS 1997).

Peatlands develop at such a slow rate that they are for all practical purposes, irreplaceable. For example, peat accumulates in Colorado at rates of 4.3 – 16.2 inches per thousand years Cooper 1990, as cited in USDI Fish and Wildlife Service 1997). Removal of peat deposits profoundly alters hydrology and the substrate that peatland species need to grow, curtailing or setting back Holocene succession. Thus, they fall outside the wetland mitigation framework and "functioning fens" have been placed within "Resource Category 1" of the USFWS wetland mitigation policy (Federal Register Vol. 46. No 15. Feb. 4 1981).

They are also threatened at some level. In adjoining states, active peat-mining capitalizes on the commercial values of peatlands. Peat has high water-absorption capacity, and is sold commercially for improving soil structure, increasing organic content, and shifting pH. Peat has also been considered as an alternate energy fuel elsewhere in the country (Farnham 1978). Information is not widely available on the vulnerability and risks to peatland resources in the Rocky Mountains except under direct threat (e.g., peat-mining activities in Colorado are summarized in Cooper 1990a, as cited in USDI FWS 1997) but real estate development, water development and other changes to hydrology, grazing and haying are among potential impacts (USDI FWS 1997). Baseline information is needed to assess effects of land use practices in the peatland and in the immediate watershed. Direct and indirect threats have been particularly well-documented in Europe (Barber 1993, Grunig 1994).

What are peatlands? They are defined as wetlands with waterlogged substrates and organic substrates (i.e., peat substrate, or "histosols") that have 20% or greater organic carbon content by weight (USDA Soil Conservation Service 1992). The depth threshold ranges from 20-60 cm minimum, depending on degree of decay and clay content (USDA Soil Conservation Service 1992). Commonly, peatlands are characterized as having a minimum 30 cm depth of peat at the surface or greater (USDI 1997, Chadde et al. 1998). The anaerobic conditions and slow rate of decay fosters peat accumulation, a unique autogenic process that results in an exceptionally stable habitat over centuries. They are very low in essential nutrients Nitrogen and Phosphorus, and some peatlands are high in potentially toxic elements Manganese and Aluminum (discussed in Small 1972). They are extensive in northern latitudes with cool, humid conditions (Farnham 1978, Grunig 1994). In the Rocky Mountains of the United States, peatlands are uncommon, in large part due to unfavorable climate (USDI FWS 1997).

> "The combination of habitat rarity, habitat stability, and extreme habitat conditions explain the distinctiveness of the flora in peatlands, as well as the high concentrations of rare species that are restricted to peatland environments in the Western United States." (Chadde et al. 1998).

The unique characteristic of peatland habitat, namely their autogenic development, means that the presence and abundance of peat-forming species determines the nature of the peat substrate over time in the absence of disturbance. These peat-forming species have rootstocks that are slow to decay, often high in lignin, various adaptations to anaerobic water-logged conditions, and often have elevated terminal buds to preclude being literally buried alive. Peat deposits accumulate as undecayed organic material that originates from sedges and other graminoid dominants, as well as from mosses. Some of the most fundamental distinctions in peatland habitat depend on whether the peat substrate is derived from graminoids or from bryophytes (especially *Sphagnum* mosses).

This document provides a synthesis and expansion of information on peatland sites in a northern part of Shoshone National Forest. The results of this broadened inventory at four select peatland sites provide a springboard for documenting the collective botanical and ecological resources of peatlands, the "search images" for identifying peatlands using remote-sensing techniques, and more systematic documentation of peatland distribution on the Forest.

METHODS

The criteria for study site selection, techniques used in the field, references used in specimen review and methods used in the analysis of vegetation sampling data are summarized in the following sections.

Site Selection

Prospective study sites were identified prior to fieldwork. Two very well-documented sites were included, Swamp Lake (Fertig and Jones 1992) and a peatland basin northeast of Lily Lake (Jones and Fertig 1999), referred to as Lily Lake in the rest of this report. Two other sites were identified based on the presence and precise location information for peatland indicator species, i.e., those Wyoming plant species of special concern that are "obligate" peatland species and are not known to occur in other wetland types. We used the list of vascular plant species that occupy peatlands compiled in Chadde et al. (1998) and made provisional interpretations of peatland obligates from Wyoming element occurrence records, the literature, and past experience. The other two sites are Little Moose Lake and a peatland basin south of Clay Butte. They represent an array of peatland types as indicated by rare species present, but not necessarily the full array of peatland types present on Shoshone National Forest.

Field Inventory

A record and overview of each site was prepared documenting its location, access, tentative peatland boundaries, and general description. Topographic maps and aerial photos were used to delimit the study area and sort the range of habitats present. Different patterns on the aerial photographs were marked as tentative indication of different vegetation structure.

The initial vegetation structure delimitations were checked and merged or split in the field. Within each area of discrete vegetation structure, predominant plant associations and distinctions in plant associations were noted. Vegetation plots were subjectively placed in homogeneous areas on the scale of the 0.5 m^2 plot, within each major vegetation structure zone and representative samples within them. Homogeneity was visually judged by uniform patterns of stature, density, and the patterns associated with composition and species' dominance in particular. Each plot was demarcated with a 0.5 x 1.0 m PVC frame. Within each plot, cover values were determined by ocular estimates for all vascular plant species to the nearest 10% (also recognizing trace, 1%, and 5% as sparse cover values). Cover values were also determined for bryophyte species. Vouchers were collected for unknown species including all bryophyte specimens from all plots. The number of plots per site ranged from 4 (Clay Butte) to 21 (Swamp Lake), with a total of 38 plots.

The vascular and bryophyte floras of the peatland were recorded in visiting all major vegetation zones and their representative plant associations for associated species, also targeting microhabitat features such as wetland margins, springs and seeps, stream margins, and the hummocks around isolated trees in each wetland. In surveying the vascular flora, a running floristic list of species was kept. The best-documented and largest peatland site flora is that compiled for Swamp Lake (211 species; Fertig and Jones 1992; and later Fertig collections), so it was used in creating a database file for compiling floristic information from all sites in the Shoshone National Forest study, as well from all peatland sites in a parallel study on the Medicine Bow National Forest. Survey for rare plant species not previously documented was considered in the course of floristic documentation.

Two of the peatland sites had pH readings taken at the same time as survey, in tandem University of Wyoming peat samplings that targeted the most acidic habitats within peatland sites, at Lily Lake and Little Moose Lake. This provides the low end of the pH range at the two sites, but does not necessarily reach the high end of the pH range.

The original taxonomic nomenclature of the Swamp Lake checklist was modified using current taxonomic treatments (Dorn 2001). References that were used for vascular plant identification in the field included Dorn (1997, 2001), Fertig and Markow (2001), Johnston (2001), and Hurd et al. (1998). All vascular plant specimens that were collected are deposited at the Rocky Mountain Herbarium (RM.)

Moss specimens were examined upon returning from the field using the keys and characteristics presented in Lawton (1977), Vitt et al. (1988), and comparison with the checklist of the moss flora of Wyoming (Eckel 1996). Determination of each specimen was made by Joe Elliott, bryologist who conducted the first bryophyte inventory of Swamp Lake. Bryophyte moss specimen vouchers will be deposited at RM.

Vegetation Classification

Multivariate analyses were run to contribute to a peatland vegetation classification scheme for the Forest, add to the peatland plant community information described previously on Swamp Lake Fen (Fertig and Jones 1992) and on Lily Lake (Jones and Fertig 1999), and cross-reference results with other peatland vegetation classification results in and around Wyoming including preliminary results from Medicine Bow National Forest. The sampling and analysis of peatland vegetation in this study and the refinements in Wyoming vegetation classification that have been made since 1992 provide more complete vegetation classification information. The plant association types do not have adequate sample numbers from different sites to support a "new" system of classification, and the focus on plot uniformity excludes the heterogeneity in microtopography that is inherent in some plant associations. But it expands existing descriptions of plant associations in Wyoming and has potential for expanded analysis in the future. They are named according to species dominance or co-dominance of vascular species under natural conditions. It differs from the naming conventions of Cooper and Andrus (1994) which includes moss species dominance, and appears to include indicator species.

Plot data, including bryophyte and vascular plant cover values, were entered into a peatland database. A detrended correspondence analysis (DCA) was run using PC-ORD (Version 4.0), including both vascular and nonvascular species. A second DCA was run including vascular species alone. These analyses were performed to visually inspect the relative similarity of plot composition. One forested peatland stand and one shrubland stand were sampled that shared no species with other wetland stands (both in Swamp Lake). Since the lack of continuity in the vegetation dataset resulted in poor analysis using DCA, these two stands were removed from analysis.

The next step in formally classifying vegetation associations was then to run a two-way species indicator analysis (TWINSPAN). TWINSPAN is a divisive and hierarchical classification system that uses the species present within each plot and their coverage values to make dichotomous breaks between plots. Again, one TWINSPAN analysis was performed using the cover values of all species and another using the cover values of only vascular species. Six levels of divisions were considered with the vascular species data, using a minimum number of 5 indicator species per division. The data were not transformed before analysis. The final plot groups are referenced by the dominant species as corresponding with previously documented and published plant association names. Plant associations that are represented by only 1-2 plots are provisional unless they have been documented and published elsewhere.

Complete bryophyte data was not available for Medicine Bow National Forest at the time of analysis, so all final analyses were run using just the vascular species plot data, pooling datasets from both national forests for both the DCA and TWINSPAN analyses to document similarities and dissimilarities.

A synopsis of the plant associations was prepared and cross-referenced to all previously published peatland plant association names in Wyoming as presented in Cooper and Andrus (1994), the results of 2002 peatland inventory on Medicine Bow National Forest, and the northern Rocky Mountains classification presented by Chadde et al. (1998). In addition, plant associations that sorted out in the first five TWINSPAN divisions of ordination were identified, and types that did not sort out but which may correspond with other vegetation classifications are in parentheses. These include the earliest semblances of wetland classifications in the region, like that of Windell et al. (1986) with its brief descriptions of communities dominated by several peatland species (*Betula glandulosa, Carex aquatilis, C. utriculata, Eleocharis pauciflora [E. quinqueflora*], and *Salix wolfii*), the information sources include Research Natural Area establishment reports, and wetland classifications from adjoining areas (e.g., Hansen et al. 1995). Copies of the detailed vegetation reports of Cooper (1990b, 1992, and 1993 as cited in USDI 1997) were not available in time for this study. These plant association names have not standardized and include permutations with moss species dominants and indicator species as well as vascular species dominants. Results are also cross-referenced to a working national vegetation classification that includes peatland plant associations as part of the NatureServe ecology plant community information resources (2003), posted electronically at: http://www.natureserveexplorer.org

Black and white orthophotos taken in 1994 were referenced at all study sites (posted at http://www.wygisc.uwyo.edu/doqq/), used in the field along with U.S.G.S. topographic maps (7.5' quads). Discrete vegetation zones were penciled onto the orthophotos for reference in the field, and then peatland boundaries and vegetation zones were digitized from the aerial photos back in the office. Vegetation mapping in the field consistently delimited physiognomic vegetation zones and "texture" differences within some zones, but is not consistently at the plant association level in its current form.

STUDY AREAS

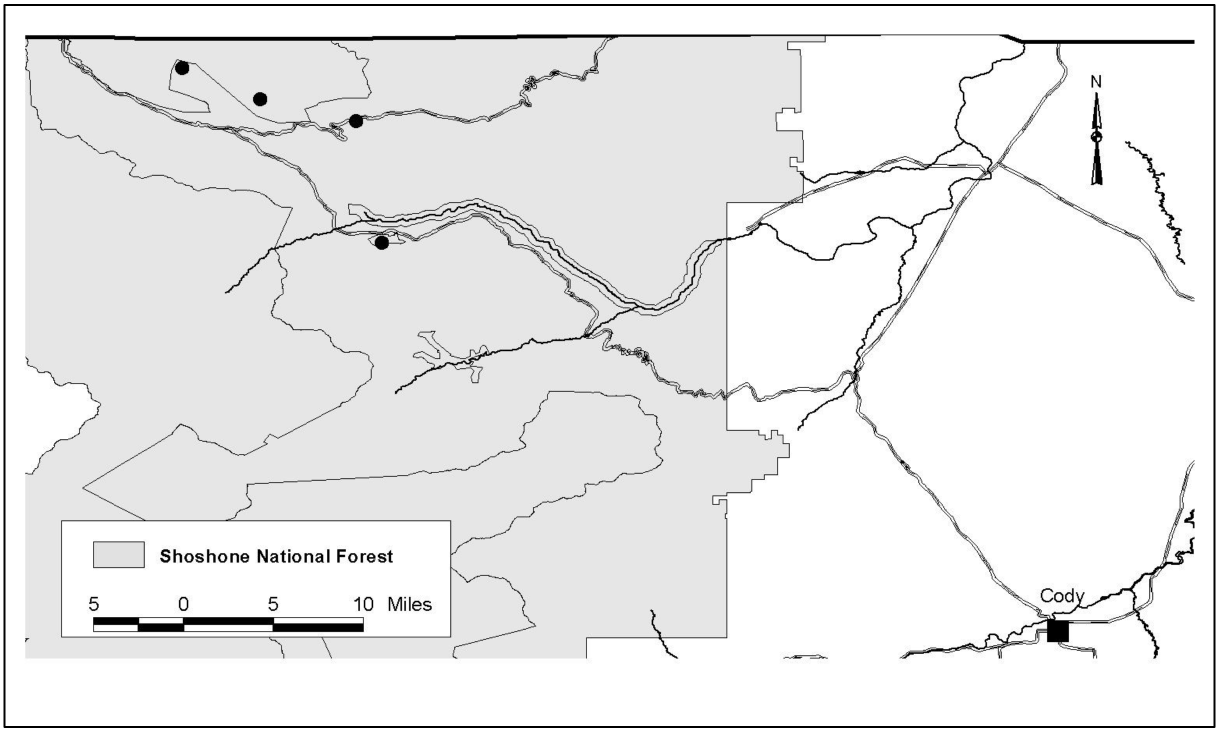

Figure 1. Map of Shoshone National Forest peatland study sites

The four study sites lie within the Clarks Fork District of Shoshone National Forest, located northwest of Cody in Park County, Wyoming (Figure 1). They are in montane and subalpine elevation zones (6,600-8,990 ft). They represent a wide range of minerotrophic peatlands, called "fens,"as found in the Rocky Mountains. "True bogs" are ombrotrophic systems and are not present in the Rocky Mountains (Chadde et al. 1998). The study sites include Swamp Lake, an extremely rich fen (pH>7), Clay Butte, inferred to represent a rich fen (pH 5.8-7), and both Lily Lake and Little Moose Lake as poor fens (pH 4.2-5.8), after the definitions of Glaser (1987). The water source(s), setting and parent material dictate over pH. Most of the Shoshone National Forest study sites are in basin settings where water comes almost exclusively from percolation in a small catchment, with exception of Swamp Lake.

Peatlands have classified based on many parameters, including water source, vegetation structure, floristics, and wetland function. It is not the purpose of this paper to discuss the classification systems in the Rocky Mountains but to cross-reference them. They are discussed by Moore and Bellamy (1974), USDI FWS (1997), and Chadde et al. (1998).

Peatlands are comprised of up to six vegetation zones that can readily be discerned on aerial photographs, corresponding with vegetation stature and pattern. All six were present among Shoshone National Forest study sites but only Swamp Lake had all six zones. They include:

Forested peatland (Spruce swamp)
Shrub peatland (grading into carr)
Graminoid peatland
Sphagnum mat, a form of graminoid peatland with floating mats in poor fen basins
Patterned peatland, a form of graminoid peatland in flow-through settings characterized by linear parallel patterns of vegetated mounds and open water pools
Sphagnum mat, a combination of graminoid peatland in a floating Sphagnum mat
Pond peatland, an open water peatland habitat in a basin setting

Only shrub- and graminoid-peatlands are generally large enough to be included as mapping units of the National Wetland Inventory in keeping with the classification system of Cowardin et al. (1977). A summary of site characteristics, including environmental attributes and vegetation zones, is presented below.

Table 1. Shoshone National Forest Peatland Study Sites and Characteristics

Site	pH	Types	Elev. (ft)	Hydrology	Size (ha)	Carr	Gramininoid	Sphagnum Mat	Spruce Swamp	Pond	Patterned peatland
Swamp Lake	6.9-7.9	Extremely rich fen	6,600	FLOW-THROUGH, and Large BASIN	137.83	X	X		X	X	X
Clay Butte	Unk.	Rich fen	8,990	Small BASIN	5.40	X	X				
Lily Lake	4.34-5.0	Poor fen	8,080	Small BASIN	5.21		X	X		X	
Little Moose Lake	4.9-5.5	Poor fen	7,980	Lake BASIN	2.58	X	X	X			

Study area documentation for each of the four sites is incorporated in the following results section.

RESULTS

Rare Species Results

The Shoshone National Forest study sites harbor 23 rare peatland plant species. There were no new populations documented, but the compilation and status update provides a synthesis for interpreting botanical significance (Table 2). The highest concentration by far is present at Swamp Lake (19 species). An additional 9 species documented at Swamp Lake and reported as rare in Wyoming (Fertig and Jones 1992) are no longer tracked as species of special concern, in part because they are protected at multiple sites or have been documented to be more common than previously known. Seven of the 23 species are designated Sensitive by Region 2 of the U.S. Forest Service (1994); a list that is undergoing revision.

The 23 rare peatland plants species at the four Shoshone National Forest sites represent over 40% of the rare peatland species in Wyoming. Of the 23 species, at least 6 of them have their largest documented numbers or extent present in the four sites compared to the rest of known occurrences in Wyoming. One of them, Red manzanita (*Arctous rubra*) is known in Wyoming only from Swamp Lake, and this is the only known site of the species in the United States south of the 49th parallel. Greenland primrose (*Primula egaliksensis*) is similarly disjunct and only known south of the 49th parallel in Colorado and Wyoming. A moss of similar distribution and possibly with habitat similarities is being added to the Wyoming plant species of concern list as part of this study, *Scorpidium scorpidioides*. Many of the other rare vascular species are separated by lesser distances of 100 miles from nearest populations, including such species as English sundew (*Drosera anglica*), at the southern limits of its distribution in the Rocky Mountain portion of its range.

Northwestern Wyoming has the highest known concentration of rare peatland species, so the high numbers in Shoshone National Forest study sites (23) compared with Medicine Bow National Forest study sites (7) is expected. The rare species richness of Swamp Lake compared with all other study sites skews the overall comparison. There is low degree of overlap between rare species in Shoshone National Forest and Medicine Bow National Forest, in part due to biogeographic differences or habitat differences. Three of the rare peatland species previously only known from northwestern Wyoming were documented in the largest of the Medicine Bow National Forest study sites for the first time in 2002.

Table 2 on the following page presents the rare plant species on Shoshone National Forest peatland study sites.

Scientific Name	**Common Name**	**G Rank**	**S Rank**	**SHOSHONE NATIONAL FOREST**				**Medicine Bow NF**
				Clay Butte	Lily Lk.	Little Moose Lk.	Swamp Lk.	
Amerorchis rotundifolia (Orchis rotundifolia)	Round-leaved orchid	G5	S1				X	
Arctous rubra (Arctostaphylos rubra)	Red manzanita	G5	S1				X	
Botrychium virginianum	Rattlesnake fern	G5	S1				X	
Carex concinna	Beautiful sedge	G4G5	S1				X	
Carex diandra	Lesser panicled sedge	G5	S1S2			X	X	
Carex leptalea	Bristly-stalk sedge	G5	S2			X	X	X
Carex limosa	Mud sedge	G5	S2	X	X	X	X	
Carex livida	Livid sedge	G5	S1	X		X		
Carex microglochin	False uncinia sedge	G5	S2				X	
Carex paupercula	Bog sedge	G5	S1					X
Carex scirpodes var. scirpiformis	Canadian single-spike sedge	G5	S1				X	
Drosera anglica	English sundew	G5	S2		X	X		
Epilobium oregonense	Oregon willow-herb	G5	S1					X
Eriophroum gracile	Slender cottongrass	G5	S1	X	X	X		X
Eriophroum viridicarinatm	Green keeled cottongrass	G5	S1				X	
Kobresia simpliciuscula	Simple kobresia	G5	S1				X	
Muhlenbergia glomerata	Marsh muhlt	G5	S1				X	
Potamogeton praelongus	White-stem pondweed	G5	S1		X	X		
Primula egaliksensis	Greenland primrose	G4	S1				X	
Salix candida	Hoary willow	G5	S2				X	X
Salix farriae	Farr's willow	G4	S2			X		
Salix myrtillifolia var. myrtillifolia	Myrtleleaf willow	G5T5	S1				X	
Salix serrisima	Autumn willow	G4	S1					X
Sparganium natans (Sparganium minimum)	Small bur-reed	G5	S1				X	
Trichophrorum pumilum (Scirpus pumilus)	Pygmy bulrush	G3Q	S1				X	X
Utricularia minor	Lesser bladderwort	G5	S2				X	

Vegetation Association Results

Detrended Correspondence Analysis (DCA) ordination of 76 peatland plots analyzes vascular plant data to show similarities between vegetation plots on Shoshone and Medicine Bow National Forests (Figure 2.) Stands that are from the same site are represented by the same symbol, and each symbol is labeled by plot number. The plot numbers 1-38 are from Shoshone National Forest (minus the two wooded plots that skewed DCA). The Shoshone National Forest study sites are in all sectors of the ordination, reflecting the range of peatland vegetation associations relative to the sample set as a whole.

Four major vegetation associations sort out in DCA ordination, two that are shared in common between Shoshone and Medicine Bow national forests, and two that are separate. The one that is present only in the Shoshone National Forest is dominated by Mud sedge (*Carex limosa*) usually with codominance by Bog buckbean (*Menyanthes trifoliata*). The Few-flowered spikerush (*Eleocharis quinqueflora)* plots of the Medicine Bow National Forest sort out in a tight cluster that is separate from those of Swamp Lake. The other two present in both Shoshone and Medicine Bow national forests include vegetation associations dominated by Analogue sedge (*Carex simulata*) and Beaked sedge (*Carex utriculata*). None of the wooded vegetation associations sorted out as distinct, and two of the 78 are so dissimilar that they were removed from analysis to eliminate skewing, including the single spruce forest (*Picea glauca*) plot on Swamp Lake and a shrub plot at Swamp Lake. The four major vegetation associations represent only 27 of the plots (Figure 2).

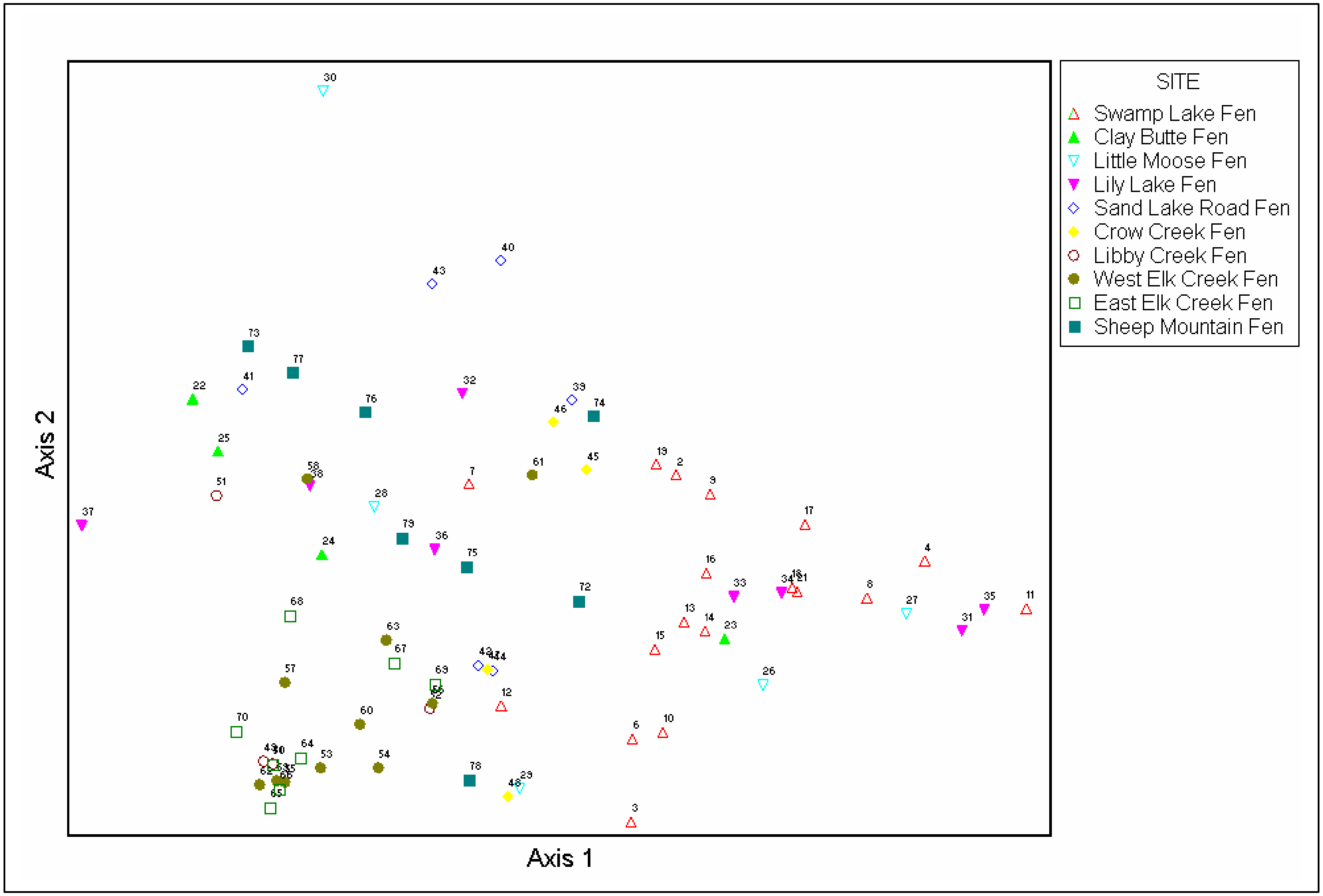

Figure 2. Detrended correspondence analysis ordination of the peatland vascular plant data from Shoshone and Medicine Bow national forests.

The four groups, starting at the top, are associations dominated by *Carex simulata*, *Eleocharis quinqueflora* of Medicine Bow National Forest, *Carex utriculata, and Carex limosa – Menyanthes trifoliata* of Shoshone National Forest.

Twinspan distinguished the same discrete peatland plant associations identified in DCA. All four peatland plant associations sorted out, also noting high dissimilarity between northern and southern (Shoshone and Medicine Bow) plots of *Carex simulata*, much like the *Eleocharis quinqueflora* plots on Medicine Bow National Forest sorted out from the scattering of *Eleocharis quinqueflora* plots on Swamp Lake that were not a natural group.

In addition to these, Twinspan delimited discrete peatland plant associations of water sedge (*Carex aquatilis*). Both *Carex aquatilis* and *C. utriculata* were also distinguished from but closely related to carr associations dominated by Plane-leaf willow (*Salix planifolia/ Carex aquatilis* and *Salix planifolia/Carex utriculata*, respectively) in ordination results. The balance of the plots did not sort out in a pattern consistent with prior classification or replicated species' dominance. It also distinguished four plant associations described elsewhere in the state or region, including plant associations dominated by *Carex lasiocarpa, Carex vesicaria, Eleocharis rostellata* and vegetation associations that are not strictly peatland dominated by *Scirpus acutus*. In addition, a peatland association dominated by *Salix wolfii* has been reported in Colorado (Windell et al. 1985) and the Centennial valley in Montana but not described. Non-peatland vegetation dominated by *Alnus incana* and *Typha latifolia* were present in Swamp Lake but not sampled.

At least two of these vegetation plant associations are circumboreal. The plant association dominated by *Carex lasiocarpa* is referred to as Slender sedge swamp (Caricetum lasiocarpae in Braun-Blanquet conventions for plant association nomenclature) by Grunig in Grunig (1994). The plant association dominated by *Carex limosa* is referred to as Mud sedge hollow (Caricetum limosae) by Grunig in Grunig (1994.)

All plots with 90-100% *Sphagnum* cover grouped together in Twinspan ordination and represented floating vegetation mats encroaching on open water with vascular plant species dominance by *Carex limosa – Menyanthes trifoliata.* The *Carex limosa – Menyanthes trifoliata* plant association also occurs separate from floating *Sphagnum* mats, under more circumneutral conditions, as sampled in three plots in Swamp Lake that grouped separate from those with Sphagnum. Peat derived from *Sphagnum* spp. is a separate order of soil taxonomy, the fibrist histosols (USDA SCS 1992), and Twinspan results suggest that the vegetation dominated by *Sphagnum* spp. is different at some level of classification from vegetation lacking Sphagnum. The three locally-dominant *Sphagnum* species included from *Sphagnum warnstorfii* (Little Moose Lake), *S. teres* (water margin of Lily Lake) and *S. angustifolium* (inner zone from the preceding on Lily Lake). *Sphagnum* species have been differentiated along water-chemistry niche parameters and these three species tend to sort out as dominants from low-to-high pH as follows: *Sphagnum angustifolium, S. teres*, and *S. warnstorfii*, respectively (Andrus 1986). Some rare peatland vascular species are found only in association with *Sphagnum* mats, like *Drosera anglica*.

The ~15 peatland plant associations on the four Shoshone National Forest study sites are presented by site in Table 3. Note: This table includes all peatland plant associations reported for Wyoming, not just those found on the study sites, cross-referenced by Cooper and Andrus (1994) and Chadde et al. (1998).

Table 3. Vegetation Associations on Shoshone National Forest Peatland Study Sites in Comparison with other Regional Peatland Classifications

Plant Associations	**Common Name**	**Structure**	**SHOSHONE NATIONAL FOREST**				**Medicine Bow NF**	**Cooper and Andrus (1994) in B-T NF**	**Chadde et al. (1998) in N. Rocky Mts.**
			Clay Butte	Lily Lk.	Little Moose Lk	Swamp Lk.			
Carex aquatilis - Viola epipsela	Water sedge	Graminoid fen	X				X	X	X
(Carex canescens)	Hoary sedge	Graminoid fen					X		
(Carex lasiocarpa)	Slender sedge	Graminoid fen		X					X
Carex limosa - Menyanthes trifoliata	Mud sedge – Bog buckbean	Graminoid fen		X	?	X		X	X
Carex simulata	Analogue sedge	Graminoid fen				X	X		X
Carex utriculata	Beaked sedge	Graminoid fen	X		X	X	X	X	X
(Carex vesicaria)	Lesser bladder sedge	Graminoid fen		X			X		
Eleocharis quinqueflora - Drepanocladus aduncus	Few-flowered spikerush	Graminoid fen				X	X	X	X
(Eleocharis rostellata)	Beaked spike-rush	Graminoid fen				?			X
Schoenoplectus acutus (Scirpus acutus)	Hardstem bulrush	Graminoid marsh				X			
Typha latifolia	Broad-leaved cattail	Graminoid marsh				X			
Alnus incana	Speckled alder	Shrub carr				X			
Betula glandulosa	Bog birch	Shrub carr					X		
Ledum glandulosum	Labrador tea	Shrub fen or carr		X					
Salix planifolia/ Carex aquatilis	Planeleaf willow / Water sedge	Shrub fen or carr	X				X		
Salix planifolia/ Caltha leptosepala	Planeleaf willow /	Shrub fen or carr						X	

Salix planifolia/ Carex utriculata	Planeleaf willow / Beaked sedge	Shrub fen or carr					X		
(Salix wolfii)	Wolf willow	Shrub fen or carr				?			X
Picea glauca "muskeg"	White spruce woodland	Stunted forested swamp					X		
Picea glauca/ Equisetum arvense	White spruce forest	Forested swamp				X			
Isoetes bolanderi - Calliergon sarmentosum	Bolander's quillwort	Submerged in pools						X	
Potamogeton perfoliatus	Clasping-leaf pondweed	Submerged in pools						X	
Sparganium angustifolium - Callitriche sp.	Narrowleaf bur-reed	Submerged in pools					?	X	
Nuphar polysepalum - Potamogeton natans	Floating pondweed	Floating in lakes						X	

Floristic Results

The collective flora documented at the Shoshone National Forest peatland sites includes 245 vascular plant species and 41 moss species (Appendix A). The latter includes the wetland and terrestrial bryophyte flora documented within Swamp Lake Botanical Interest Area by J. Elliott in 1992 (Elliott personal communication to P. Eckel.) The documented vascular flora is greater than that of the vascular flora documented in the Medicine Bow National Forest sites (Total=160), and possible explanations are the greater species richness of northern peatlands, the prior floristic inventory in Shoshone National Forest studies over the course of growing seasons, and preliminary nature of floristic documentation to date in Medicine Bow National Forest. There are 2800 different vascular taxa below the genus level in Wyoming (Dorn 2001), so this represents an estimated 8.75% of the state vascular flora. While this is not a large value, it may be relatively high for wetlands, and extremely high in the proportion of the flora that is restricted to this wetland type. At the well-documented Swamp Lake, only 14 species were added to the prior flora, almost all of these wetland species. The current site flora has 225 species, the great majority of the species collectively known from 2002 study sites.

Likewise, the state moss flora documented to date includes 315 species (Eckel 1996) so the 41 species of the study sites represent ca. 13 % of the state bryophyte flora. The documented moss flora includes many peatland obligates. One of them is known in Wyoming only from Shoshone National Forest (*Scorpidium scorpidioides* at Swamp Lake) and has been added to the Wyoming Plant Species of Concern list (2003). This species was first documented there by Joe Elliott (1992 specimens deposited at NY), and occurs in Colorado at its southernmost location in

North America (Sanderson and March 1996, as cited in USDI 1997). The Swamp Lake moss flora has 33 of 41 species.

Site Overviews

The information that follows presents a summary of site-by-site results and background information for context. It includes a concise description of location and directions, record of the survey, and expanded text on the site characteristics summarized above, accompanied by maps and annotated aerial photos. This background information provides context for the botanical and ecological synthesis that are the primary results.

Swamp Lake

County: Park
Location: T56N R106W Sec.'s 10-12 (S ½) and Sec.'s 13-15 (N ½)
Topographic map: Windy Mountain, WY (4110975)
Directions: Shoshone National Forest, ca. 14 miles west of Sunlight Creek on Hwy 296, at base (north of) Cathedral Cliffs. Turn south on a gravel road that is gated after ¼ mile at the eastern end of Swamp Lake. This road marks the eastern boundary of the Swamp Lake Botanical Area, which is bordered to the north by Hwy 296 and to the south and west by a Z bar X Ranch access road.
Field survey dates: 30 June, and parts of 1–2 July 2002
Field survey investigators: Bonnie Heidel and Scott Laursen
Elevation: 6,600 ft (2012 m)
Setting: valley drainage
pH: 6.9-7.9 (from Fertig and Jones 1992)
Size: 137.8 ha

Figure 3. Aerial overview of Swamp Lake area

Setting and wetland descriptions:

Swamp Lake is an extremely rich fen in the montane zone along the Clarks Fork of the Yellowstone River. It had a pH of 6.9-7.9 (Fertig and Jones 1992). Measurements of pH and temperature at calcareous springs were taken documenting pH readings that ranged from 8.0-8.4 (Evert 1984). It is fed by seeps and springs along the toe slopes of the cliff, springs along the central part of the wetland, surface flow entering through Corral Creek at the southwest end, subsurface flow entering through debris fans off the cliff, and via groundwater discharge that emanates from glacial deposits on the other sides. Water leaves through Rocky Ford via a highway culvert at the northeast end of the wetland and by evaporation. Swamp Lake lies among Quaternary glacial deposits that fill a portion of the valley (Love and Christianson 1985) at the base of Cathedral Cliffs that rise 2700 feet above it, above the deeply-incised canyon of the Clarks Fork valley that lies over 500 feet below it. Three discrete layers outcrop in the Cathedral Cliffs, with Pilgrim Limestone at the base, overlain by Bighorn Dolomite and capped by the volcanic Wapiti Group. Above the cliff is a Heart Mountain Fault Block and below the wetland is impervious Precambrian granitic rock that outcrops to the north (Pierce and Nelson 1971), igneous bedrock sandwiching the thick sedimentary layers. This is the only 2002 study site with a setting that is rich in calcium bicarbonates.

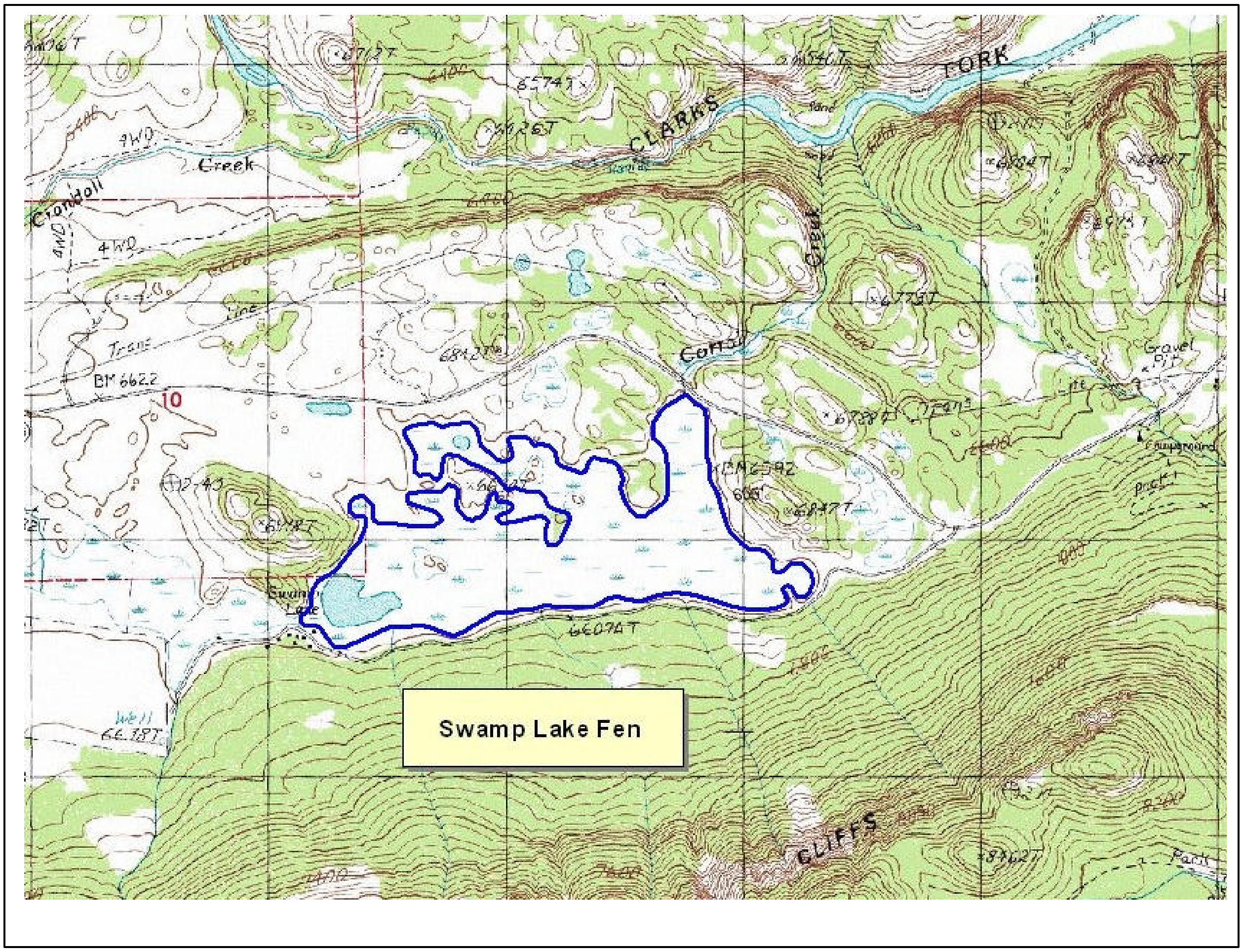

Figure 4. Map of Swamp Lake Fen (Windy Mountain Quad, 7.5')

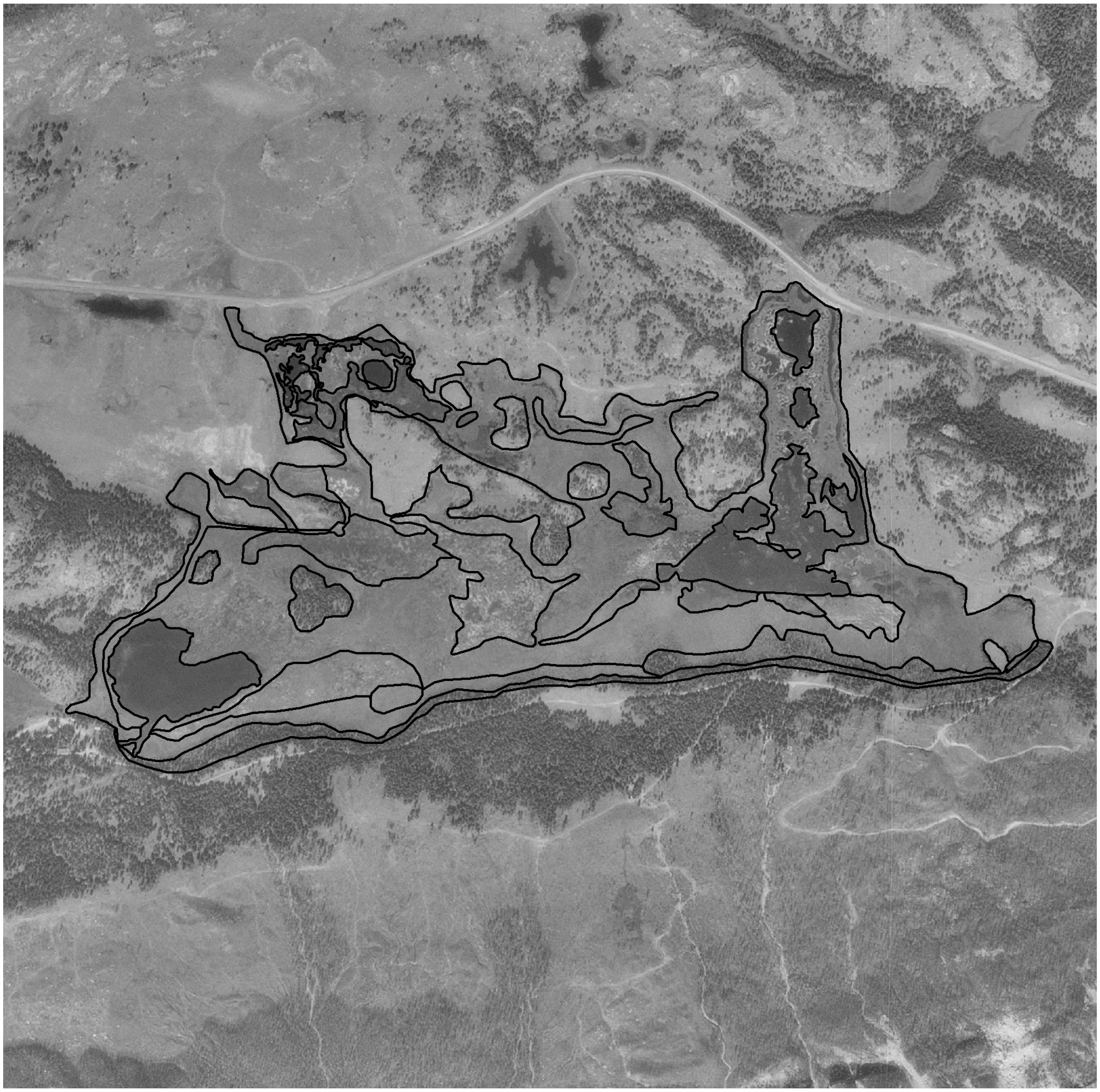

Figure 5. Vegetation zones of Swamp Lake Fen (1994 aerial photo)

Swamp Lake is an elongate east-to-west basin with an even southern margin at the foot of Cathedral Cliffs and an irregularly-lobed northern margin inset in moraine topography. It is app. 2 miles long and up to 0.6 miles across. Its expansiveness is apparent from many vantages, including a pull-off along Hwy 296, but its full array of herbaceous vegetation, involving dominants less than 2 m tall, is only apparent from the cliff slopes above.

All of the largest bands of vegetation are graminoid fen (Figure 5), with *Typha* and *Scirpus* as emergents having a mottled pattern compared to *Carex* and *Eleocharis* plant associations. There are at least four distinct islands, scattered open water zones, and a convoluted northern shoreline that contribute to irregular zonation.

One of the more unusual characteristics of the wetland basin is its net relief in elevation. At its upper limits, the White spruce (*Picea glauca)* forest is over 2 m higher than the open water zone due north of it. This relief confounds the prospect of getting a vegetation overview from eye-level. It also has microrelief that dictates over plant distribution on a small scale. The moss hummocks that rise over 0.5 meets at the base of *Picea glauca* trees within the forest and "muskeg" zones are "habitat islands" where some of the rare species like (*Amerorchis rotundifolia* syn. *Orchis rotundifolia*), Red manzanita (*Arctous rubra;* syn. *Arctostaphylos rubra*), and (*Carex leptalea)* are concentrated. Fallen logs become "nurse logs" that support vascular and nonvascular species different from surrounding peat habitat. One of the more unusual microhabitat patterns are what appear to be strings and flarks, features of extremely rich fens with series of low marl ridges and intervening pools that run parallel to the slope and have distinct floras associated with these differences in microtopography (e.g., Slack et al. 1980).

Distinguishing botanical features:

Swamp Lake is the largest known peatland with the highest number of rare peatland species known on national forests in Wyoming and Wyoming in general. In recognition of it unusual botanical features, it was designated as the Swamp Lake Botanical Interest Area in 1987. It represents an extremely rich fen, a type that is generally not well-documented in western North America with several notable exceptions (e.g., Slack 1980, Lesica 1986.) The rare species include 7 that are recognized as sensitive (USFS 1994) and 18 that are Wyoming species of concern (Fertig and Heidel 2002). Swamp Lake was reported in 1992 as harboring 28 species of concern (Fertig and Jones 1992) but nine of these have since been documented as more widespread than previously known, or presumed secure. One of these, *Arctous rubra*, is known in the state only from this site and is the only known population south of the 49th parallel. (12) are ranked "S1" generally indicating that Swamp Lake is one of five or fewer places where they occur in the state. Moreover, five of the occurrences are considered outstanding examples of large, healthy populations as indicated by the "A" rank.

Table 4. Rare Plant Species of Swamp Lake Fen

Scientific Name	Common Name	G Rank	S Rank	EO Rank
Amerorchis rotundifolia (Orchis rotundifolia)	Round-leaved orchid	G5	S1	AB
Artous rubra (Arctostaphylos rubra)	Red manzanita	G5	S1	A
Botrychium virginianu,	Rattlesnake fern	G5	S1	?
Carex concinna	Beautiful sedge	G4G5	S1	B
Carex diandra	Lesser panicled sedge			AB
Carex leptalea	Bristly-stalk sedge	G5	S2	B
Carex limosa	Mud sedge	G5	S2	A
Carex livida	Livid sedge	G5	S1	AB
Carex microglochin	False uncinia sedge	G5	S2	AB
Carex scirpodes var. scirpiformis	Canadian single-spike sedge	G5	S1	AB
Eriophroum viridicarinatm	Green keeled cottongrass	G5	S1	AB
Kobresia simpliciuscula	Simple kobresia	G5	S1	AB
Muhlenbergia glomerata	Marsh muhly	G5	S1	AB

Primula egaliksensis	Greenland primrose	G4	S1	A
Salix candida	Hoary willow	G5	S2	A
Salix myrtillifolia var. myrtillifolia	Myrtleleaf willow	G5T5	S1	BC
Scorpidium scorpidiodes	A moss	G4?	S1	A
Sparganium natans (Sparganium minimum)	Small bur-reed	G5	S1	B
Trichophrorum pumilum (Scirpus pumilus)	Pygmy bulrush	G3Q	S1	AB
Utricularia minor	Lesser bladderwort	G5	S2	B?

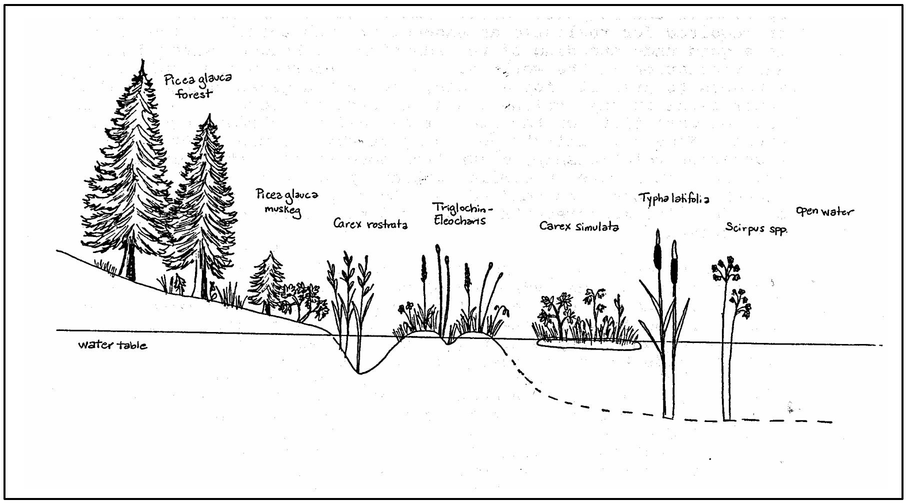

Figure 6. Schematic vegetation zone patterns at Swamp Lake Fen (to the right is North) By W. Fertig, from Fertig and Jones (1992)

The vegetation map in Fertig and Jones (1992) is presented as a vegetation overview (Figure 6). The only forested vegetation runs along the southern margin, a *Picea glauca* forest. A *Picea glauca* "muskeg" runs inside the margin of the forest on the eastern end. Fertig and Jones (1992) recognized eight wetland vegetation types, including the two *Picea glauca* types. We sampled within all but the *Alnus incana* and *Typha latifolia* types. The other four sampled types included vegetation dominated by *Carex simulata*, "*Carex rostrata*" (previously misapplied by taxonomists and ecologists in the Rocky Mountains, redetermined as *Carex utriculata*), *Scirpus acutus*, and *Eleocharis quinqueflora – Triglochin maritima.*

The zonation of vegetation types are represented schematically by Fertig (Figure 6; from Fertig and Jones 1992). In the interior of the wetland, both *Typha latifolia* and *Scirpus acutus* grow in standing water. There are two main areas of open water, rather than a continuous zone, centered at the southwestern inlet and associated with the northeastern outlet. For all of the regularity of vegetation along the southern margin, patterns are irregular and discontinuous along the northern margin where the irregular shoreline is likely to correspond with irregularities in water depth if not also hydrology. In general, the same herbaceous vegetation units are present on the north as on the southern side of Swamp Lake, except that the "*Triglochin – Eleocharis*" herbaceous vegetation is almost absent, and smooth gradients between the other four herbaceous vegetation types is not in as evenly-banded or complete series as on the south side.

In addition to these, at least three additional types were sampled in this study. The additions include semi-inundated vegetation dominated by *Carex limosa* and *Menyanthes trifoliata*, semi-inundated vegetation dominated by *Eleocharis rostellata*, and short-stature shrub communities locally dominated by *Salix wolfii* and possibly by *Betula glandulosa* with *Potentilla fruticosa.* The *Eleocharis rostellata* type is mentioned by Fertig and Jones (1992) as dominant and extensive in places but was not included among mapping units. One of the possible explanations for these unmapped types is that these are simply inclusions in the prevailing vegetation. Alternatively, there may have been vegetation shifts in the intervening decade (discussed at the end of site information). In any case, they are represented by 1-2 plots and warrant further evaluation. Submerged vegetation of open water habitat was not sampled and represents an additional type.

There is limited basis for comparing the diversity of different plant associations at Swamp Lake with that of other Wyoming peatlands, or their condition vs. other peatlands. But at least 5 of the 15 plant associations are distinct at Swamp Lake compared to the other Shoshone National Forest study sites by one or both ordination analyses: 1. *Carex limosa - Menyanthes trifoliata* occupies comparatively alkaline habitat compared to other study sites, with distinct vascular species composition and lacking floating *Sphagnum* mats. 2. *Carex simulata* is not present in other study sites. 3. *Eleocharis quinqueflora - Drepanocladus aduncus* is not present in other study sites, harbors the highest concentration of rare species at Swamp Lake, and is extremely species-rich compared to this plant association in the Medicine Bow National Forest. Aerial photos and ground-truthing show evidence of patterned peatland areas within this type, a unique microtopography that contributes to its species' diversity. 4. *Eleocharis rostellata* is not present in other study sites and has not been reported before as a peatland plant association in Wyoming apart from thermally-influenced settings. 5. *Picea glauca/ Equisetum arvense* is not known from other sites, and harbors plants like Red manzanita, a rare species that is known in Wyoming and the lower 48 only from Swamp Lake. 6. The *Picea* "muskeg" may or may not be a distinct plant association and is not known from elsewhere in Wyoming.

Table 5. Vegetation Associations of Swamp Lake

Scientific Name	**Common Name**	**Structure**	**G Rank**	**S Rank.**
Carex limosa - Menyanthes trifoliata	Mud sedge [– Bog buckbean] Herbaceous Vegetation	Graminoid fen	G4	S2?
Carex simulata	Analogue sedge Herbaceous Vegetation	Graminoid fen	G4	S2
Carex utriculata	Beaded sedge Herbaceous Vegetation	Graminoid fen	G5	S3
Eleocharis quinqueflora - Drepanocladus aduncus	Few-flowered spikerush Herbaceous Vegetation	Graminoid fen	G4	S2
(Eleocharis rostellata)	Beaked spikerush Herbaceous Vegetation	Graminoid fen	G3	-
Scirpus acutus	Hardstem bulrush Herbaceous Vegetation	Graminoid emergent	?	-
Typha latifolia	Broad-leaved cattail Herbaceous Vegetation	Graminoid emergent	G5	S?

Alnus incana/ Cornus stolonifera	Speckled alder Shrubland	Shrub carr	G3Q	SP
Picea glauca "muskeg"	White spruce woodland	Stunted wooded swamp	?	-
Picea glauca/ Equisetum arvense	White spruce forest	Forested swamp	G4	-

Evidence of alteration:

In 1987, Highway 296 was reconstructed and the Swamp Lake outlet flowing through Rocky Ford was changed by the highway culvert positioned above Swamp Lake water levels.

The following year in 1988, the forest cover of Cathedral Cliffs was killed in a crown fire, immediately upslope and throughout much of the watershed. Observations were made by George Jones in 1989 and 1992, and by Walter Fertig in 1992, that at least three debris flows entered the wetland from destabilized cliff faces above. The authors infer that the presence of numerous ravines on the slopes indicate that debris flows have been recurrent events in the past. In 1990, standing dead trees south of Swamp Lake on the lower slopes of Cathedral Cliff were logged in a salvage logging operation.

The height of the culvert above Swamp Lake water levels signified partial impoundment. The inundation phenomena were increased by accelerated runoff after crownfire, probably further enhanced by the 12-year period of above-average annual precipitation that followed. Annual precipitation totals in 1991, 1992, and 1995 as recorded nearby in Cody (USDI NOAA 2003) were 140% or more of the mean, and 1989-2000 annual precipitation totals have all been above mean annual rainfall.

The orthophotos that were intended for use in fieldwork to map vegetation were photographed in 1994, five years after the wildfire. The authors saw numerous signs that water levels have risen in Swamp Lake since the time when the photos were taken, rendering the photos undependable for mapping vegetation. First, the outlet arm was essentially 100% open water at the time of visit in 2002. In the 1994 photo, it was about 40% open water, including a discrete open water moat at the margins. It was mapped in the Fertig and Jones (1992) report as predominantly *Typha latifolia*, with open water in patterns that matched the 1994 orthophoto. In 2002, however, this arm was over 95% open water, and cattail was restricted to a sparse, narrow band a short distance off shoreline.

The 39 collecting stations of rare plants species documented by Fertig in Fertig and Jones (1992) are mapped on an enlargement of the topographic map (on file at WYNDD). They were not systematically revisited but the original collection station sites for *Carex diandra* and *Salix candida* in the outlet arm were observed to be under water at the time of visit. While the 2002 fieldwork was conducted seven weeks earlier in the growing season than the 1992 fieldwork, it appears that these portions of the Swamp Lake population have been flooded. More thorough review of rare species reported at each of the 39 collection stations is warranted to document persistence/loss of subpopulations and possible shifts. Second, in a small adjoining pothole wetland that has no inlets or outlets, there was open water in 2002 but only about 50% open water in the 1994 orthophoto. It also bears evidence of a high water mark on a shoreline boulder that is 2 feet above the current level. This pothole wetland is directly along Hwy 296, on the south side, in the SW ¼ of the NE ¼ of Sec. 11. Third, the dominance by *Menyanthes trifoliata* and *Carex limosa* that was not mapped and reported in 1992 is more of a floating vegetation association than the other rooted plant associations. It is possible that it has displaced some rooted vegetation. Fourth, the *Picea* "muskeg" with its stunted spruce has high tree mortality, particularly at the outer margins. This is consistent with interpretations that there has been prolonged inundation.

Eleocharis quinqueflora is recognized as a monodominant in other wetland classifications (Hansen et al. 1995).The prevalence of *Triglochin maritimum* associated with it may be an artifact of grazing pressure, whether by domestic or native ungulates. The latter is unpalatable and increases with grazing. The cover of *Triglochin maritimum* was high in most but not all of the plots that were taken within this mapped unit. It is possible that closer comparisons between plots and their inferred history and accessibility will help evaluate whether this is a shift under grazing/browsing or other circumstances.

A more extended comparison between upland and wetland range condition and patterns of use may also help characterize the relative contribution of native vs. domestic ungulates. At the time of visit, there had been no utilization on the southeastern sections, but …

Noxious weeds were not noted in the wetland except that Canada thistle (*Cirsium arvense)* was present as an uncommon, localized species along the wetland margin.

Clay Butte

County: Park
Location: T57N R106W Sec. 12 (NE ¼ of SW ¼)
Topographic map: Beartooth Butte WY, (4410985)
Directions: Shoshone National Forest, on Hwy 212, 8 miles east of junction Hwy 212 and Hwy 296, on the south side of the highway.
Field survey date: 2 July 2002
Field survey investigators: Bonnie Heidel and Scott Laursen
Elevation: 9360 ft (2853 m)
Setting: small basin
pH: unknown
Size: 5.4 ha

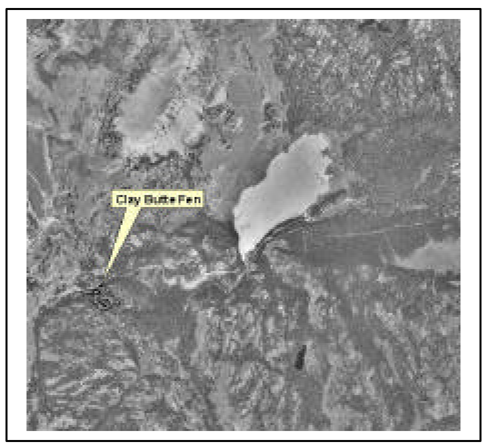

Figure 7. Aerial overview of Clay Butte area

Setting and wetland description:

Clay Butte is a rich fen in the subalpine zone in a small basin at the head of a Beartooth Creek tributary. Measurements of pH are not available, but it is inferred to have circumneutral values based on its vegetation and substrate characteristics. Its more-or-less rectangular outline has small lobes and it is about 0.2 miles long. It has a small outlet and is fed by groundwater.

The parent material is Archean gneiss possibly with a mixture of landslide and glacial till deposits (Love and Christianson 1985).

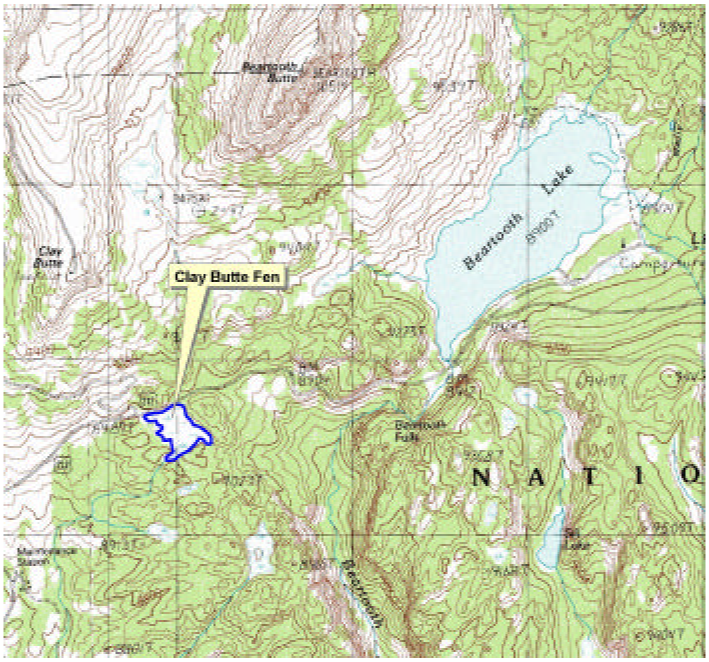

Figure 8. Map of Clay Butte (Beartooth Butte Quad, 7.5')

Figure 9. Vegetation zones of Clay Butte Fen (1994 aerial photo)

Clay Butte is surrounded by dry, open woodland. It has broad willow vegetation bands at its perimeter, particularly on northern margins, codominated by *Salix planifolia* and *S. drummondiana*. There is a small northcentral open water pool. It is covered mainly by concentric bands of graminoid vegetation, with a band of *Carex utriculata* around the open water. The most ubititious species in both graminoid and willow vegetation is *Carex aquatilis*.

Distinguishing botanical features:

Two plant species of special concern are documented from Clay Butte Fen (Table 6). The *Carex limosa* population is notably large and the species is locally dominant. In general, species diversity is greater at low elevation peatlands than at high elevations (Chadde et al. 1998) and this is consistent with species numbers documented to date at Clay Butte. There were no distinguishing arctic-alpine species present here as are sometime present in high elevation sites, but more collecting at the margins would be needed to draw this conclusion.

The species diversity in Clay Butte plots was consistently lower than other study sites. High elevation sites are characteristically not as species-rich (Chadde et al. 1998). The vegetation had a stature similar to that in montane sites and there was no other general difference.

Table 6. Rare Plant Species of Clay Butte

Scientific Name	Common Name	G Rank	S Rank	EO Rank
Carex limosa	Mud sedge	G5	S2	A
Eriophorum gracile	Slender cottongrass	G5	S1	B

The three plant associations that were documented are all shared in common with other study sites in this project. Open water habitat was not sampled.

Table 7. Plant Associations of Clay Butte

Scientific Name	Common Name	G Rank	S Rank
Carex aquatilis - Viola epipsela	Water sedge Herbaceous Vegetation	G5	S3
Carex utriculata	Beaked sedge Herbaceous Vegetation	G5	S3
Salix planifolia/ Carex aquatilis	Planeleaf willow/ Water sedge Shrubland	G5	SP

Evidence of alteration:

Highway 212 borders Clay Butte Fen on its northern margin. The highway runs between it and Clay Butte, and though it crosses a gentle grade with no discrete watercourse, the highway may impede upslope groundwater flow into the basin. Some of the highway embankment is rubble that may contribute at least low levels of sedimentation and runoff.

Water levels at the time of visit on 2 July 2002 were high, whether because of the delay in thaw at the higher elevation, or some other factor. The orange, organic-rich clayey marl that supports the rare plants was partially submerged.

Clay Butte vegetation dominated by *Carex aquatilis* and *C. utriculata* was robust, and the arcuate vegetation zones in areas dominated by these species that appeared on aerial photos were not are apparent on the ground. This is the only aerial photo zonation pattern in the coverages for the four study sites that was not discerned on the ground. It is not known whether the arcs were obscured by the robust graminoid vegetation or there were some other environmental or biological changes that might have modified the pattern.

Lily Lake

County: Park
Location: T57N R106W Sec. 5 (SW ¼ of NE ¼)
Topographic map: Muddy Creek, WY (4410986)
Directions: On Hwy 212 0.9 miles east of the Hwy 212/Hwy 296 junction, take the road heading northwest up a steep incline. In 1.5 miles take a right at the fork in the road and head 0.6 miles to Lily Lake. Hike to the northeast side of the lake and head up the drainage 0.7 miles to the west-northwest to the peatland opening holding two large open bodies of water.
Field survey date: 3 July 2002
Field survey investigators: Bonnie Heidel and Scott Laursen
Elevation: 8080 ft (2463 m)
Setting: Small Basin
pH: 4.34-5.0
Size: 5.21 ha

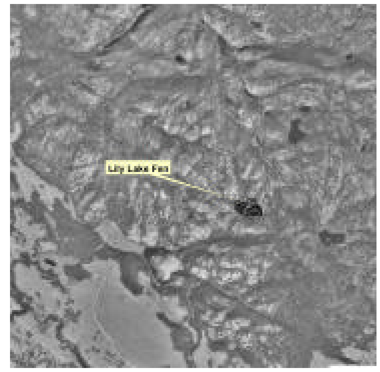

Figure 10. Aerial overview of Lily Lake area

Setting and wetland description:

Lily Lake fen is a poor fen in a small basin that has an outlet at the head of a tributary feeding into Lily Lake. It is the most acidic of peatland sites at 4.34-5.0 pH. There is at least one other smaller basin in a similar setting filled with peatland to the west. In addition, the western arm of Lily Lake that is now filled with meadow may have held peatland. The surface geology is near the interface of Archean gneiss and mixtures of landslide and glacial till deposits (Love and Christianson 1985).

Lily Lake fen lies in a shallow basin surrounded by Lodgepole pine (Pinus contorta) and open, granite outcrops. It was once a lake, though presently has less than 40% open water in two pools at east and west ends. The open water areas are encircled by floating Sphagnum mats with *Carex limosa* and *Menyanthes trifoliata*. A narrow band of willows line the perimeter, and the east end has hummocks covered by Labrador tea (*Ledum glandulosum*). The balance is covered by sedge-dominated communities that include *Carex lasiocarpa* and *C. vesicaria* among the dominants.

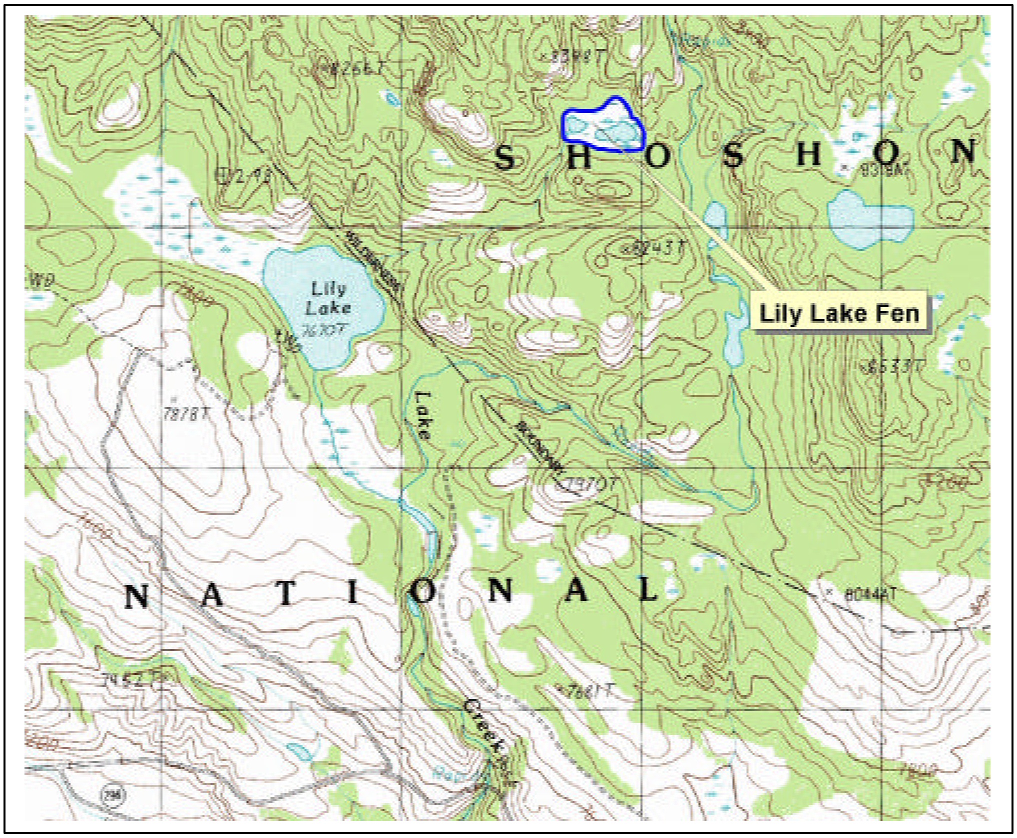

Figure 11. Map of Lily Lake Fen (Muddy Creek Quad, 7.5')

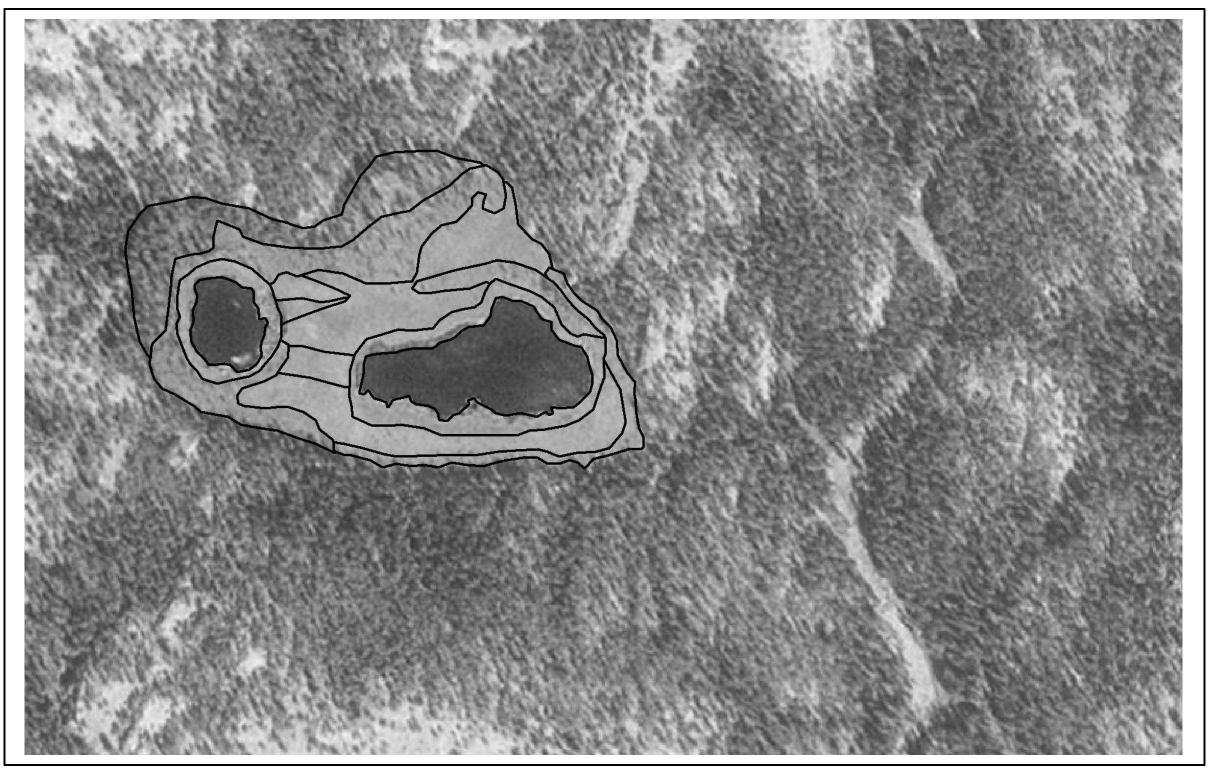

Figure 12. Vegetation zones of Lily Lake Fen (1994 aerial photo)

Figure 13. Floating *Sphagnum* mat at Lily Lake, by Walter Fertig

Figure 14. Lily Lake Fen, looking southwest, by Scott Laursen

Distinguishing botanical features:

Six plant species of special concern are documented from Lily Lake Fen (Table 8). The *Carex limosa* and *Drosera rotundifolia* populations are notably large and occupy the same habitat in the floating Sphagnum mats at the margin of open water.

Table 8. Rare Plant Species of Lily Lake

Scientific Name	Common Name	G Rank	S Rank	EO Rank
Carex diandra	Lesser panicled sedge	G5	S1S2	AB
Carex limosa	Mud sedge	G5	S2	A
Drosera rotundifolia	English sundew	G5	S2	A
Eriophorum gracile	Slender cottongrass	G5	S1	AB
Potamogeton praelongus	White-stem pondweed	G5	S1	B

Four plant associations were sampled but scattered bands and pockets of wet forest and submerged vegetation of open water was not. Most of the plant associations are not recognized in the current Wyoming system.

Table 9. Plant Associations of Lily Lake

Scientific Name	Common Name	G Rank	S Rank
Carex lasiocarpa	Slender sedge Herbaceous Vegetation	G4?	-
Carex limosa – Menyanthes trifoliata	Mud sedge (– Bog buckbean) Herbaceous Vegetation	G4	S2?
Carex vesicara	Lesser bladder sedge Herbaceous Vegetation	G4Q	-
Ledum glandulosum	Labrador tea Shrubland	?	-

Evidence of alteration:
There were no direct or indirect signs of habitat alteration.

Little Moose Lake

County: Park
Location: T58N R107W
Topographic map: Jim Smith Peak, WY (4410987)
Directions: On Hwy 212 0.9 miles east of the Hwy 212/Hwy 296 junction, take the road heading northwest up a steep incline. In 1.5 miles take a left at the fork in the road and head 1.2 miles to a left turn four wheel drive road. Take this left turn and head 2.5 miles to Little Moose Lake on the left side of the road.
Field survey date: 1 July 2002
Field survey investigators: Bonnie Heidel and Scott Laursen
Elevation: 7,980 feet (2432 meters)
Setting: Lake Basin
pH: 4.9-5.5
Size: 2.58 ha

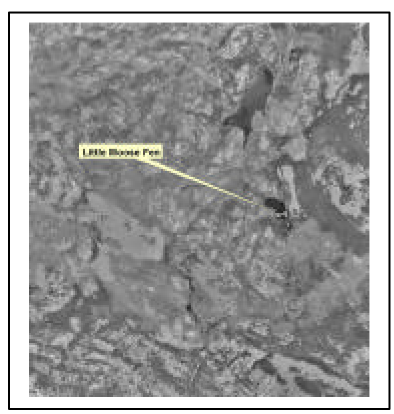

Figure 15. Aerial overview of Little Moose Lake area

Setting and wetland description:

Little Moose Lake fen is a poor fen that fills almost half of a small lake basin with no inlets or outlets. It has 4.9-5.5 pH. There are other small peatland extensions off Ivy Lake to the north. The surface geology is near the interface of Archean gneiss and mixtures of landslide and glacial till deposits (Love and Christianson 1985). It is surrounded by mesic conifer forest and parkland to the east and dry, sparsely-wooded granite knolls to the west.

Figure 16. Map of Little Moose Lake Fen (Jim Smith Peak Quad, 7.5')

Figure 17. Vegetation zones of Little Moose Lake Fen (1994 aerial photo)

Distinguishing botanical features:

Seven species of special concern are documented from Lily Lake Fen (Table 10). The *Carex limosa* and *Drosera rotundifolia* populations are notably large and occupy the same habitat in the floating Sphagnum mats at the margin of open water.

Table 10. Rare Plant Species of Little Moose Lake

Scientific Name	Common Name	G Rank	S Rank	EO Rank
Carex diandra	Lesser panicled sedge	G5	S1S2	BC
Carex leptalea	Bristly-stalk sedge	G5	S2	B
Carex limosa	Mud sedge	G5	S2	A
Drosera rotundifolia	English sundew	G5	S2	A
Eriophorum gracile	Slender cottongrass	G5	S1	AB
Potamogeton praelongus	White-stem pondweed	G5	S1	B
Salix farriae	Farr's willow	G4	S2	B

Table 11. Plant Associations of Little Moose Lake

Scientific Name	Common Name	G Rank	S Rank
Carex limosa – Menyanthes trifoliata	Mud sedge (– Bog buckbean) Herbaceous Vegetation	G3	S2?
Carex utriculata	Beaked sedge Herbaceous Vegetation	G5	S3
Salix planifolia/ Carex aquatilis	Planeleaf willow/ Water sedge Shrubland	G5	SP

Evidence of alteration:

There is a large open meadow directly above Little Moose Lake and the Lake provides a ready water source. There were possible affects of livestock trampling that were noted in the original sensitive plant surveys. Long-term livestock use may also affect water chemistry.

A gated road on the ridge above the Lake leading through the meadow is not open for public use and has no apparent affects on the Lake.

DISCUSSION

Seven botanical and ecological research tasks were presented as recommendations at Swamp Lake Special Botanical Area in the Fertig and Jones report (1992; pp. 97-99). The 2002 study provides an opportunity to re-evaluate the research needs of this site and peatlands collectively. Five core research tasks are identified.

1. Describe the qualitative changes to Swamp Lake hydrology before and after the 1988 fire by assembling all available aerial photography, and quantitatively monitor water levels as well as inflow and outflow to see if within-season fluctuations approach the magnitude of peak post-fire change.

A recommendation was presented in the earlier report to determine the relation between water depth and vegetation. In the case of Swamp Lake, water levels have oscillated and perhaps unusually so for a peatland. Evaluation of water-depth relations, if pursued, should include GPS points for re-locating the data stations, and would ideally be preceded or accompanied by the aerial photointerpretation and water depth monitoring tasks above for context. As part of this, pH readings are needed. There were no pH readings in Swamp Lake apart from measurements taken of pH and temperature at calcareous springs by Evert at 8.0-8.4 (1984). Jones and Fertig documented readings that ranged from 6.9-7.9 (1992) but it is not known if the same spring sites were measured. Is it possible that there has been a shift in pH across Swamp Lake? What were the locations, methods and accuracies of the two sets of pH readings?

There is an excellent photo of the vegetation zonation in the western end of Swamp Lake that appears in the Fertig and Jones (1992) report. It would be valuable to replicate this photo for zone-by-zone comparison, which may offer more detail than any aerial photo comparison.

A hydrological model was proposed in the 1992 monitoring report. This might be developed to give either or both of the preceding tasks more meaning, and evaluate options for watershed management if appropriate.

2. Monitor the distributions of the rare plants and qualitative information on numbers as sign of change that may be of management concern. The 39 collecting stations of rare plant species documented by Fertig in Fertig and Jones (1992) are mapped on an enlargement of the topographic map (on file at WYNDD). The imperative for systematic revisiting was not identified in planning the 2002 project. The original collection station data was reviewed upon return, and it appears that at least two species (*Carex diandra* and *Salix candida*) have been flooded in at least the northeastern "arm" of Swamp Lake where there was only open water at the shore. While there is not information on the frequency or approximate numbers at any of the collecting stations, the persistence/loss of each species where it was originally documented warrants concerted evaluation. A copy of the map with the 39 collecting stations and a table of which species were documented at which stations is provided in Appendix 4.

Other species monitoring tasks were identified, recommending a quantitative sampling of rare species if distribution data and qualitative information (above) indicate downward trend. A census or random sample would be extremely time consuming for any individual species in Swamp Lake. Systematic revisit is needed to first determine if there are habitat zones, segments of Swamp Lake, or guilds of rare species that may have suffered loss. The guidelines for effective monitoring design laid out by Elzinga et al. (1998) in identifying the question and designing the appropriate monitoring scheme are recommended.

Likewise, a demographic sampling designed was recommended contingent on census results to determine key life history stages and possible causes for decline if quantitative sampling (above) documents a downward trend is very labor intensive and is warranted only if a single species has been determined to represent a special case warranting monitoring. In the course of revisiting each of the 39 collection stations, it should be noted whether the rare species that are present show signs that fruit are aborted, plants are heavily browsed, or plants show signs of disease or stress and then the preliminary monitoring results projected to look for spatial patterns. Since peatlands are considered to represent exceptionally stable environments, downward trends in any single species are more likely to reflect habitat decline and collective downward trends in species of the same habitat. In Swamp Lake as an exceptionally high concentration of rare species, there needs to be a compelling reason to focus on a single species, and need to prioritize monitoring work as it addresses their collective, long-term conservation.

3. Expanded vegetation sampling is needed to capture microtopography patterns and contribute to standardized state wetlands classification. Species' affinities for microtopography settings have been documented in other work (Slack et al. 1980) along with the accompanying increases in species diversity (Karlin and Bliss 1984). This is particularly true for the *Picea glauca* "muskeg" and patterned peatland with *Eleocharis quinqueflora*. Cooper and Andrus (1994) used a 25 m sq plot which would capture small-scale topographic relief, and WYNDD is moving toward modified Whittaker plots (Stohlgren et al. 1995) that are compatible with this earlier work, and other vegetation documentation.

This would ideally involve the collection of additional environmental data with each vegetation plot. Some of the vegetation classification challenges faced in this study stem from the ecological amplitude of common species. For example, the *Carex limosa – Menyanthes trifoliata* plant association occurs in both the extremely rich fen site (Swamp Lake) and in the poor fen sites (Lily and Little Moose Lakes). In the latter sites, it occupies floating *Sphagnum* mats with distinguishing vascular flora as well as bryophyte flora. This broad ecological amplitude of the codominant vascular species has been reported before in the literature, and the highly specialized habitat where it is codominant with *Sphagnum* mosses. The addition of pH and conductivity data would advance this portion of the classification. Similarly, the *Eleocharis quinqueflora* plots of the extremely rich Swamp Lake sorts out separately from the *Eleocharis quinqueflora* plots of the rich fens in the Medicine Bow National Forest with their very different and smaller floras. The addition of pH and conductivity data would also advance this portion of the classification. As previously stated in Fertig and Jones (1992), measurement of water depth to determine relationships with vegetation zones would also be valuable. Water depth and peat depth measurements might also be collected.

More data, coordination, collaboration and critical review are needed as new peatland types are described. Consistency or cross-walks in peatland naming conventions needed to be developed as it involves nonvascular species, indicator species, and natural conditions. In a special case, two of the dominant vascular plant species reported in the previous classification for the Bridger-Teton National Forest in Wyoming (Cooper and Andrus 1994) are not known from the state flora (Dorn 2001) though the *Viola epipsela* has been reported in Hulten (1968) from Wyoming. There has not been review of Colorado State University specimens as a first step in accepting these new plant associations.

4. Systematic inventory using remote sensing is needed if peatland resources are to be addressed collectively. Remote-sensing and ground-truthing of histosol mapping units are being initiated in Medicine Bow National Forest in such a project that is to help provide protocol and context for such work in Shoshone National Forest. This might be pursued on a small-scale testing different signatures in select areas, or systematically inventorying large areas where peatlands are recurrent on the landscape.

The most effective way to expand the vegetation sampling design and peatland classification (above) may be to expand the sample size by identifying more sites and prioritizing/stratifying among them.

5. Finally, it is possible to pursue phytogeographic analyses with robust floristic data from Swamp Lake and growing floristic datasets from peatlands elsewhere in Wyoming. The results of this study and the parallel Medicine Bow National Forest study compare reasonably well with the floristic documentation of peatlands of the northern Rocky Mountains (Bursik 1990) where 327 vascular species were documented in 58 families. Robust floristic datasets have been used for comparing peatland floras between sites (Lesica 1986), within regions and across regions (Bursik 1990) using Sorenson's Index of Similarity. The information compiled to date from the five study sites could be used for preliminary comparisons but only the Swamp Lake flora is close to complete. At Swamp Lake, only 14 species were added to its flora in 2002 (Total=225). They did not consistently fall into any taxonomic group or habitat, though several wetland grasses and submerged aquatics were among the added species. While the Swamp Lake floristic checklist includes upland species and is the only 2002 study site that has inclusion of upland species, the great majority are wetland species and the checklist could be revised for this purpose.

The emerging picture of peatland resources on Shoshone National Forest might be used for more intense site studies, more extensive systematic inventories, or related efforts to evaluate watershed, wildlife and other values associated with peatlands. Two of the most pressing research tasks above are focused exclusively on Swamp Lake, where the status and trend of one of the state's most diverse peatland sites and its significant biological resources are in question.

The compiled information in this report represents a wide array of peatland types but does not necessarily represent the full array on Shoshone National Forest. Alpine sites were not considered. Preliminary review of histosol mapping on Shoshone National Forest indicates high accuracy and a potential tool for systematic inventory using soils mapping, in addition to peatland indicator species information and aerial photointerpretation, for broad systematic inventory.

LITERATURE CITED

Andrus, R.E. 1986. Some aspects of *Sphagnum* ecology. Can. J. Bot. 64: 416-426.

Barber, K.E. 1993. Peatlands as scientific archives of past biodiversity. Biodiversity and Conservation 2: 474-489.

Bursik, R. 1990. Floristic and phytogeographic analysis of northwestern Rocky Mountain Peatlands, U.S.A. M.S. Thesis. University of Idaho, Moscow.

Chadde, S. W., P. L. Hansen, and R.D. Pfister. 1988. Wetland plant communities of the northern range, Yellowstone National Park. Final contract report. School of Forestry, University of Montana, Missoula.

Chadde, S. W., J.S. Shelly, R.J. Bursik, R.K. Moseley, A.G. Evenden, M. Mantas, R. Rabe and B. Heidel. 1998. Peatlands on national forests of the Northern Rocky Mountains: ecology and conservation. Gen. Tech. Rep. RMRS-GTR-11. Ogden, UYT: USDA Forest Service, Rocky Mountain Research Station.

Cooper, D. J. 1990a. An evaluation of the effects of peat mining on wetlands in Park County, Colorado. Unpublished report prepared for Park County, Colorado.

Cooper, D. J. 1990b. Ecological studies of wetlands in South Park, Colorado. Classification, functional analysis, rare species inventory and the effects of removing irrigation. Report prepared for Park County, Colorado.

Cooper, D. J. 1993. Ecological studies of wetlands in South Park, CO. Classification, functional analysis, rare species inventory and the effects of removing irrigation. Report prepared for Park County, CO.

Cooper, D. J. 1993. The vegetation and flora of High Creek Fen, South Park, Colorado. Preliminary report to Colorado Nature Conservancy, Boulder.

Cooper, D.J. and R.E. Andrus. 1994. Patterns of vegetation and water chemistry in peatlands of the west-central Wind river Range, Wyoming, U.S.A. Can. J. Bot. 72: 1586-1597.

Cowardin, L., V. Carter, F. Golet, and E. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, FWS/OBS-79-31.

Dorn, R. D. 1997. Rocky Mountain Region Willow Identification Field Guide. Publication R2-RR-97-01. USDA Forest Service Rocky Mountain Research Station, Fort Collins, CO.

Dorn, R.D. 2001. Vascular Plants of Wyoming, third edition. Mountain West Publishing, Cheyenne, WY.

Eckel, P. 1996. Synopsis of the mosses of Wyoming. Great Basin Naturalist 56(3): 197-204.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. BLM Technical Reference 1730-1. Denver, CO.

Evert, E.F.. 1984. A research natural area proprosal and suitability investigration report for the Cathedral Cliffs wetland complex. Unpublished report to U.S. Forest Service.

Farnham, R. S. 1978. Wetlands as energy sources. Pp. 661-672. *In*. Greeson, P. E., J. R. Clark and J. E. Clark, eds. Wetland Functions and Values: The State of our Understanding. National Symposium on Wetlands. American Water Resources Association, Minneapolis, MN.
Fertig, W. 1998. The status or rare plants on Shoshone National Forest: 1995-97 survey results. Report prepared by the Wyoming Natural Diversity Database, Laramie.

Fertig, W. and G. Jones. 1992. Plant communities and rare plant species of the Swamp Lake Botanical Area, Clark's Fork Ranger District, Shoshone National Forest. Unpublished report to Shoshone National Forest. Wyoming Natural Diversity Database, Laramie.

Fertig, W. and S. Markow. 2001. Guide to the willows of Shoshone National Forest. USDA Forest Service General Technical Report RMRS-GTR-83. Rocky Mountain Research Station.

Fertig, W. and B. Heidel. 2002. Wyoming plant species of special concern. Unpublished list by the Wyoming Natural Diversity Database, Laramie.

Glaser, P. H. 1987. The ecology of patterned boreal peatlands of northern Minnesota: a community profile. Report 85 (7.14). Washington, DC. U.S. Fish and Wildlife Service. 98 pp.

Grunig, A. (ed.) 1994. Mires and Man. Mire Conservation in a Densely Populated Country – the Swiss Experience. Symposium of the International Mire Conservation Group (IMCG) to Switzerland 1992. Birmensdorf, Swiss Federal Institute for Forest, Snow and Landscape Research. F. Fluck-Wirth, International Booksellers. Teufen, Switrzerland.

Hansen, P., K. Boggs, R. Pfister, and J. Joy. 1995. Classification and management of Montana's riparian and wetland sites / Montana Forest and Conservation Experiment Station, School of Forestry, The University of Montana, [1995] xvi, 646 p.

Heidel, B and S. Laursen. 2003. Botanical and Ecological Inventory of Peatland Sites on the Medicine Bow National Forest. Wyoming Natural Diversity Database, Laramie, WY.

Hulten, E. 1968. Flora of Alaska and neighboring territories. Stanford Univ. Press, Palo Alto, CA.

Hurd, E.G., N.L. Shaw, J. Mastroguiseppe, L.C. Smithman and S. Goodrich. 1998. Field Guide to Intermountain Sedges. Gen. Tech. Report RMRS-GTR-10. USDA Forest Service Rocky Mountain Research Station, Ogden, UT.

Ivanov, K.E. 1981. Water movement in mirelands. Academic Press, New York, NY.

Jankovsky-Jones, M., 1995. M., G. Jones, and W. Fertig. 1995. Ecological assessment for the potential Standard Park and Bogs Research Natural Area within the Medicine Bow National Forest, Carbon County, Wyoming. Unpublished report prepared by the Wyoming Natural Diversity Database, Laramie.

Jankovsky-Jones, M., G. P. Jones, and W. Fertig. 1996. Ecological evaluation of the potential Sheep Mountain Research Natural Area within the Medicine Bow National Forest, Albany County, Wyoming. Unpublished report prepared for the Medicine Bow National Forest by the Wyoming Natural Diversity Database, Laramie WY. 103 pp.

Jeglum, J.K. 1971. Plant indicators of pH and water level in peatlands at Candle Lake, Saskatchewan. Can. J. Bot. 49:1661-1676.

Johnston, B.C. 1987. Establishment report, Swamp Lake Botanical Area. USDA Forest Service, Rocky Mountain Region, Lakewood, CO.

Johnston, B.C. 2001. Field Guide to Sedge Species of the Rocky Mountain Region. Publication R2-RR-01-03. USDA Forest Service Rocky Mountain Research Station, Fort Collins, CO.

Jones, G. and W. Fertig. 1999. Ecological evaluation of the potential Lake Creek Research Natural Area within the Shoshone National Forest, Park County, Wyoming. Prepared for the Shoshone National Forest, Wyoming Natural Diversity Database, Laramie.

Lawton, E. 1971. Keys of the Identification of the Mosses of the Pacific Northwest. Hattori Botanical Lab, Japan.

Lesica, P. 1986. Vegetation and flora of Pine Butte Fen, Teton County, Montana. Great Basin Naturalist 46:22-32.

Love, J. D. and A. C. Christiansen. 1985. Geologic Map of Wyoming. US Geological Survey.

Moore, P.D. and D. Bellamy. 1974. Peatlands. Springer-Verlag., New York.

NatureServe. 2003. Explorer – an encyclopedia of life. Plant, animal, and plant community data posted at www.natureserveexplorer.org, Arlington, VA.

Pennak, R. W. 1963. Ecologcal and radiocarbon correlations in some Colorado mountain lake and bog deposits. Ecology 44(1): 1-15.

Sanderson, J. and M. March. 1996. Extreme rich fens of South Park, Coloado: Their distribution, identification, and natural heritage significance. Prepared for: Park County, the Colorado Department of Natural Resources, and the U. S. Environmental Protection Agency. Colorado Natural Heritage Program, Fort Collins, CO.

Stohlgren, T.J., M. B. Falkner, and L. D. Schell. 1995. A Modified-Whittaker nested vegetation sampling method. Vegetatio 117:113-121.

Sturges, D. L. 1967. Water quality as affected by a Wyoming mountain bog. Water Resources Research 3(4): 1085-1089.

Sturges, D. L. 1968a. Hydrologic properties of peat from a Wyoming mountain bog. Soil Science 106:262-264

Sturges, D. L. and R. E. Sundin. 1968. Gross alpha and beta radiation in waters at a Wyoming mountain bog. Water Resources Research 4(1): 159-162.

Verry, E. S. and D. H. Boelter. 1978. Peatland hydrology. Pp. 389-402. *In*. Greeson, P. E., J. R. Clark and J. E. Clark, eds. Wetland Functions and Values: The State of our Understanding. National Symposium on Wetlands. American Water Resources Association, Minneapolis, MN.

Vitt, D. H., J. E. Marsh and R. B. Bovey. 1988. Mosses, Lichens and Ferns of Northwest North America. Lone Pine Press, Edmonton, Alberta.

Windell, J. T., B. E. Willard, D. J. Cooper, S. Q. Foster, C. F. Knud-Hanson, L. P. Rink, and G. N. Kladis. 1986. An ecological characterization of Rocky Mountain montane and subalpine wetlands. U. S. Fish and Wildlife Service, Biological Report 86(11).

USDA Soil Conservation Service. 1992. Keys to Soil Taxonomy. Soil Management Support Services Tech. Monograph No. 19. Pocahantas Press, Inc. Blacksburg, VA.

USDI Fish and Wildlife Service. 1998. Regional policy on the protection of fens. Unpublished memo from Mary Gessner, Region 6 Director, sent to project leaders for ecological services, refuges and wildlife, and fish and wildlife management assistance in Region 6.

Zielinski, R. A. and A. L. Meier. 1988. The association of uranium with organic matter in Holocene peat – an experimental leaching study. Applied Geochemistry 3:631-643.