Kootenai National Forest Peatlands: Description and Effects of Forest Management

Prepared for:
The Kootenai National Forest

By:
W. Marc Jones

Montana Natural Heritage Program
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ABSTRACT

I examined the relationship between upland land use and peatland vegetation in the Kootenai National Forest. Specifically, I evaluated the effects of human disturbances (timber harvesting and road building) in different sized buffers around peatlands on peatland plant diversity. The buffer sizes evaluated were 50, 100, 150, and 200-m from peatland boundaries. I compared the effects of land use on vegetation both directly and indirectly by examining the relationship between buffer integrity and soil nutrient levels. Potential shifts in species composition were assessed by examining interactions between the abundance of a competitively dominant sedge, *Carex utriculata*, and both soil nutrient concentrations and plant diversity. The average width of intact buffers was found to be negatively associated with NH_4 concentrations at distances up to 100 m and positively associated with vascular plant diversity at distances of up to 50 m. The abundance of *Carex utriculata* was positively associated with the increased concentration of NH_4 and negatively associated with vascular plant diversity. Rare species were associated with high vascular plant diversity. These results suggest that existing buffers are inadequate in ameliorating increased nutrient inputs associated with human land uses. This may have adverse consequences for peatland-associated rare plants.

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INTRODUCTION

Peatlands are generally nutrient-poor wetlands characterized by wet, organic substrates comprised of partially decomposed plant material (Vitt 1994). Due in part to saturated substrates, plant productivity exceeds decomposition in these systems, and peat may accumulate to depths in excess of 30-40 cm (Vitt 1994). Given the exceptional water-holding capacity of organic substrates, peatlands are very stable and may persist for centuries (Chadde et al. 1998). Peatlands are distinctive in that they are one of the only ecosystems largely dominated by bryophytes (Keddy 2000, Vitt 2000).

Although abundant in northern latitudes, peatlands are uncommon in Montana, largely due to unfavorable climatic conditions (Chadde et al. 1998). Peatlands support a large number of rare taxa and are consequently of great conservation value. Forty plant species of concern, constituting 9% of the state's rare flora, are associated with peatlands, as is one animal, the Northern Bog Lemming (*Synaptomys borealis*) (Heidel 2001, Carlson 2003). Of the 48 species on the Kootenai National Forest sensitive plant list, 20 species (42%) are associated with peatlands, with 12 of those species entirely restricted to peatland habitats (Table 1).

Two types of peatlands are generally recognized, fens and bogs. Fens receive groundwater and/or surface water from surrounding uplands, whereas bogs receive hydrologic and nutrient inputs primarily from atmospheric deposition (Bridgham et al. 1996). Fens are further classified as being either poor or rich. Poor fens are characterized by a bryophyte layer dominated by *Sphagnum* moss and low surface water pH (4.0-5.5), likely due to limited inputs of minerotrophic surface or groundwater and acidification caused by *Sphagnum* (Vitt 1994). In Montana, species characteristic of poor fens include *Carex lasiocarpa* (Slender Sedge), *Carex limosa* (Mud Sedge), *Dulichium arundinaceum* (Dulichium), *Sphagnum angustifolium*, *S. fuscum*, and *S. subsecundum* (Chadde et al. 1998). Rich fens, in contrast, are moderately to strongly alkaline (surface water pH 5.5-7.0). Rich fens with surface water pH > 7.0 are often referred to as extreme rich fens (Vitt 1994). Rich and extreme rich fens were grouped for the purpose of this study. Rich fens tend to have greater bryophyte and vascular plant diversity than poor fens (Vitt et al. 1995b, Chadde et al. 1998). Bryophytes in rich fens are dominated by true mosses, mostly of the family Amblystegiaceae (*sensu lato*) (Vitt 1994). Characteristic species of Montana rich fens include *Carex lasiocarpa*, *Carex utriculata* (Beaked Sedge), and *Carex flava* (Yellow-Green Sedge) and the mosses *Aulacomnium palustre*, *Campylium stellatum*, and *Scorpidium cossonii* (Chadde et al. 1998). Rich fens often have a shrub component dominated by *Betula glandulosa* (Bog Birch) and *Salix candida* (Hoary Willow). The terms rich and poor can be misleading, as they refer to pH-alkalinity and base cation (especially calcium and magnesium) gradients and do not necessarily correspond to nutrient availability (Vitt 1990, Vitt et al. 1995a).

Most Montana peatlands are either flow-through or basin-fill wetlands. Except for bog-like microsites, such as raised *Sphagnum* mounds within some poor fens, bogs do not occur in Montana (Chadde et al. 1998). As fens, Montana peatlands receive hydrologic and nutrient inputs from their surrounding uplands, and upland land uses that alter hydrologic or nutrient regimes can affect the functionality and biological integrity of peatlands (Siegel 1988, Chadde et al. 1998). Much of northwestern Montana, which has the greatest abundance of peatlands in the state, has been highly fragmented by timber harvesting and associated road building (Figure 1). These activities can alter hydrologic fluxes, nutrient inputs, and sedimentation rates and can facilitate the spread of invasive exotic species (Bormann and Likens 1981, Saunders et al. 1991, Walbridge and Lockaby 1994, Bursik and Moseley 1995, Maul et al. 1999, Parendes and Jones 2000, Trombulak and Frissell 2000). Changes in these factors have been shown to affect plant species diversity in peatlands and other wetlands (Panno et al. 1999, Weltzin et al. 2000, Drexler and Bedford 2002, Werner and Zedler 2002).

To minimize these potential adverse effects, the U.S. Forest Service and State of Montana require that buffers be left around wetland and riparian areas, although some timber harvesting is still allowed within these buffers (U.S. Forest Service 1991). The buffer requirement for a typical peatland is from 8 to 30 m (U.S. Forest

Table 1. Peatland-associated plants listed on the Kootenai National Forest sensitive plant list. Obligate (OBL) species are entirely restricted to peatlands; facultative (FAC) species occur in peatlands but may also be found in other habitats.

	MTNHP Rank		Peatland
Species	**State**	**Global**	**Affinity**
Vascular Plants			
Amerorchis rotundifolia	S2S3	G5	FAC
Betula pumila	SR	G5	FAC
Brasenia schreberi	S2	G5	FAC
Carex chordorrhiza	S2	G5	OBL
Carex livida	S3	G5	OBL
Carex magellanica ssp. *irrigua* (=*Carex paupercula*)	S3	G5	OBL
Carex prairea	S2	G5?	OBL
Carex rostrata	S1	G5	OBL
Cypripedium parviflorum	S3	G5	FAC
Cypripedium passerinum	S2	G4G5	FAC
Drosera anglica	S2	G5	OBL
Drosera linearis	S1	G4	OBL
Dryopteris cristata	S2	G5	FAC
Epipactis gigantea	S2	G4	FAC
Eriophorum gracile	S2	G5	OBL
Scheuchzeria palustris	S2	G5	OBL
Scirpus subterminalis	S2	G4G5	FAC
Utricularia intermedia	S1	G5	OBL
Mosses			
Meesia triquetra	S2	G5	OBL
Scorpidium scorpioides	S2	G4G5	OBL

Service 1991). Even narrow buffers have been shown to be effective at reducing sediment and nutrient loadings (reviewed in Castelle et al. 1994, Desbonnet et al. 1994); however, other studies have shown wetland plant and animal diversity to be negatively associated with land use and road density at much greater distances. Findlay and Houlahan (1996) reported significant negative relationships between road density and richness of birds, herpetofauna, and plants and positive relationships between proportion of forest cover and richness of herpetofauna and mammals. Both these associations were found at distances of up to 2,000 m from study wetlands. Mensing et al. (1998) reported a negative association between the diversity of shrub carr vegetation and land use at distances up to 1,000 m from wetland sites.

Although hydrology is often considered the primary factor influencing wetlands, fertility is also an important factor (Keddy 2000). Previous research has demonstrated positive associations between nutrient availability and plant productivity and negative associations between productivity and species richness in wetlands (reviewed in Bedford et al. 1999). Thus increased nutrient availability may lead to reduced diversity, possibly through the increased dominance of competitive nitrophilous species (Wilson and Keddy 1986, Verhoeven et al. 1996). Large-scale studies have also shown that the occurrence of rare species is highly associated with infertile and species-rich sites (Moore et al. 1989, Wisheu and Keddy 1992, Venterink et al. 2001).

It is likely that upland land use changes affect hydrological and biogeochemical processes in peatlands at distances greater than those of existing buffers. The primary purpose of this study was to examine the effects of land use within different sized buffers on peatland vegetation. Specifically, I examined associations between land use, soil nutrient levels, and the diversity of bryophytes and vascular plants.

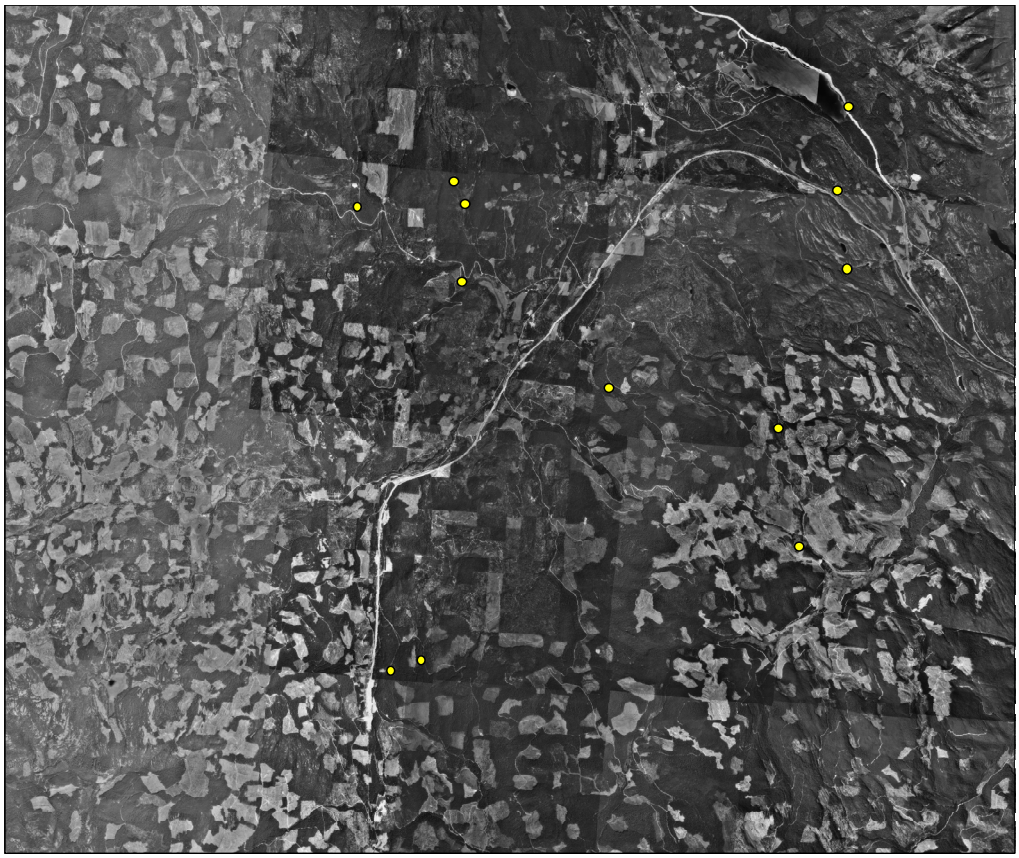

Figure 1. Representative portion of the study area showing pervasive forest fragmentation. Imagery is 1990 and 1991 1:24,000 U.S. Geological Survey Digital Orthophoto Quadrangles.

I evaluated the following hypotheses: (1) that increased timber harvest and road densities in buffers will increase soil nutrient levels and thereby decrease plant diversity in peatlands, (2) that increased fertility will increase the abundance of competitively dominant species, and (3) that the occurrence of rare species will be positively associated with high plant species diversity. The second assumption was tested by examining the relationships between the competitively dominant sedge *Carex utriculata* (Gaudet and Keddy 1995) and soil nutrient levels and plant diversity. I also examined the relationship between peatland size and plant species richness.

METHODS

Study Area

Peatlands surveyed for this study were restricted to the Kootenai National Forest in northwestern Montana (Figure 2). Surveyed sites included both rich and poor fens. Poor fens are associated with Belt formation metasedimentary quartzite, siltite, and argillite that underlie most of the study area (Kuennen and Nielsen-Gerhardt 1995). Rich fens occur mostly in and around the Rocky Mountain Trench in areas underlain by calcareous glacial till (Kuennen and Nielsen-Gerhardt 1995).

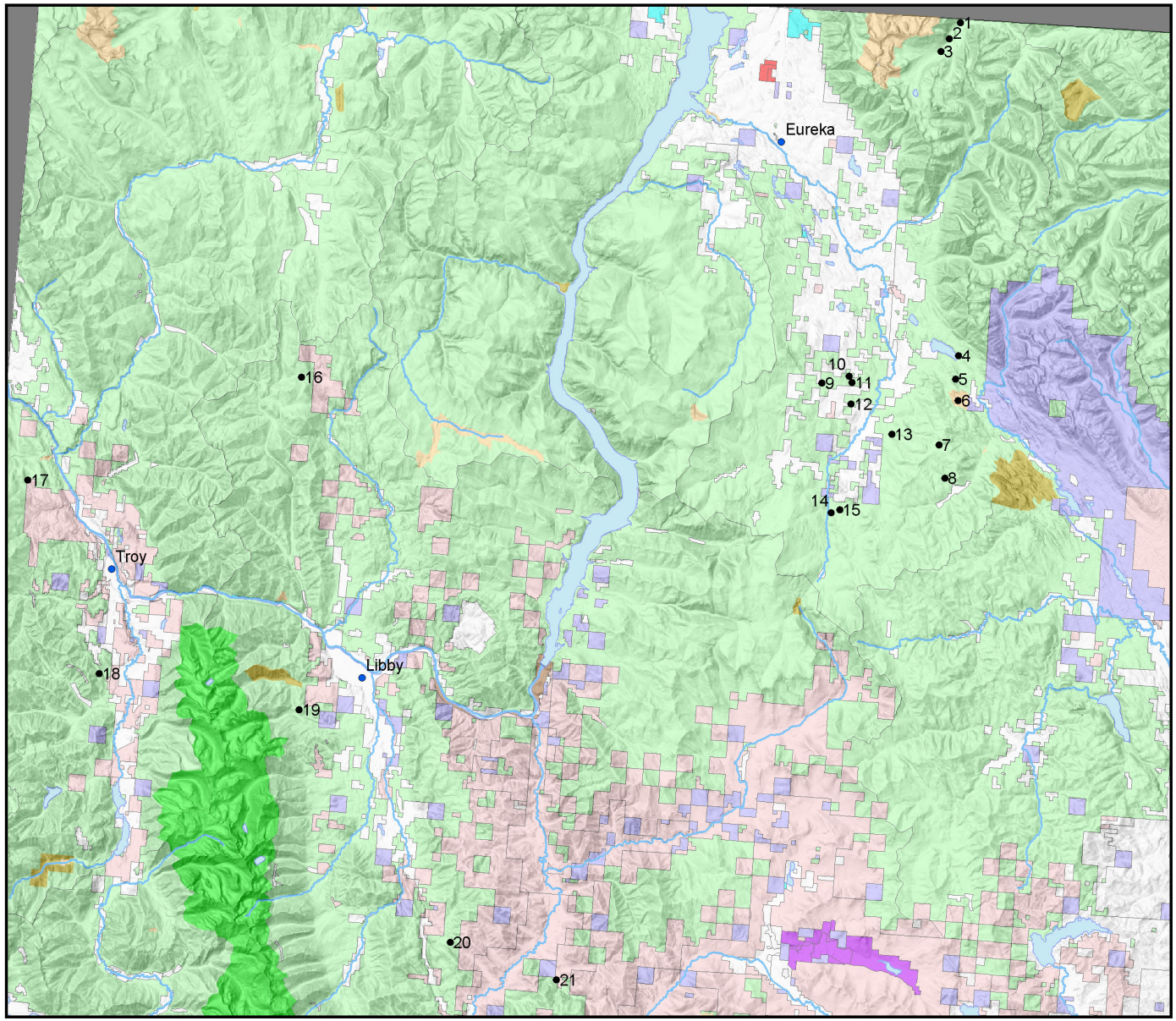

Figure 2. Study Area

Legend

Land Ownership

- U.S. Forest Service
- U.S. Fish & Wildlife Service
- Corps of Engineers
- State Trust
- MT Fish, Wildlife & Parks
- Plum Creek Timber Company
- The Nature Conservancy
- Other private

Management Designations

- Research Natural Area
- Special Interest Area
- Wilderness
- Towns
- Surveyed Peatlands

Peatland Sites

1. Border Fen
2. Wigwam Beaver
3. Wigwam Carr
4. Little Dickey Fen
5. Rattlebone Fen
6. Hidden Lake
7. Louis Lake
8. Paul Creek Fen
9. Little Edna Fen
10. Little Ivor Fen
11. Ivor Creek Fen
12. Edna Creek Fen
13. Magnesia Fen
14. White Creek Fen
15. Little White Fen
16. Rainbow Lake
17. Ruby Fen
18. Grouse Lake
19. Flower Lake
20. Tepee Lake
21. McKillop Fen

Site Selection

Locations of peatlands on the Kootenai National Forest were identified based on previous inventory work (Chadde et al. 1998, T. Spribille, pers. comm.). Twenty-one sites (nine poor fens and 12 rich fens) were selected from the 39 peatlands known to occur on the Kootenai National Forest. These sites were selected to represent both pH-alkalinity and human disturbance gradients. All sites were sampled in July and August of 2003. Site elevations ranged from 900 to 1,500 m.

A subset of eight of the 12 rich fens was selected to evaluate relationships among land use, soil nutrient concentrations, and plant diversity. These sites were all flow-through rich fens (pH ranged from 5.9 to 7.6) occurring between 1,000 and 1,300 m elevation.

Vegetation Sampling

At each site, vegetation was sampled using 50-m^2 plots. Plots were placed subjectively but without preconceived bias to characterize representative plant communities (Mueller-Dombois and Ellenberg 1974). All vascular plant and bryophyte species were recorded to trace and species abundance was recorded using cover classes similar to those used in U.S. Forest Service ECODATA methods (Bourgeron et al. 1992). Cover class midpoints were used to calculate abundance measures. Two measurements of species diversity were calculated: species richness (alpha diversity (Whittaker 1972)), calculated as the number of species per 50-m^2 plot, and the Shannon-Wiener Index (H´), calculated as $-\Sigma\ p_i \log p_i$, where p_i is the percent cover of species *i*. Although not as easily interpretable as species richness, H´ is useful in that it takes into account both richness and evenness of species. Diversity measures were calculated separately for bryophytes and vascular plants.

Nomenclature follows Kartesz (1999) for vascular plants, Anderson (1990) and Anderson et al. (1990) for mosses, and Stotler and Crandall-Stotler (1977) for liverworts. Exceptions are three genera where I follow the Flora of North America: *Betula* (Furlow 1997), *Paludstriella* (=*Cratoneuron* in part, Hedenäs 2000a), and *Scorpidium* (=*Limprichtia* in part, Hedenäs 2000b).

Water and Soil Chemistry

At each plot, pH was recorded using a Horiba U-10 water quality checker (Horiba Ltd., Kyoto, Japan). Readings were taken from soil pore water (depth to water table varied from 0 to 40 cm). At 12 plots in eight sites, soil samples were collected for chemical analysis. Sites selected for soil analysis were chosen to encompass a human disturbance gradient. To reduce variability caused by pH-alkalinity gradients, soil sampling was restricted to ecologically similar rich fens. Samples were collected from the upper 15 cm of soil and stored in coolers maintained at or below 4°C until processed. Energy Laboratories, Inc., Helena, Montana, analyzed soil samples. Nitrate (NO_3) and ammonium (NH_4) were extracted with 2M KCl and phosphorus (P) was extracted with 0.5M $NaHCO_3$; concentrations of all nutrients were analyzed colorimetrically (Page et al. 1982). Phosphorus concentrations were highly negatively correlated with pH values (Pearson's $r = -0.852$) and were therefore omitted from further analysis.

Land Use Characterization

Land use adjacent to each site was characterized using a Geographic Information System (ArcView 3.2a, ESRI, Redlands, California). Sites boundaries were digitized and buffers were created at 50, 100, 150, and 200 m from site polygon boundaries. Recently clearcut areas (cut within the past 20 yr) were identified using the U.S. Forest Service Region 1 Timber Stand Management Record System. Roads were identified using 2000 TIGER 1:100,000 line files. The presence and accuracy of roads and logging activities were confirmed by visually inspecting buffers using 1990, 1991, and 1995 U.S. Geological Survey Digital Orthophoto Quadrangles and paper-copy 1998 1:24,000 true color aerial photographs.

The integrity of each buffer area was measured by calculating road density within the buffer and the proportion of the buffer clearcut. As these two factors are not correlated at the buffer sizes considered, I calculated a third measure, average buffer width, which incorporated the extent of both logging and roading in a buffer (Figure 3). Average buffer width was calculated by measuring the distance from wet-

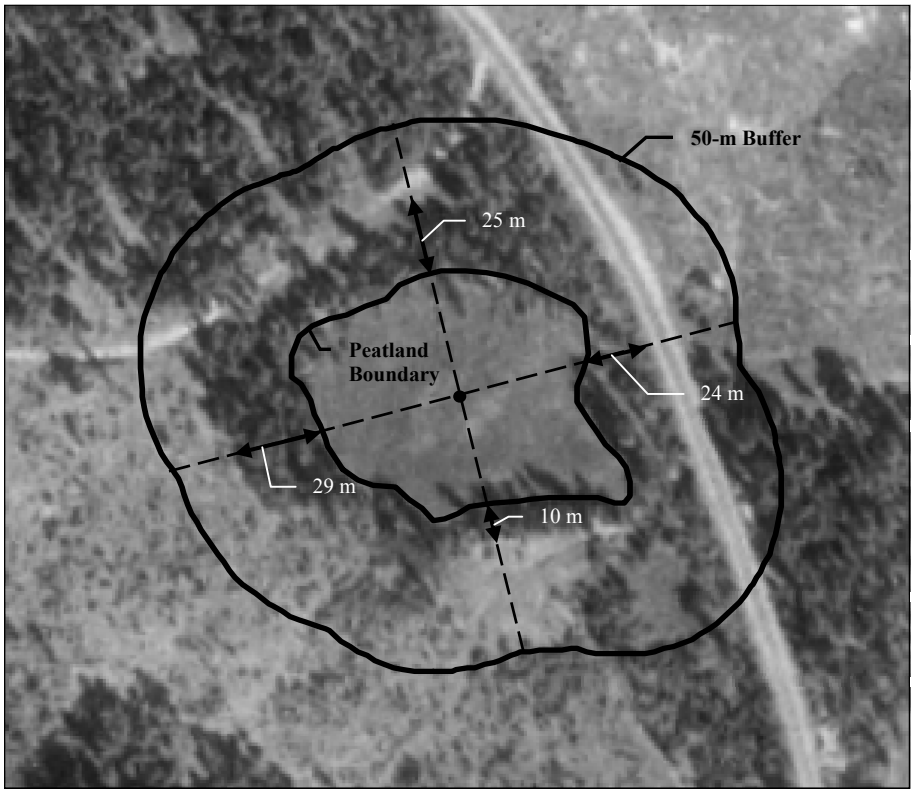

Figure 3. Illustration of how average buffer width was calculated. The distance from the peatland boundary to the nearest road or clearcut within the prescribed buffer was measured. Measurements were made along the major and minor axes of the site polygon that passed through the polygon's centroid. For the 50-m buffer shown above, the average buffer width is (25m+24m+10m+29m)/4 = 22 m. Imagery is the 1995 1:24,000 Fisher Mountain U.S. Geological Survey Digital Orthophoto Quadrangle.

land edge to the nearest road or clearcut within the prescribed buffer size. Measurements were made along the major and minor axes of the site polygon that passed through the polygon's centroid. The resulting four measurements were then averaged. All three measures of buffer integrity were calculated for each buffer size category.

Statistical Analyses

Relationships among land use variables, nutrient concentrations, peatland size, and vegetation diversity were evaluated with linear regressions, as were relationships among nutrient levels, abundance of *Carex utriculata*, and vegetation diversity. A Mann-Whitney U test was used to assess the association between occurrence of rare species and plant diversity. The normality of variables was visually inspected with normal probability plots. Non-normally distributed variables were log transformed prior to analysis. Proportion data were arcsine-squareroot transformed. Because of small sample size and strong multicollinearity among environmental variables, only simple linear regressions were performed. All analyses were performed with SYSTAT Version 10.2 (SYSTAT 2002).

RESULTS

Buffer integrity was significantly related to vascular plant diversity. In rich fens, average buffer width of 50-m buffers was positively associated with vascular plant richness (df = 1, 21, F = 6.007, p = 0.023) and Shannon-Weiner diversity (H′) (df = 1, 21, F = 6.110, p = 0.022) (Figure 4). A statistically significant relation-

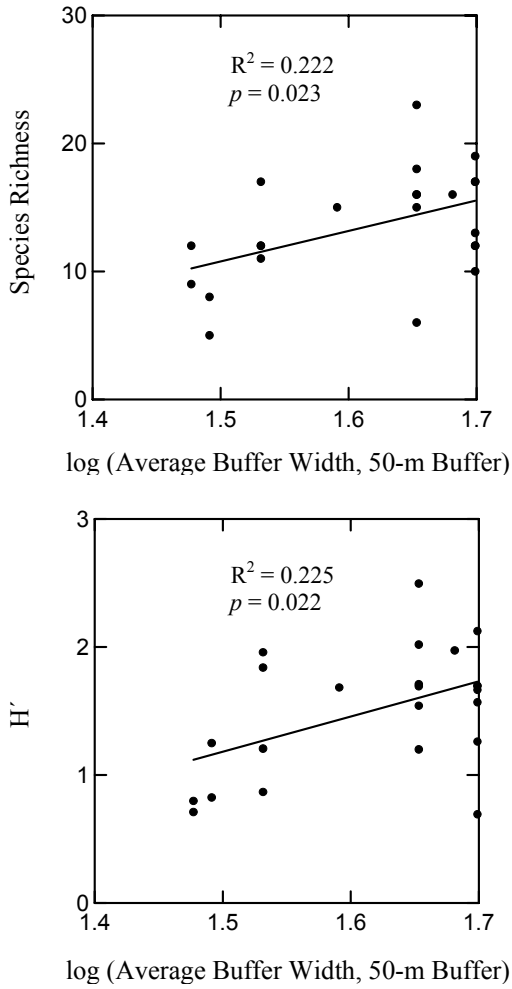

Figure 4. Relationship between average width of 50-m buffers and vascular plant diversity (species richness and H′) in rich fens (n = 23).

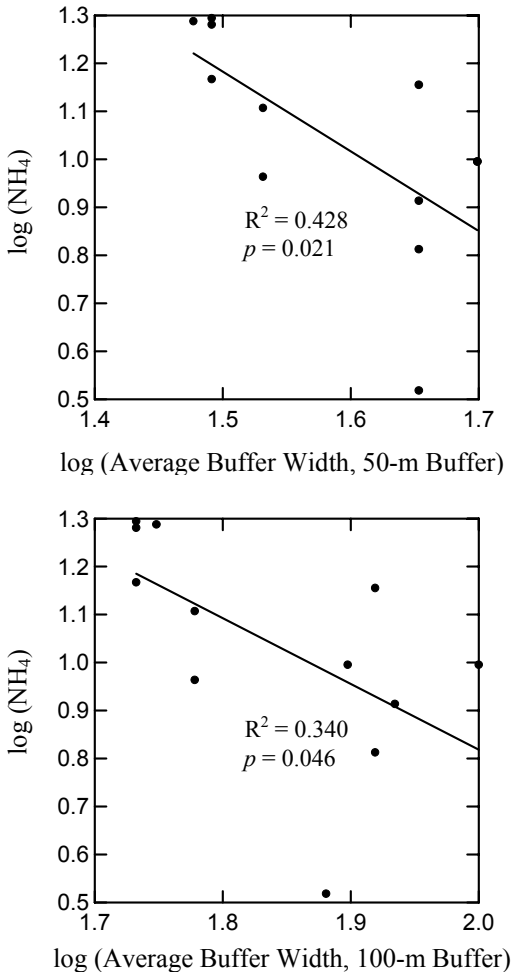

Figure 5. Relationship between average buffer width (50- and 100-m buffers) and concentrations of NH_4 (n = 12).

ship between buffer integrity and plant diversity was not observed in poor fens. Increased nutrient levels were also significantly associated with the relative intactness of buffers around peatlands. Average buffer width for both 50- and 100-m buffers was negatively related to NH_4 concentrations (50-m buffer: df = 1, 10, F = 7.497, p = 0.021; 100-m buffer: df = 1, 10, F = 5.159, p = 0.046) (Figure 5). Neither road density nor proportion of buffer clearcut was significantly related to nutrient concentrations.

Vascular plant diversity was negatively associated with soil nutrient levels. Both species richness and diversity (H′) was strongly negatively related to NH_4 concentrations (richness: df = 1, 10, F = 11.346, p = 0.007; H′: df = 1, 10, F = 18.871, p = 0.001) (Figure 6). There was no statistically significant relationship between bryophyte diversity and soil nutrient levels (Figures 6 and 7), although total bryophyte cover was negatively related to NO_3 concentrations (df = 1, 10, F = 19.313, p = 0.001) (Figure 7).

The abundance of *Carex utriculata* was positively associated with concentrations of NH_4 (df = 1, 7, F = 10.121, p = 0.015) (Figure 8), and negatively associated with vascular plant diversity (richness: df = 1, 18, F = 5.183, p = 0.035; H′: df = 1, 18, F = 13.726, p = 0.002) (Figure 9). Rare species were associated with high vascular plant diversity (H′) (df = 1, χ^2 = 8.842,

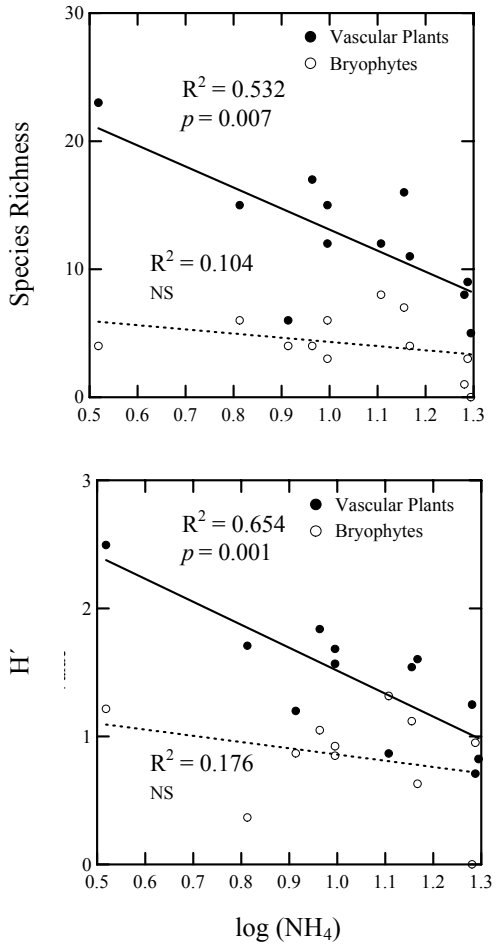

Figure 6. Relationship between concentrations of NH_4 and diversity (richness and H′) of vascular plants and bryophytes (n = 12).

p = 0.003) (Figure 10). Rare species occurred equally among rich and poor fens (n = 9 and n = 10, respectively), so this result is unlikely to be an artifact of increased vascular plant diversity in rich fens. The sample size was too small to directly compare the occurrence of rare species with soil nutrient levels. There was no statistically significant correlation between peatland size and species richness in either rich or poor fens.

DISCUSSION

Human disturbances (timber harvesting and roading) were directly related to the decreased diversity of vascular plants in rich fens, perhaps

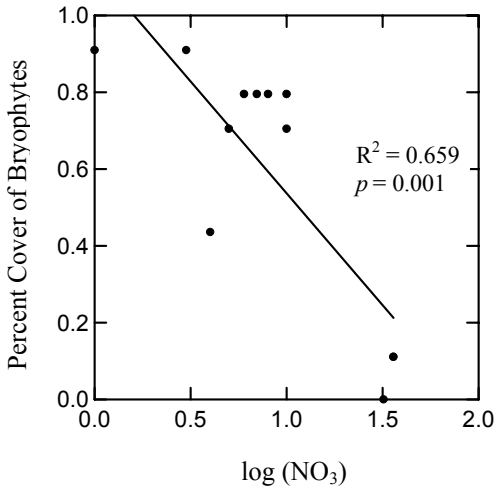

Figure 7. Relationship between concentrations of NO_3 and abundance of bryophytes (n = 12).

mediated by increased soil nutrient levels associated with these land use activities. These findings support the importance of limiting timber harvest and road construction around peatlands as required by existing regulations. However, the maximum buffer distance of 30 m required under the 1987 Kootenai National Forest Plan (U.S. Forest Service 1991) may be insufficient. Logging and roading were associated with increased soil nutrient levels at distances of up to 100 m from peatland sites. Increased nutrient

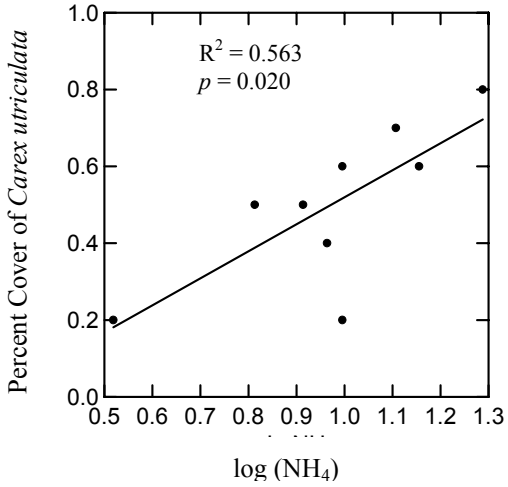

Figure 8. Relationship between concentrations of NH_4 and abundance of *Carex utriculata* (n = 9).

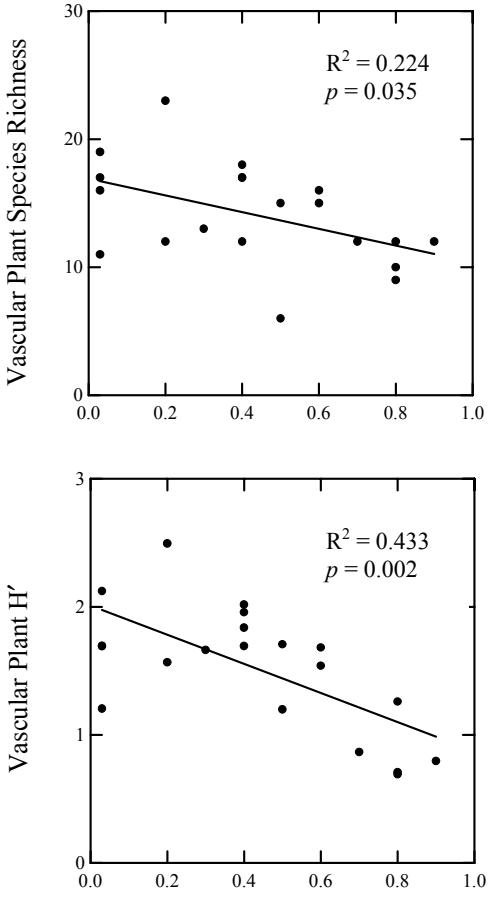

Figure 9. Relationship between abundance of *Carex utriculata* and vascular plant diversity (species richness and H′) in rich fens (n = 20).

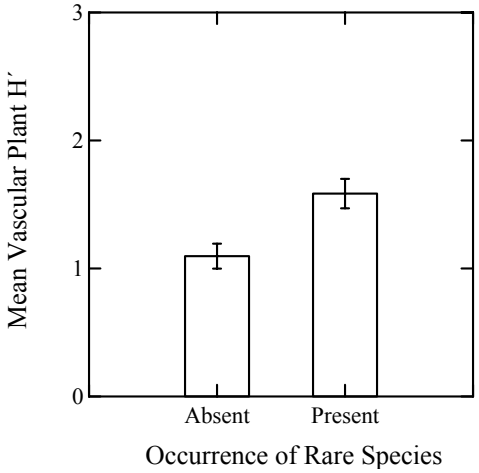

Figure 10. Comparison of vascular plant diversity (H′) between plots with and without rare species (n = 19 and n = 25 respectively). Error bars are ±1 SE.

levels, in turn, were clearly associated with decreased diversity of vascular plants.

This pattern is consistent with the findings of previous research in both peatlands and other systems. Grime (1979) has proposed a "hump-shaped" model relating species richness to community biomass. The model proposes that richness is greatest at intermediate levels of community biomass (a surrogate for site productivity) and is reduced at both low and high biomass. The general applicability of this model to wetland communities has been supported by the work of Keddy and others (Day et al. 1988, Moore and Keddy 1989, Wisheu and Keddy 1989), and has been reported by Bedford et al. (1999) in an extensive literature review of the relationship between nutrient availability and wetland plant diversity.

Two mechanisms that could contribute to this pattern are direct adverse effects of nutrient enrichment on individual species and changes in interspecific competitive interactions. The first mechanism has been observed for species occurring in extremely nutrient-poor sites, such as ombrogenous bogs. Studies concerned with the effects of increased atmospheric N deposition on bogs have found negative associations between increased N and the vigor, establishment, and persistence of a number of bog species, including the pitcher plant *Sarracenia purpurea* and several species of *Sphagnum* (Press et al. 1986, Li and Vitt 1994, Thormann and Bayley 1997, Gotelli and Ellison 2002).

In rich fens, reduction of species diversity with increased nutrient availability may be more the result of altered competitive interactions. Keddy and others have observed that the distribution of species along a fertility gradient is positively related to those species' competitive ability (Wilson and Keddy 1986, Gaudet and Keddy 1995). A corollary of this finding is that species restricted to nutrient-poor sites tend to be poor competitors. Twolan-Strutt and Keddy (1996), in comparing above- and belowground competition intensity between an infertile and

fertile wetland, found that aboveground competition intensity was greater at the fertile site. This supports the general observation that greater coexistence of species is possible where nutrients are a limiting resource (nutrient-poor sites) than where light is limiting (nutrient-rich sites), perhaps due to the greater ability of species to partition the extraction of nutrients (Huston 1994, Verhoeven et al. 1996).

The conversion of species-rich wetlands to wetlands dominated by a few common native or exotic species has been widely reported (Bedford et al. 1999). The association in this study between increased nutrient levels and decreased vascular plant diversity may be at least partially explained by increasing abundance of the competitively dominant sedge, *Carex utriculata*, with higher concentrations of NH_4. Increased nutrient concentrations and the attendant reduction in species richness may also facilitate the invasion of exotic species. Although only documented in one plot, the aggressive colonizer *Phalaris arundinacea* (Reed Canary Grass) occurred in the plot with the highest concentration of NO_3 and the third highest concentration of NH_4 observed in the study. This species is a widespread invasive of North American wetlands (Galatowitsch et al. 1999) and has established monospecific stands in riparian areas and marshes in northwestern Montana (Jones and Hendricks 2002). There is evidence that increased species richness inhibits establishment of *P. arundinacea* in fens (Lindig-Cisneros and Zedler 2002).

Measures of bryophyte diversity were not significantly correlated to soil nutrient levels. This observation corresponds to previous research that relates bryophyte composition in peatlands to pH-alkalinity gradients and not to nutrient concentrations (Vitt and Chee 1990, Bragazza and Gerdol 2002). However, other studies have found individual bryophyte species to respond both positively and negatively to increased nutrient concentrations when nutrient levels are experimentally manipulated (Rochefort and Vitt 1988, Li and Vitt 1994, Thormann and Bayley 1997) or when time series data are considered (Kooijman 1992). Increased nutrient levels can indirectly influence bryophytes by changing competitive interactions with vascular plants. Bergamini et al. (2001) found that the shoot density and species richness of bryophytes was negatively associated with vascular plant biomass in calcareous fens. If vascular plant biomass is positively associated with increased nutrient levels, the reduction of bryophyte cover associated with increased NO_3 found in this study may be an indirect effect of increased competition with vascular plants.

The importance of peatlands is due in part to the large number of rare taxa that these wetlands support. Maintaining viable populations of these species is an important component of peatland conservation. The association between the occurrence of rare species and high vascular plant diversity observed in this study is consistent with previous research that has found that rare species tend to occur in low to intermediate biomass, species-rich sites (Moore et al. 1989, Wisheu and Keddy 1992, Bedford et al. 1999, Venterink et al. 2001). Increased fertility of peatlands caused by human land uses could adversely affect many of these rare taxa, due to increasing interspecific competition or other mechanisms.

MANAGEMENT AND STEWARDSHIP OPPORTUNITIES

This study suggests that upland land uses may be increasing nutrient loadings in peatlands at distances of up 100 m from peatland boundaries. Based on this, it appears that the existing set-asides of 8-30 m required under streamside management zone regulations are too narrow to fully buffer peatlands from the effects of upland land uses. The results of this study suggest that 100 m may be an adequate buffer distance; however, several limitations of this study should be noted. First, this study did not address possible modifications to peatland hydrology caused by upland land uses. Hydrological modifications are likely: forestry practices such as road building have been shown to alter wetland hydrology at distances greater than 100 m (Forman and Deblinger 2000, Trombulak and Frissell 2000). Second, the sample size for soil nutrient data is small (n = 12). A larger sample size would help elucidate the general applicability of the relationships observed in this study, and would provide for the use of more sophisticated statistical analyses, such as multiple regressions or general

linear models. These methods would allow an examination of the interactions among predictor variables and their relative effects on vegetation diversity. Also, the soil nutrient dataset is restricted to rich fens, although poor fen vegetation is likely to respond similarly.

In the absence of additional research, these findings are strong evidence that existing buffers are inadequate for the long-term protection of these sites. Eutrophication of peatlands may lead to irreversible changes in species composition, replacing diverse and species rich systems with ones increasingly dominated by common or possibly exotic species.

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Appendix A. Global/State Rank Definitions

Heritage Program Ranks

The international network of Natural Heritage Programs employs a standardized ranking system to denote global (range-wide) and state status (NatureServe 2002). Species are assigned numeric ranks ranging from 1 (critically imperiled) to 5 (demonstrably secure), reflecting the relative degree to which they are "at-risk". Rank definitions are given below. A number of factors are considered in assigning ranks — the number, size and distribution of known "occurrences" or populations, population trends (if known), habitat sensitivity, and threat. Factors in a species' life history that make it especially vulnerable are also considered (e.g., dependence on a specific pollinator).

Rank Definitions

G1 S1	Critically imperiled because of extreme rarity and/or other factors making it highly vulnerable to extinction.
G2 S2	Imperiled because of rarity and/or other factors making it vulnerable to extinction.
G3 S3	Vulnerable because of rarity or restricted range and/or other factors, even though it may be abundant at some of its locations.
G4 S4	Apparently secure, though it may be quite rare in parts of its range, especially at the periphery.
G5 S5	Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery.
GU SU	Possibly imperiled, but status uncertain; more information needed.
GA SA	Native in nearby states, but in Montana believed to be accidentally introduced, deliberately planted, or escaped from plantings.
GH SH	Historical, known only from records over 50 year ago; may be rediscovered.
GX SX	Believed to be extinct; historical records only.

Combination Ranks

G#G# or S#S# Indicates a range of uncertainty about the rarity of the species.

Subranks

T#	Rank of a subspecies or variety; appended to the species' global rank of the full species, e.g. G4T3.

Qualifiers

Q	Taxonomic questions or problems exist, more information needed; appended to the global rank, e.g. G3Q.
?	Denotes uncertainty or for numeric ranks, inexactness.

Appendix B. Site Descriptions

Border Fen

Directions

This site lies in the Whitefish Range of northwestern Montana. From Fortine, travel north on U.S. 93 for approximately 3 miles to Grave Creek Road (Forest Route 114). Follow this road for about 14 miles. At Drip Creek, veer left onto Forest Route 319 and continue for another 13 miles to Forest Route 7086. After crossing the Wigwam River, turn onto Forest Route 7090. Hike up this road for approximately 2.5 miles. The site is in the valley bottom about 380 m south of the Canadian border.

Description

Border Fen is a relatively small (0.5 ha) peatland that occurs in the valley bottom of the Wigwam River. This wetland is an alkaline fen (pore water pH = 7.3) with relatively low levels of dissolved solutes (electrical conductivity = 210 µS/cm). Fibric peat underlies the site to a depth of at least 120 cm. The fen occurs on a very gradual slope and receives groundwater discharge. Microtopographic variation is minor and consists of shallow, small ponds and channels. An undescribed *Carex flava* (Yellow-Green Sedge) community dominates this site. Graminoid cover is high; the dominant species are *Carex flava*, *Juncus* sp. (Rush), *Eriophorum viridicarinatum* (Tassel Cotton-Grass), and *Carex interior* (Inland Sedge). Two forbs, *Dodecatheon pulchellum* (Dark-Throat Shootingstar) and *Parnassia fimbriata* (Fringed Grass-of-Parnassus), are abundant. The moss layer is nearly continuous and dominated by the brown mosses *Scorpidium cossonii*, *Tomentypnum nitens*, and *Campylium stellatum*.

Key Environmental Factors

Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to high pH and alkalinity of the inflowing waters, are the primary determinants of plant species composition at the site.

Rarity
A rare moss, *Meesia triquetra* (S2 / G5), occurs at this site. This site also contains an undocumented community dominated by *Carex flava*. This site is an excellent example of a rich fen, which is a rare wetland type in Montana.

Land Use
No disturbance was noted at the site.

Exotics
No exotics are present at the site; however, several exotic species are present in the adjacent uplands. *Bromus inermis* (Smooth Brome), *Agrostis stolonifera* (Redtop), *Phleum pratense* (Common Timothy), *Poa pratensis* (Kentucky Blue Grass), and *Cirsium arvense* (Canada Thistle) are all present though not abundant. These species are largely associated with old logging roads. None are likely to establish in the peatland.

Uplands
The lower valley slopes of this entire portion of the Wigwam drainage have been logged. The valley bottom adjacent to the site has also been logged, although not recently. The average buffer distance around the site is 80 m.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Carex flava Dominance Type	S*	G*	A

* Rank not assigned

Edna Creek Fen

Directions

This site lies in the Salish Mountains of northwestern Montana. From Trego, travel south on Forest Route 36 for approximately 3 miles, then turn west onto Edna Creek Road (Forest Route 433). Continue for about 2 miles to Forest Route 3588. Turn south onto this road and continue for about 300 m. The site lies 30 m east of the road.

Description

Edna Creek Fen is a relatively small (0.6 ha) groundwater-fed slope fen adjacent to Edna Creek. Pore water pH ranged from 6.7 to 7.1 and electrical conductivity ranged from 490 to 510 µS/cm. A *Carex utriculata* (Beaked Sedge) community dominates this site. In a few patches in the center of the fen, *Carex prairea* (Prairie Sedge), a state rare species, is codominant. Other common species include *Carex leptalea* (Bristly-Stalk Sedge), *Carex interior* (Inland Sedge), and *Parnassia fimbriata* (Fringed Grass-of-Parnassus). A near continuous and diverse moss layer is dominated by *Tomentypnum nitens*, *Bryum pseudotriquetrum*, *Plagiomnium rugicum*, *Cratoneuron filicinum*, *Palustriella falcata*, and *Calliergon giganteum*. *Salix candida* (Hoary Willow) is present at low cover throughout. There is also a small patch of *Typha latifolia* (Broad-Leaf Cattail).

Key Environmental Factors

Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to high pH and alkalinity of the inflowing waters, are the primary determinants of plant species composition at the site.

Rarity
This site supports a robust patch of *Carex prairea* (Prairie Sedge, S2 / G5?). This site is an excellent example of a rich fen, which is a rare wetland type in Montana.

Land Use
The site is largely undisturbed; however, mature *Picea engelmannii* (Engelmann Spruce), primarily from the edges of the fen, have been logged.

Exotics
No exotic species were noted.

Uplands
Some of the uplands immediately adjacent to the fen have been logged. Forest Route 3588 is only 30 m from the site border and the upslope adjacent to the road has been clearcut.

Management Needs
The small patch of *Typha latifolia* (Broad-Leaf Cattail) present in the fen is troubling. It may be indicative of increased nutrients levels and/or sedimentation rates in the fen due to adjacent roads or clearcuts.

Plant Community Information

	Rarity Ranks		Viability
Plant Association / Dominance Type	**State**	**Global**	**Rank**
Carex utriculata Herbaceous Vegetation	S5	G5	B

Flower Lake

Directions

Flower Lake lies in the foothills of the Cabinet Mountains of northwestern Montana. From Libby, travel south on U.S. Highway 2 for about 1 mile. Turn southwest onto Forest Route 618. After approximately 1.5 miles, turn west onto Forest Route 128. Follow this road for approximately 5 miles to the Flower Creek trailhead. Continue past trailhead on an unnamed logging road for a little over 2 miles. Flower Lake lies 250 m downslope of the road approximately 550 m before the road deadends.

Description

This poor fen encompasses an organic floating mat around Flower Lake that grades into an attached fen ringed by a narrow *Spiraea douglasii* (Hardhack) carr. Pore water pH ranged from 4.6 and 4.8; electrical conductivity was very low at 40 µS/cm. A species-poor *Carex lasiocarpa* (Slender Sedge) community occupies most of the floating mat and adjacent fen. *Dulichium arundinaceum* (Dulichium) and *Carex chordorrhiza* (Creeping Sedge) form small patches within this *Carex lasiocarpa*-dominated matrix. Along the edge of the floating mat, there are very small patches of a relatively diverse community dominated by *Sphagnum subsecundum*. Common vascular species in this community include *Carex lasiocarpa*, *Dulichium arundinaceum*, *Drosera anglica* (English Sundew), *Comarum palustre* (Purple Marshlocks), *Menyanthes trifoliata* (Buck-Bean), and *Scheuchzeria palustris* (Pod Grass). *Brasenia schreberi* (Watershield) and *Nuphar lutea* (Yellow Pond-Lily) form a discontinuous aquatic community within the lake.

Key Environmental Factors

Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and

substrate, in addition to low pH and alkalinity, are the primary determinants of plant species composition at the site.

Rarity
This site supports populations of four rare (S2 / G5) plant species: *Brasenia schreberi* (Watershield), *Carex chordorrhiza* (Creeping Sedge), *Drosera anglica* (English Sundew), and *Scheuchzeria palustris* (Pod Grass). It also supports a breeding population of Boreal Toad (*Bufo boreas*, S3 / G4). This site is an excellent example of a poor fen, which is a rare wetland type in Montana.

Land Use
On-site disturbance is minimal and includes a campfire ring and some trailing by ungulates and/or recreationalists.

Exotics
No exotic species were noted.

Uplands
Portions of the catchment to the north, east, and south have been clearcut. The buffer width along the most recent clearcut is 30 m.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Carex lasiocarpa Herbaceous Vegetation	S4	G4?	A
Carex lasiocarpa / *Sphagnum* Dominance Type	S*	G*	A
Dulichium arundinaceum Herbaceous Vegetation	S2	G3	A
Spiraea douglasii Shrubland	S4	G5	A

* Rank not assigned

Grouse Lake

Directions
Grouse Lake lies in northwestern Montana. From Troy, travel south on U.S. Highway 2 for about 1.5 miles. Turn onto Forest Route 384 and travel south for approximately 6 miles. Veer right onto Forest Route 473 and travel for about 1.5 miles to the Grouse Lake trailhead. From the trailhead, hike north a little over a mile to Grouse Lake.

Description
This poor fen encompasses floating mats and an attached fen around Grouse Lake. Pore water pH was 4.8; electrical conductivity ranged from 50 to 120 µS/cm. A species-poor community dominated by *Spiraea douglasii* (Hardhack), *Carex lasiocarpa* (Slender Sedge), and *Phragmites australis* (Common Reed) occupies a large embayment and dominates most of the site. The greatest species richness occurs on small floating mats. These areas are characterized by a continuous moss layer dominated by *Sphagnum teres* and *Aulacomnium palustre*. Common vascular species include *Carex lasiocarpa*, *Carex interior* (Inland Sedge), *Comarum palustre* (Purple Marshlocks), *Menyanthes trifoliata* (Buck-Bean), and *Lycopus uniflorus* (Northern Water-Horehound). These mats are interspersed among local high points, such as tree bases and beaver dam remnants. These areas support stunted *Pinus contorta* (Lodgepole Pine), *Alnus viridis* (Sitka Alder), *Spiraea douglasii*, and *Kalmia microphylla* (Alpine-Laurel) and provide habitat for the rare *Dryopteris cristata* (Crested Wood Fern).

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to low pH and alkalinity, are the primary determinants of plant species composition at the site.

Rarity
This site contains populations of two rare (S2 / G5) plants: *Dryopteris cristata* (Crested Wood Fern) and *Scheuchzeria palustris* (Pod Grass). This site is an excellent example of a poor fen, which is a rare wetland type in Montana.

Land Use
No disturbance was noted at the site.

Exotics
No exotic species were noted. Based on stem color, the population of *Phragmites australis* (Common Reed) at the site appears to be the native genotype.

Uplands
Surrounding upland in the catchment appears to be undisturbed.

Plant Community Information

	Rarity Ranks		Viability
Plant Association / Dominance Type	**State**	**Global**	**Rank**
Spiraea douglasii / *Carex lasiocarpa* Dominance Type	S*	G*	A
Carex lasiocarpa / *Sphagnum* Dominance Type	S*	G*	A

* Rank not assigned

Hidden Lake

Directions
This site is located in the Rocky Mountain Trench of northwestern Montana. The site lies along a tributary to Jumbo Lake, just west of Stryker.

Description
This fen lies within the larger Hidden Lake Botanical Special Interest Area. A *Carex lasiocarpa* (Slender Sedge) community dominates most of this peatland; however, a new beaver dam had flooded most of the site at the time of the field visit. An area fringing an older beaver dam that appeared representative of the flooded peatland was sampled. *Carex lasiocarpa* dominates this area; other common species include *Carex flava* (Yellow-Green Sedge), *Carex utriculata* (Beaked Sedge), *Glyceria striata* (Fowl Manna Grass), *Mentha arvensis* (American Wild Mint), *Symphyotrichum eatonii* (Bracted American-Aster), and *Symphyotrichum boreale* (Boreal American-Aster). In places *Betula glandulosa* (Bog Birch) and *Salix candida* (Hoary Willow) form an open canopy. The abundant moss layer is dominated by *Scorpidium cossonii*, *Calliergon giganteum*, and *Hypnum lindbergii*. *Typha latifolia* (Broad-Leaf Cattail) is encroaching into this community.

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to pH and alkalinity, are the primary determinants of plant species composition at the site.

Rarity
A population of the rare moss *Scorpidium scorpioides* (S2 / G5) was documented from this site.

Land Use
No human disturbance was noted at this site. A beaver dam constructed earlier in the season has flooded most of the site under 50-60 cm of water.

Exotics
Cirsium arvense (Canada Thistle) is abundant on the old beaver dam near the area surveyed. *Typha latifolia* (Broad-Leaf Cattail) is encroaching into the site.

Uplands
The area in the immediate catchment has not been logged.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Betula glandulosa / *Carex lasiocarpa* Dominance Type	S4	G*	A
Carex lasiocarpa Herbaceous Vegetation	S4	G4?	A

* Rank not assigned

Ivor Creek Fen

Directions

This site is located in the Salish Mountains of northwestern Montana. From Trego, travel south on Forest Route 36 for approximately 3 miles, then turn west onto Edna Creek Road (Forest Route 433). Continue for about 1.5 miles to Ivor Creek Road (Forest Route 3590). Travel north for approximately 1.5 miles. The site lies about 150 m east of the road.

Description

This site is a large (10.8 ha) rich fen and carr. Fibric peat and marl underlie the site to a depth of at least 120 cm; pH measurements ranged from 6.6 to 6.7 and electrical conductivity ranged from 660 to 780 µS/cm. A *Betula glandulosa* (Bog Birch) carr dominates most of this site. *Carex prairea* (Prairie Sedge) is the dominant graminoid; other common species are *Dasiphora fruticosa* (Shrubby Cinquefoil), *Carex aquatilis* (Water Sedge), and *Carex leptalea* (Bristly-Stalk Sedge). Moss cover is very high, and *Aulacomnium palustre* and *Scorpidium cossonii* are the dominant species. The fen portion of the site is dominated by a *Carex utriculata* (Beaked Sedge) community. *Carex prairea* and *Carex aquatilis* are both codominants. *Salix candida* (Hoary Willow) is present at low cover throughout. The mosses *Calliergon giganteum* and *Drepanocladus aduncus* are common. There is an old beaver dam at the outflow of the site, and it is likely that the fen has been influenced by beaver-induced inundation in the past. This may explain the current limit of the carr. Both of these communities are extensively hummocked.

Key Environmental Factors

Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and

substrate, in addition to high pH and alkalinity of the inflowing waters, are the primary determinants of plant species composition at the site.

Rarity
This site supports a robust population of *Carex prairea* (Prairie Sedge, S2 / G5). This site is a very good example of a rich fen, which is a rare wetland type in Montana.

Land Use
The southernmost portion of the site may have been planted to pasture grasses and hayed in the past.

Exotics
Agrostis stolonifera (Redtop), *Phleum pratense* (Common Timothy), and *Phalaris arundinacea* (Reed Canary Grass) are present in the southernmost portion of the site. This area may have been hayed in the past. *Cirsium arvense* (Canada Thistle) is present on an old beaver dam.

Uplands
The adjacent uplands have been logged, although not recently. Roads run along both sides of this site, the eastern road within 30 m of the peatland.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Betula glandulosa / *Carex prairea* Dominance Type	S*	G*	A
Carex utriculata Herbaceous Vegetation	S5	G5	A

* Rank not assigned

Little Dickey Fen

Directions
Little Dickey Fen is located in the Rocky Mountain Trench of northwestern Montana. From Fortine, travel south on U.S. Highway 2 for about 7.5 miles. The site is located east of the highway near the south end of Dickey Lake.

Description
This site is a small (0.8 ha) intermediate-poor fen that occurs in a shallow glacial depression. A species-poor *Carex lasiocarpa* (Slender Sedge) community occupies most of the site. Forb cover varies from low to high, with *Comarum palustre* (Purple Marshlocks) and *Menyanthes trifoliata* (Buck-Bean) being the most common species. Moss cover, mostly of *Hamatocaulis vernicosus*, is moderate. *Typha latifolia* (Broad-Leaf Cattail) fringes most of the peatland, and there is one small patch of *Phalaris arundinacea* (Reed Canary Grass). Pore water pH was measured at 5.5.

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to low pH and alkalinity, are the primary determinants of plant species composition at the site.

Rarity
No rare plants, animals, or communities were documented at this site. This site is a good example of a poor fen, a rare wetland type in Montana.

Land Use
No disturbance was documented at the site.

Exotics
A small patch of *Phalaris arundinacea* (Reed Canary Grass) was documented at the site.

Uplands
The western site boundary is separated from U.S. Highway 2 and a cleared powerline right-of-way by a 20 m buffer.

Management Needs
The populations of *Typha latifolia* (Broad-Leaf Cattail) and *Phalaris arundinacea* (Reed Canary Grass) may be indicative of increased nutrients levels and/or sedimentation rates in the fen due to the adjacent highway and cleared right-of-way.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Carex lasiocarpa Herbaceous Vegetation	S4	G4?	A

Little Edna Fen

Directions
This site lies in the Salish Mountains of northwestern Montana. From Trego, travel south on Forest Route 36 for approximately 3 miles, then turn west onto Edna Creek Road (Forest Route 433). Continue for a little over 4.5 miles to an unnamed road. Turn north and continue for about 300 m. The site lies 60 m west of the road.

Description
Little Edna is a very small (0.2 ha) carr. The substrate is peat to a depth of at least 120 cm; however, the vegetation is dominated by shrubs and mesic grasses, implying a change in hydrology. *Betula glandulosa* (Bog Birch) forms an open canopy over a mixed stand of *Agrostis scabra* (Rough Bent Grass), *Poa pratensis* (Kentucky Blue Grass), and *Carex aurea* (Golden-Fruit Sedge). Other common species are *Agrostis stolonifera* (Redtop), *Calamagrostis stricta* ssp. *inexpansa* (Slim-Stem Reed Grass), *Carex leptalea* (Bristly-Stalk Sedge), and *Symphyotrichum eatonii* (Bracted American-Aster). The moderate moss layer is dominated by *Aulacomnium palustre* and *Tomentypnum nitens*.

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to high pH and alkalinity of the inflowing waters, are the primary determinants of plant species composition at the site.

Rarity
Populations of two rare (S2 / G5) plant species have been documented at this site: *Carex prairea* (Prairie Sedge) and *Eriophorum gracile* (Slender Cotton-Grass). This site is also a fair example of a rich fen, a rare wetland type in Montana.

Land Use
No disturbance was noted at the site. However, given the peaty substrate, the dominance of mesic grasses and shrubs at the site implies that it is drier now than in the past.

Exotics
The exotic grasses *Agrostis stolonifera* (Redtop) and *Poa pratensis* (Kentucky Blue Grass) are fairly common.

Uplands
The uplands have been logged, although a 100 m buffer around the site is relatively intact.

Plant Community Information

	Rarity Ranks		Viability
Plant Association / Dominance Type	**State**	**Global**	**Rank**
Betula glandulosa / Mesic Graminoids Dominance Type	S*	G*	C

* Rank not assigned

Little Ivor Fen

Directions
This site is located in the Salish Mountains of northwestern Montana. From Trego, travel south on Forest Route 36 for approximately 3 miles, then turn west onto Edna Creek Road (Forest Route 433). Continue for about 1.5 miles to Ivor Creek Road (Forest Route 3590). Travel north for approximately 2 miles and turn onto an unnamed logging road. Travel south on this road for about 450 m. The site lies along Ivor Creek approximately 80 m from the road.

Description
This site is a rich slope fen that occurs along Ivor Creek. The site also appears to receive groundwater discharge. Marly fibric peat underlies the site to a depth of 105 cm, below which is black sapric peat. Pore water pH was measured at 7.2. This small (0.27 ha) fen is codominated by *Carex prairea* (Prairie Sedge) and *Carex utriculata* (Beaked Sedge). Other common species include *Muhlenbergia glomerata* (Spiked Muhly), *Elymus trachycaulus* (Slender Wild Rye), *Dodecatheon pulchellum* (Dark-Throat Shootingstar), and *Parnassia fimbriata* (Fringed Grass-of-Parnassus). The near-continuous moss layer is dominated by *Tomentypnum nitens*, *Aulacomnium palustre*, and *Palustriella falcata*.

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to high pH and alkalinity of the inflowing waters, are the primary determinants of plant species composition at the site.

Rarity
This site supports a robust population of *Carex prairea* (Prairie Sedge, S2 / G5). This site is a good example of a rich fen, which is a rare wetland type in Montana.

Land Use
No disturbance was noted at the site.

Exotics
Agrostis stolonifera (Redtop) occurs at low cover in drier portions of the site.

Uplands
The surrounding uplands up to the wetland boundary have been logged, although not recently. Uplands are now young mature second-growth forest.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Carex prairea Dominance Type	S*	G*	A

* Rank not assigned

Little White Fen

Directions
Little White Fen is located in the Salish Mountains of northwestern Montana. From Trego, travel south on Forest Route 36 for approximately 10 miles. Turn east onto Forest Route 3529 and travel for about 1 mile. The site is along White Creek about 70 m west of the road.

Description
This narrow, small peatland occurs along White Creek and is probably supported by groundwater discharge. The depth of peat deposition measured from one soil pit was only 70 cm, below which was a fine sandy loam. A relatively species-poor *Carex utriculata* (Beaked Sedge) community dominates this site. *Carex utriculata* cover is very high; the few other common vascular species include *Bromus ciliatus* (Fringed Brome), *Equisetum arvense* (Field Horsetail), and *Mimulus guttatus* (Seep Monkey-Flower). Woody species, including *Picea engelmannii* (Engelmann Spruce), *Rhamnus alnifolia* (Alder-Leaf Buckthorn), and *Betula glandulosa* (Bog Birch), are present at low cover throughout the site. Moss cover ranges from minimal to abundant; common species include *Aulacomnium palustre*, *Cratoneuron filicinum*, *Plagiomnium rugicum*, and *Campylium stellatum*. Pore water pH ranged from 6.3 to 7.1; electrical conductivity ranged from 520 to 730 µS/cm.

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to high pH and alkalinity of the inflowing waters, are the primary determinants of plant species composition at the site.

Rarity
No rare plants, animals, or communities were documented at this site. This site is a fair example of a rich fen, a rare wetland type in Montana.

Land Use
No disturbance was evident at the site.

Exotics
No exotic species were noted.

Uplands
This site occurs within a highly fragmented landscape. The site has a narrow (30 m) buffer along its east side, and the upslope catchment is partially logged with no buffer in places.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Carex utriculata Herbaceous Vegetation	S5	G5	B/C

Louis Lake

Directions
Louis Lake is located in the Salish Mountains of northwestern Montana. From Stryker, travel south on Forest Route 315 for approximately 4.5 miles. Turn upslope onto Forest Route 3733 and follow this road for about 4 miles to Louis Lake.

Description
Louis Lake is a glacial depression fringed by an organic floating mat. Vegetation on these floating mats is dominated by a *Carex lasiocarpa* (Slender Sedge) community. Other common species include *Carex utriculata* (Beaked Sedge), *Carex limosa* (Mud Sedge), *Eriophorum gracile* (Slender Cotton-Grass), *Menyanthes trifoliata* (Buck-Bean), and *Comarum palustre* (Purple Marshlocks). Moss cover is abundant, and the dominant species include *Scorpidium cossonii*, *Aulacomnium palustre*, *Tomentypnum nitens*, and *Hamatocaulis vernicosus*. *Equisetum fluviatile* (Water Horsetail) with patches of either *Schoenoplectus acutus* (Hard-Stem Club-Rush) or *Schoenoplectus tabernaemontani* (Soft-Stem Club-Rush) fringe the lake boundary. Measurements of pH from the soil water within the floating mat ranged from 4.6 to 5.1. Some areas had pH measurements as high as 6.5; however, a recently created beaver dam had caused lake levels to rise, and this measurement probably reflects the influence more circumneutral lake water.

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to low pH and alkalinity, are the primary determinants of plant species composition at the site.

Rarity
This site supports populations of three rare plants: *Eriophorum gracile* (Slender Cotton-Grass, S2 / G5), *Utricularia intermedia* (Flat-Leaf Bladderwort, S1 / G5), and the moss *Meesia triquetra* (S2 / G5).

Land Use
A road runs adjacent to this site and the lake receives fishing and camping use. Beaver had recently dammed the lake's outlet and flooded anchored portions of the surrounding fen.

Exotics
Small populations of *Phalaris arundinacea* (Reed Canary Grass) and *Phleum pratense* (Common Timothy) are located near a camping area at the lake's outlet.

Uplands
The surrounding uplands have been extensively logged. Roads run near the lakeshore along the southern and eastern borders.

Management Needs
The population of *Phalaris arundinacea* (Reed Canary Grass) should be monitored. Likewise, a small population of *Typha latifolia* (Broad-Leaf Cattail) that occurs in a small embayment at the lake's southern edge should also be monitored.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Carex lasiocarpa Herbaceous Vegetation	S4	G4?	B
Equisetum fluviatile Herbaceous Vegetation	S4	G4	B

Magnesia Fen

Directions
This site lies in the Salish Mountains of northwestern Montana. From Trego, travel south on Forest Route 36 for approximately 2.5 miles to Lime Creek Road (Forest Route 3780). After about 1.5 miles, turn onto Forest Route 3770 and continue approximately 1.5 miles to the site.

Description
This rich fen/carr is fed by groundwater and surface water from Magnesia Creek as well as groundwater from adjacent toeslopes. A soil pit revealed fibric marly peat to a depth of at least 120 cm; pH was measured at 7.0 and electrical conductivity at 580 µS/cm. A diverse and species rich *Betula glandulosa* / *Carex utriculata* (Bog Birch / Beaked Sedge) community dominates this site. *Betula* cover varies, but mostly forms a very open canopy. The shrubs *Dasiphora fruticosa* (Shrubby Cinquefoil) and *Salix candida* (Hoary Willow) are also present at low cover. *Carex utriculata* is the dominant graminoid; other common species include *Carex leptalea* (Bristly-Stalk Sedge), *Carex prairea* (Prairie Sedge), and *Muhlenbergia glomerata* (Spiked Muhly). Forbs are fairly abundant in this community, with *Dodecatheon pulchellum* (Dark-Throat Shootingstar), *Parnassia fimbriata* (Fringed Grass-of-Parnassus), *Symphyotrichum leave* (Smooth Blue American-Aster), *Galium boreale* (Northern Bedstraw), and *Menyanthes trifoliata* (Buck-Bean) being the most common species. Moss cover is very high; *Scorpidium cossonii*, *Tomentypnum nitens*, *Campylium stellatum*, and *Palustriella falcata* are the most abundant species.

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and

substrate, in addition to high pH and alkalinity of the inflowing waters, are the primary determinants of plant species composition at the site.

Rarity
This site supports populations of four rare plant species: *Carex prairea* (Prairie Sedge, S2 / G5), *Amerorchis rotundifolia* (Round-Leaf Orchid, S2S3 / G5), *Cypripedium parviflorum* (Lesser Yellow Lady's-Slipper, S3 / G5), and the moss *Meesia triquetra* (S2 / G5). This site is an excellent example of a rich fen, which is a rare wetland type in Montana.

Land Use
No disturbance is evident at the site.

Exotics
No exotic species were documented at the site.

Uplands
The adjacent uplands have been logged with a buffer around the site.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Betula glandulosa / *Carex utriculata* Shrubland	S4	G4?	A

McKillop Fen

Directions
This site is located in the Salish Mountains of northwestern Montana. From Happy's Inn, travel west on U.S. Highway 2 for about 3 miles to the Fisher River Road (Forest Route 535). Travel on this road for about 5.5 miles. The site is just west of the road.

Description
This site is a small (0.6 ha) poor fen in a shallow glacial depression. An organic mat covers the entire site. A *Carex limosa* (Mud Sedge) community dominates the wettest area in the center of the fen. *Carex interior* (Inland Sedge) codominates and *Scorpidium cossonii* forms a dense moss layer. A species-poor *Carex lasiocarpa* (Slender Sedge) community rings this area and is the dominant community at the site. This community has small inclusions where *Comarum palustre* (Purple Marshlocks) becomes codominant. A wet seepy area at the edge of the fen supports an undescribed community dominated by *Eriophorum chamissonis* (Chamisso's Cotton-Grass) and *Sphagnum teres*. Measurements of pH ranged from 4.7 to 5.3.

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to low pH and alkalinity, are the primary determinants of plant species composition at the site.

Rarity
A population of *Eriophorum gracile* (Slender Cotton-Grass, S2 / G5) was documented at this site in 1970. This population was not relocated during a field visit in 2002. This site is a good example of a poor fen, which is a rare wetland type in Montana.

Land Use
No disturbance was evident within the site.

Exotics
No exotic species were documented at the site.

Uplands
The uplands have been extensively logged. Almost 50 percent of the immediate catchment has been recently clearcut and road density is high. These factors could alter both the hydrology and biogeochemical cycling of the site. The buffer width is only 15 m for much of this site.

Plant Community Information

	Rarity Ranks		Viability
Plant Association / Dominance Type	**State**	**Global**	**Rank**
Carex lasiocarpa Herbaceous Vegetation	S4	G4?	B
Carex limosa Herbaceous Vegetation	S2	G2	B
Eriophorum chamissonis / *Sphagnum* Dominance Type	S*	G*	B

* Rank not assigned

Paul Creek Fen

Directions
This site is located in the Salish Mountains of northwestern Montana. From Stryker, travel south on Forest Route 315 for approximately 7 miles. Turn onto Forest Route 3525 and travel for about 0.5 mile. The site lies west of Forest Route 3525A just after it's split with Forest Route 3525.

Description
This site is a rich fen-carr complex. Major hydrologic inputs are ground and surface water from Paul Creek and seepage from adjacent toeslopes. A beaver dam across Paul Creek has created a small pool. This area is surrounded by a *Carex utriculata* (Beaked Sedge) community with inclusions of *Carex lasiocarpa* (Slender Sedge) and *Carex flava* (Yellow-Green Sedge). A diverse assemblage of bryophytes forms a nearly continuous moss layer. Common species include *Scorpidium cossonii*, *Campylium stellatum*, *Tomentypnum nitens*, *Calliergon giganteum*, *Palustriella falcata*, and *Bryum pseudotriquetrum*. A *Betula glandulosa* / *Carex utriculata* (Bog Birch / Beaked Sedge) carr, fed by groundwater discharge, dominates much of the site. *Betula glandulosa*, *Dasiphora fruticosa* (Shrubby Cinquefoil), and *Salix candida* (Hoary Willow) form a closed canopy over a *Carex utriculata*-dominated herbaceous layer. Other common vascular species include *Carex lasiocarpa*, *Carex leptalea* (Bristly-Stalk Sedge), *Carex aurea* (Golden-Fruit Sedge), *Juncus balticus* (Baltic Rush), *Geum macrophyllum* (Large-Leaf Avens), and *Symphyotrichum boreale* (Boreal American-Aster). *Tomentypnum nitens* and *Campylium stellatum* dominate a nearly continuous moss layer. The shrub cover diminishes where groundwater discharges from the toeslope. This much wetter area is dominated by *Carex utriculata*, *Carex buxbaumii* (Brown Bog Sedge), *Carex leptalea*, *Petasites frigidus* var. *sagittatus* (Arctic Sweet-Colt's-Foot), *Scorpidium cossonii*, *Tomentypnum nitens*, *Calliergon giganteum*, and *Sphagnum warnstorfii*.

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to high pH and alkalinity of the inflowing waters, are the primary determinants of plant species composition at the site.

Rarity
A population of the rare moss *Scorpidium scorpioides* (S2 / G4G5) has been documented at this site. This site is a good example of a rich fen, a rare wetland type in Montana.

Land Use
No disturbance was noted in the site.

Exotics
Cirsium arvense (Canada Thistle) and *Taraxacum officinale* (Common Dandelion) are present in the drawdown zone of an old beaver dam. *Cirsium arvense* is also present in small swales in the carr.

Uplands
The surrounding uplands have been extensively logged. There is no buffer between a clearcut area and toeslope seep along the western boundary of the site.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Betula glandulosa / *Carex utriculata* Herbaceous Vegetation	S4	G4?	B
Carex flava Dominance Type	S*	G*	B
Carex utriculata Herbaceous Vegetation	S5	G5	B

* Rank not assigned

Rainbow Lake

Directions
This site is located in the Purcell Mountains of northwestern Montana. From Libby, travel north on Forest Route 68 for approximately 23 miles. Turn onto Forest Route 4712 and travel for about 0.75 mile. Follow signs to Rainbow Lake.

Description
This site consists of floating organic and anchored mats around Rainbow Lake. The floating mats are 5-10 m wide and support a community dominated by *Carex lasiocarpa* (Slender Sedge) and *Sphagnum teres*. Other common species are *Carex limosa* (Mud Sedge), *Carex rostrata* (Swollen Beaked Sedge), *Menyanthes trifoliata* (Buck-Bean), *Comarum palustre* (Purple Marshlocks), and *Drosera anglica* (English Sundew). Surrounding this community, and dominating most of the site, is a species-poor *Carex lasiocarpa* community. *Calamagrostis canadensis* (Bluejoint Reed Grass) becomes dominant near the upland boundary. This site is an excellent example of a poor fen (pH was measured at 4.7).

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to low pH and alkalinity, are the primary determinants of plant species composition at the site.

Rarity
This site supports populations of three rare plants: *Carex rostrata* (Swollen Beaked Sedge, S1 / G5), *Drosera anglica* (English Sundew, S2 / G5), and *Scheuchzeria palustris* (Pod Grass, S2 / G5). Rainbow

Lake is also a known breeding site for Common Loon (*Gavia immer*, S2B / G5). This site is an excellent example of a poor fen, which is a rare wetland type in Montana.

Land Use
There is a hiking trail to the lake. Recreational use of the lake has resulted in some trailing.

Exotics
There is a small patch of *Phalaris arundinacea* (Reed Canary Grass) where the hiking trail accesses the lake.

Uplands
The immediate catchment around the lake has not been recently disturbed.

Management Needs
The *Phalaris arundinacea* (Reed Canary Grass) population needs to be monitored and should be controlled if necessary.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Calamagrostis canadensis Herbaceous Vegetation	S4	G4	A
Carex lasiocarpa Herbaceous Vegetation	S4	G4?	A
Carex lasiocarpa / *Sphagnum* Dominance Type	S*	G*	A

* Rank not assigned

Rattlebone Fen

Directions
This site is located in the Salish Mountains of northwestern Montana. From Trego travel east on Forest Route 36. After 1 mile, turn south onto Forest Route 857 and travel for about 2 miles. At the powerlines, turn onto the maintenance road and continue for about 1 mile to the site.

Description
This intermediate-poor fen occurs in a shallow glacial depression. A *Carex limosa* (Mud Sedge) community dominates the center of the fen. This community has high forb cover, mostly of *Menyanthes trifoliata* (Buck-Bean), and *Comarum palustre* (Purple Marshlocks). Moss cover, dominated by *Aulacomnium palustre* and *Scorpidium cossonii*, is nearly continuous. The rare moss *Meesia triquetra* is common. A *Carex lasiocarpa* (Slender Sedge) community with abundant cover of *Typha latifolia* (Broad-Leaf Cattail) surrounds the central fen. High *Typha* cover persists along the site's outlet, until it grades into a dense stand of *Phalaris arundinacea* (Reed Canary Grass). Pore water pH was measured at 5.4 in the *Carex limosa*-dominated central portion of the fen. Pore water pH increased nearer the site outlet: it was 5.9 in the *Carex lasiocarpa*-*Typha latifolia* community and 6.2 in the *Phalaris arundinacea* community.

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to low pH and alkalinity, are the primary determinants of plant species composition at the site.

Rarity
This site supports populations of three rare (S2 / G5) plants: *Eriophorum gracile* (Slender Cotton-Grass) and the mosses *Meesia triquetra* and *Scorpidium scorpioides*. The *Scorpidium scorpioides* population, documented in 1996 and 1997, was not relocated in 2002. However, the site was much drier in 2002 due to regional drought. This site is a good example of an intermediate-poor fen, which is a rare wetland type in Montana.

Land Use
No disturbance was observed at the site; however, *Typha latifolia* (Broad-Leaf Cattail) and *Phalaris arundinacea* (Reed Canary Grass) are encroaching into the fen.

Exotics
Phalaris arundinacea (Reed Canary Grass) is dominant along the outflow of the site. *Agrostis stolonifera* (Redtop) and *Cirsium arvense* (Canada Thistle) are present in drier portions of the site.

Uplands
The western boundary of the site has been cleared for a powerline and its associated maintenance road. The surrounding uplands have been logged; the forests are young with pole-sized trees.

Management Needs
The abundance of both *Typha latifolia* (Broad-Leaf Cattail) and *Phalaris arundinacea* (Reed Canary Grass) is cause for concern. Areas where these species are dominant had very high nitrate levels (32 and 36 mg/kg). In contrast, the *Carex limosa*-dominated portion of the fen had only 1 mg/kg of nitrate. Land use practices in the adjacent uplands may be responsible for these elevated nitrate (and ammonium) levels, which in turn has led to the dominance of *Typha* and *Phalaris* in large portions of the fen.

Plant Community Information

	Rarity Ranks		Viability
Plant Association / Dominance Type	**State**	**Global**	**Rank**
Carex lasiocarpa Herbaceous Vegetation	S4	G4?	B
Carex limosa Herbaceous Vegetation	S2	G2	A
Phalaris arundinacea Herbaceous Vegetation	S4	G5	B

Ruby Fen

Directions
This site is located near the Montana-Idaho border in northwestern Montana. From Troy, travel west on U.S. Highway 2 for about 2 miles, then turn onto Forest Route 4402. Follow this road for approximately 7 miles to forest Route 1055. After a mile on this road, continue on Forest Route 14339 for almost a mile to the site.

Description
Most of this poor fen is a floating mat dominated by *Carex lasiocarpa* (Slender Sedge) and *Dulichium arundinaceum* (Dulichium) communities. There is a large patch dominated by *Scirpus microcarpus* (Red-Tinge Bulrush) in the northern portion of the site.

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to low pH and alkalinity, are the primary determinants of plant species composition at the site.

Rarity
This site supports a good example of the rare *Dulichium arundinaceum* (Dulichium, S2 / G3) community. This site is a good example of a poor fen, a rare wetland type in Montana.

Land Use
No disturbance was noted at the site.

Exotics
No exotic species were documented at the site.

Uplands
The uplands have been logged.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Carex lasiocarpa Herbaceous Vegetation	S4	G4	A
Dulichium arundinaceum Herbaceous Vegetation	S2	G3	A
Scirpus microcarpus Dominance Type	S*	G*	A

* Rank not assigned

Tepee Lake

Directions
This site is located in the Salish Mountains of northwestern Montana. From Libby, travel south on U.S. Highway 2 for a little over 20 miles. Turn east onto Forest Route 6740. Continue on this road for approximately 7 miles. Veer left onto Forest Route 6738 and travel about 0.25 mile to the site.

Description
This poor fen consists of floating and anchored mats around a glacial depression. The floating mat is dominated by a *Dulichium arundinaceum* (Dulichium) community. Codominants include *Carex lasiocarpa* (Slender Sedge) and *Carex limosa* (Mud Sedge). The rare plant *Drosera anglica* (English Sundew) codominates in one small patch. A species-poor *Carex lasiocarpa* community dominated the surrounding anchored mat. A narrow fringe of *Calamagrostis canadensis* (Bluejoint Reed Grass) occurs between the peatland and surrounding uplands.

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to low pH and alkalinity, are the primary determinants of plant species composition at the site.

Rarity
This site supports populations of two rare plants (S2 / G5): *Drosera anglica* (English Sundew) and *Scheuchzeria palustris* (Pod Grass). It also supports a rare *Dulichium arundinaceum* (Dulichium) community. This site is a very good example of a poor fen, which is a rare wetland type in Montana.

Land Use
No disturbance was noted at the site.

Exotics
No exotic species were documented at the site.

Uplands
The adjacent uplands have been extensively logged, although the immediate catchment is buffered.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Carex lasiocarpa Herbaceous Vegetation	S4	G4?	A
Dulichium arundinaceum Herbaceous Vegetation	S2	G3	A

White Creek Fen

Directions
This site is located in the Salish Mountains of northwestern Montana. From Trego, travel south on Forest Route 36 for approximately 10.5 miles. The site is immediately east of the road.

Description
This site is an extremely rich fen (pH measured at 7.6) fed by groundwater and surface water from White Creek. There are extensive marl deposits along the banks of White Creek where it enters into the fen. This flow-through fen sits on a gently sloping flat with fibric marly peat to a depth of at least 120 cm. A *Betula glandulosa* / *Carex utriculata* (Bog Birch / Beaked Sedge) community dominates this site, characterized by a very open canopy of *Betula glandulosa*. *Carex utriculata* is the dominant graminoid; other common species include *Carex leptalea* (Bristly-Stalk Sedge), *Dodecatheon pulchellum* (Dark-Throat Shootingstar), *Parnassia fimbriata* (Fringed Grass-of-Parnassus), and *Symphyotrichum boreale* (Boreal American-Aster). The moss layer is nearly continuous. *Tomentypnum nitens* and *Scorpidium cossonii* are the dominant species.

Key Environmental Factors
Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and substrate, in addition to high pH and alkalinity of the inflowing waters, are the primary determinants of plant species composition at the site.

Rarity
Three rare plant species have been documented at this site: *Carex vaginata* (Sheathed Sedge, S1 / G5), *Cypripedium passerinum* (Sparrow-Egg Lady's-Slipper, S2 / G4G5), and *Amerorchis rotundifolia*

(Round-Leaf Orchid, S2S3 / G5). This site is an excellent example of a rich fen, which is a rare wetland type in Montana.

Land Use
No disturbance was noted at the site.

Exotics
No exotic species were documented at the site.

Uplands
The surrounding uplands have been logged, but not recently.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Betula glandulosa / *Carex utriculata* Shrubland	S4	G4?	A

Wigwam Beaver

Directions

This site lies in the Whitefish Range of northwestern Montana. From Fortine, travel north on U.S. 93 for approximately 3 miles to Grave Creek Road (Forest Route 114). Follow this road for about 14 miles. At Drip Creek, veer left onto Forest Route 319 and continue for another 13 miles to Forest Route 7086. After crossing the Wigwam River, turn onto Forest Route 7090. Hike up this road for a little over 1 mile. The site lies in the valley bottom about 150 m from the road.

Description

This site consists of a series of rich peatlands formed by past beaver activity. The substrate is 30 cm of sedge peat over silty loam. These peatlands are dominated by a relatively species-rich *Carex utriculata* (Beaked Sedge) community. *Carex utriculata* is very abundant, but other common species include *Calamagrostis canadensis* (Bluejoint Reed Grass), *Carex canescens* (Hoary Sedge), *Bromus ciliatus* (Fringed Brome), *Petasites frigidus* var. *sagittatus* (Arctic Sweet-Colt's-Foot), *Epilobium palustre* (Marsh Willowherb), and *Comarum palustre* (Purple Marshlocks). Although present at low cover, shrub cover is diverse and includes *Salix drummondiana* (Drummond's Willow), *Salix boothii* (Booth's Willow), *Salix tweedyi* (Tweedy's Willow), *Betula glandulosa* (Bog Birch), *Dasiphora fruticosa* (Shrubby Cinquefoil), and *Ledum glandulosum* (Glandular Labrador-Tea). Moss cover ranges from common to abundant; the dominant species include *Campylium stellatum*, *Bryum pseudotriquetrum*, *Plagiomnium rugicum*, and *Scorpidium cossonii*.

Key Environmental Factors

Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and

substrate, in addition to high pH and alkalinity of the inflowing waters, are the primary determinants of plant species composition at the site.

Rarity
A population of *Carex magellanica* ssp. *irrigua* (=*Carex paupercula*, Boreal-Bog Sedge, S3 / G5) was documented in a wet meadow adjacent to the site. This site is a very good example of a rich peatland, a rare wetland type in Montana.

Land Use
No disturbance was noted at the site.

Exotics
No exotic species were documented at the site.

Uplands
The lower valley slopes of this entire portion of the Wigwam drainage have been logged. The 100-m buffer around the site is intact.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Carex utriculata Herbaceous Vegetation	S5	G5	A

Wigwam Carr

Directions

This site lies in the Whitefish Range of northwestern Montana. From Fortine, travel north on U.S. 93 for approximately 3 miles to Grave Creek Road (Forest Route 114). Follow this road for about 14 miles. At Drip Creek, veer left onto Forest Route 319 and continue for another 13 miles to Forest Route 7086. After crossing the Wigwam River, turn onto Forest Route 7090. Hike up this road for approximately 0.5 mile. The site lies in the valley bottom about 150 m from the road.

Description

This rich carr lies in the floodplain of the Wigwam River, but the site's hydrology appears to be strongly influenced by groundwater and surface water inflow from the adjacent toeslope. The carr is dominated by a previously undescribed *Betula glandulosa* / *Carex buxbaumii* (Bog Birch / Brown Bog Sedge) community. This species-rich community is characterized by a nearly closed canopy of *Betula glandulosa* over abundant cover of *Carex buxbaumii* and *Calamagrostis canadensis* (Bluejoint Reed Grass). Other common species include *Carex utriculata* (Beaked Sedge), *Petasites frigidus* var. *sagittatus* (Arctic Sweet-Colt's-Foot), *Polygonum bistortoides* (American Bistort), *Valeriana dioica* (Marsh Valerian), and *Symphyotrichum boreale* (Boreal American-Aster). The moss layer is patchy but diverse; common species include *Hypnum pratense*, *Tomentypnum nitens*, *Plagiomnium rugicum*, *Campylium stellatum*, and *Pseudotaxiphyllum elegans*. The carr has herbaceous openings dominated by *Carex buxbaumii*.

Key Environmental Factors

Hydrology and water chemistry are the primary influences on vegetation at this site. A stable hydrologic regime and continuously saturated conditions have led to the development of peat soils. Hydrology and

substrate, in addition to high pH and alkalinity of the inflowing waters, are the primary determinants of plant species composition at the site.

Rarity
An undescribed community dominated by *Betula glandulosa* (Bog Birch), *Carex buxbaumii* (Brown Bog Sedge), and *Calamagrostis canadensis* (Bluejoint Reed Grass) was documented at this site. This site is an excellent example of a rich peatland, a rare wetland type in Montana.

Land Use
No disturbance was noted at the site.

Exotics
No exotic species were documented at the site.

Uplands
The lower valley slopes of this entire portion of the Wigwam drainage have been logged. The 100-m buffer around the site is intact.

Plant Community Information

Plant Association / Dominance Type	Rarity Ranks		Viability Rank
	State	Global	
Betula glandulosa / Carex buxbaumii Dominance Type	S*	G*	A

* Rank not assigned

Appendix C. Species List

Vascular Plants

Agrostis scabra
Agrostis stolonifera
Alnus viridis
Angelica arguta
Betula glandulosa
Bromus ciliatus
Calamagrostis canadensis
Calamagrostis inexpansa
Carex aquatilis
Carex aurea
Carex buxbaumii
Carex canescens
Carex chordorrhiza
Carex diandra
Carex flava
Carex gynocrates
Carex interior
Carex lasiocarpa
Carex leptalea
Carex limosa
Carex prairea
Carex rostrata
Carex utriculata
Carex vesicaria
Castilleja spp.
Cirsium arvense
Comarum palustre
Cornus canadensis
Dasiphora fruticosa ssp. *floribunda*
Dodecatheon pulcellum
Drosera anglica
Drosera rotundifolia
Dulichium arundinaceum
Eleocharis quinquifolia
Elymus trachycaulis
Epilobium palustre
Epilobium spp.
Equisetum arvense
Equisetum fluviatile
Equisetum variegatum
Eriophorum angustifolium
Eriophorum chammisonis
Eriophorum gracile
Eriophorum viridicarinatum
Fragaria virginiana
Galium biflorum
Galium boreale
Galium trifidum
Galium triflorum
Geum macrophyllum
Geum rivale
Glyceria striata
Juncus balticus
Juncus filiformis
Juncus nodosus
Juncus spp.
Ledum glandulosa
Lemna minor
Linnaea borealis
Lycopus uniflorus
Maianthemum stellatum
Mentha arvensis
Menyanthes trifoliata
Mimulus guttatus
Muhlenbergia glomerata
Packera pseudaureus
Parnassia fimbriata
Petasites frigidus var. *sagittata*
Phalaris arundinacea
Phragmites australis
Picea engelmannii
Pinus contorta
Platanthera dilatata
Poa pratensis
Polygonum amphibium
Polygonum bistortoides
Pyrola spp.
Ranunculus gmelinii
Rhamnus alnifolia
Ribes spp.
Rubus pubescens
Rubus spp.
Salix bebbiana
Salix boothii
Salix candida
Salix drummondiana
Salix planifolia
Salix tweedyi
Scheuchzeria palustris
Scirpus microcarpa
Scirpus pallidus
Senecio triangularis
Sium suave
Spiraea douglasii
Spiranthes romanzoffia
Symphyotrichum boreale
Symphyotrichum eatonii
Symphyotrichum laeve
Taraxacum officinale
Triglochin palustris
Typha latifolia
Valeriana dioica
Veronica americana
Viola macloskeyi ssp. *pallens*
Viola nephrophylla
Zigadenus elegans

Bryophytes

Aneura pinguis
Aulacomnium palustre
Bryum pseudotriquetrum
Calliergon giganteum
Calliergon stramineum
Campylium stellatum
Cratoneuron filicinum
Drepanocladus aduncus
Drepanocladus spp.
Hamatocaulis vernicosus
Hypnum lindbergii
Hypnum pratense
Meesia triquetra
Palustriella falcata
Plagiomnium rugicum
Pseudotaxiphyllum elegans
Scorpidium cossonii
Sphagnum russowii
Sphagnum subsecundum
Sphagnum teres
Sphagnum warnstorfii
Tomentypnum nitens

Appendix D. Multivariate Analysis and Indicator Species for Rich and Poor Fens

PURPOSE AND METHODS

An additional goal of this study was to describe general patterns of peatland vegetation. To accomplish this, I characterized vegetation community patterns (variation in species composition and abundance among plots) in relation to a pH-alkalinity gradient using nonmetric multidimensional scaling (NMS; McCune and Mefford 1999). NMS is an indirect ordination technique that works without assumptions of linear or unimodal response and avoids many of the distortions of eigenvector-based ordination methods, such as detrended correspondence analysis (Kenkel and Orlóci 1986, Minchin 1987). To reduce beta diversity (compositional heterogeneity among sample units (Whittaker 1972)) and improve the interpretability of results, species occurring in fewer than 5% of plots were omitted from the analysis and abundance values were log transformed. The ordination was based on Sørensen (city block) distance measurement. I used joint plot overlays to illustrate the relationship between pH and species occurrences and ordination scores. Multi-response permutation procedures (MRPP), a nonparametric procedure that tests for differences among groups, was used to assess whether plant communities associated with rich and poor fens were significantly different (McCune and Mefford 1999). In addition to a *p*-value, MRPP also provides a chance-corrected within-group agreement statistic *A* that describes within-group homogeneity compared to that expected by chance. *A* values in community ecology studies are commonly less than 0.1, while $A > 0.3$ is considered high (McCune and Grace 2002).

Finally, species with a high fidelity to either rich or poor fens were identified using indicator species analysis (Dufrêne and Legendre 1997). This method gives each species an indicator value for a particular group (in this case rich or poor fen) ranging from 0 (no indication) to 100 (perfect indication). The statistical significance of indicator values was tested by a Monte Carlo procedure using 1000 randomized iterations (McCune and Mefford 1999).

RESULTS

Plant communities were significantly structured along a pH-alkalinity gradient (MRPP; $A = 0.167$, $p < 0.001$). This is graphically illustrated by the NMS ordination diagram (Figure 1). Axis 1, which is highly correlated with pH ($R^2 = 0.739$), represents the greatest variance among sample plots. Axis 2 may represent a hydrological gradient: in rich fens, plots with greater shrub cover are in the upper right portion of the ordination diagram, while plots dominated by *Carex utriculata* are in the lower right. As observed in previous research, rich fens supported higher richness of vascular plants and bryophytes (Vitt et al. 1995, Chadde et al. 1998). One interesting result of this study is the high fidelity of *C. lasiocarpa* to poor fens. This is in contrast to other observations from northwestern Montana peatlands where it is known to dominate both rich and poor fens (Chadde et al. 1998, M. Jones, pers. observation) and likely represents a sampling artifact.

Indicator species significantly associated with rich and poor fens (indicator value ≥ 25, $p \leq 0.05$) are shown in Table 1.

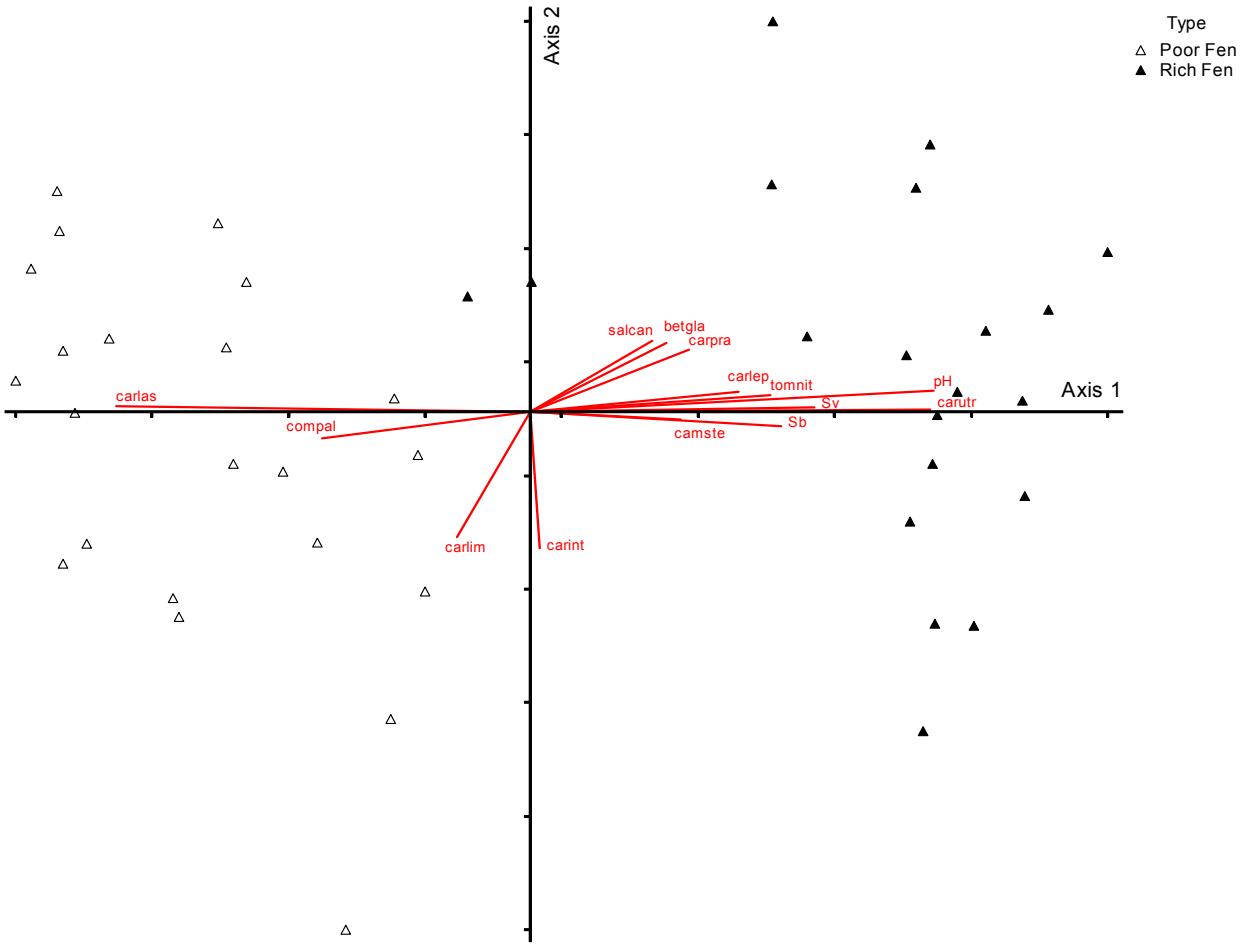

Figure 1. Graphical representation of the NMS ordination. Points represent sample units; distance between units is proportional to dissimilarity between samples. Joint plots show vectors of environmental variables, diversity measures, and species composition. Vector length represents strength of correlation with ordination axes. The proportion of variance represented (R^2) by Axis 1 is 0.694; for Axis 2 it is 0.120. pH = pore water pH, S_V = richness of vascular plants, S_B = richness of bryophytes, betgla = *Betula glandulosa*, camste = *Campylium stellatum*, carint = *Carex interior*, carlas = *C. lasiocarpa*, carlep = *C. leptalea*, carlim = *C. limosa*, carpra = *C. prairea*, compal = *Comarum palustre*, salcan = *Salix candida*, tomnit = *Tomentypnum nitens*.

Table 1. Significant indicator species for rich and poor fens.

Species	Indicator Value	*p*
Poor Fens		
Carex lasiocarpa	82.8	0.001
Carex limosa	45.5	0.001
Comarum palustre	78.7	0.001
Dulichium arundinaceum	36.4	0.004
Menyanthes trifoliata	39.6	0.010
Sphagnum teres	27.3	0.032
Rich Fens		
Betula glandulosa	65.0	0.001
Bromus ciliatus	30.0	0.008
Bryum pseudotriquetrum	42.6	0.018
Calliergon giganteum	44.0	0.003
Campylium stellatum	48.7	0.002
Carex leptalea	60.0	0.001
Carex prairea	40.0	0.002
Carex utriculata	86.8	0.001
Dasiphora fruticosa	45.0	0.002
Dodecatheon pulchellum	25.0	0.027
Epilobium palustre	36.7	0.005
Galium boreale	25.0	0.013
Geum macrophyllum	25.0	0.023
Glyceria striata	30.0	0.003
Palustriella falcata	30.0	0.007
Parnassia fimbriata	50.0	0.001
Picea engelmannii	35.0	0.001
Plagiomnium rugicum	23.6	0.031
Rhamnus alnifolia	35.0	0.005
Salix candida	57.3	0.001
Symphyotrichum laeve	25.0	0.021
Tomentypnum nitens	55.7	0.001

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