Inventory of Fens in a Large Landscape of West-Central Colorado

Grand Mesa, Uncompahgre, and Gunnison National Forests

April 6, 2012

Beaver Skull Fen in the West Elk Mountains – a moat surrounding the floating mat

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N. Kashi, J. Simonsen, B. Ogata, S. Louis-Prescott.
High Mesa, Cimarron Overlook, August 1, 2009.

J. Simonsen, S. Jay.
Above Silverton, July 14, 2010.

Johnston, Barry C.; Benjamin T. Stratton; Warren R. Young; Liane L. Mattson; John M. Almy; and Gay T. Austin. 2012. Inventory of Fens in a Large Landscape of West-Central Colorado: Grand Mesa, Uncompahgre, and Gunnison National Forests. Report to Forest Supervisor, 209 pp. Delta, Colorado: Grand Mesa, Uncompahgre, and Gunnison National Forests. April 6, 2012. Published on World Wide Web.

Summary

As part of on-going resource management and forest planning activities, the Grand Mesa, Uncompahgre, and Gunnison National Forests (GMUG) began an effort in 2008 to better understand the abundance and distribution of fens on lands managed by the GMUG. To complete this effort, the forest assembled a multi-disciplinary team composed of specialists in soil science, geology/hydrogeology, hydrology, botany, and range management. This group was directed by forest leadership to provide information in three areas:

- Distribution and characterization of fens
- Evaluation of the condition of fens
- Land management implications for fens

This report details the results of efforts to better characterize the unique and important fen resource present on GMUG lands. It is intended to inform local resource specialists on the GMUG, as well as others interested in wetland and fen research, of the methods and results of all fen investigation efforts that have been conducted on the GMUG.

This report is the result of three years of investigation. Photointerpretation of the entire Grand Mesa, Uncompahgre, and Gunnison National Forests for potential fens was completed in 2009, identifying 3,270 potential fen sites covering 17,485 acres, about 0.65% of the Forest.

Prior to the selection of a field verification sample set, the Forest was divided into twelve landscape areas based on similarities of geologic and hydrologic settings, climate, and glaciation. About two hundred 1 × 1 km cells across the Forest were selected for inventory using a spatially balanced sampling process. During the field seasons of 2009 and 2010, 204 of those cells and 336 potential fens were visited and sampled. One hundred forty-seven fens were documented and complete data collected. From this sample it can be estimated with 95% confidence that there are approximately 1,738 (±827)[g] fens covering 11,034 (±6,936) acres on GMUG lands.

Some general spatial attributes were common to the fens visited. About half the fens found are less than four acres; 20% of them are less than one acre. Most of the fens found are fen-wetland complexes with several to many different communities in the same wetland. The majority (90%) of the fens found are between 9,000 ft and 11,900 ft elevation. Most of the fen acres are associated with unconsolidated glacial drift or mass wasting geologic map units.

Most fens were observed to have some form of disturbance, with a wide variety of different disturbance factors present. The most common general disturbances documented during the field work, in order of frequency of occurrence, were browsing, grazing, trampling, trails, beaver activity, flooding, and vehicle tracks. However, disturbances such as flooding, de-watering, and the presence of vehicle tracks, though less frequent are of greater consequence because they are much more likely to disturb or threaten the functioning quality of the fen. Six fens had no apparent disturbances.

Disturbances were also investigated in a 100-meter buffer (outward from the edge of the fen-wetland complex). The most common general disturbances in the buffer, in order of frequency of occurrence, are browsing, grazing, trails, roads, erosion, tree cutting, trampling, and vehicle tracks. Again, disturbances such as tracks, roads, and campsites, while being less often encountered, are of much greater consequence than the more frequently observed disturbances because they increase the risk to fen function.

Using similar factors used by other scientists, a rating system for the assessment of fen condition was devised. Based on this system, 81% of the fens we investigated in 2009-2010 would be classed as high condition, 18% in moderate condition, and 1% in low condition. To further test this system, data from other sources describing lower-condition “modified fens” (or “former fens”), were ranked according to the score sheet, and the rating system seems to correctly characterize those sites as well.

[g]. Standard Error.

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I. Introduction

A. Fens

Fens are important, unique wetlands in the Rocky Mountains. They are ancient ecosystems 8,000 to 12,000 years old. Even though they occupy less than 0.5% of the landscape, they "provide important headwater quality functions," including carbon storage, water storage, wildlife habitat, and biodiversity (Austin 2008, Cooper and Andrus 1994, Chadde and others 1998). Fens are "tightly connected to complex local groundwater flow systems," consequently disruptive changes to groundwater flows can cause severe degradation or loss of functions. Restoration of fens is possible if most of the key fen functions are still active; yet restoration can take many years of work and is expensive (Cooper and MacDonald 2000).

Many scientists accept Mitsch and Gosselink's definition of *fen* simply as "a peat-accumulating wetland that receives some drainage from surrounding mineral soil" (Mitsch and Gosselink 2000), although some prefer to emphasize chemical (pH) or hydrological (surface-saturated) or physiological (anaerobic) characteristics (Bedford and Godwin 2003). Others have required sites to meet the formal criteria established for organic soils (Histosols) in the USDA soil taxonomy (Sikes and others 2010, Soil Survey Staff; see Appendix I). The criteria include the duration of saturated conditions, organic carbon content, and a minimum thickness. Generally 40 cm of peat (in the upper 80 cm of soil) is considered a minimum requirement.

More recently, as additional fen inventories have taken place, there have been increasing discussions that the rigid requirements of the USDA soil taxonomy may not be appropriate for defining fens, as leading scientists have recently suggested (Cooper 2009). The USDA soil taxonomy was not designed to describe fens, and at present its description of organic soils (Histosols) is in early formative stages, especially in regards to peat thickness and organic carbon content.

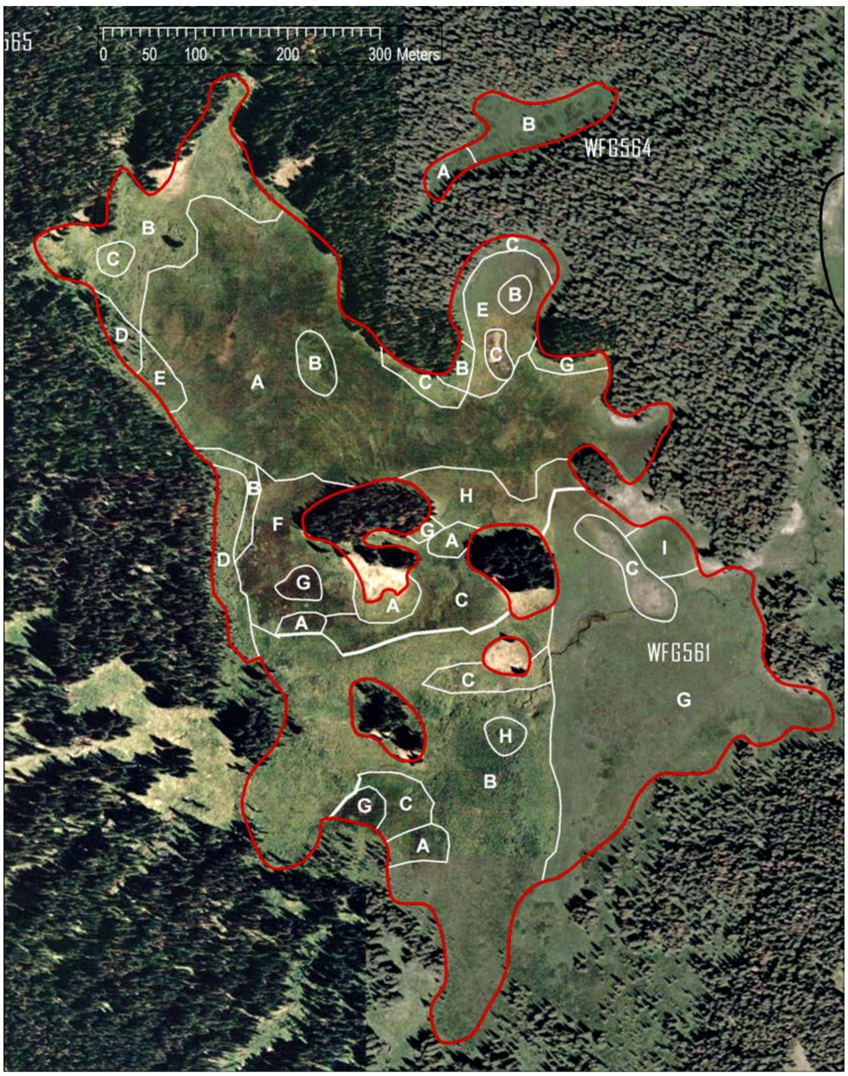
According to Driver (2010), a fen should be "characterized as having water tables near the soil surface with little annual variance and short periods with deeper water tables" and "the surficial accumulation of ≥ 20 cm of peat and the presence of common fen species". There is even debate within the community about whether it is necessary to demonstrate that the soil is actually peat, which would entail some minimum requirement for organic carbon or organic matter. Table 1-1 provides an overview of some of the definitions and terms used in previous studies of fens.

Table 1-1. Various definitions for peatlands, fens, and organic soils.

Term	Definition	Reference
Peatland, Canada	[Wetland with] peat > 40 cm deep	Ovenden 1990
Fens, British Columbia	Wetlands composed of accumulations of well to poorly decomposed, nonsphagnic peats. Most fens have more than 40 cm of peat accumulation. Fen waters come mostly from groundwater and runoff from adjacent mineral uplands	Pojar 1991
Peatland (Fen), Colorado	Wetland with soils that consist of at least 25% organic matter (i.e., decomposed leaves, stems, etc.)	Sanderson and March 1996
Peatland, northern Rocky Mountains, USA	Wetlands with waterlogged substrates and approximately 30 cm or more of peat accumulation	Chadde and others 1998
Organic Soil, Canada	Contain more than 17% organic C (about 30% or more organic matter)	Soil Classification Working Group 1998
Peatlands, Rocky Mountains	Wetlands with at least 40 cm of organic soils that consist of at least 12-18% organic-carbon content	Rocchio 2006a
Peatland, Northern Europe	"A peatland is an area covered by peat of a certain minimum depth, usually 30 cm"	Moen 1995, Cooper and Wolf 2006
Peatlands, World	"30-40 cm of 'peat,' but what is 'peat'? (Is it what USDA classifies as 'organic soil'?) What % organic matter? What % organic carbon? What % mineral sediment? No criteria for these topics because most peatlands studied are large unconstrained mires"	Cooper 2009
Histosol, USA	Organic C ≥ 12% to 18% depending on clay content, thickness of organic material ≥ 40 cm	Soil Survey Staff 2010
Fen, California	[Wetland] with "at least 40 cm of peat in the upper 80 cm of the soil profile… definition of a[n] Histosol," and with water table "within 20 cm of the soil surface during July and August of a normal precipitation year"	Sikes and others 2010
Fen, Colorado	"Characterized as having water tables near the soil surface with little annual variance and short periods with deeper water tables" and "the surficial accumulation of ≥20 cm of peat and the presence of common fen species"	Driver 2010

Fens may be found as discrete features, and are commonly found associated with wetlands supported by mineral soils within a “wetland-fen complex”. These complexes often include a number of distinct plant communities; each a different combination of plant species, hydrology, soils, and landform. One or more of the communities may meet the criterion for a fen while others may not. For efficiency, often the entire complex is considered to be a fen. Figures 1-1 and 1-2 illustrate the intricate nature of these complexes.

Figure 1-1. Horse Fen, on Grand Mesa. Note the concentric bands of different community types. August 5, 2008.



CT	%	Vegetation
A	25	ELAC-DREPA3
B	25	SAPL2
C	10	CAUT-CAAQ
D	5	ABBI3-SAPL2-DECE
E	5	ELAC-DREPA3-CAUT
F	5	CAAQ-ELAC-DREPA3
G	10	CACA4-VETE4-SETR
H	10	CAJO-CACA4-CAPR5-CAAQ
I	5	DECE-CASA10

Figure 1-2. An example of a fen-wetland complex, comprised of several different communities. Fen WFG561 on the Grand Mesa. Background imagery is 1 m 2008 NAIP imagery (USDA Farm Service Agency 2010).

For the purposes of this inventory, we concluded that any wetland with anaerobic conditions where peat is accumulating should be considered a fen. As a practical matter, some minimum thickness of peat should be required. We used 30 cm in this inventory (in the top 80 cm of soil, if there is an intervening mineral layer). Although any thickness is arbitrary, since different Rocky Mountain peatlands have been demonstrated to have different peat accumulation rates (Table 1-2). The thicker peat deposits tend to have faster accumulation rates (Figure 1-3).

Several of the large, Forest-wide inventories of the past (timber, range, soils, Integrated Resource Inventory) left out wetlands and fens, in most cases because wetland features did not meet minimum size requirements. The more-recent fisheries inventory did inventory some wetlands, yet did not inventory all wetlands, or distinguish fens. The National Wetlands Inventory (U. S. Fish and Wildlife Service 2005), while being of great value, is not detailed enough to distinguish fens. The Colorado Riparian Mapping Project (Colorado Division of Wildlife 2004) usually doesn't identify fens or non-riverine wetlands.

Table 1-2. Peat accumulation rates for Colorado fens. (adapted from Cooper 2005-2009)

Location	Basal Date, YBP	Peat Thickness, cm	Accumulation Rate mm/yr	cm/ 1000 yr	yr/ m	Reference
Placer Gulch Bog	8,790±260	85	0.10	9.67	10,341	Carrara et al. 1991
High Ck. Windmill Fen	8,270±140	90	0.11	10.88	9,189	Cooper 1990b
Green Mountain Pond	11,820±170	150	0.13	12.69	7,880	Cooper 1990a
Big Meadows	11,230±170	150	0.13	13.36	7,487	Cooper 1990a
Sacramento Creek	9,820±150	213	0.22	21.69	4,610	Cooper 1990b
Buffalo Pass	7,730±250	193	0.25	24.97	4,005	Madole 1980
East Lost Park Fen	10,080±150	264	0.26	26.19	3,818	Cooper 1990b
Mt. Emmons Iron Fen	8,260±220	220	0.27	26.63	3,755	Fall 1997
Silver Lake Fen	6,190±300	175	0.28	28.27	3,537	Pennak 1963
Eureka Gulch Fen	6,180±160	240	0.29	38.83	2,575	Carrara et al. 1991
Cottongrass Fen	10,460±240	340	0.33	32.50	3,076	Cooper and Arp 2002
Carpenter's Fen	9,280±180	320	0.34	34.48	2,900	Cooper 1990b
McMaster's Fen	9,220±110	333	0.36	36.12	2,769	
Dome Creek Meadow	7,800±100	362	0.46	46.41	2,155	Feiler et al. 1997
Church Camp Fen	4,250±80	590	1.39	138.82	720	USGS 2010
Spruce Fen	8,750±50	255	0.29	29.14	3,431	USGS 2010
Averages		248.75	0.33	33.17	4,515.5	

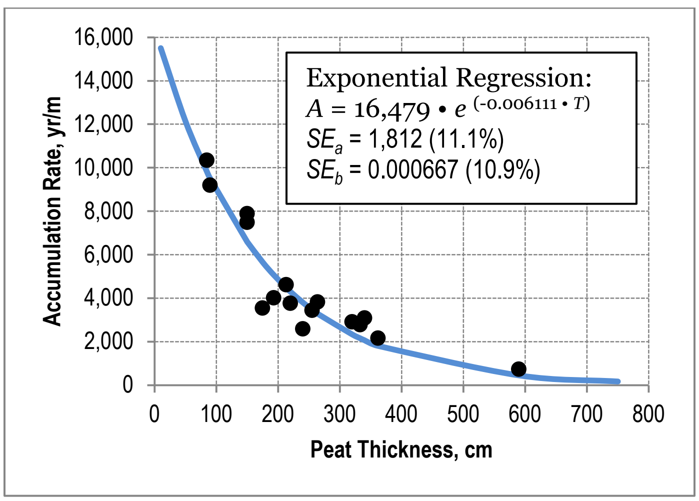


Figure 1-3. Peat accumulation rates as a function of peat thickness. Data from Table 1-2 (n = 16)[h].

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h . n = Number of samples.

B. Other Fen Inventories on the National Forests

Several localized monitoring and research projects addressing fens have been conducted in the past decade on the GMUG. These studies have resulted in knowledge about some fens on the Grand Mesa, the Northern San Juan Mountains near Telluride, and the Taylor Park area (see Figure 3-1). The delineations from these three studies were merged into potential fen sites from the photointerpretation.

David Bathke in Taylor Park, 2000 – 2003

In the years 2000, 2001, and 2003, David Bathke conducted inventories for fens in and around Taylor Park, in the Sawatch Mountains Area (Bathke 2000-2001-2003). Using National Wetland Inventory maps (U. S. Fish and Wildlife Service 2005), Bathke identified the map units that were most likely to describe fens. He visited 236 of these sites, which were mostly in Taylor Park and adjacent creeks; his investigations didn't include many high-elevation sites.

For each site, he recorded location, general soil surface type, wetness of soil surface, and water sources. He described apparent disturbances and whether frogs were present, and took GPS readings at selected points in the site. He estimated size of site (length and width), and interpolated the elevation from quadrangle map. He recorded all plant species seen, without any quantification. In complex sites, he also provided a sketch map showing different conditions in different parts of the site. He took several photographs of each site, then estimated whether the site was a wetland and whether it was a fen. For the most part, he used presence of bryophytes, saturated surface, and "sponginess" of each site to make his determinations. Subsequent investigations have shown that those sites Bathke identified as fens and fen complexes do meet our definition of fen described above. His estimates of kinds of wetlands are shown in Table 1-3.

Table 1-3. Wetlands and fens in Taylor Park, 2000-2003. (Bathke 2000-2001-2003)

Wetland Type	No.	Acres
Fen	8	36.7
Fen Complex	20	1,263.5
Wetland	188	610.0
Not Wetland	20	23.0
Totals	236	1,933.2

Bathke's was not a random-based inventory, but rather a more intensive inventory of a portion of the landscape of Taylor Park, the major river bottoms and closely adjacent sites. So his results cannot be extended to other areas. From Table 1-3, his fen complexes were very large, averaging over 60 acres; and these fen complexes are larger in Taylor Park than in other parts of the National Forests. For consistency across the Forest, several of these large fen complexes were split into smaller units in the 2009-2010 inventory. Since Bathke didn't quantify plant species, we couldn't use his data in vegetation classification.

All of Bathke's polygons, as drawn on paper maps, were transferred to digital format. Most of these were accepted into the 2009-2010 inventory as potential fen sites.

Gay Austin on Grand Mesa, 2003 – 2008

Gay Austin investigated most of the top of Grand Mesa starting in the early years of this century, culminating in her Master's thesis under David Cooper at Colorado State University, and the data set that accompanied it (Austin 2008). Her remarkable study included over 120 sites, within which she sampled over 320 different plant communities, although only 111 sites and 307 plant communities were included in analysis for her thesis. She began with photointerpretation of much of the top of Grand Mesa, using the 1:24,000 natural-color aerial photos then available.

Through photointerpretation, she identified a number of sites for field investigation. Over several years these sites were visited, and some of those sites were found to be fens, each site usually comprising several different communities. At some of these communities, a soil sample was taken and tested in the laboratory for organic carbon. Water chemistry samples included pH and electrical conductivity in each community.

The cover of all vegetation species, including bryophytes, was estimated on approximately 16 m^2 relevé in each community. Disturbances at each site were carefully described using both aerial photography and on-site observations, using a number of scalar measurements that Austin devised. She also identified potential sites for restoration, and provided recommendations to resource managers.

Austin also studied the effects of various disturbance factors on fens, especially reservoir management, ditches, recreational vehicles, and grazing. There was a great deal of analysis, ordination and clustering in Austin's thesis, leading to a plant community classification (Table 1-4).

Table 1-4. Plant community classification for Grand Mesa fens and associated wetlands. (n = 307)
All communities within a fen-wetland complex were sampled. "Communities with an asterisk * were found only in fens" (Austin 2008).

Semi-aquatic communities
A1. *Nuphar lutea* ssp. *polysepala – Potamogeton nodosus*
A2. *Eleocharis macrostachya – Potamogeton foliosus*
Large sedge communities
B1. *Carex vesicaria*
B2. *Carex utriculata*
B3. *Carex saxatilis – Drepanocladus aduncus*
Floating mat & bryophyte communities
C1. *Menyanthes trifoliata**
C2. *Carex limosa – Sphagnum teres - Calliergon cordifolium**
C3. *Calliergon stramineum – Carex limosa – Menyanthes trifoliata**
C4. *Sphagnum teres – Calliergon cordifolium - Carex canescens**
Small sedge communities
D1. *Carex aquatilis – Drepanocladus aduncus*
D2. *Carex simulata – Drepanocladus aduncus*
D3. *Eleocharis quinqueflora – Drepanocladus aduncus – Carex simulata*
D4. *Carex illota – Aulacomnium palustre – Pedicularis groenlandica*
D5. *Eleocharis acicularis – Hippuris vulgaris**
Shrub communities
E1. *Salix planifolia - Calamagrostis canadensis*
Tree communities
F1. *Picea engelmannii - Salix planifolia – Climacium dendroides*

In the 2009-2010 inventory, we adapted many of Austin's concepts and procedures. Her experience with photointerpretation was adapted and improved as we moved to the larger-scale 1:15,860 aerial photos. We used the same 4 × 4 m relevé design, with some improvements for better ground cover and bryophyte cover estimation; we sampled only one community within a fen-wetland complex, whereas Austin sampled all of them. We added several features to Austin's inventory design, including a sketch map and ground water flow diagrams. Photograph locations were standardized, and we considerably improved and standardized her inventory design for disturbances.

Chimner, Cooper, and Lemly in the San Juan Mountains, 2006 – 2008

Rod Chimner of Michigan Technological University, and David Cooper and Joanna Lemly of Colorado State University worked together in this EPA-funded study of the fens of the San Juan Mountains (Chimner and others 2008, Chimner and others 2010). Using photointerpretation of natural-color aerial photographs, they identified 624 potential fens in eighteen randomly-selected watersheds, and did complete field sampling at 182 of these fen sites. The field sampling protocol was similar to that used by Gay Austin on the Grand Mesa, with additional laboratory chemical tests.

Chimner, Lemly, and Cooper also estimated disturbance kind, frequency and intensity.

> "The most common disturbance encountered was impacts by animals, mostly by elk and deer. Disturbances from animals were generally limited to small bare patches where elk wallowed or in trampled areas from elk grazing fen vegetation. The disturbances were generally limited in size and were generally classified as low severity. Recreation (e. g., skiing, hiking) was the second most common disturbance encountered in the study. Most of the recreation impacts were very low severity and did not impact fen functioning. … Heavy recreational use can cause trampling of fen vegetation or alteration of fen hydrology. Roads were the most numerous impact that altered fen functioning. Roads impacted the flow of water to fens, bisected fens, and were a source of mineral sediment into the fens. Road impacts were numerous… Most road disturbances were classified as moderate severity … a few roads caused more severe impacts when bad culvert placement created channelization and erosion in the fens. Off-roading was also common in the much of the San Juans, where many old mining roads have been turned into 4×4 roads. Several fens in this area showed signs of off-road vehicles haven driven through or adjacent to them. Off-roading adjacent to fens was frequently ranked as low severity as it typically only had minor influence to the fens, unless it cut into the soil and altered groundwater flow to the fen. However, off-roading in a fen can cause severe disturbance as deep tire tracks in fens can act as ditches. In some fens the tire tracks moved enough water to cause erosion in the tracks, a precursor to gully formation" (Chimner and others 2008).

A major feature of the study by Chimner and others was their estimation of the restoration potential of the fens they inventoried. This was based in part on their subjective estimation of the condition of their fens: "Overall, the majority of fens (88) were in good condition, with 76 in excellent condition. However, 22 were evaluated to be in fair condition and 9 were found in poor condition." Their field subjective estimates of restoration potential were in four categories, very high, high, medium, and low.

A portion of their study area was within the Uncompahgre National Forest; they did not collect data from the Cimarron River and Gunnison River watersheds. They identified 162 potential fens in selected watersheds on the Uncompahgre National Forest, of which 30 were subjected to complete field sampling. Their random sampling design allowed them to estimate that there are roughly 6,300 fens in the San Juan Mountains, aggregating about 19,000 acres. They classified the fens in their data set several different ways, including by landform and chemistry (Figure 1-4) and vegetation and landform (Table 1-5).

In the 2009-2010 inventory of the Grand Mesa, Uncompahgre, and Gunnison National Forests, we used several of the ideas and methods from Chimner and others' (2008-2010) study. Photointerpretation technique was very similar; however, we randomly selected cells containing potential fens, whereas they randomly selected watersheds. They sampled a select number of potential fens within a selected watershed. How they did this is uncertain; the 2009-2010 inventory sampled all fens within a selected cell.

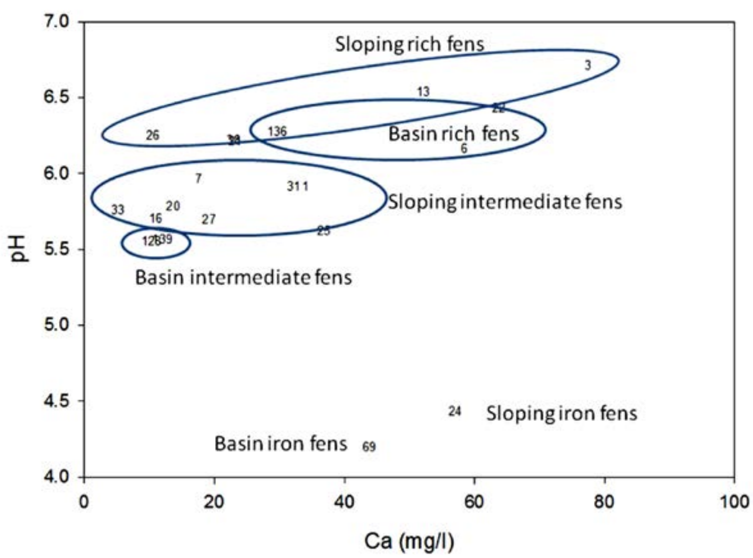


Figure 1-4. Classification of San Juan Mountains fens based on Calcium, pH, and landform. (Chimner and others 2008)

RICH FENS
Sloping Rich Fens
Salix monticola–Alnus incana
Salix wolfii–Pentaphylloides floribunda
Carex buxbaumii–Eriophorum angustifolium
Eriophorum angustifolium–Deschampsia caespitosa
Deschampsia caespitosa–Psychrophila leptosepala
Basin Rich Fens
Carex utriculata–Galium trifidum
Carex magellanica–Carex utriculata
Carex limosa–Menyanthes trifoliata
INTERMEDIATE FENS
Sloping Intermediate Fens
Picea engelmannii–Calamagrostis canadensis
Salix planifolia–Carex aquatilis
Eleocharis quinqueflora–Carex aquatilis
Carex illota– Pedicularis groenlandica
Carex aquatilis– Psychrophila leptosepala
Carex aquatilis–Pedicularis groenlandica
Carex saxatilis–Scorpidium cossonii
Eleocharis quinqueflora–Warnstorfia fluitans
Basin Intermediate Fens
Carex canescens–Calamagrostis canadensis
Carex lasiocarpa–Drosera anglica
IRON FENS
Betula glandulosa–Sphagnum spp.
Carex aquatilis–Sphagnum fimbriatum

Table 1-5. Classification of San Juan Mountains fens based on vegetation. (Chimner and others 2008)

In the study by Chimner and others (2008-2010), relevé sampling was similar to that of Austin (2008) on the Grand Mesa; all communities within a selected fen-wetland complex were sampled, whereas in the GMUG inventory only one community was sampled per fen-wetland complex.

The field evaluation form used by Chimner and others (2008) was greatly expanded for the inventory of the Grand Mesa, Uncompahgre, and Gunnison National Forests. As much as possible, we tried to keep field estimates to easily-observed disturbances and other observations, and to give the crews well-defined categories for their estimates (Appendix H). We used a number of concepts from their field evaluation form, including degree of hydrologic alteration, percent bare soil (or bare peat), and percent of the flora in wetland species.

C. Objectives of This Inventory

As part of on-going resource management and forest planning activities, the Grand Mesa, Uncompahgre, and Gunnison National Forests began an effort in 2008 to better understand the abundance and distribution of fens. To complete this effort, National Forest leadership assembled a multi-disciplinary team composed of specialists in soil science, geology and hydrogeology, hydrology, botany, and range management. This group, called the Fen Technical Working Group was directed by forest leadership via a Steering Committee to provide information in three areas:

- Distribution and characterization of fens
- Evaluation of the condition of fens
- Management implications for fens

Among the desired outcomes were: estimates of the number of fens, their size; identification of different types or classes; an overall sense of the landscapes and the natural circumstances under which they occur; and description and evaluation of effects that current land management activities and use have on them.

Because an exhaustive inventory was not feasible, the Technical Working Group developed the following sequence of steps in order to address the distribution and condition of fens across the National Forests:

- Delineation via photo-interpretation of potential fen-wetland complexes (termed potential fen sites)
- Landscape stratification
- Statistically valid selection of spatially-balanced sampling locations
- Field validation and sampling of potential fen sites, and review of areas not containing potential fens.

Field methods were designed to complement and supplement existing field methods (Johnston and others 2009a). Field work was completed over the summer field seasons of 2009 and 2010.

This report largely presents the results of our spatially-balanced sample inventory, and also summarizes and incorporates pertinent information from previous studies on the Grand Mesa, Uncompahgre, and Gunnison National Forests. It is intended to inform local resource specialists, as well as others interested in wetland and fen research of the methods and results of all fen investigation efforts on the Grand Mesa, Uncompahgre, and Gunnison National Forests.

II. Study Area

The Grand Mesa, Uncompahgre, and Gunnison National Forests comprise part of a very diverse landscape in central-western Colorado. The Forest Boundary area covers over 3,100,000 acres, 1,275,000 hectares (Figure 2-1).

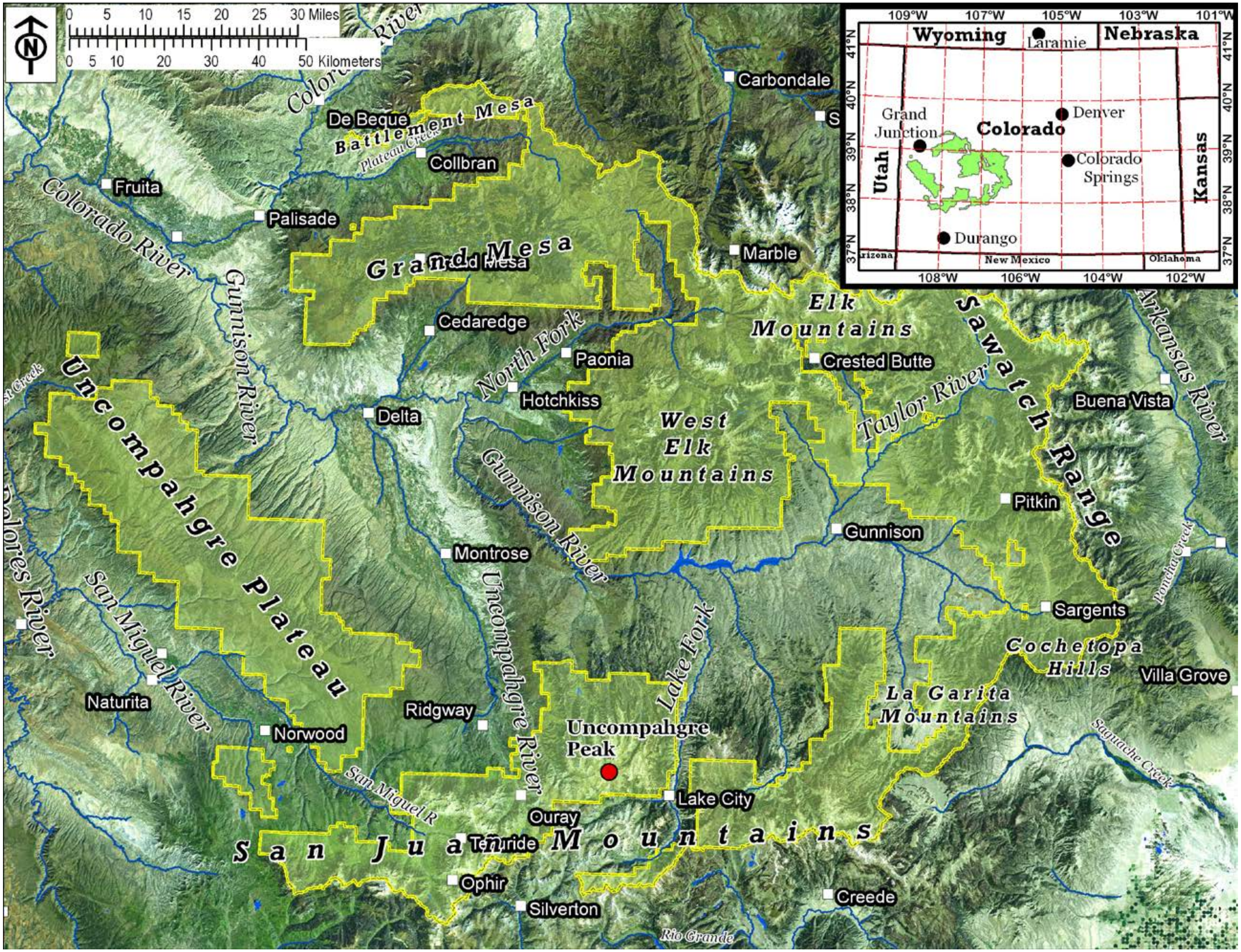


Figure 2-1. The Grand Mesa, Uncompahgre, and Gunnison National Forests in west-central Colorado, showing cities and towns, names of major mountain ranges, and physiographic features.

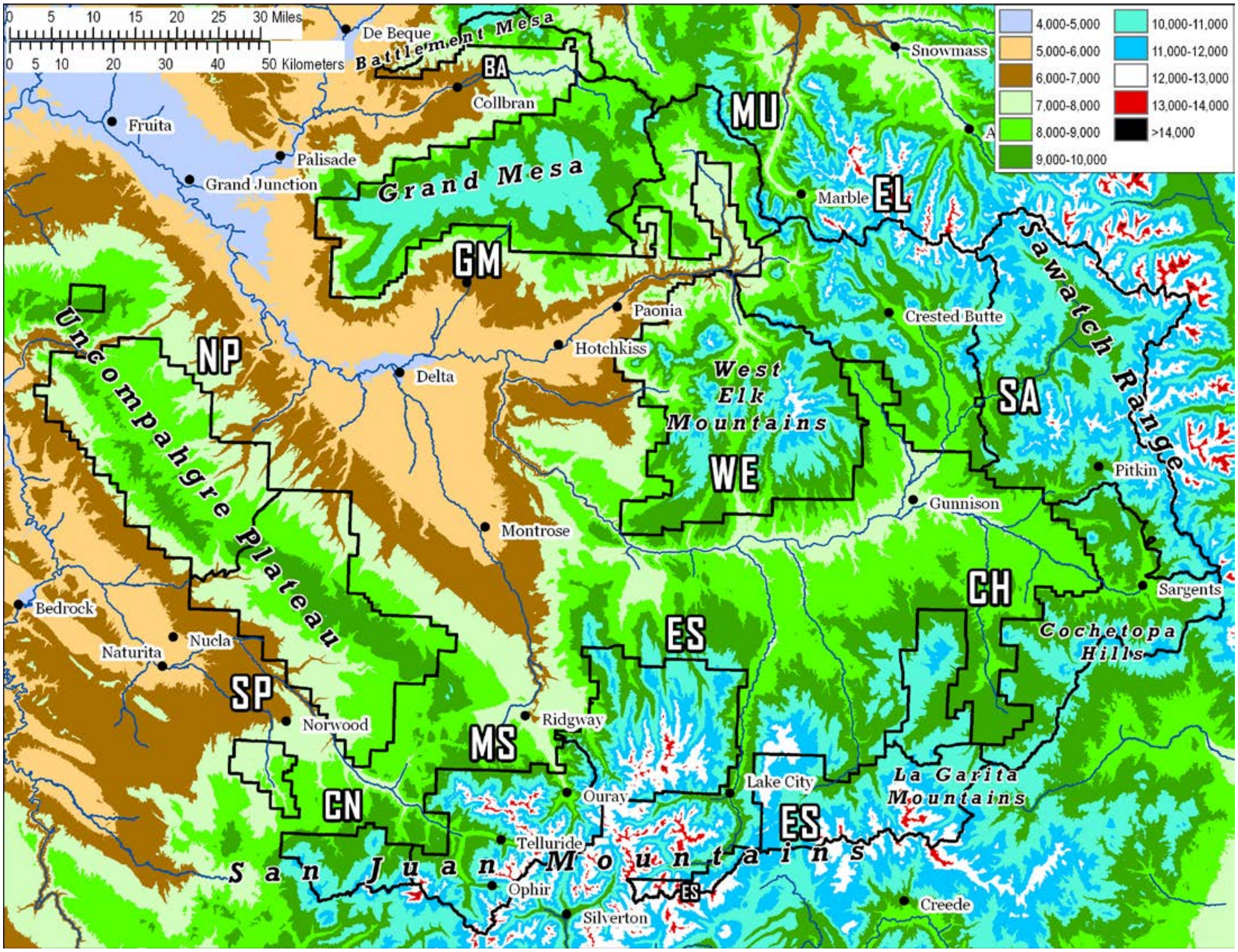


Figure 2-2. Elevations of the Grand Mesa, Uncompahgre, and Gunnison National Forests. Landscape areas are shown by black lines; abbreviations for them are shown in Table 2-1.

Elevations of the Grand Mesa, Uncompahgre, and Gunnison National Forests range from about 5,800 ft (1,770 m) on the west foothills of Battlement Mesa, to over 14,200 ft (4,330 m) on the high peaks of the San Juan and Sawatch Mountains (Figure 2-2, Table 2-1). The Battlement Mesa, Southern Plateau, and Muddy areas are lower in average elevation, while the Sawatch Mountains and San Juan Mountains are higher.

Table 2-1. Elevations of Landscape Areas shown in Figures 2-3 through 2-7.

Code	Landscape Area Name	Elevation, feet Minimum	Mean	Maximum
BA	Battlement Mesa	5,840	8,551	11,053
CH	Cochetopa	8,222	9,922	12,670
CN	Cones	8,363	10,108	13,464
ES	Eastern San Juans	7,657	11,031	14,350
EL	Elk Mountains	7,029	9,924	14,219
GM	Grand Mesa	6,001	9,519	11,322
MS	Middle San Juans	7,313	10,741	14,117
MU	Muddy	6,355	8,769	12,733
NP	Northern Plateau	6,227	8,270	9,875
SA	Sawatch Mountains	8,320	10,658	13,822
SP	Southern Plateau	5,830	8,218	10,010
WE	West Elks	6,263	9,489	13,031

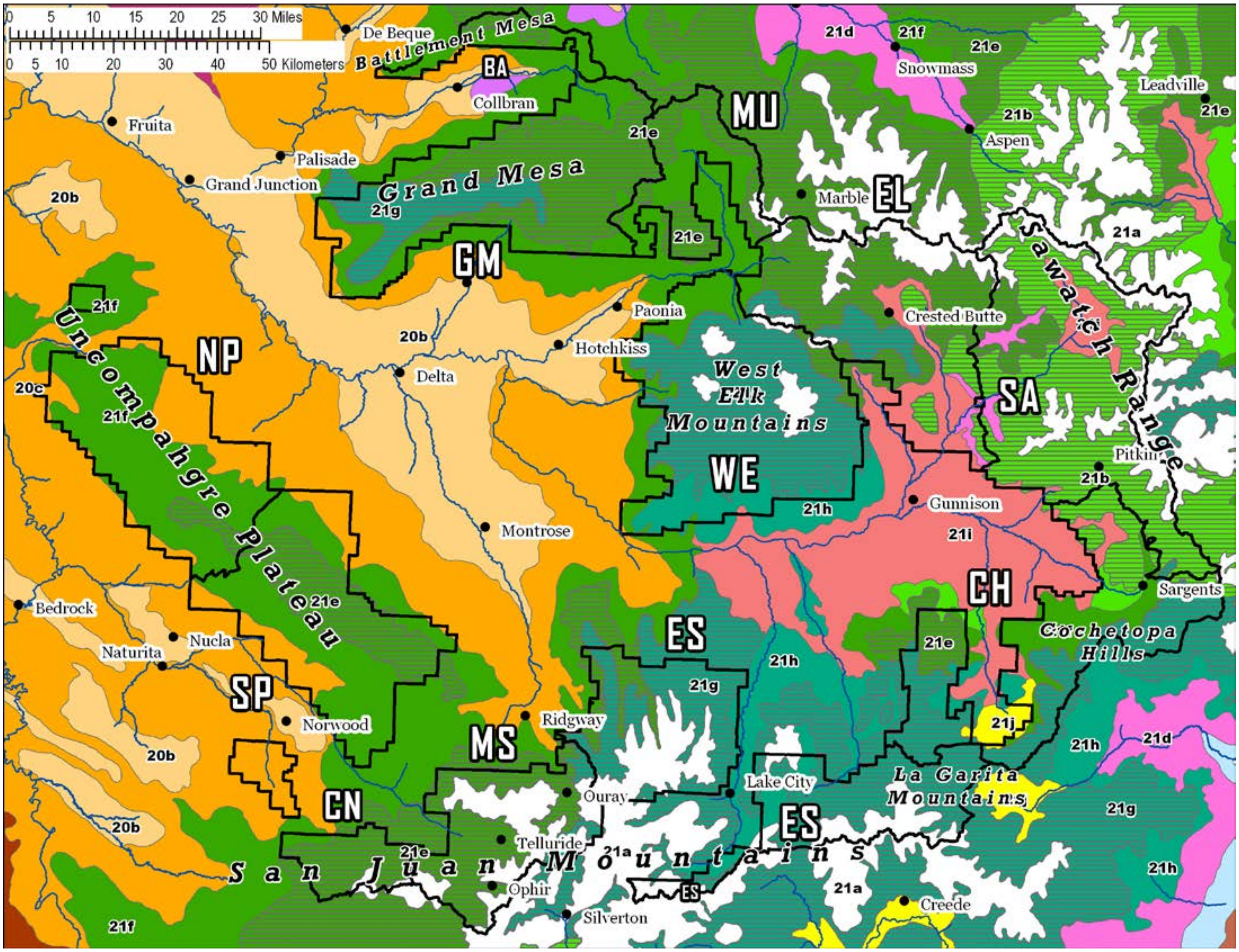


Figure 2-3. Ecoregions of the Grand Mesa, Uncompahgre, and Gunnison National Forests. (Chapman and others 2006) Landscape areas are shown by black lines; abbreviations for them are shown in Table 2-1.

All of the Grand Mesa, Uncompahgre, and Gunnison National Forests are on the western slope, as the Continental Divide forms the eastern and southeastern boundaries of the National Forests.

Ecoregions of the Grand Mesa, Uncompahgre, and Gunnison National Forests are shown in Figure 2-3, legend in Figure 2-4. The Uncompahgre and Gunnison River valleys below Montrose are in Ecoregion 20b, *Shale and Sedimentary Basins*; the upper Gunnison Basin is a large example of 21i, *Sagebrush Parks*. Subalpine forests dominate the Grand Mesa, Sawatch Area, and the West Elk Mountains; the Alpine Zone, above timberline, is prominent in the Eastern and Middle San Juans and the Elk Mountains.

The ecoregions shown in Figure 2-3 were developed in 2006 by a cooperating group of agencies, including USDA Forest Service and Natural Resources Conservation Service, Colorado Division of Wildlife and Department of Public Health, Bureau of Land Management, U. S. Geological Survey, and the Environmental Protection Agency (Chapman and others 2006).

Figure 2-4. Legend for Figure 2-3.

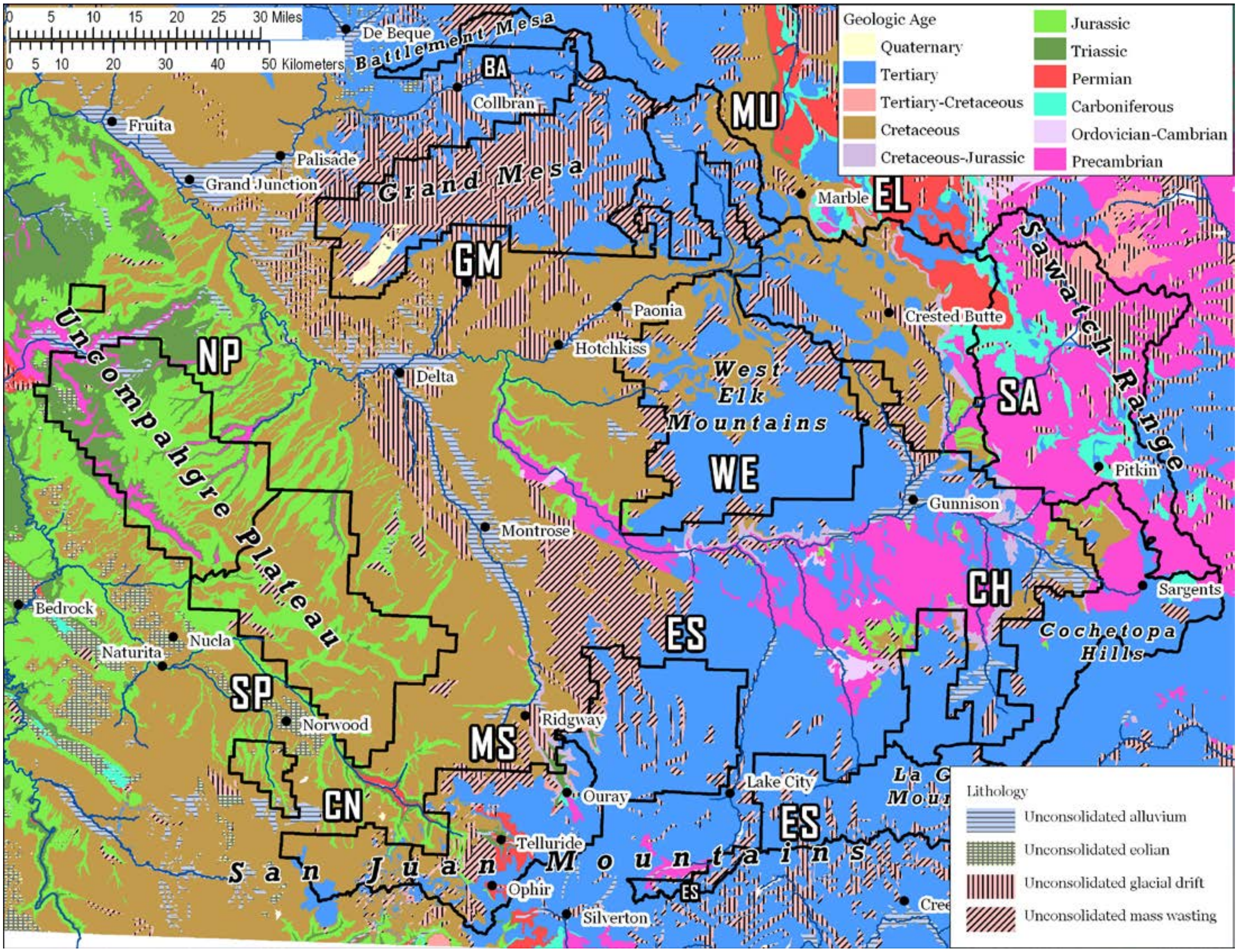


Figure 2-5. Geologic Age of the Grand Mesa, Uncompahgre, and Gunnison National Forests. (Day and others 1999) Landscape areas are shown by black lines; abbreviations for them are shown in Table 2-1.

The Grand Mesa, Uncompahgre, and Gunnison National Forests have considerable geologic diversity (Figure 2-5). Bedrock types include Precambrian metamorphic, igneous and metavolcanic rocks; Mississippian, Devonian, Ordovician and Cambrian carbonates (limestones), Jurassic and Cretaceous-aged sedimentary rocks; Eocene-aged sedimentary rocks; volcanic lava flows, ash flow deposits and intrusive rocks of Miocene and Oligocene ages, along with recent unconsolidated deposits as a result of glaciation (glacial drift), alluvial activity, and mass wasting events (for example, landslides).

Most of the Grand Mesa, West Elk, and Eastern San Juan areas are Tertiary volcanics and flows; a lot of the surface of the Grand Mesa was later changed by glaciation and mass-wasting (shading in Figure 2-5). The Muddy and Battlement Mesa areas are mostly comprised of Tertiary sedimentary rocks. The Sawatch area is largely Precambrian, with some glaciation evident in the northeastern portion. The Middle San Juans, Elk Mountains, and Cochetopa Hills are mixed.

The Southern Plateau and Cones areas are dominated by Cretaceous sedimentary rocks; the Northern Plateau area has more Jurassic and Triassic rocks.

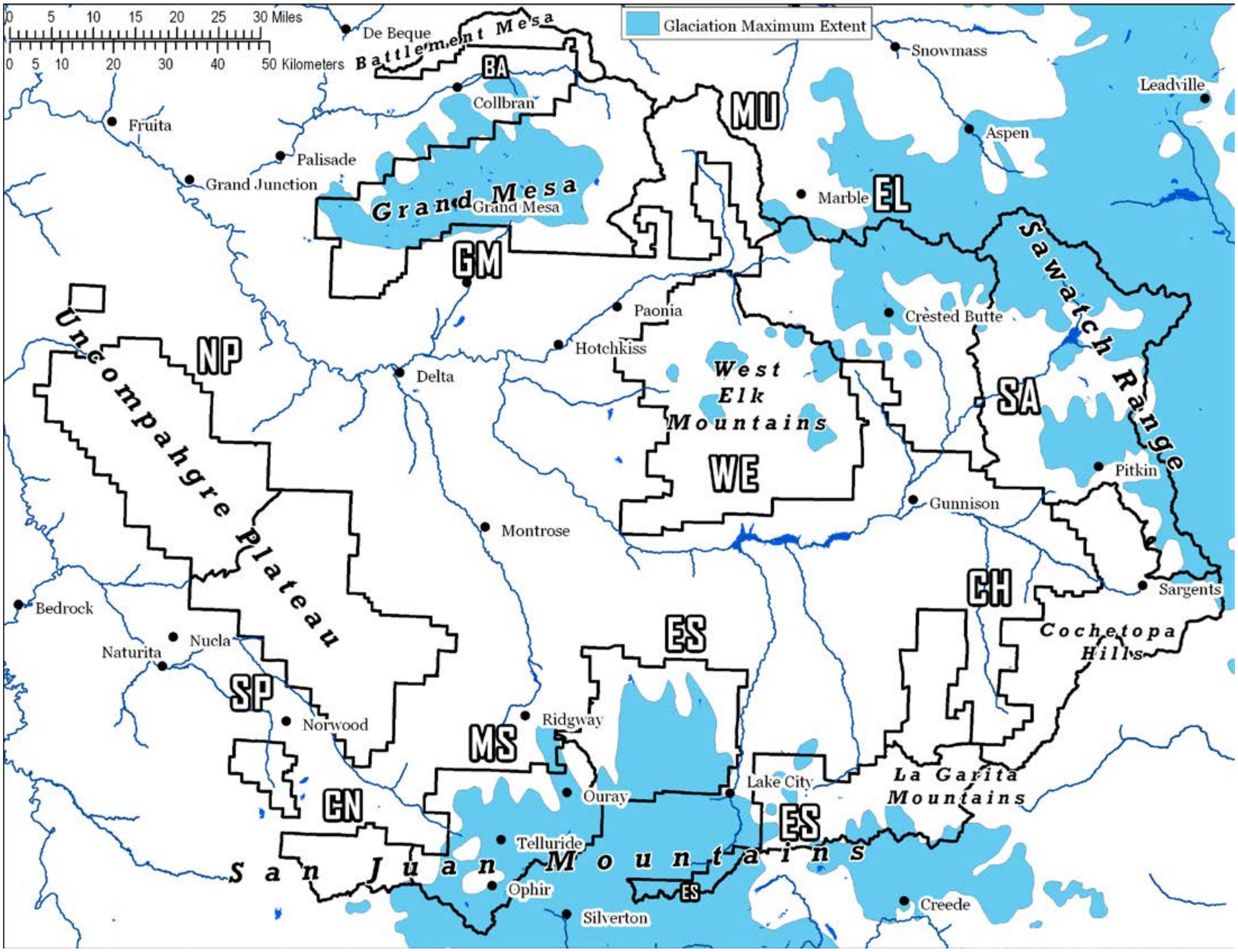


Figure 2-6. Glaciated areas of the Grand Mesa, Uncompahgre, and Gunnison National Forests. (Matthews and others 2003) Landscape areas are shown by black lines; abbreviations for them are shown in Table 2-1.

Glaciers have covered much of the top of the Grand Mesa and the higher-elevation portions of the Sawatch Range, Middle San Juans, and Eastern San Juans areas, and the eastern part of the Elk Mountains (Figure 2-6). The West Elk Mountains and La Garita Mountains had smaller, patchier glaciers. Glaciation has been absent in the Northern Plateau, Southern Plateau, Muddy, Battlement Mesa, and Cochetopa Hills areas.

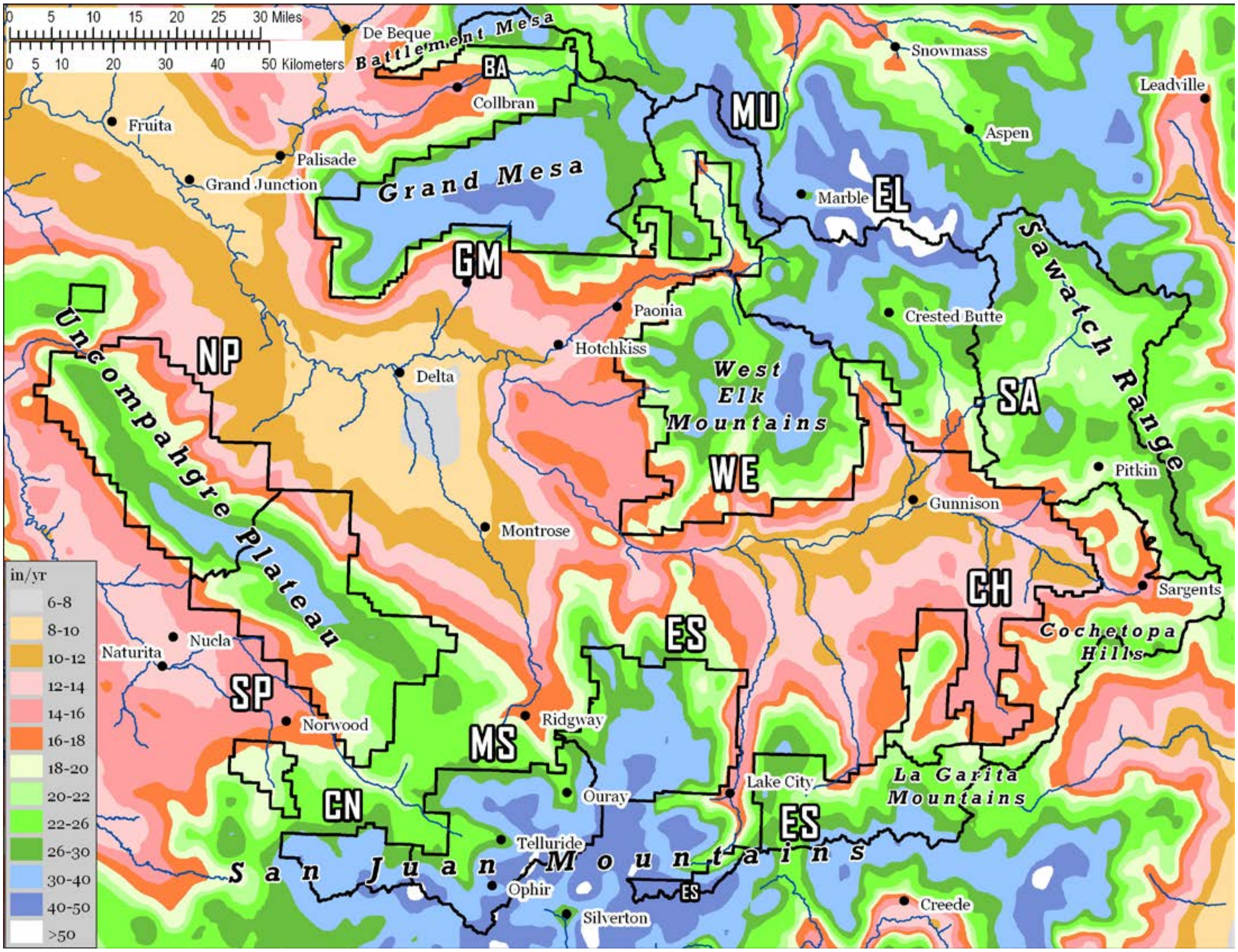


Figure 2-7. Average annual precipitation of the Grand Mesa, Uncompahgre, and Gunnison National Forests and surrounding areas, 1960-1990. (USDA Natural Resources Conservation Service 1998)
Landscape areas are shown by black lines; abbreviations for them are shown in Table 2-1.

Annual precipitation largely parallels elevation (see Figure 2-2) with some notable exceptions in the rain-shadows in the bottom of the Upper Gunnison Basin and the Cochetopa Hills area (Figure 2-7). Thus the higher-precipitation areas are those associated by the higher mountain ranges – the Elk and West Elk Mountains, the San Juan Mountains, and the Grand and Battlement Mesas. The Sawatch and Muddy areas are more mixed. The Cochetopa Hills and the Uncompahgre Plateau are on the low end of precipitation range for the Forests.

III. Methods

A. Photointerpretation

Several monitoring and research projects have been conducted in the past decade that have identified fens on selected portions of the Grand Mesa, Uncompahgre, and Gunnison National Forests, as described above. These studies have resulted in knowledge about some fens on the Grand Mesa, the northern San Juan Mountains, and the Taylor Park area (Bathke 2000-2001-2003, Austin 2008, Chimner and others 2008, see Figure 3-1). Those results provided a starting point for development of a spatial geographic information system (GIS) layer representing potential fens. They also served to develop a "search or training image" by examining the aerial photo characteristics (color, texture, landform position) of known fens (notably those of Bathke 2000-2001-2003) and Austin 2008). Because fens are a narrow subset of wetlands and the complex pattern in which they normally occur, a broad wetland search image was used during the photointerpretation phase.

Strictly as a matter of convenience, the National Forests were subdivided into seven geographic "photointerpretation areas" to facilitate the photointerpretation process (Figure 3-1). To assure forest-wide consistency, previously identified fens were reviewed and included or omitted from the geodatabase; and new sites were delineated and added.

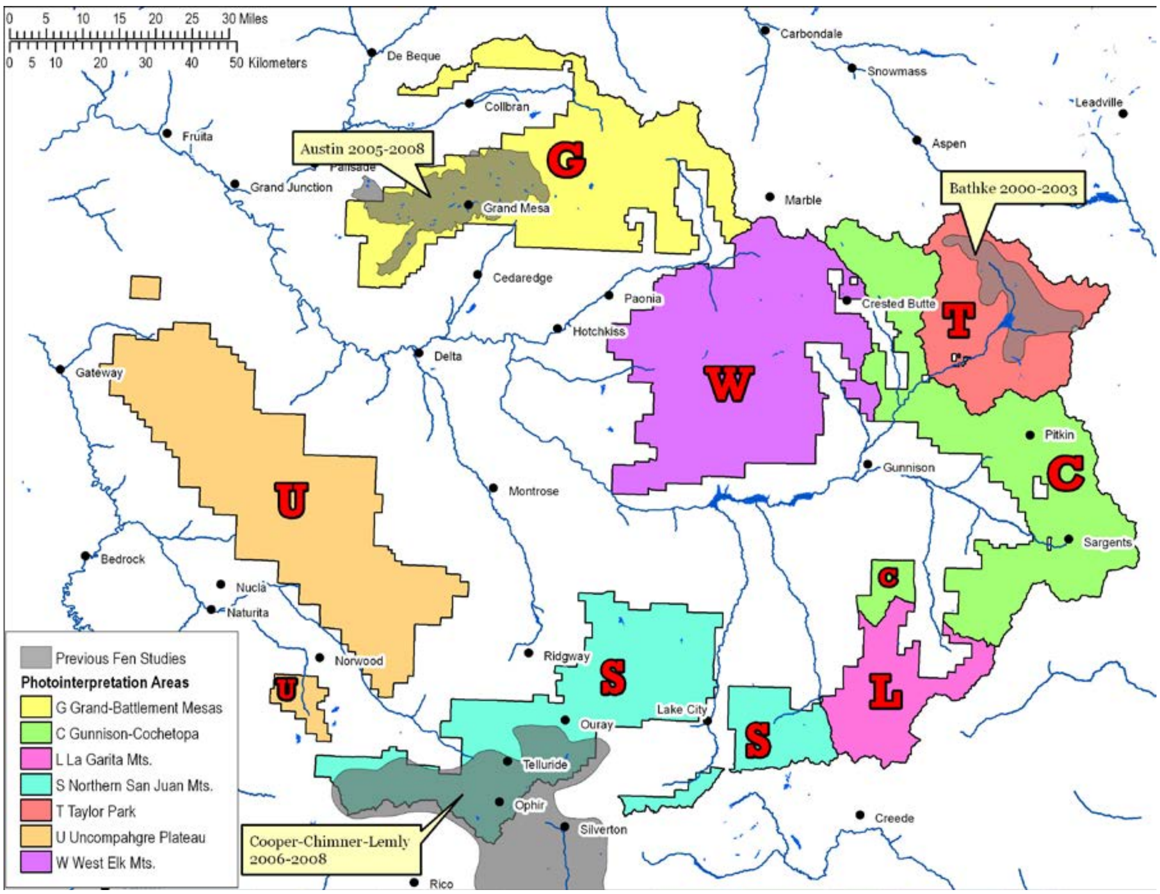


Figure 3-1. Areas of the Grand Mesa, Uncompahgre, and Gunnison National Forests used for photointerpretation.

The photointerpretation step of this inventory used 10 × 10 inch prints of natural-color aerial photographs, taken of the National Forests in 2005, at an approximate scale of 1:16,000. Each photo was scanned with a magnifying glass; if an area was found that might possibly fit the search image, that portion of the photo was examined using a hand stereoscope (10-15×). Based on the search training image described above, all potential fen sites (PFS) were delineated that were visible on the aerial photographs. There were no specified lower limits on size of delineated sites; the smallest site delineated was about 0.05 acre (0.02 hectare). Potential fen sites were delineated on-screen into a geodatabase in ArcMap® (ESRI 2009), with NAIP imagery, 1 m resolution, 2005 (USDA Farm Service Agency 2010) as a background. In this report, the term *potential fen site* (PFS) is used to refer to the results of the photointerpretation efforts that were called *polygons* in previous draft reports, and in our forms and instructions to the crews found in Appendices C and D.

A total of 3,270 potential fen sites were identified on National Forest System lands, covering an estimated 17,485 acres, about 0.6 % of the land under administration of the Grand Mesa, Uncompahgre, and Gunnison National Forests. Table 3-1 displays the size of each photointerpretation area, the number of photos for a particular area, the number of potential fen sites and the estimated acreage as calculated in the geographic information system. The photointerpretation results show a concentration of potential fen sites in Taylor Park and on the Grand Mesa, followed by the Northern San Juan Mountains and West Elk Mountains photointerpretation areas.

Table 3-1. Time taken to photointerpret the Photointerpretation Areas. (Figure 3-1)

Map Code	Photointerpretation Area	Total Acres	Photointerpreted			PFS* on NFS		Percent Photo-interpreted	Time (hours)	Time (8 hr days)	Hours/ 100K ac	Photos/ Hour
			Photos	PFS*	Acres	No.	Acres					
G	Grand Mesa	522,907	537	783	6,000	783	6,169	1.15%	21.5	2.7	7.8	25.0
C	Gunnison-Cochetopa	498,069	313	263	869	262	942	0.17%	7.5	0.9	3.5	41.7
L	La Garita	152,645	1,041	89	698	85	715	0.46%	18.5	2.3	3.5	56.3
S	Northern San Juan Mountains	537,433	1,072	702	5,770	561	2,927	1.07%	14.0	1.8	2.6	76.6
T	Taylor Park	274,936	949	706	4,293	695	3,929	1.56%	12.8	1.6	2.3	74.1
U	Uncompahgre Plateau	614,994	1,034	380	556	380	569	0.09%	11.8	1.5	1.9	87.6
W	West Elk Mountains	548,549	1,036	504	2,175	504	2,234	0.40%	11.0	1.4	2.2	94.2
	Totals	3,149,533	5,982	3,427	20,361	3,270	17,485	0.65%	97.1	12.1	3.0	61.6

*. Potential fen sites.

B. Sample Site Selection

1. Choice of Cells for Field Sampling

In order to adequately sample the variety of settings on the National Forests, we designed a method for stratification based on geology, climate, ecological landscape units, and glaciation, as described above. This stratification resulted in twelve landscape areas (Table 3-2, Figure 3-2).

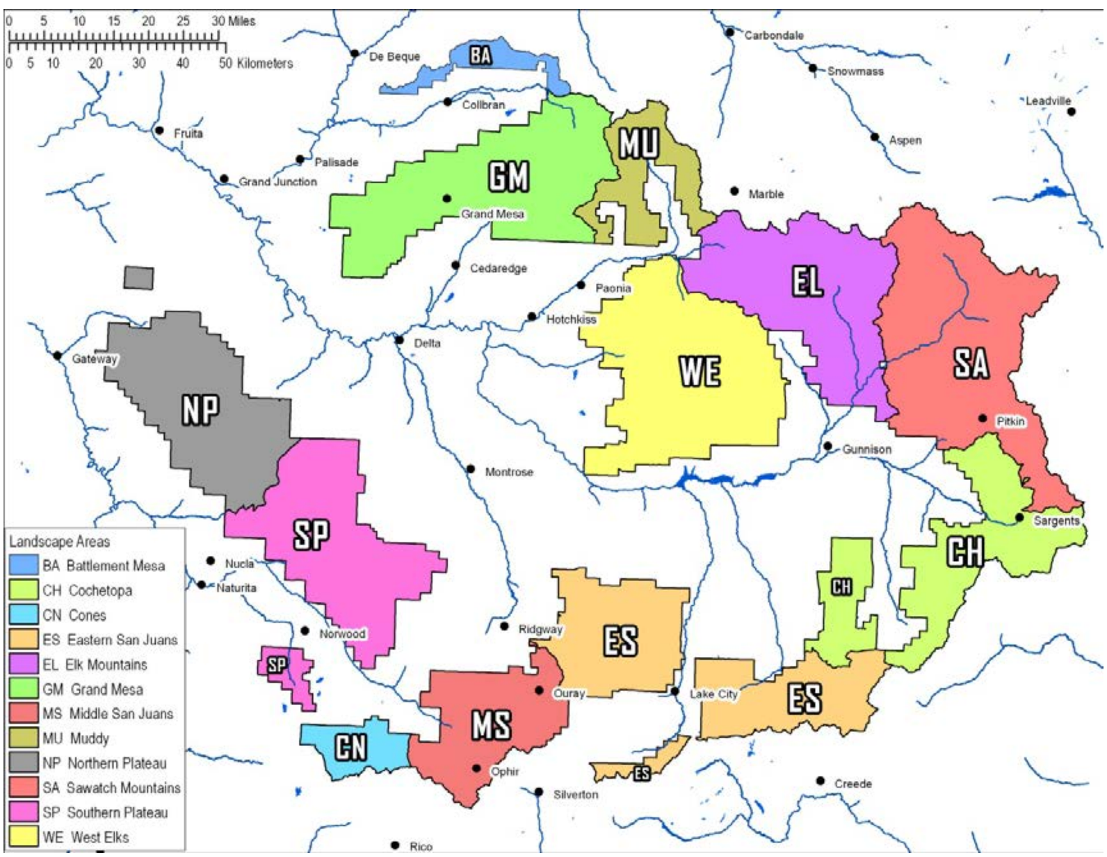


Figure 3-2. Twelve landscape areas used to stratify the Forest.

A regular grid network of 1 Km × 1 Km cells was superimposed across the forest. This grid was stratified into two classes:

1. Those 1 Km × 1 Km cells that had potential fen sites in them, and
2. Those cells that did not.

We then incorporated suggestions from statisticians at the Rocky Mountain Station to concentrate sampling effort to the cells where potential fen sites are known to be present, and minimize the effort in areas where potential fen sites are uncommon.

A sample was developed utilizing the Generalized Random Tessellation Stratified (GRTS) method, as commonly used for aquatic resources by the U. S. Environmental Protection Agency (Olsen 2005, U. S. Environmental Protection Agency 2008). A spatially balanced sample of 198 1 × 1 Km cells was then selected from the set of grid cells containing photo-interpreted potential fen sites using the GRTS sampling method. Cells were sampled at an equal proportion for all the landscape areas, since different landscape areas had different numbers and sizes of potential fen sites. The sample size of 198 cells was constrained by funding and field time available to conduct field work. It was thought that 198 cells was a sample that could be visited by two field crews in a single field season.

Table 3-2 and Figure 3-3 summarize the results of the stratification and selection process that determined the 198 cells for field examination. The objective of the field verification was to visit each cell in the sample to evaluate all photointerpreted potential fen sites as well as to identify any fens within the cell that may have been omitted during photointerpretation. Almost 18% of the National Forests is covered by cells that contain potential fen sites (Table 3-2).

Table 3-2. Summary of the total number of 1Km x 1Km cells in each Landscape Area. Also shown are number of cells with PFS*, and the number selected for sampling.

Landscape	All NFS† lands		With PFS*		Selected Sample	
Area Name	Cells	Acres	Cells	Acres	Cells	Acres
Battlement Mesa	264	47,292	8	1,685	1	247.1
Cochetopa	1,417	294,756	40	9,380	3	546.4
Cones	281	59,240	42	9,194	4	712.8
Eastern San Juans	1,714	369,595	307	72,877	26	6,187.6
Elk Mountains	1,373	290,780	199	47,676	17	4,188.2
Grand Mesa	1,566	354,199	507	124,789	44	10,833.0
Middle San Juans	859	187,862	145	33,833	12	2,914.2
Muddy	606	121,463	81	18,529	7	1,729.7
Northern Plateau	1,305	292,470	99	23,554	8	1,652.9
Sawatch Mountains	1,868	419,725	573	139,218	49	11,439.8
Southern Plateau	1,454	322,432	110	26,884	10	2,471.1
West Elks	1,712	389,969	216	53,153	17	4,200.9
	14,419	3,149,783	2,327	560,773	198	47,123.7

*. PFS = Potential fen sites, as photointerpreted. †. National Forest System.

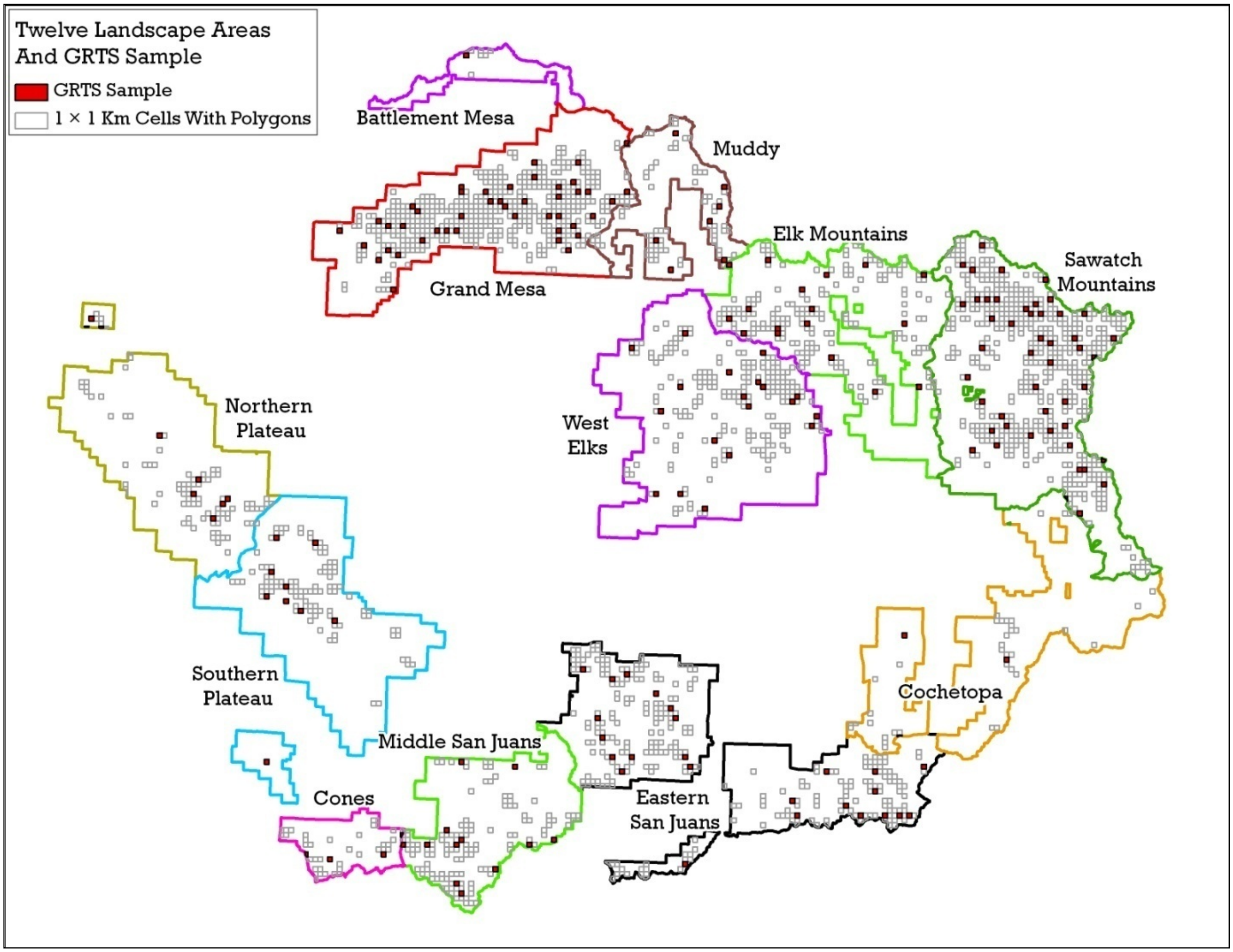


Figure 3-3. The solid-colored red cells show the 198 cells that make up the GRTS sample.
The gray-outlined cells are, the cells with potential fen sites remaining after the GRTS sample was chosen.

In several cases, it was necessary to substitute another cell for a selected cell. This usually occurred because most of the cell was on private land or was not safely accessible by field crews. In these cases, the GRTS method allows the next available cell in the sampling sequence to be chosen while maintaining a spatially balanced sample. Seven cells needed to be substituted from the original sample. One cell was reassigned in the Cones Area, two in the Elk Mountains, two in the Eastern San Juans, and one each in the Middle San Juans, Sawatch Mountains, and Southern Plateau Areas.

2. Independent Review of Cells Without PFS

We also utilized the GRTS sampling methodology to select a sample for a second photointerpretation examination of cells that didn't contain any PFS. A total of 242 cells were selected for review (2% of all cells without PFS identified). The distribution of those cells is shown in Figure 3-4. The purpose was to use an independent photointerpreter to identify the possible extent of 'missed' potential fen sites as a measure of the quality of the initial photointerpretation. The same methods and materials were utilized as in the original photointerpretation process. Eight potential fen sites within seven separate cells were identified, which represents slightly less than 3% of the 242 cells reviewed. These results suggest that the initial photointerpretation delineated almost all of the potential fen sites.

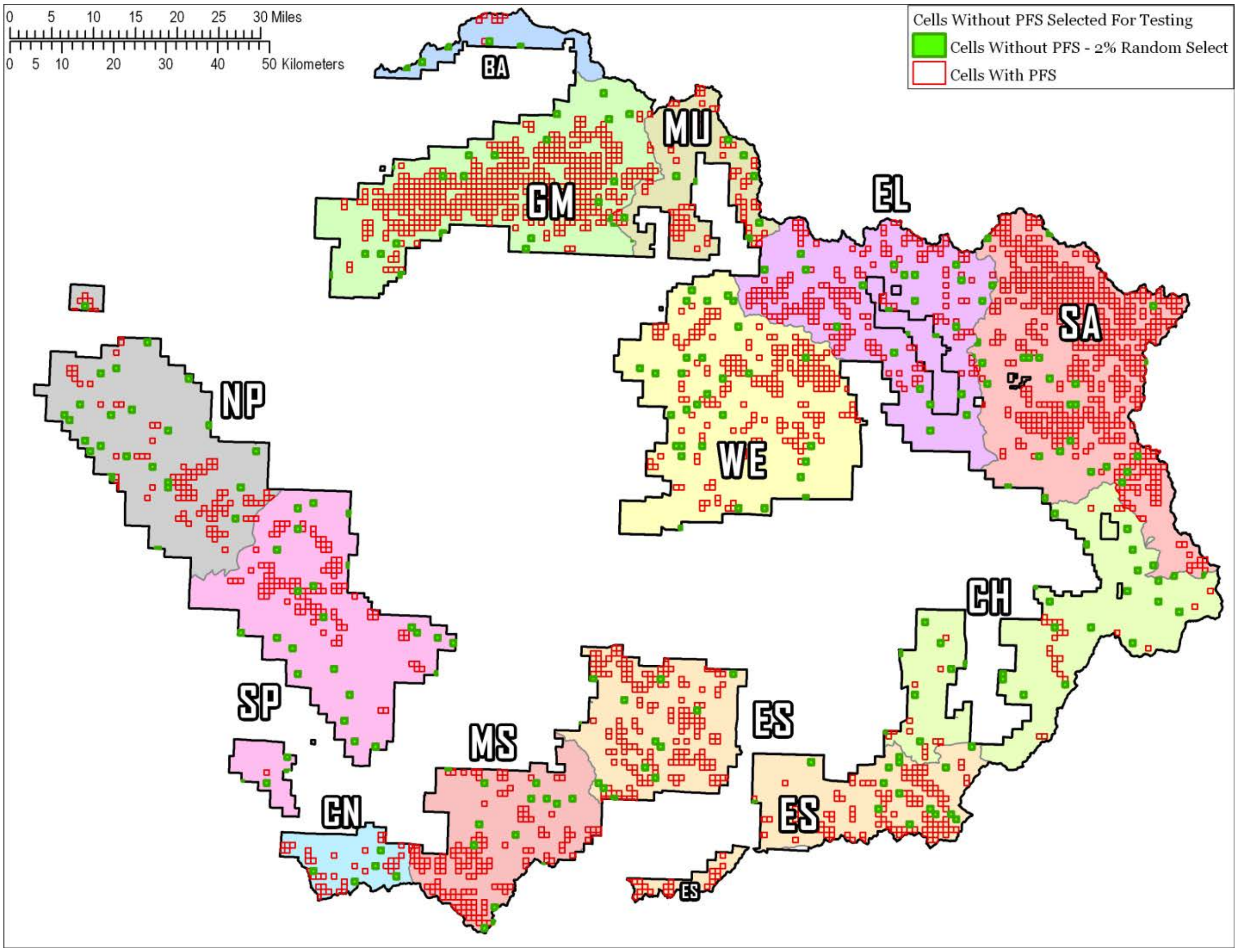


Figure 3-4. The green squares show the 2% of cells without potential fen sites selected for validation.

3. Field Sampling

We designed and tested a protocol for investigating each 1 × 1 Km cell, and gathering appropriate information about each fen within that cell. Instructions were created for the protocol to assure consistency among multiple sampling crews (Appendix B). The field data collection protocol comprises data on five forms (Appendices C and D). Most field data was recorded using Trimble® units – Juno® Model SB (Trimble Corporation 2006) running TerraSync® software v3. 30 – combination global positioning system (GPS) and personal data recorder (PDR). Vegetation cover and community types were recorded on paper forms (Appendix D), and entered into a Paradox® relational data base (Corel Corporation 1999).

We trained the field crews in the field procedures and plant identification in a two- to three-week session at the beginning of each field season. Each crew leaders was qualified in identification of wetlands and wetland plants. Throughout the field season, at least one day a week one of the authors accompanied each field crew to further the training.

For each cell selected, the field crew visited the potential fen sites, starting with the photointerpreted potential fen sites. In addition, the crew was instructed to investigate each landform within the cell that might possibly contain any potential fen site missed in the photointerpretation. If any additional site was determined to be a fen, it was delineated on the map and inventoried.

Having determined whether the photointerpretation of the site was correctly delineated, the crew then decided whether the site, or part of it, was a wetland (U. S. Army Corps of Engineers 1987). If the site was a wetland, then the crew determined whether the site, or part of it, was a fen, on the basis of peat accumulation of thirty centimeters or more. It was usually necessary to dig up to three test pits with a tile spade, to make this determination.

If the site, or part of it, was determined to be a fen, then the crew sampled vegetation, water, and soil. If there was any uncertainty, the crew collected the same samples. The crew drew a rough sketch map, delineating each different community within the fen-wetland complex and describing its dominant plant species, water table, and wetness scalar (Austin 2008). The crew chose one community for sampling that had the most apparent fen characteristics; however, only one community was sampled in each potential fen site. Within that chosen community, the crew chose a location for sampling that was typical or representative of that community ("subjective with no preconceived bias" of Mueller-Dombois and Ellenberg 1974). The crew avoided ecotones with other communities and minor (in area) wetter or dryer spots. The crew located both the relevé (Figure 3-5) and the soil pit as close together as feasible (usually within a few meters of each other) and within the same relatively homogeneous patch of vegetation, landform, and water table.

The crew dug a soil pit with a tile spade as deeply as possible, to at least 40 cm. The width of the soil pit varied, but was usually 30-40 cm in diameter. Usually they removed the soil plug so that a photo could be taken of it, and left the pit for a while (usually about one hour) so that water could rise to its natural level.

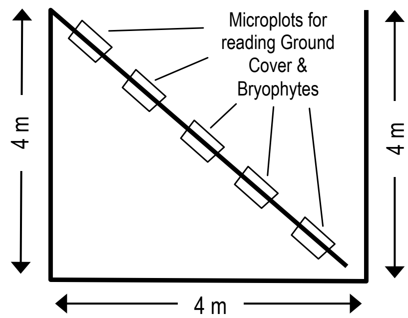


Figure 3-5. Layout of relevé and ground cover measurements.

They laid out a 4 m × 4 m relevé (Figure 3-5) using a tape and spikes. The crew estimated canopy cover (to the nearest ten percent, see classes in Appendix C) of all vascular plants that covered the relevé; they collected a specimen of any unknown plant and later had it identified by a botanist. The crew estimated total bryophyte cover and ground cover on five 20 cm × 50 cm microplots laid uniformly (1 m apart) on the diagonal (Daubenmire 1959). Identification of bryophyte species was optional. Aspect and slope were measured using a compass and clinometers at the location of the relevé and soil pit.

Bare soil cover was estimated across the community where the soil pit was located, to the nearest 1% (< 10%) or to the nearest 5% (> 10%). Ground cover categories were also estimated in the five microplots shown in Figure 3-5, and included bare soil, recent sediment deposits, litter and duff, and rock fragments (Appendix C).

When the water in the pit had reached a stable level (usually within about an hour), the crew recorded its depth and the pit depth. They recorded peat thickness from the pit unless peat went below the depth of the pit, in which case they used a steel tile probe to measure peat thickness. They measured electrical conductivity, temperature, and pH directly on the water in the pit using hand-held meters. They took a sample of the peat (using the protocol in Appendix B) and estimated Von Post value (Appendix C) from about the same depth.

5. Post-Field Analysis

Through an agreement with Rod Chimner's laboratory at Michigan Technological University, organic matter and organic carbon measurements were taken from the soil samples collected. The protocol for soil sampling is shown in Appendix B. For the 2009 samples, both organic matter (OM) and organic carbon (C) were measured from the soil samples. After the 2009 samples were analyzed, a regression was established between OM and C (Figure 3-6). For the 2010 samples, only OM was measured directly; C was calculated using the regression equation in Figure 3-6.

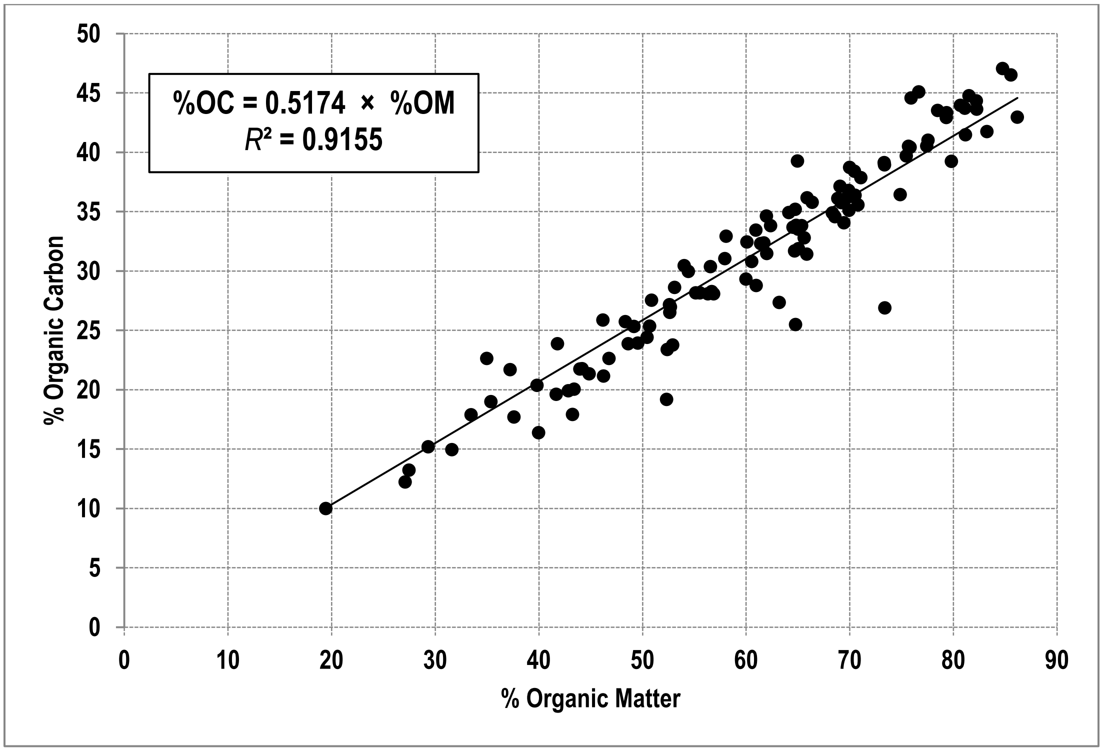


Figure 3-6. Regression between organic carbon and organic matter in the samples from 2009. (n = 107)[i] This regression was used to calculate organic carbon in 2010 (Chimner, personal communication 2010).

Statistics involving the data were calculated using Statistix® (Analytical Software 2008). Samples were subjected to ordination and clustering using the programs DECORANA and WINTWINS (Hill 1994, Hill and Šmilauer 2005). Plant species were identified using Weber and Wittmann 2001a for vascular plants, and Weber and Wittmann 2007 for bryophytes. Population statistics used the R language (R Development Core Team 2011) and several GRTS package developed by EPA (U. S. Environmental Protection Agency 2011).

[i] n = number of samples.

IV. Results of Inventory 2009-2010

A. General Results

For the inventory, a total of 198 cells (Table 3-2) were visited by one or more crews; 336 potential fen sites were investigated in the field. Documented fens fell mostly in three of the twelve landscape areas of the Forest: Grand Mesa, Sawatch Mountains, and Eastern San Juan Mountains (Table 4-1). The data presented in this section apply to the results from the inventory sites selected by GRTS: 198 cells containing 147 verified fens.

A total of about 47,000 acres were investigated, of which about 1,100 acres were found to include fens. However, since only the cells that had potential fen sites were visited, Table 4-1 does not directly represent an accurate proportion of the Grand Mesa, Uncompahgre, and Gunnison National Forests that might have fens. Of the 336 potential fen sites (PFS) field-verified, 121 (36%) of them included fens (Figure 4-1). In addition to the PFS verified to be fens, 26 fens were located and identified by field crews that had not been previously delineated through photointerpretation (Fen-not PFS in Table 4-1 and Figure 4-1).

Of the 336 potential fen sites visited, 271 (81%) were found to be wetlands. The photointerpretation protocol used often included wetlands that proved to not be fens. This was expected given the broad wetland search image. Some PFSs were visited that were not wetlands, but upland habitat types. This error of commission of uplands as PFS was often in lands heavily grazed by wildlife and livestock.

The overall user's accuracy of the photointerpretation-based identification of fens was 36% (% of PFS in Table 4-1) and wetlands was 81%. User's accuracy represents a measure of the error of commission of non fen sites to the PFS class (Congalton and Green 1998). The PFS-fen user's accuracy in the West Elks and Elk Mountains landscape areas, both areas with an abundance of PFSs, was notably non-zero and lower (17% and 28% respectively), perhaps a result of the environmental differences of these areas or the use of a non-suitable training image during photointerpretation. This suggests the possible need for a unique training image for each landscape area.

Table 4-1. Summary of potential fen sites (PFS) investigated as part of the 2009-2010 inventory.

Landscape Area		Total PFS in Area		PFS Visited		PFS-Fens			PFS-Wetlands			Fen-not PFS	
Name	Acres	No.	Acres	No.	Acres	No.	Acres	% of PFS	No.	Acres	% of PFS	No.	Acres
Battlement Mesa	47,291	8	61	1	2			0%	1	2	100%		
Cochetopa	294,756	42	161	6	17	1	0.4	17%	5	16	83%		
Cones	59,239	51	233	8	23	4	11	50%	7	21	88%		
Eastern San Juans	369,618	325	2,351	38	337	20	223	53%	34	325	89%	1	3
Elk Mountains	290,781	263	1,335	25	141	7	32	28%	18	136	72%		
Grand Mesa	354,197	696	5,625	78	950	32	462	41%	63	762	81%	4	15
Middle San Juans	187,861	213	832	21	73	14	29	67%	19	59	90%	2	2
Muddy	121,468	86	350	7	22	1	1	14%	6	17	86%	1	
Northern Plateau	292,473	159	253	10	10			0%	8	11	80%	1	2
Sawatch Mountains	419,742	867	4,790	81	453	36	334	44%	69	435	85%	15	485
Southern Plateau	322,428	225	305	25	34			0%	22	28	88%		
West Elks	389,971	335	1,190	36	92	6	14	17%	19	43	53%	2	1
Totals	3,149,824	3,270	17,485	336	2,155	121	1,106	36%	271	1,854	81%	26	508

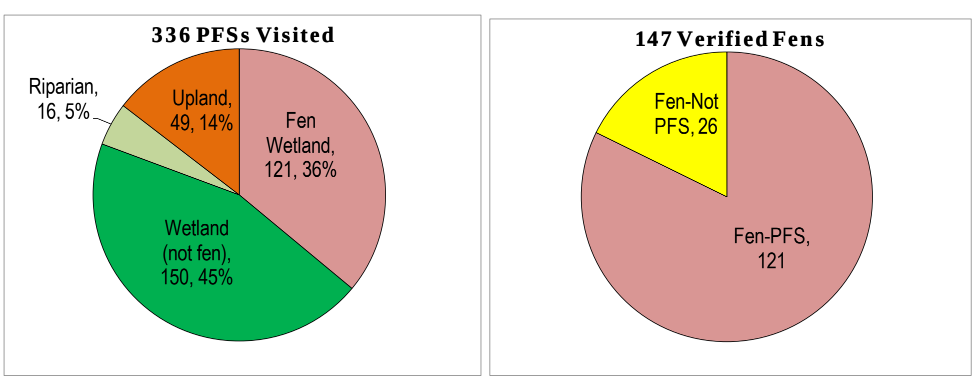


Figure 4-1. Summary of the 336 potential fen sites – PFS (left) and of all fens field verified (right) in the 2009-2010 inventory.

1. Fen Population Estimates

A fundamental task of this work wass to quantify the abundance and distribution of fens on the Grand Mesa, Uncompahgre, and Gunnison National Forests. This can be estimated statistically by scaling up the GRTS sample results to represent the total population using simple random sample estimators with a finite population correction factor (SRS-FPC). A finite population correction factor, applied to the standard error, is appropriate when sample sizes are larger than 5% of the population to account for the sampling having been conducted without replacement (Cochrane 1977). Estimates for both the expected number of fens and their acreage per cell were calculated for each landscape area for the cells that contained PFSs. The mean values of fen area and fen number of the field verified cells were then multiplied by the number of cells that contained PFS in the respective landscape areas, to arrive at population estimates. The results from this analysis are summarized in Table 4-2 and Figure 4-2. To illustrate these results, a discussion of one landscape area, the Grand Mesa, follows.

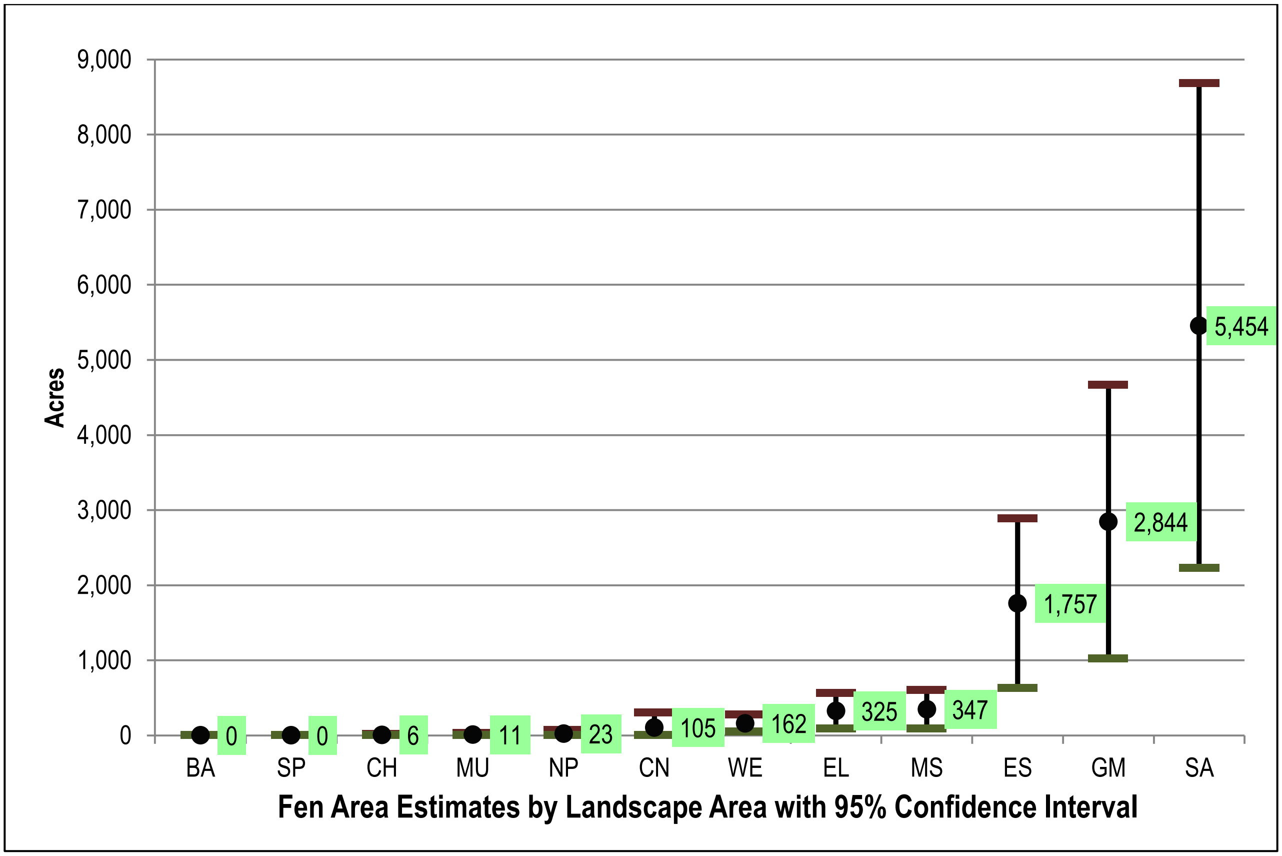
Based on the sampling conducted, there is an average of 0.84 fens per cell in the Grand Mesa landscape area in the total population. Given a total of 507 cells containing potential fen sites, there are an estimated 426 fens within the Grand Mesa area. The 95% confidence interval for this estimate is ± 213 fens. Similarly, the population estimate for the Grand Mesa's total acreage with 95% confidence based on an average area of fens of 5.6 acres per cell is 2,844 ± 1,820 acres.

The sum of the estimates for total number of fens across the twelve landscape areas is 1,738 fens bounded by a 95% confidence minimum of 911 and a maximum of 2,625 fens (Figure 4-3). The total estimate of fen acreage for all twelve landscapes is 11,034 acres bounded by a 95% confidence minimum of 4,098 acres and a maximum of 18,098 acres.

Across the twelve landscape areas, the 95% confidence intervals range from 28-192% of the estimate for fen number, and 59-192% for fen acreage. These large error bands suggest that photointerpretation efforts have limited ability to accurately delineate fens across all the landscape areas of the Grand Mesa, Uncompahgre, and Gunnison National Forests and that further sampling of the population is required in some areas. A larger sample of the population will allow more accurate estimates of the population characteristics of abundance and acreage of fens within each landscape area.

Table 4-2. Population estimates of total number of fens and their areas.
Based on simple random sample estimators with a finite population correction factor (SRS-FPC) analysis.

Area Code	Area Name	Estimated Number of Fens	SRS 95% Confidence Error (±)	Estimated Acreage of Fens	SRS 95% Confidence Error (±)
BA	Battlement Mesa	0		0	
SP	Southern Plateau	0		0	
CH	Cochetopa	13	192%	6	192%
MU	Muddy	23	191%	11	191%
NP	Northern Plateau	12	192%	23	192%
CN	Cones	42	135%	105	187%
WE	West Elks	102	62%	162	71%
EL	Elk Mountains	82	57%	325	74%
MS	Middle San Juans	193	67%	347	74%
ES	Eastern San Juans	248	47%	1,757	64%
GM	Grand Mesa	426	50%	2,844	64%
SA	Sawatch Mountains	596	28%	5,454	59%



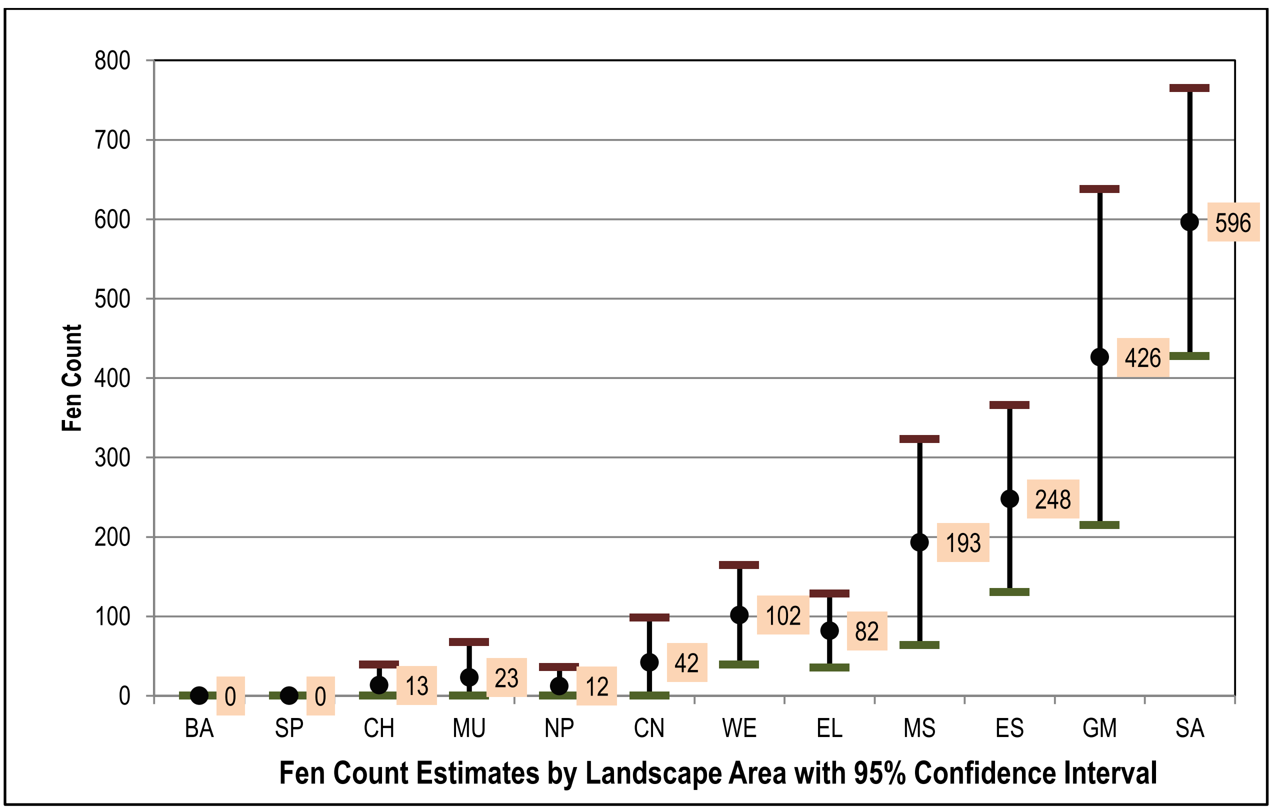


Figure 4-2. Summary population estimates showing estimate of total acreage (above) and total number (below) of fens. Shows the 95% confidence interval.

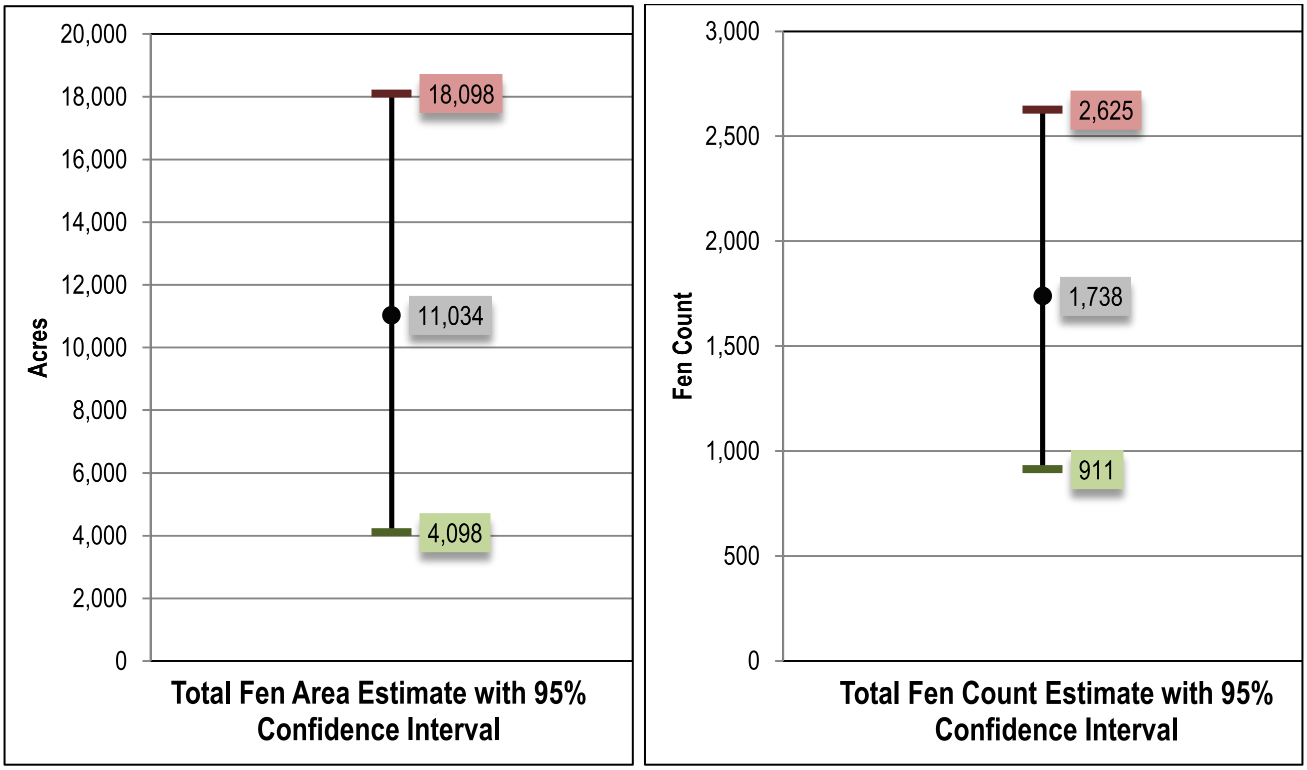


Figure 4-3. Total estimates of fen area (left) and numbers (right), showing the 95% confidence interval.

2. Elevation, Aspect, Slope, Precipitation

The size distribution of fens documented in this inventory is shown in Figure 4-4. Most (>50%)of the 147 fens inventoried in 2009-2010 are smaller than 4 acres with 20% of them being less than one acre. These results are fairly similar to results from other sources (Austin 2008, Chimner and others 2008) .

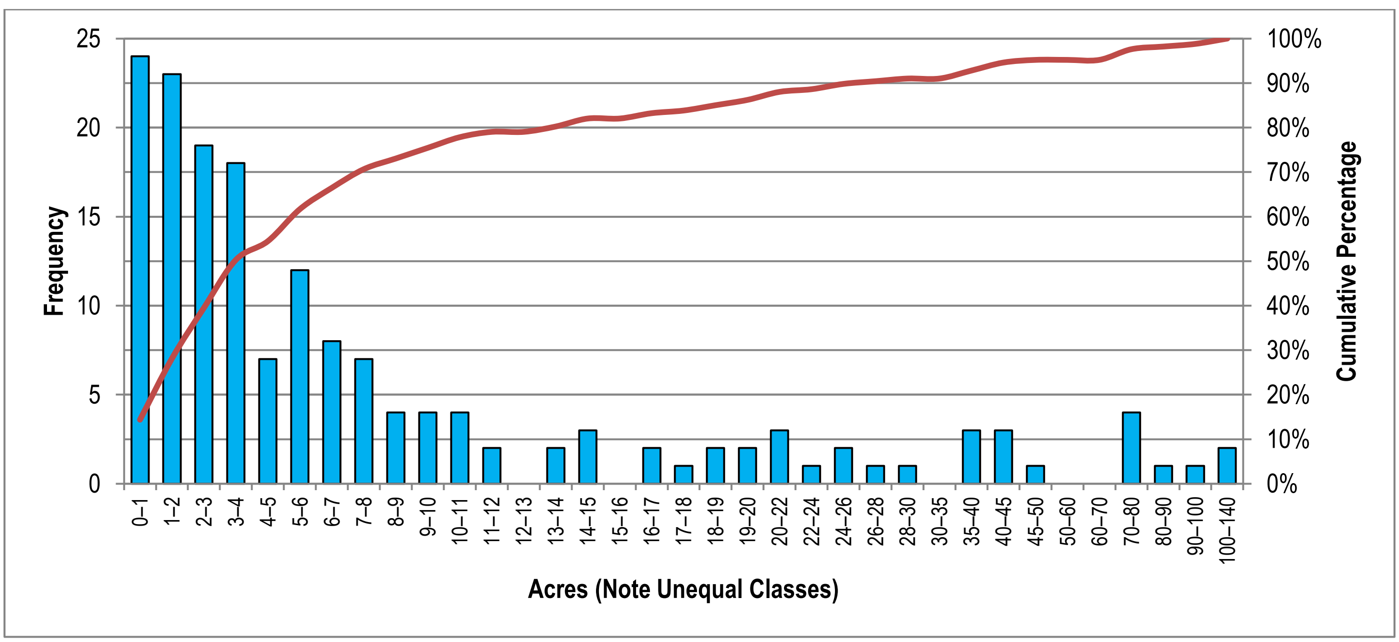


Figure 4-4. Size of fens documented as part of this inventory. The unequal classes on the horizontal axis are necessary to be able to see detail at small acreages (n = 147, $\overline{x}$ = 11.0 ac, sd = 20.9 ac)[j].See Figure 5-4 for frequency distribution of acreage for all fens known on the GMUG.

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[j] . n = sample size, $\overline{x}$ = mean, sd = standard deviation. Same convention throughout report.

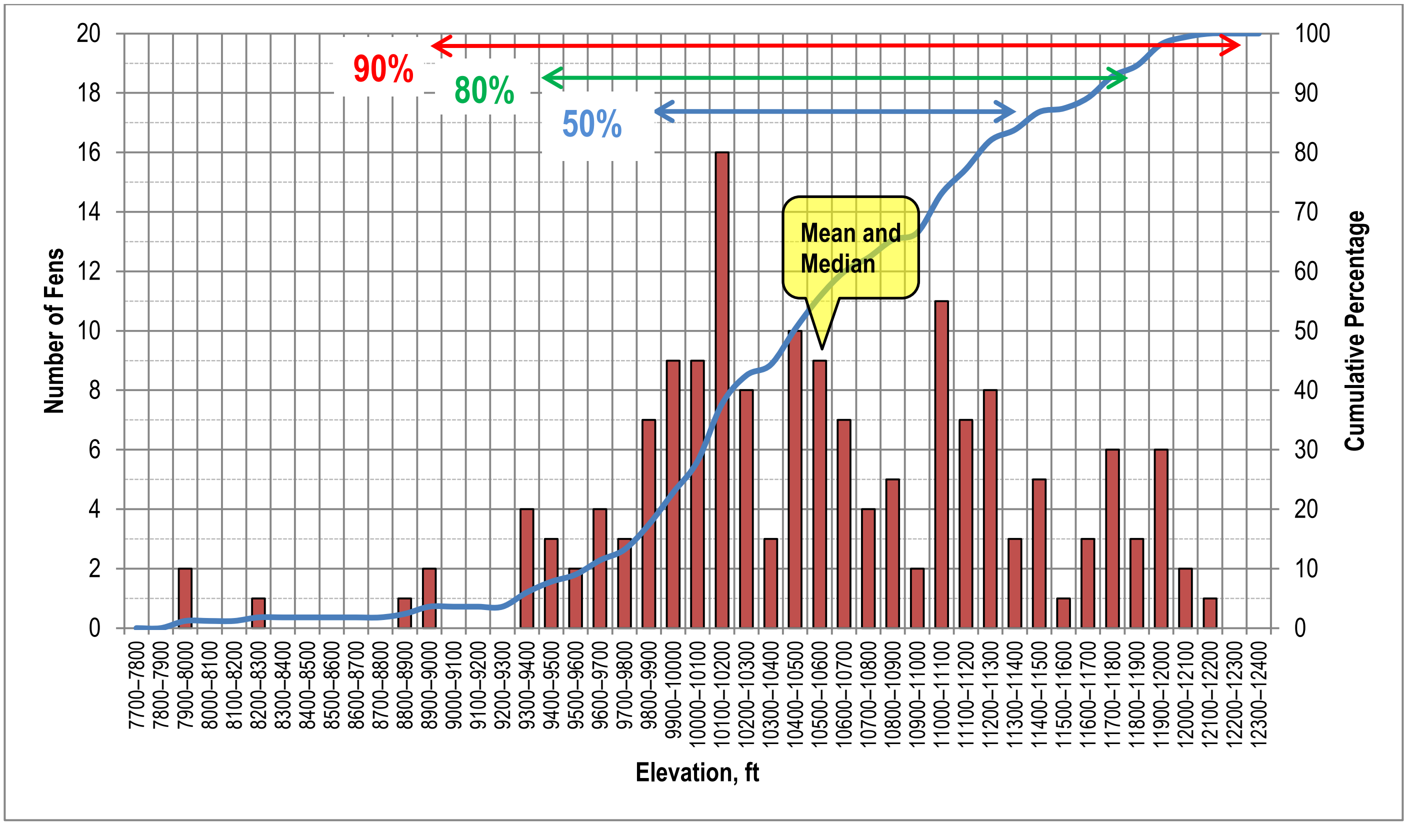


Figure 4-5. Frequency distribution of elevation for the fens documented during 2009-2010 inventory. (n = 147, $\bar{x}$ = 10,589 ft, sd = 803 ft)

Elevation range of the fens is shown in Figure 4-5. Elevation of fens ranges from 7,900 ft (two occurrences) to over 12,100 ft (one occurrence), contrasted with the range of elevations for the whole Grand Mesa, Uncompahgre, and Gunnison National Forests, which is 5,830 – 14,350 ft (Table 2-1). Ninety percent of fens occurred between 9,000 ft and 11,900 ft; eighty percent between 9,400 ft and 11,500 ft. The mean elevation is 10,589 ft, and the median is 10,515 ft. There is a clear primary peak in the graph at 10,100 ft and several secondary peaks around 10,000 ft and 11,000 ft.

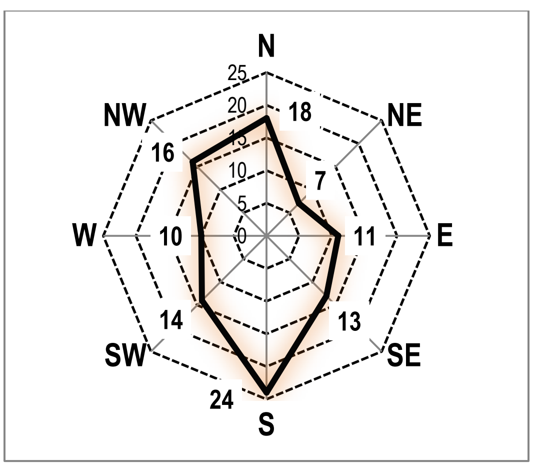


Figure 4-6. Distribution of aspects among inventoried fens. The radial axis (out from the center) represents number of samples. 32 fens had zero slope recorded (n = 145).

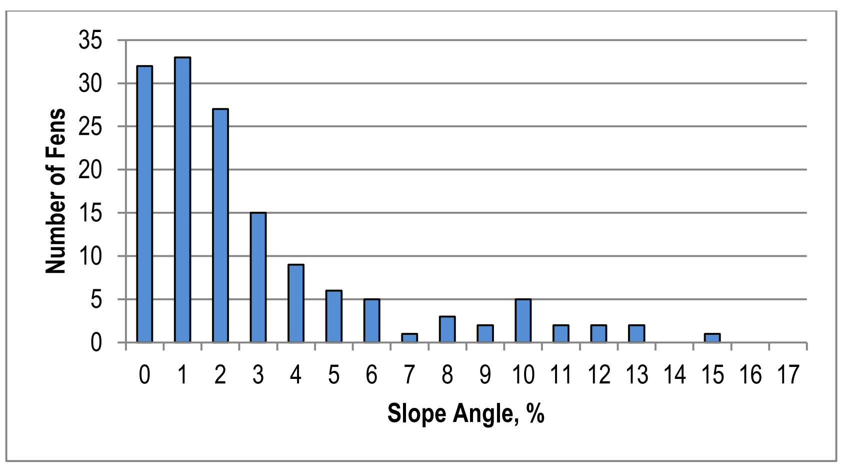


Figure 4-7. Distribution of slope angle. 25 fens were recorded aspect none and slope zero; another seven had slope zero with aspect azimuth recorded (n = 145, $\bar{x}$ = 2.8%, sd = 3.3%).

Fen aspects range as in Figure 4-6. Slightly more fens occurred on southerly and north-northwesterly aspects. Some fens (32) were in basins or depressions, and so had zero slope and no aspect. Slopes range as in Figure 4-7. Inventoried fens had predominantly very low slopes: eighty-seven percent of the fens occurred on slope angles less than 6%, and 64% on slopes less than 2%. Twelve fens were inventoried with slopes greater than or equal to 10%.

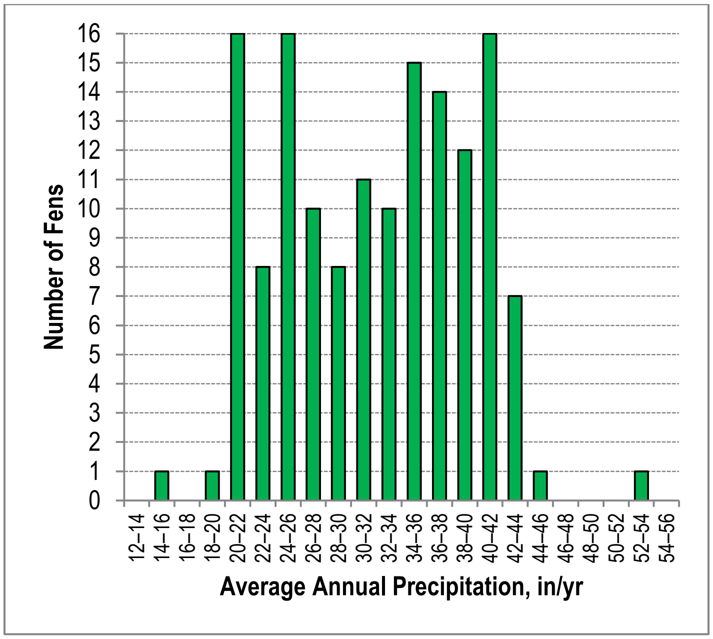


Figure 4-8. Frequency distribution of average annual precipitation (1961-1990) for 147 fen wetlands. (n = 147, $\bar{x}$ = 31.9 in/yr, sd = 7.4 in/yr) Precipitation data from PRISM (USDA Natural Resources Conservation Service 1998).

Frequency distribution for average annual precipitation is shown in Figure 4-8. This table was derived from overlaying a map of inventoried fens and a PRISM map of average annual precipitation (Figure 2-7). Almost all of the fens (93%) are in precipitation zones from 20 in/yr to 42 in/yr average annual precipitation.

3. Peat Characteristics

a. Peat Thickness

Measured peat thickness was a principal characteristic used to determine whether a site is a fen. Based on the field sampling protocol, potential fen sites were not sampled if the peat thickness was less than 30 cm (Driver 2010), which establishes 30 cm as the lower limit of observed peat thickness in this inventory. See discussion in Introduction. On the upper end, the length of the tile probe used for peat depth measurement is 150 cm. A frequency distribution of peat thickness is shown in Figure 4-9, showing the median of 50 cm.

Peat thickness is negatively correlated with Von Post values (Appendix C), indicating that the sites with thicker peat are less decomposed at the sampling depth. Some of the species that occur in deeper-peat sites are *Carex simulata* (short-beaked sedge) and *Comarum palustre* (purple cinquefoil). Shallower-peat sites have *Pedicularis groenlandica* (elephantella) and *Psychrophila leptosepala* (marsh marigold).

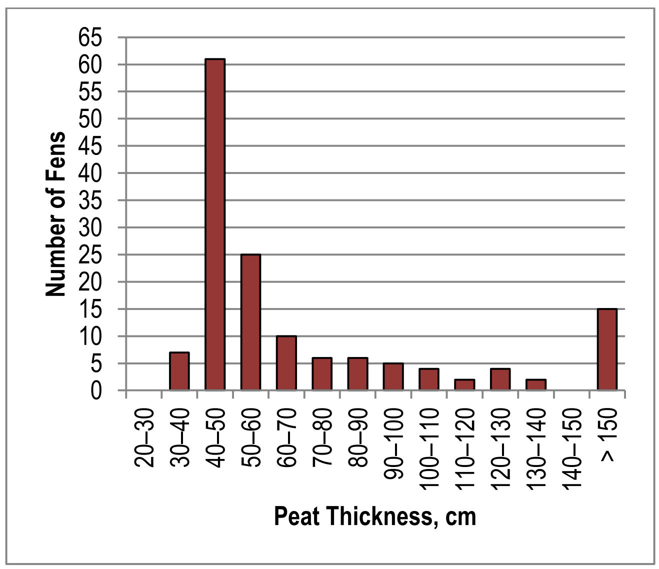


Figure 4-9. Frequency distribution of peat thickness. (n = 147, $\bar{x}$ = 66.5 cm, sd = 36.1 cm).

b. Von Post Decomposition Scale

The Von Post decomposition scale is a widely used field method to indicate the stage of peat decomposition (National Wetlands Working Group 1997). The degree of decomposition is determined by squeezing a peat sample in the hand and examining the compressed peat and water. A rating is made on a scale from one (undecomposed) to ten (completely decomposed). Although the method is subjective, it can be readily determined in the field with experience. Slightly decomposed peat has a loose structure. As decomposition proceeds, the particle size diminishes and the structure of peat becomes denser and less porous. A low von Post value may indicate lack of peat decomposition. The higher Von Post values may indicate peat decomposition or net loss. Von Post Values are explained in more detail in Appendix C.

Results were obtained on 146 sites, ranging from 1 to 8, with an average value of 3.92. The frequency distribution reflects an approximately normal distribution about the mean (Figure 4-10). Well over half the samples had a Von Post value of 4 or less, which indicates that for most of our sites, peat is relatively little decomposed, in good condition.

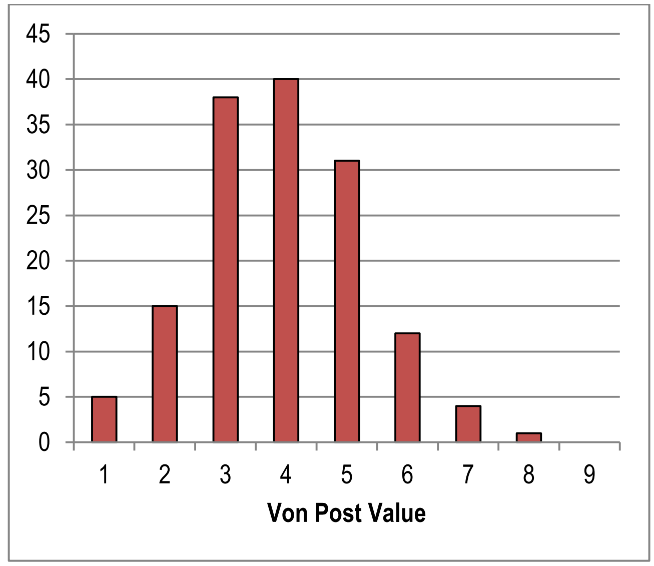


Figure 4-10. Frequency distribution of Von Post values. (n = 146, $\bar{x}$ = 3.9, sd = 1.4).

c. Organic Carbon Content

A frequency distribution of organic carbon in the 2009-2010 samples is shown in Figure 4-11. For the 2009 samples, organic carbon was directly measured. In 2010, organic matter was measured, and organic carbon was estimated based on the linear relationship between organic matter and carbon.

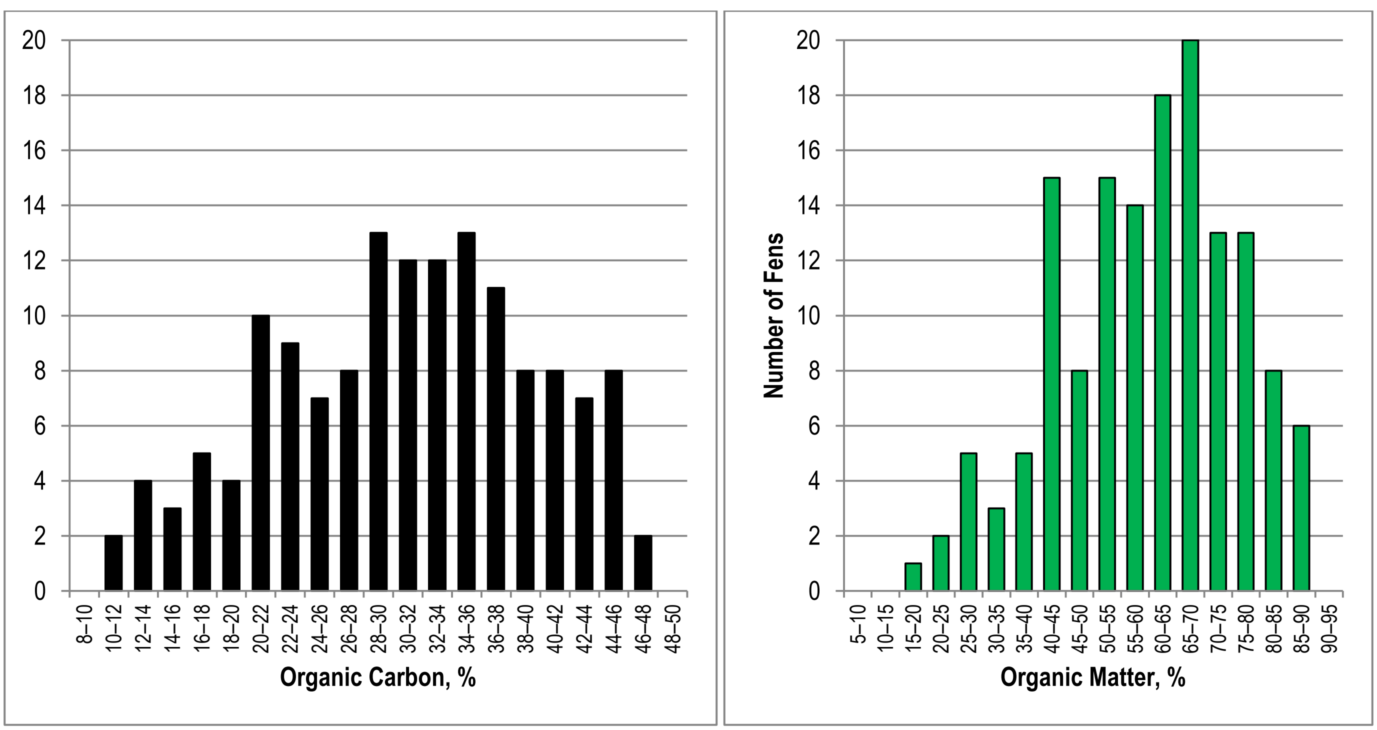


Figure 4-11. Frequency Distribution of organic carbon content and organic matter.
OC (n = 146, $\bar{x}$ = 30.8%, sd = 8.9%), OM (n = 146, $\bar{x}$ = 59.4%, sd = 15.9%).
Note that for 2010 samples, organic carbon was calculated using the regression in Figure 3-6.

4. Water Table Depth

A high water table is critical for creating and sustaining peat-forming plant communities. Deeper ground water depths may alter species composition, and can accelerate loss of peat due to increased aeration and peat decomposition leading to subsidence (Armentano 1980, Clymo 1983, Price and others 2003, Grace 2006). Depth to water was measured in the soil pit dug at each site. The pit was excavated and allowed to fill with water for approximately one hour prior to measurement. Saturation at the soil surface was recorded as a water table depth of zero. Water levels observed below the surface were assigned negative values and standing water above the soil surface positive values. Depth to water was obtained at 147 sites and is skewed toward a value of zero (Figure 4-12). Saturation to the surface is the most common level observed. A total of 48 sites (47%) had water at the soil surface or higher.

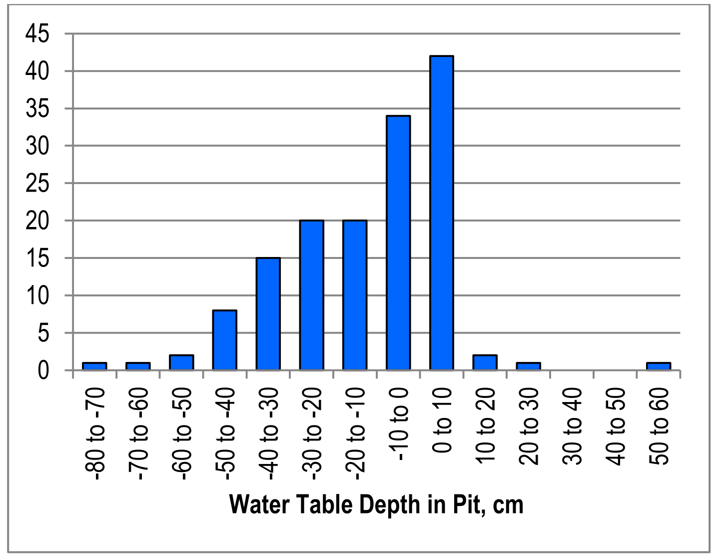


Figure 4-12. Frequency distribution of water table depth. Positive values indicate water above the soil surface (n = 147, $\bar{x}$ = -14.2 cm, sd = 18.6 cm).

5. pH and Electrical Conductivity

The measured site ground water pH varied from 3.x to 8.0, with a median of 5.6 (Figure 4-13). Among the species that tend to occur in sites with high pH are *Salix brachycarpa* (barrenground willow) and *Carex capillaris* (hair sedge); and those that tend to occur in sites with low pH include *Carex nigricans* (black alpine sedge).

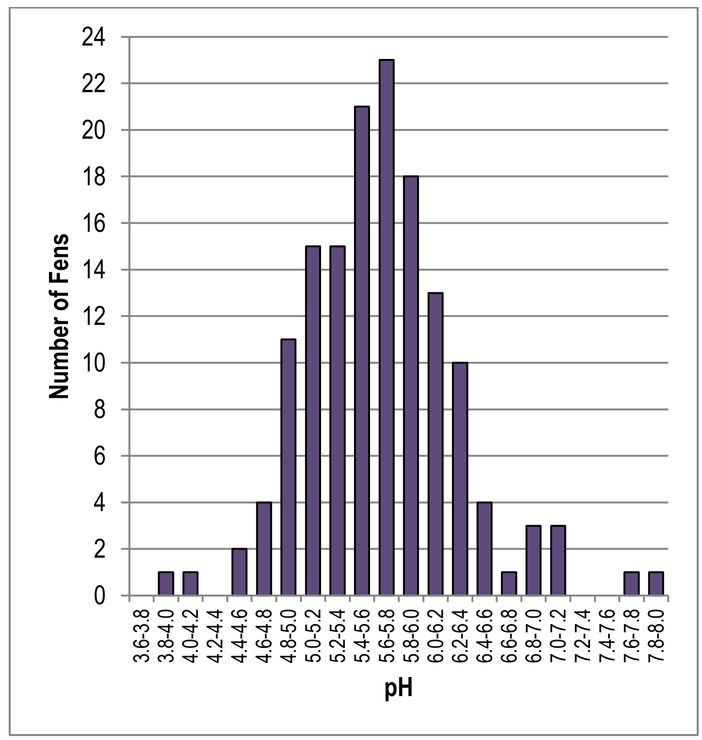


Figure 4-13. Frequency distribution of pH. (n = 147, $\bar{x}$ = 5.7, sd = 0.6).

The values of electrical conductivity (EC) vary widely, from 7 μS/cm to 652 μS/cm; the majority of the fens are in the range of 20-100 μS/cm (Figure 4-14). EC is significantly positively correlated with pH, slope angle, and open water presence; and negatively correlated with elevation. Higher EC values tend to occur at lower elevations, at higher slope angles, and in areas where open water is apparent (Appendix E). Among the species that tend to occur in sites with high EC values are *Salix brachycarpa* (barrenground willow), *Calamagrostis canadensis* (bluejoint reedgrass), and *Senecio triangularis* (arrowleaf groundsel); and sites with low EC values have more *Eleocharis quinqueflora* (few-flowered spike-rush).

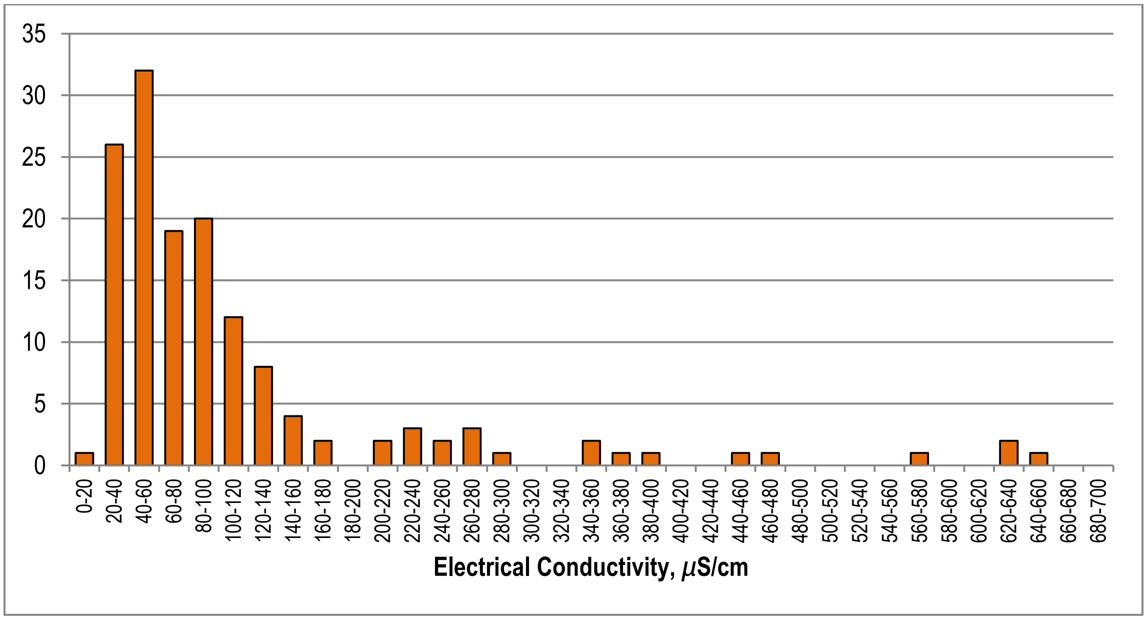


Figure 4-14. Frequency distribution of electrical conductivity. (n = 145, $\overline{x}$ = 108.7 μS/cm, sd = 121.2 μS/cm)

6. Percent Bare Soil

The presence of bare soil (exposed peat) exposes the peat body to degradation due to decomposition and erosion (Weixelman and Cooper 2009). The extent of bare ground or peat has been positively correlated with net carbon loss (Cooper and others 2005). Percent bare soil was determined based on the average of the five Daubenmire microplots (Daubenmire 1959) within the vegetation relevé that was used to characterize ground cover at each site. A total of 122 (or 84%) of the sites sampled had no exposed peat, with the frequency distribution highly skewed as a result (Figure 4-15); this indicates that most of our sites are in non-degraded condition by the standards of Weixelman and Cooper (2009).

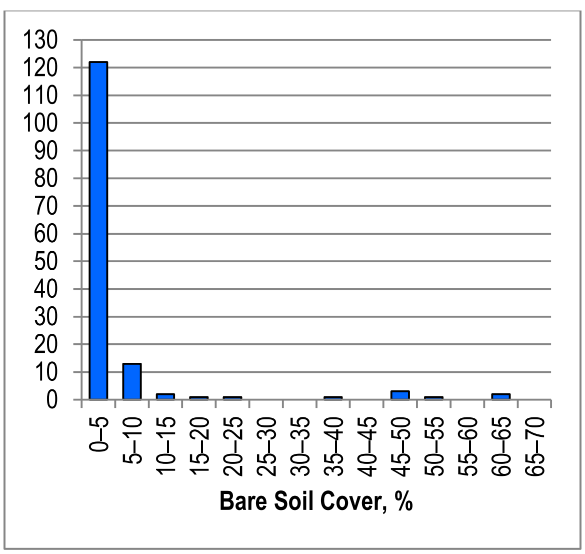


Figure 4-15. Frequency distribution of bare soil cover as measured in microplots. (n = 147, $\overline{x}$ = 3.8%, sd = 11.2%)

7. Plant Species

a. Species Composition and Cover

Plant communities sampled in this inventory were dominated by a wide variety of plant species. There are 24 plant taxa (species and genera) that occur ten or more times (Table 4-3). Some of these may be indicators of type or of condition, because they occur across a wider range of sites than less-common species.

Table 4-3. Plant taxa that occur ten or more times in the 147 fen samples.

Species	Code	Growth Form	No. Fens	Common Name(s)
Carex aquatilis	CAAQ	Graminoid	106	water sedge
Carex utriculata	CAUT	Graminoid	67	beaked sedge, Northwest Territory sedge
Pedicularis groenlandica	PEGR2	Forb	63	elephantella, elephant-head pedicularis, elephanthead
Psychrophila leptosepala	PSLE	Forb	63	elkslip marsh-marigold, elkslip, white marsh-marigold
Salix planifolia	SAPL2	Shrub	58	planeleaf willow, tea-leaved willow, diamondleaf willow
Deschampsia cespitosa	DECE	Graminoid	40	tufted hairgrass
Clementsia rhodantha	CLRH2	Forb	38	rose crown, redpod stonecrop
Epilobium hornemannii	EPHO	Forb	27	Hornemann willow-herb
Swertia perennis	SWPE	Forb	27	star gentian, alpine bog swertia
Calamagrostis canadensis	CACA4	Graminoid	22	bluejoint reedgrass, bluejoint
Carex canescens	CACA11	Graminoid	22	pale sedge, gray sedge, silvery sedge
Galium trifidum	GATR2	Forb	19	small bedstraw, small cleavers, threepetal bedstraw
Carex scopulorum	CASC12	Graminoid	17	cliff sedge
Viola	VIOLA	Forb	17	Violet
Bistorta vivipara	BIVI2	Forb	16	viviparous bistort
Carex simulata	CASI2	Graminoid	15	short-beaked sedge
Salix wolfii	SAWO	Shrub	14	Wolf's willow
Eleocharis quinqueflora	ELQU2	Graminoid	14	few-flowered spike-rush
Aulacomnium	AULAC2	Bryophyte	14	aulacomnium moss
Dasiphora floribunda	DAFL3	Shrub	13	shrubby cinquefoil, bush cinquefoil
Carex jonesii	CAJO	Graminoid	10	Jones's sedge
Ligusticum tenuifolium	LITE2	Forb	10	fern-leaf lovage, fern-leaf ligusticum, Idaho liquoriceroot
Thalictrum alpinum	THAL	Forb	10	alpine meadow-rue

Total live cover was calculated two different ways, once including only vascular plants (TLC), and once including both vascular plants and bryophytes (TLCB). Total live cover of vascular plants (TLC) varies from 30% to 477%, with a median of about 204% (Figure 4-16). Total live cover including bryophytes (TLCB) varies from 30% to 577%, with a median of about 250%. The correlations with TLC are obvious and not very revealing. TLC is negatively correlated with *Carex utriculata* (beaked sedge), because that species tends to occur in sites with low cover and higher water tables. TLC is also negatively correlated with peat-forming species and wetland plant species.

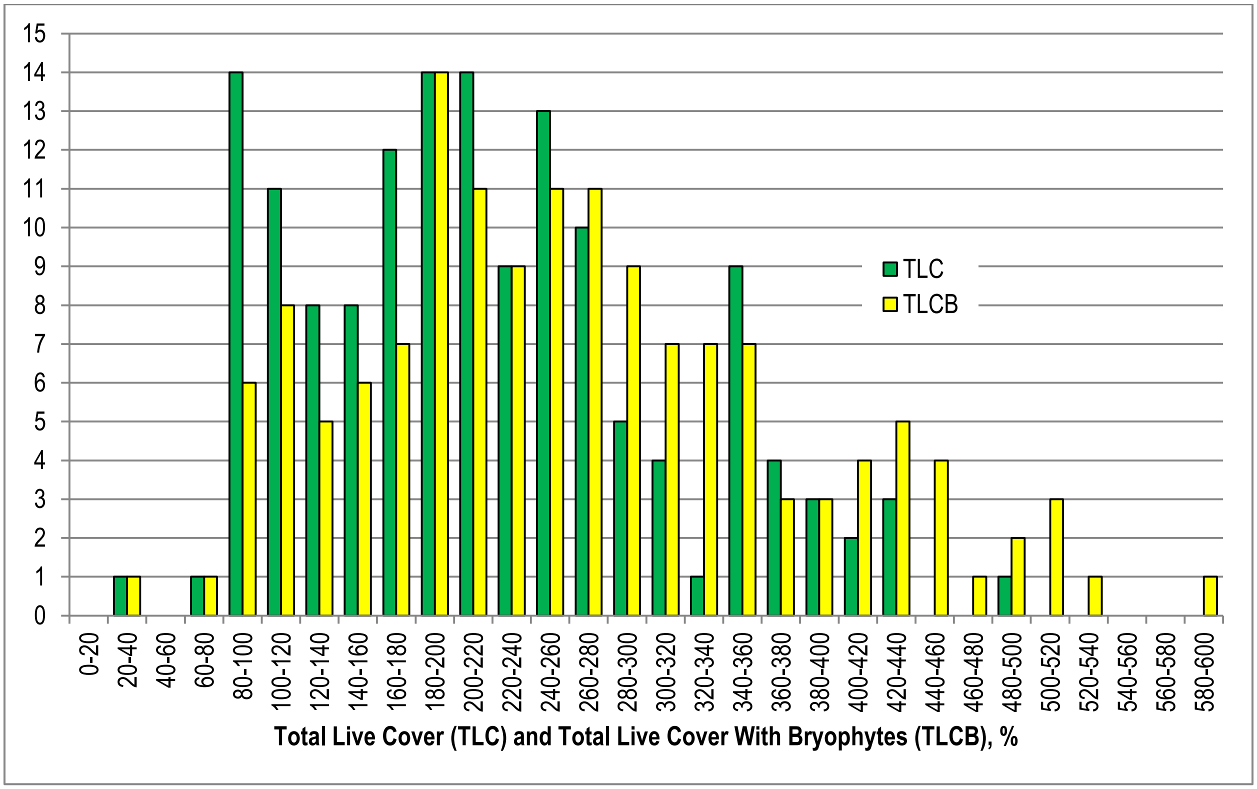


Figure 4-16. Frequency distributions of Total Live Cover (TLC) of vascular plants and of vascular plants plus bryophytes (TLCB). TLC (n = 147, $\overline{x}$ = 215.3%, sd = 92.1%) & TLCB (n = 147, $\overline{x}$ = 261.5%, sd = 112.8%)

A simple diversity index was calculated, total live cover of vascular plants divided by number of vascular plant species (Figure 4-17), sometimes called *species evenness* (Wilsey and Potvin 2000). This diversity index (TLX) is simply the average cover per species, higher numbers indicate a less diverse species makeup of the total live cover. TLX is negatively correlated with bryophyte cover, showing that the vascular plant communities are less diverse in sites with high bryophyte cover. TLX is also positively correlated with water depth. In other words, plant diversity goes up when water table depths are closer to the soil surface. TLX is negatively correlated with Nitrogen content in the soil sample (Appendix E).

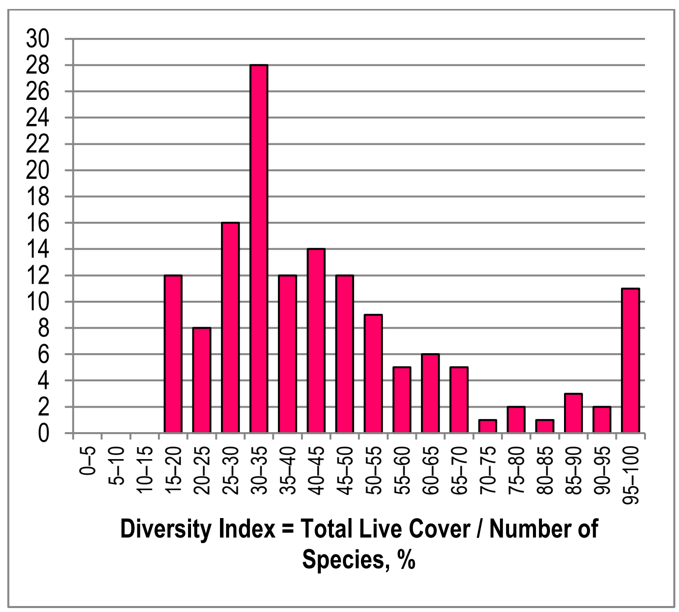


Figure 4-17. Frequency distribution of the diversity index (TLX). Derived by dividing total live cover of vascular plant species by the number of vascular plant species in fen relevés (n = 147, $\overline{x}$ = 44.8, sd = 21.9).

We calculated three indices based on species composition of the site. Not all wetland species are capable of forming peat, hence we used both peat-forming plants and wetland plants as metrics for analysis.

One of the indices was Floristic Quality Index (FQI), a weighted average of Coefficient of Conservatism (C) values. C values range from 0-10, where a value of 10 means that a plant is more likely to occur in a native pre-settlement landscape (Rocchio 2007). We used the C values in Rocchio (2007), and calculated Floristic Quality Index:

$$FQI = \frac{1}{TLC}\sum_{i=1}^{ns} c_i \times v_i \times 100$$

where FQI = Floristic Quality Index, TLC = Total Live Vascular Plant Cover, ns = Number of vascular plant species, c_i = C value for species i, and v_i = cover for species i. The distribution of FQI is shown in Figure 4-18.

Peat-forming species are particularly important for the continued maintenance and accumulation of a peat body (Weixelman and Cooper 2009). Chimner and others (2008) included in their condition rating whether the site is dominated by peat-forming plants. We determined whether each species is capable of forming peat, based on Rocchio 2006a, Weixelman and Cooper 2009, and experience (Appendix F). We then calculated the percentage of the total cover of a plot comprised of peat-forming plants, including all bryophytes.

$$PFP = \frac{1}{TLCB}\sum_{i=1}^{ns} p_i \times v_i \times 100$$

where PFP = Percent Peat-Forming Plants, $TLCB$ = Total Live Plant Cover (including bryophytes), ns = Number of plant species, p_i = 1 if species i is peat-forming, and v_i = cover for species i. The frequency distribution of percentage of peat-forming plants is shown in Figure 4-19. This distribution shows that we have sampled high-quality fens that are dominated by peat-forming species.

The presence and relative abundance of species adapted to wetlands is generally considered to be an indicator of wetland health or condition. The metric of percent wetland plants represents the respective proportion of all plants identified on a site that are wetland species, obligate or facultative (Lichvar and others 2011). Overall, wetland species dominated the plant communities present by comprising at least half of the total cover present across all sites, and representing 75% or more of the total cover on 102 of the sites (Figure 4-20).

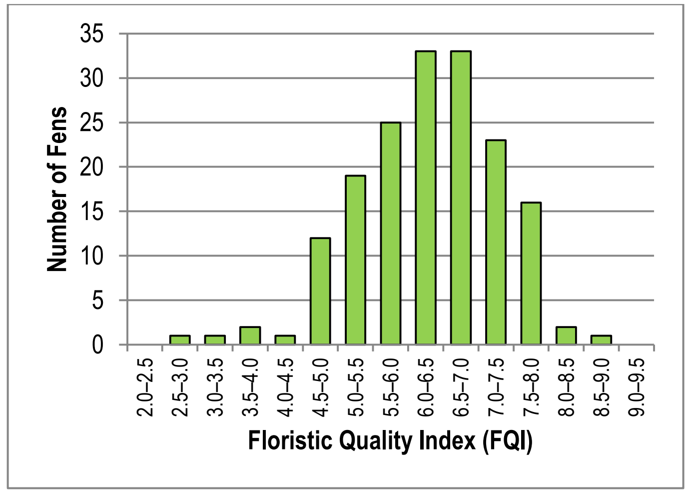


Figure 4-18. Frequency of floristic quality index. (n = 147, $\bar{x}$ = 6.3, sd = 0.9)

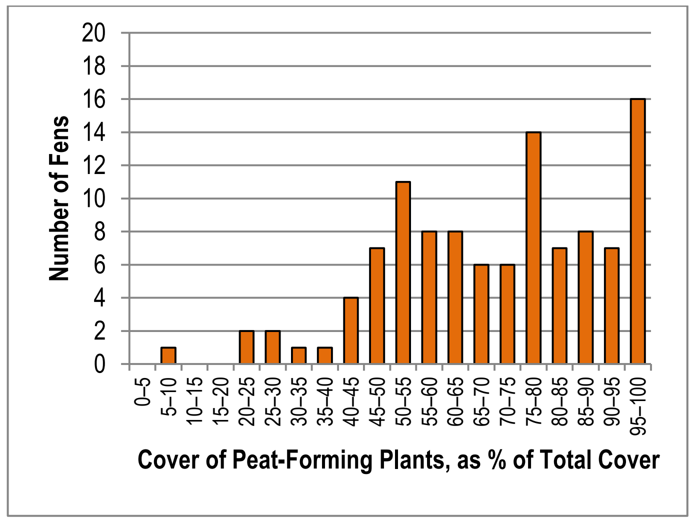


Figure 4-19. Frequency of percent peat-forming plants. (n = 147, $\bar{x}$ = 78.0%, sd = 22.2%)

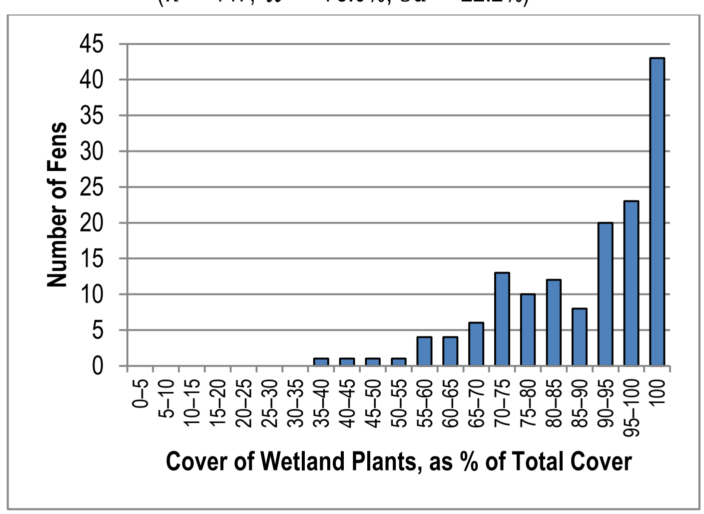


Figure 4-20. Frequency of percent wetland plants. (n = 147, $\bar{x}$ = 87.6%, sd = 14.4%)

b. Special Status Species

There were no Federally threatened, endangered, proposed, or candidate species documented in the inventory; however, there were six vascular plant species found that are tracked by the Colorado Natural Heritage Program (Colorado Natural Heritage Program 2010). They are all vascular plants (Table 4-4), no tracked bryophytes were documented in the inventory. One of the six plants is considered a Sensitive Species by the Bureau of Land Management in Colorado; none are Forest Service Sensitive Species.

Table 4-4. Plant species found in 2009 inventory that are tracked by CNHP. (Colorado Natural Heritage Program 2010)

Name	Code	GF	NS*	Avg Cvr	Family Code	Common	Peat Forming	Wetland Status	GRank / SRank†	T & E	Sensitive	CNHP Track
Carex lasiocarpa	CALA11	G	2	50.0%	CYP	woollyfruit sedge	Yes	OBL	G5 / S1	-	-	Y
Carex leptalea	CALE10	G	3	0.5%	CYP	bristlystalked sedge	Yes	OBL	G5 / S1	-	-	Y
Carex limosa	CALI7	G	3	23.5%	CYP	mud sedge	Yes	OBL	G5 / S2	-	-	Y
Carex scirpoidea	CASC10	G	1	0.5%	CYP	northern singlespike sedge	Yes	FACW	G5 / S2	-	BLM	Y
Comarum palustre	COPA28	F	6	31.7%	ROS	purple cinquefoil	Yes	OBL	G5 / S1S2	-	-	Y
Luzula subcapitata	LUSU9	G	3	6.8%	JUN	Colorado woodrush	Yes	OBL	G3? / S3?	-	-	Y

*. NS – Number of samples in which species occurs. †. Global and State ranks assigned by CNHP (Colorado Natural Heritage Program 2012).

8. Ecological Classification with Vegetation Emphasis

The data collected from the fens were subjected to simple correlation, as it is one way to distill a complex data set into simpler forms. Correlation can show which factors are closely related to other factors including indicators of quality and function. Of particular interest is which factors are tied to disturbance, or lack of disturbance. Correlation is also used as an aid in determining what might be important indicators of condition or communities (Clements 1920).

Although there are a number of significant correlations, they do not result in many meaningful graphs or interpretations. As an example of the complexity of the data, Figure 4-21 shows organic carbon as a function of pH, with the points labeled with Von Post values. The lower Von Post Values (1, 2, and 3) are grouped towards the high end of the carbon scale, but the higher Von Post values (4, 5, and 6) are not grouped at all. Organic carbon and Von Post values are highly significantly negatively correlated.

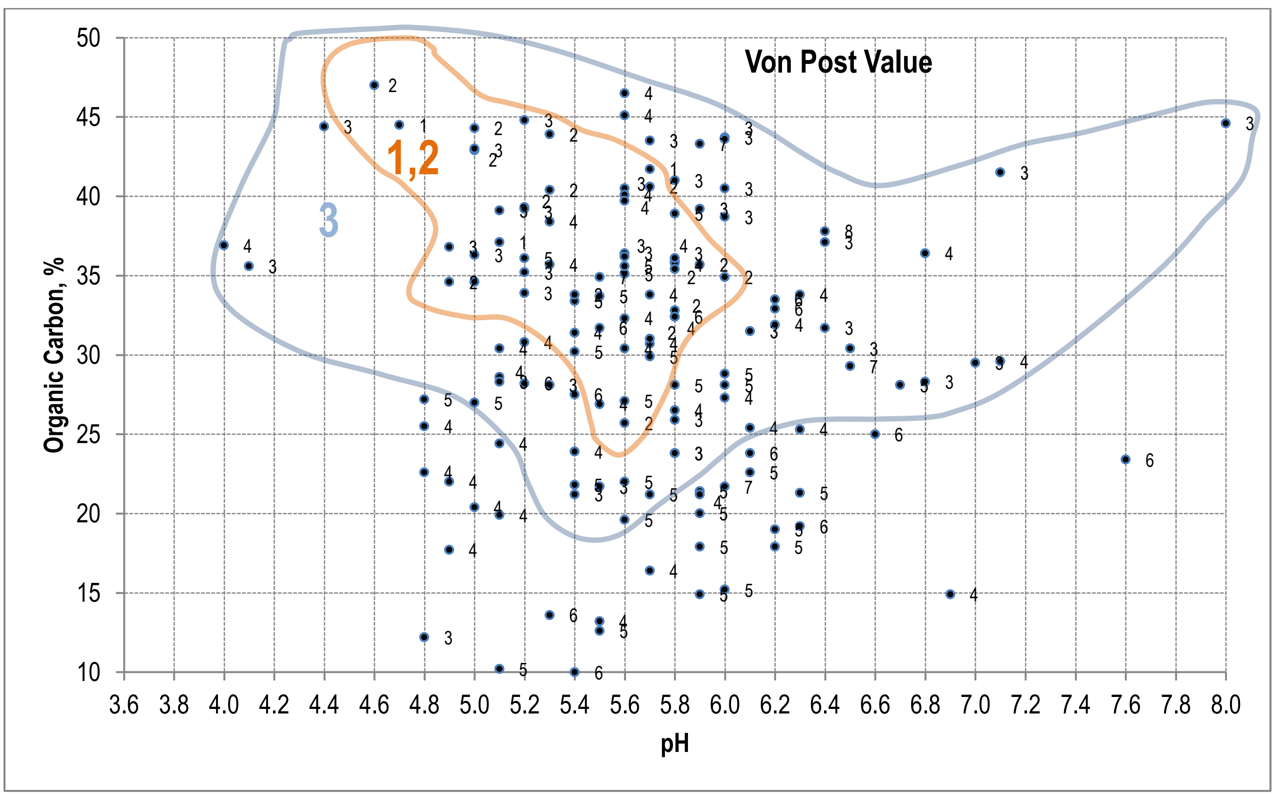


Figure 4-21. Organic carbon as a function of pH. The labels show Von Post Value.

The following ecological classification is based on current conditions at the sites sampled in 2009-2010. Tables of vegetation, physical characteristics, and summary variables are shown in Appendix G. The groupings shown in Appendix G were arrived at by many successive iterations of ordination and clustering processes. From Appendix E, the most important indicators, the indicators that have the greatest sum of correlations, are listed in Table 4-5.

Table 4-5. Factors with the highest correlation and indicator value. Full list in Appendix E

Factor*	Meaning	Total Correlation†
TLC	Total live cover of vascular plants	18.4605
NSP	Number of vascular plant species	18.3363
TLCB	Total live cover, including bryophytes	16.6063
PEATFOX	Percentage peat-forming plants	14.8534
FQI	Floristic quality index	14.2399
TLX	Total live cover divided by no. species	13.5118
WETPLX	Percentage wetland plants	13.2640
THAL	*Thalictrum alpinum*	13.1736
UTMX	UTM X-coordinate	12.6624
SAWO	*Salix wolfii*	12.3695
PSLE	*Psychrophila leptosepala*	11.8980
CHANX	Channels present or absent	11.7554
DAFL3	*Dasiphora floribunda*	11.6715
ELEVX	Elevation scalar	11.6667
OM	Percent organic matter	11.6245
PEGR2	*Pedicularis groenlandica*	11.5077
OPENWX	Open water present	11.4559
C	Percent organic carbon	11.3623
CAUT	*Carex utriculata*	11.3255
WATER	Water cover, %	11.2996
SWPE	*Swertia perennis*	11.0529
FENTYPEX	Fen (landform) type scalar	11.0344
SAPL2	*Salix planifolia*	11.0007
SURFROCK	Surface rock cover	10.9886
CASC12	*Carex scopulorum*	10.9801
PEATDEP	Peat depth, cm	10.9299
BEAVX	Beaver absent, present, or dominant	10.7919
BAREX	Bare soil estimated on potential fen site	10.6877
BEGL	*Betula glandulosa*	10.6438

Factor*	Meaning	Total Correlation†
BIVI2	*Bistorta vivipara*	10.5650
CAAQ	*Carex aquatilis*	9.7309
PITDEP	Pit depth, cm	9.6571
GULLYFX	Gully frequency 0 (none) to High (3)	9.5855
ACRES	Acres of the fen-wetland complex	9.5847
UTMY	UTM Y-coordinate	9.5596
SEDX	Sediment cover estimated on potential fen site	9.5338
WATDEPX	Water depth, cm	9.5001
SLOPE	Slope angle, %	9.3417
LITT	Litter cover, %	9.2373
HALTERX	Level of hydrologic alteration	9.2024
ASPXY	Aspect X-coordinate	9.0996
TEXIB	Total disturbance in the buffer	9.0546
PROBEAX	Average tile-probe depth	9.0240
EC	Electrical conductivity	9.0176
CLRH2	*Clementsia rhodantha*	8.9324
PROBEMX	Maximum tile-probe depth	8.7913
FLOATX	Floating mat presence	8.7433
GWX	Ground-water (Fetter) diagram	8.7326
TEXI	Total disturbance in the wetland	8.7268
EQAR	*Equisetum arvense*	8.6868
CALE10	*Carex leptalea*	8.6318
ELQU2	*Eleocharis quinqueflora*	8.5123
VIMA2	*Viola macloskeyi*	8.4414
SABR	*Salix brachyphylla*	8.3832
PH	pH of water in the pit	8.2131
BAVE	Live basal plant cover	8.0231
VONPOST	Von Post scale	8.0229

*. Explanation in Appendix E. †. Sum of absolute values of all correlation coefficients ($\sum \left| r^2 \right|$).

Using iterative combinations of ordination (Hill 1994) and clustering (Hill and Šmilauer 2005), all the fens were grouped into clusters based on cover by species, and numerous abiotic characteristics such as pH, EC, and groundwater type. An example ordination plot is shown in Figure 4-22.

This resulted in 91 associations, which were grouped further into ten large clusters. A description of the ten large clusters (Appendix J) follows. Summary of selected characteristics of these ten large clusters is shown in Table 4-6.

Not included here is one sample (WFS236) from the eastern San Juan Mountains, described in Appendix G as community type O1. Classification of larger data sets indicate that this represents a rare high subalpine and lower alpine fen type. Creation of another large cluster was not justified, since the 2009-2010 inventory had only one site in that type, yet it could not be lumped into one of the existing large clusters.

There were no plots dominated by trees or semi-aquatic species in the 2009-2010 samples.

The ecological classification summarized below was based only on the 147 fens detected in the 2009-2010 inventory, and so it is limited in scope. As is often the case with sampling a large population, it is likely that rare individuals, or types of fens in this case, were not included in the sample. This classification fits reasonably well with a summary classification made for a broader area (Johnston 2008).

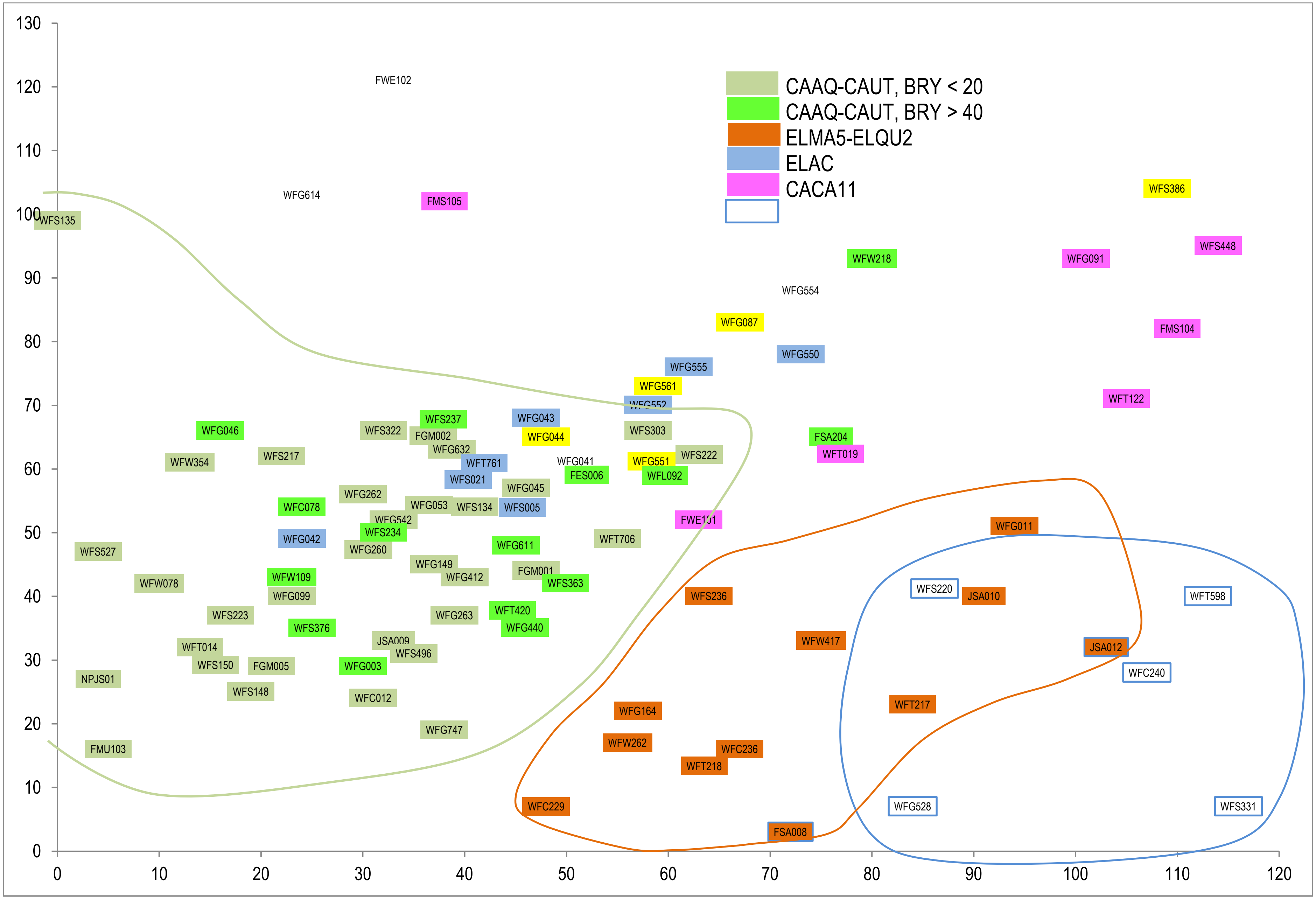


Figure 4-22. Example of an ordination plot, using DECORANA. The axes are artificial, calculated by the program. (Hill 1994)

Table 4-6. Selected characteristics of the ten large clusters.

Cluster	NS	Elevation Aspect X Aspect Y Slope	pH EC	Fen Landform	PROBEX* PEATDEP VONPOST	TExI† TExIB	BRY‡ BARE	Total Live Cover No. Species	Floating Mat	Channels	Gully Freq.	Hydrologic Alteration	Ground Water Diagram§	Peat-Forming[1] Wetland[2] Floristic Quality[3]
I	5	8,959–9,595–10,200 0.1–10.3–16.9 5.0–15.3–19.8 0–2.8–12	5.40–5.90–6.40 70–223.0–355	BA 0 SL 1 SD 1 VS 3 TS 0	40–65–100 42–82.4–150 3–4.4–6	8–18.5–37 0–9.3–16	2–30.2–84 0–11.7–46	120–226–372 3–7.2–12	Yes 0 No 5	Yes 5 No 0	None 5 Low 0 Med. 0 High 0	None 3 Low 0 Med. 2 High 0	A 1 D 4 B 0 E 0 C 0 F 0	48–76–93 57–80–96 5.1–6.1–6.9
II	17	9,814–10,578–11,734 0.0–8.2–17.7 0.6–11.8–20.0 0–2.9–13	4.80–5.61–7.10 20–104.2–390	BA 4 SL 9 SD 0 VS 2 TS 2	35–71–150 35–52.6–110 2–3.9–8	0–14.3–38 0–9.4–26	0–26.2–59 0–4.2–37	101–215–388 3–6.6–13	Yes 1 No 16	Yes 13 No 4	None 12 Low 1 Med. 0 High 1	None 14 Low 2 Med. 0 High 1	A 6 D 3 B 4 E 1 C 3 F 0	51–81–100 67–91–100 4.9–6.1–7.2
III	11	9,683–10,543–11,969 0.0–7.8–19.8 0.0–9.1–20.0 0–5.6–11	5.30–5.93–6.70 20–160.0–570	BA 1 SL 4 SD 0 VS 5 TS 1	35–74–150 35–66.2–96 2–4.3–7	1–10.7–24 1–8.7–32	83–93.0–100 0–0.3–2	158–268–478 3–7.7–13	Yes 0 No 11	Yes 10 No 1	None 11 Low 0 Med. 0 High 0	None 10 Low 0 Med. 1 High 0	A 3 D 1 B 7 E 0 C 0 F 0	41–73–100 61–82–100 5.5–6.7–7.1
IV	16	9,381–11,113–12,184 0.0–7.1–19.1 0.1–8.7–19.9 0–3.4–10	5.00–5.74–6.30 20–59.2–110	BA 0 SL 4 SD 0 VS 6 TS 6	35–78–150 30–68.6–150 2–3.9–7	1–16.1–56 2–10.8–56	10–64.2–98 0–1.9–20	121–289–392 5–10.6–19	Yes 0 No 16	Yes 13 No 3	None 15 Low 1 Med. 0 High 0	None 16 Low 0 Med. 2 High 0	A 6 D 2 B 6 E 0 C 0 F 1	44–74–100 55–86–100 6.3–7.0–7.8
V	6	9,368–9,995–10,776 0.1–8.7–19.6 0.4–10.2–16.8 1–1.9–4	5.50–5.73–6.00 21–98.5–140	BA 0 SL 1 SD 0 VS 4 TS 1	40–88–150 40–83.8–150 3–3.3–4	2–15.0–32 2–12.6–34	66–86.7–98 0–1.4–8	231–345–431 7–12.5–16	Yes 0 No 6	Yes 5 No 0	None 6 Low 0 Med. 0 High 0	None 3 Low 1 Med. 1 High 0	A 1 D 1 B 4 E 0 C 0 F 0	55–73–99 67–82–100 6.2–6.9–7.5
VI	3	9,656–10,484–11,260 0.4–10.6–16.4 1.3–3.6–7.2 2–7.3–10	6.50–6.83–7.10 230–435.0–635	BA 0 SL 0 SD 0 VS 2 TS 1	55–67–76 55–93.7–150 3–4.7–7	7–10.9–17 6–9.1–15	76–91.0–99 0–0.0–0	213–351–433 10–14.3–18	Yes 0 No 3	Yes 3 No 0	None 3 Low 0 Med. 0 High 0	None 3 Low 0 Med. 0 High 0	A 1 D 0 B 2 E 0 C 0 F 0	31–46–63 60–69–81 6.3–6.9–7.7
VII	28	8,287–10,171–11,743 0.0–8.0–20.0 0.0–9.2–20.0 0–1.3–5	4.80–5.64–6.50 24–115.8–652	BA 6 SL 5 SD 9 VS 2 TS 6	30–63–150 30–70.8–150 2–4.2–7	0–13.0–48 0–8.0–30	0–3.0–20 0–3.8–54	30–147–257 1–3.2–9	Yes 2 No 26	Yes 17 No 11	None 23 Low 2 Med. 1 High 1	None 19 Low 3 Med. 5 High 1	A 9 D 4 B 12 E 1 C 1 F 0	47–93–100 50–96–100 4.8–5.7–7.6
VIII	14	7,927–10,855–12,031 0.0–10.2–19.5 0.1–11.1–20.0 0–3.1–13	4.10–5.59–7.00 20–121.7–620	BA 3 SL 4 SD 1 VS 4 TS 2	40–69–150 40–69.9–150 1–3.4–5	0–18.7–107 1–13.5–78	30–66.5–90 0–8.4–63	90–145–261 1–4.2–11	Yes 1 No 13	Yes 10 No 4	None 13 Low 0 Med. 0 High 1	None 13 Low 0 Med. 0 High 1	A 4 D 3 B 6 E 1 C 0 F 0	39–84–100 58–94–100 5.0–5.9–6.9
IX	31	9,352–10,726–11,993 0.1–9.9–19.9 0.0–8.4–19.8 0–2.5–15	4.40–5.43–6.80 7–83.9–470	BA 5 SL 3 SD 3 VS 8 TS 12	30–65–150 30–61.8–150 1–3.7–6	0–15.8–69 0–8.8–34	0–48.6–100 0–3.0–62	100–233–381 2–8.1–16	Yes 3 No 28	Yes 23 No 8	None 25 Low 6 Med. 0 High 0	None 23 Low 2 Med. 5 High 1	A 10 D 7 B 7 E 3 C 2 F 0	29–75–100 44–84–100 5.1–6.8–8.7
X	15	9,964–10,844–11,760 0.1–9.8–19.4 0.0–10.1–20.0 0–2.3–7	4.70–5.77–8.00 20–59.3–140	BA 4 SL 3 SD 1 VS 0 TS 7	40–83–150 35–57.9–150 1–3.9–6	0–12.4–34 0–4.3–16	0–52.6–93 0–4.6–48	70–175–290 1–5.5–12	Yes 2 No 13	Yes 9 No 6	None 13 Low 2 Med. 0 High 0	None 12 Low 1 Med. 1 High 1	A 4 D 3 B 7 E 1 C 0 F 0	10–68–100 68–88–100 3.0–5.9–8.1

When three numbers are shown, they are Minimum-Average-Maximum. HIGH — LOW

*. PROBEX = average peat depth as measured by tile probe. PEATDEP = peat depth in pit.

†. TE×I = Average disturbance Extent × Intensity in the fen-wetland complex. TE×IB = same in the buffer (100 m).

‡. BRY = Total bryophyte cover. BARE = bare soil cover as measured in microplots.

§. See Fetter (2001) and diagrams in Appendix C.

[1]. Percent peat-forming vascular plants in flora. [2]. Percent wetland plants in flora. [3]. Floristic Quality Index. See Appendix F.

I. Tall willows with understory of large sedges (SAGE2-SAMO2-SAGE2), 5 samples. Dominance by one of the taller willows, serviceberry willow (*Salix monticola*) or Geyer willow (*S. geyeri*). The understory usually has water sedge (*Carex aquatilis*) or beaked sedge (*C. utriculata*). Bryophyte cover is variable. Number of vascular species varies from three to twelve. pH ranges 5.4 – 6.2; EC seems moderately high. There are probably several plant associations here; the vegetation is better-represented along streams and in non-fen wetlands. Tentative associations shown in Table 4-7.

Table 4-7. Tentative associations for Cluster I. Tall willows. (n = 5). Each line is a sample plot from a fen

Series	Association	Elevation, ft	Landscape Area	Slope, %	pH	EC	Fen Landform	Peat depth, cm	Von Post Value	Disturbance In Fen*	Disturbance In Buffer†	Total Bryophyte Cover	Bare soil/peat, %	No. of vascular species	Total live cover	Groundwater diagram	Pct. Peat-forming spp.	Pct. wetland species	Floristic quality index
SAGE2	SAGE2-SAPL2-SAWO-CACA11-CAREX	9,644	SA	12.0	5.6	70	VS	42	5	8	12	84	0	12	372	A	77.2	84.7	6.9
	SAGE2-CAVE6-CAAQ	10,190	WE	0.0	5.4	110	SD	100	3	37	5	2	46	8	289	D	47.8	72.1	6.5
SAMO2	SAMO2-CAUT	8,984	ES	0.0	5.9	240	VS	70	5	25	16	3	6	3	120	D	82.9	91.2	5.1
	SAMO2-CASC12-CAUT-BRY	10,200	MS	1.0	6.4	355	SL	150	3	8	0	40	6.7	6	151	D	79.5	56.8	6.5
	SAMO2-CAUT-CAAQ	8,959	ES	1.0	6.2	340	VS	50	6	16	14	22	0	7	201	D	92.9	95.7	5.5

*. Total Extent × Intensity in fen-wetland complex (TEXI). †. Total Extent × Intensity in buffer (TEXIB).

II. Planeleaf willow with beaked sedge or water sedge, low bryophyte cover (SAPL2-CAUT-CAAQ), 17 samples. Dominance by planeleaf willow (*Salix planifolia*), sometimes Wolf's willow also(*Salix wolfii*) and one of the large sedges, usually beaked sedge, water sedge, or blister sedge (*Carex vesicaria*). Bryophyte cover<60%, often <40%. pH is variable, ranging 4.8 – 7.1. Number of vascular species moderate to low, usually <12. Communities meeting this definition were also observed in the San Juan Mountains (12 sites) by Chimner and others 2008, and on the Grand Mesa (9) by Austin 2008. There are probably also a few from the Upper Gunnison Basin by Johnston and others 2001. Tentative associations shown in Table 4-8.

Table 4-8. Tentative associations for Cluster II. Planeleaf willow with beaked or water sedge. (n = 17)

Series	Association	Elevation, ft	Landscape Area	Slope, %	pH	EC	Fen Landform	Peat depth, cm	Von Post Value	Disturbance In Fen	Disturbance In Buffer	Total Bryophyte Cover	Bare soil/peat, %	No. of vascular species	Total live cover	Groundwater diagram	Pct. Peat-forming spp.	Pct. wetland species	Floristic quality index
SAPL2	SAPL2-CAAQ-BRY	10,668	SA	1.0	4.8	50	TS	45	4	18	5	26	0	3	117	B	100.0	100.0	6.0
		10,648	CH	1.0	6.3	70	BA	35	5	7	13	59	0	5	207	A	95.2	92.8	6.2
		11,148	ES	2.0	5.4	50	SL	50	4	2	0	27	10	9	233	A	99.1	99.5	6.3
		11,068	SA	1.0	4.8	20	SL	48	4	13	26	57	0	4	143	D	79.0	100.0	6.4
	SAPL2-CAAQ-CAUT-BRY	10,476	GM	3.0	6.2	130	SL	45	4	13	8	40	0	3	150	D	100.0	100.0	6.1
	SAPL2-CAUT-DECE	10,975	ES	1.0	4.9	30	VS	45	4	9	11	10	0	4	210	C	52.4	76.3	4.9
	SAPL2-CAAQ-CAUT	10,165	GM	0.0	5	30	BA	40	3	2	8	0	0	4	260	A	76.5	76.5	5.7
		10,278	GM	2.0	6.3	230	SL	40	4	0	0	0	0	5	250	A	84.0	100.0	6.2
		10,679	CN	2.0	6.4	390	SL	70	8	5	5	12	0	3	197	A	100.0	100.0	5.6
		9,915	WE	3.0	5.8	72	SL	110	2	36	19	0	0	4	101	E	99.5	99.8	5.6
	SAPL2-CAAQ-ELAC	10,592	EL	4.0	5.5	90	SL	44	3	8	12	28	8	12	311	B	51.4	69.5	6.3
	SAPL2-CAAQ-CAIN11	11,734	ES	13.0	4.9	40	SL	55	3	34	11	22	8.3	8	261	B	57.5	67.2	6.2
	SAPL2-CAAQ-CALA11	10,800	SA	1.0	5	60	SL	40	3	4	2	28	2	7	114	A	87.6	97.9	6.9
	SAPL2-CAJO-CAAQ-CAUT	10,210	ES	3.0	5.6	100	VS	55	5	38	4	6	6.1	7	271	C	77.7	85.1	7.2
SAPL2-SAWO	SAPL2-SAWO-CAAQ-CAVE6-BRY	10,030	SA	2.0	5.6	90	BA	40	4	19	20	46	0	13	388	B	75.8	93.2	6.8
	SAPL2-SAWO-CAAQ-CAUT-BRY	10,631	EL	10.0	7.1	250	TS	80	4	38	0	50	36.6	11	262	D	85.8	97.9	6.5
	DAFL3-SAWO-CABU6-CAUT-CALA11	9,814	SA	1.0	5.7	70	BA	52	3	2	19	34	0	10	177	C	57.9	92.8	5.5

III. Planeleaf willow with beaked sedge or water sedge, high bryophyte cover (SAPL2-CAUT-CAAQ-BRY), 11 samples. Dominance by planeleaf willow, sometimes Wolf's willow also, one of the large sedges, usually beaked sedge or water sedge, and bryophytes. Bryophyte cover >80%, often >90%. pH is variable, ranging 5.3 – 6.7. Number of vascular species moderate, less than 13, often <9. Communities meeting this definition were also observed in the San Juan Mountains (14) by Chimner and others 2008, and on the Grand Mesa (12) by Austin 2008. There are probably also a few from the Upper Gunnison Basin by Johnston and others 2001. Tentative associations shown in Table 4-9.

Table 4-9. Tentative associations for Cluster III. Planeleaf willow with beaked or water sedge, high bryophyte cover. (n = 11)

Series	Association	Elevation, ft	Landscape Area	Slope, %	pH	EC	Fen Landform	Peat depth, cm	Von Post Value	Disturbance In Fen	Disturbance In Buffer	Total Bryophyte Cover	Bare soil/peat, %	No. of vascular species	Total live cover	Groundwater diagram	Pct. Peat-forming spp.	Pct. wetland species	Floristic quality index
SAPL2	SAPL2-CAVE6-CAAQ-BRY	10,637	SA	5.0	5.3	50	SL	89	4	7	1	99	0	6	261	B	99.8	96.0	6.5
	SAPL2-CAAQ-BRY	11,360	SA	10.0	6.7	20	VS	50	5	6	2	83	0	4	158	D	99.7	99.8	6.4
	SAPL2-CAAQ-CANO3-BRY	11,969	ES	6.0	5.8	140	TS	85	2	1	2	91	0	10	221	A	71.4	81.9	7.1
	SAPL2-CAUT-BRY-FORBS	11,081	MS	11.0	6.6	570	VS	96	6	14	17	84	2	6	230	B	41.4	72.4	6.7
SAPL2-SAWO	SAPL2-SAWO-CAAQ-BRY	9,683	SA	6.0	5.8	60	BA	70	4	24	32	98	0	6	241	B	79.0	76.9	7.1
	SAPL2-SAWO-CAAQ-CAUT-BRY	9,802	SA	8.0	5.3	50	SL	92	2	10	6	83	0	7	241	B	65.4	82.7	6.8
		9,726	SA	0.5	5.5	50	VS	55	7	15	1	99	0	13	478	B	47.6	71.8	6.8
		9,839	SA	0.0	5.8	200	VS	40	5	13	1	89	0	3	167	B	100.0	100.0	6.4
		11,233	SA	3.0	6	260	SL	35	5	14	3	99	1.5	5	241	B	83.2	91.6	5.5
	SAPL2-SAWO-CAAQ-CACA12	10,228	SA	1.0	6.4	260	VS	52	3	9	22	100	0	13	304	A	64.1	71.2	7.0
	SAPL2-SAWO-DAFL3-CAVE6-CAREX	10,412	SA	11.0	6	100	SL	64	4	6	10	100	0	12	414	A	48.5	61.4	7.0

IV. Planeleaf willow with smaller sedges, bryophyte cover (SAPL2-CAIL-CASI2-CACA11-CASC12-ELQU2-POLE2-ELAC-BRY), 16 samples. Dominance by planeleaf willow, sometimes Wolf's willow also, one of the small sedges or spike-rushes, listed below.

- *Carex illota* (sheep sedge)
- *Carex simulata* (short-beaked sedge)
- *Carex canescens* (pale sedge)
- *Carex scopulorum* (cliff sedge)
- *Eleocharis quinqueflora* (few-flowered spike-rush)
- *Eleocharis acicularis* (needle spike-rush)
- *Poa leptocoma* (bog bluegrass) or *P. palustris* (swamp bluegrass)

Water sedge is often present to codominant also. Bryophyte cover always present, usually >20%, often >80%. pH is variable, ranging 5.0 – 6.3. EC is low, averaging 59 μS/cm^2. Number of vascular species moderate, averaging 11. Communities meeting this definition were also observed in the San Juan Mountains (12) by Chimner and others 2008, and on the Grand Mesa (3) by Austin 2008. Tentative associations shown in Table 4-10.

Table 4-10. Tentative associations for Cluster IV. Planeleaf willow with smaller sedges. (n = 16)

Series	Association	Elevation, ft	Landscape Area	Slope, %	pH	EC	Fen Landform	Peat depth, cm	Von Post Value	Disturbance In Fen	Disturbance In Buffer	Total Bryophyte Cover	Bare soil/peat, %	No. of vascular species	Total live cover	Groundwater diagram	Pct. Peat-forming spp.	Pct. wetland species	Floristic quality index
SAPL2	SAPL2-ELQU2-DECE-SPLE-BRY	10,890	SA	3.5	6	39	SL	92	3	36	19	38	6.4	8	246	d	74.4	93.3	6.8
		11,002	SA	6.0	5.6	40	SL	48	4	31	2	47	0	11	221	B	80.6	94.0	7.1
	SAPL2-CACA11-ELQU2-CAAQ-BRY	11,192	SA	9.0	5.6	40	SL	48	4	19	28	91	0	5	251	B	99.8	99.9	7.4
	SAPL2-CACA11-ELQU2-CAVE6-DECE	11,066	SA	4.0	5.6	20	SL	88	4	13	4	95	0	13	351	A	50.1	86.1	7.0
	SAPL2-CACA11-CAAQ-BRY-FORBS	10,345	SA	1.0	5.4	80	VS	42	6	4	8	87	0	19	345	A	67.5	71.5	6.7
		11,962	SA	3.0	5.9	100	TS	30	5	13	7	79	0	8	296	A	91.2	95.1	7.2
	SAPL2-CACA11-CAAQ-CASC12	12,007	SA	0.0	5	40	TS	48	2	8	6	23	0	9	363	B	80.7	84.8	7.3
	SAPL2-CAIL-CAAQ-BRY	11,058	ES	2.0	6	70	VS	32	7	1	4	87	0	10	341	D	58.8	80.8	6.6
		11,768	SA	3.0	5.6	60	TS	45	2	8	2	94	0	10	392	A	71.6	87.0	7.0
		11,484	SA	3.0	5.8	50	TS	47	3	9	4	98	0	13	262	B	79.2	90.9	7.8
	SAPL2-SAWO-CAIL-CAAQ-CAUT	9,810	SA	1.5	6.3	51	VS	92	6	56	56	10	0	9	236	F	89.0	92.4	6.8
	SAPL2-CAAQ-CALE8-ELQU2-BRY	11,034	EL	2.0	5.8	67	VS	105	5	21	3	70	0	10	121	D	93.6	93.5	7.7
	SAPL2-CASI2-CAAQ	10,953	CN	2.0	5.7	60	TS	125	2	9	4	21	0	5	237	A	98.7	100.0	6.3
	SAPL2-SAWO-CASI2-CAAQ-BRY-FORBS	9,381	SA	4.0	6	110	VS	150	3	9	22	95	0	14	360	B	54.6	74.1	6.8
	SAPL2-CASC12-CAUT-FORBS	12,184	ES	10.0	6.2	90	VS	50	5	2	2	49	20	12	371	B	48.5	74.2	7.0
SAPL2-SAWO	SAWO-CASC12-FORBS	11,677	SA	1.0	5.3	30	TS	55	2	20	4	43	3.4	13	235	A	43.7	55.3	7.2

V. Bog birch and planeleaf willow, high bryophyte cover (BEGL-SAPL2-CAREX-BRY), 6 samples. Dominance by bog birch (*Betula glandulosa*) and planeleaf willow, sometimes Wolf's willow also, some combination of sedges, often including water sedge, and bryophytes. Total live cover high, >220%, averaging 345%. Bryophyte cover > 65%, often >80%. pH low, ranging 5.5-6.0. EC <150 µS/cm, often <100 µS/cm. Peat deep, averaging >80 cm. Number of vascular species moderately high, averaging 12. In this inventory, only found in the Sawatch Mountains Area. Apparently not found on the Grand Mesa. Communities meeting this definition were also observed in the San Juan Mountains (8) by Chimner and others 2008. There are several communities in the Upper Gunnison Basin that may meet this definition as well (Johnston and others 2001). Tentative associations shown in Table 4-11.

Table 4-11. Tentative associations for Cluster V. Bog birch. (*n* = 6)

Series	Association	Elevation, ft	Landscape Area	Slope, %	pH	EC	Fen Landform	Peat depth, cm	Von Post Value	Disturbance In Fen	Disturbance In Buffer	Total Bryophyte Cover	Bare soil/peat, %	No. of vascular species	Total live cover	Groundwater diagram	Pct. Peat-forming spp.	Pct. wetland species	Floristic quality index
BEGL-SAPL2	BEGL-SAPL2-CAAQ-CAUT-BRY	9,837	SA	1.0	5.5	130	VS	44	4	25	8	97	0	8	231	D	99.4	99.6	6.2
	BEGL-SAPL2-CAAQ-CAUT-BRY	10,776	SA	2.5	5.6	21	SL	150	4	32	34	80	0.2	7	283	B	89.4	94.7	6.7
	BEGL-DAFL3-SAPL2-CAAQ-CADIG-FORBS	10,031	SA	1.0	5.6	90	TS	150	3	2	2	89	0	14	353	A	60.3	78.6	6.8
	BEGL-DAFL3-SAPL2-CAAQ-CADIG-FORBS	9,368	SA	1.0	5.8	80	VS	40	3	11	4	66	8	16	426	B	73.5	78.8	7.5
	BEGL-SAPL2-SAWO-DAFL3-CAVE6-CAAQ	9,576	SA	4.0	5.9	130	VS	64	3	14	15	91	0	14	347	B	58.8	71.5	6.7
	BEGL-SAPL2-SAWO-DAFL3-CAAQ-BRY	10,384	SA	2.0	6	140	VS	55	3	6	14	98	0	16	431	B	54.9	66.7	7.2

VI. Barrenground willow, sedges, high bryophyte cover (SABR-BRY-CASC12), 3 samples. Dominance by barrenground willow (*Salix brachycarpa*), various sedges, and bryophytes. Bryophyte cover >75%, often >80%. Number of vascular species high, always >10, often >12. pH just below neutral, 6.5-7.0. EC very high, ranging 230 – 635 μS/cm². There have been several reports of wetlands dominated by barrenground willow and bryophytes (for example, Johnston and others 2001); it is unsure whether these reports are fens. Tentative associations shown in Table 4-12.

Table 4-12. Tentative associations for Cluster VI. Barrenground willow. (*n* = 3)

Series	Association	Elevation, ft	Landscape Area	Slope, %	pH	EC	Fen Landform	Peat depth, cm	Von Post Value	Disturbance In Fen	Disturbance In Buffer	Total Bryophyte Cover	Bare soil/peat, %	No. of vascular species	Total live cover	Groundwater diagram	Pct. Peat-forming spp.	Pct. wetland species	Floristic quality index
SABR	SAPL2-CASC12-BRY	10,537	SA	10.0	7.1	440	VS	76	3	7	6	99	0	10	408	B	44.2	59.8	7.7
	SAPL2-SABE2-CAAQ-CASI2-BRY-FORBS	9,656	MS	10.0	6.9	635	VS	150	4	17	15	99	0	15	213	B	63.3	80.8	6.3
SABR-SAPL2	SAPL2-CAAQ-CASC12-BRY-FORBS	11,260	ES	2.0	6.5	230	TS	55	7	9	6	76	0	18	433	A	31.3	66.5	6.6

VII. Beaked sedge and water sedge, low bryophyte cover (CAUT-CAAQ), 28 samples. Dominance by beaked sedge or water sedge, sometimes Buxbaum's sedge (*Carex buxbaumii*) also, sometimes woolly sedge (*Carex pellita*), previously known as *Carex lanuginosa*, an invalid name, or woollyfruit sedge (*Carex lasiocarpa*) takes their place, and bryophytes. Mostly in basins and depressions. Bryophyte cover <20%, often <10%. pH variable, ranging 4.8 – 6.5. Number of vascular species low, <10, often <4. Total live cover low, averaging about 180% (compared with average of 270-460% for the willow types). Communities meeting this definition were also observed in the San Juan Mountains (36) by Chimner and others 2008, in the Upper Gunnison Basin (3) by Johnston and others 2001, and on the Grand Mesa (36) by Austin 2008. There are probably also a few from the Upper Gunnison Basin (Johnston and others 2001). Tentative associations shown in Table 4-13.

Table 4-13. Tentative associations for Cluster VII. Beaked sedge and water sedge. (*n* = 28)

Series	Association	Elevation, ft	Landscape Area	Slope, %	pH	EC	Fen Landform	Peat depth, cm	Von Post Value	Disturbance In Fen	Disturbance In Buffer	Total Bryophyte Cover	Bare soil/peat, %	No. vascular species	Total live cover	Groundwater diagram	Pct. Peat-forming spp.	Pct. wetland species	Floristic quality index
CAUT	CAUT	8,287	NP	0.5	6.1	45	BA	40	6	13	30	0	0	1	99.5	B	100.0	100.0	5.0
	CAUT	9,496	MU	0.0	5.6	24	SD	80	5	30	0	0	0	1	30	B	100.0	100.0	5.0
	CAUT	9,900	MS	0.0	5.2	37	SD	150	3	0	3	0	0	1	97	A	100.0	100.0	5.0
	CAUT	9,877	MS	0.0	5.5	73	SD	60	6	0	2	0	6.2	2	100	A	100.0	100.0	5.0
	CAUT	9,358	WE	1.0	5.7	160	VS	60	2	28	16	0	54	1	99.5	B	100.0	100.0	5.0
	CAUT-FORBS	9,443	ES	0.0	5.9	210	SL	45	7	11	1	18	0	5	160	A	62.0	71.7	5.4
	CAUT-FORBS	8,876	EL	0.0	5.8	280	BA	40	4	1	17	20	0	8	121	A	87.6	92.0	4.8
CAAQ	CAAQ	11,373	EL	0.0	5.4	30	SD	70	5	2	1	1	0	1	97	A	100.0	100.0	6.0
	CAAQ	11,289	MS	2.5	5.6	60	SD	85	4	8	0	1	4.1	3	204	D	52.5	100.0	6.6
	CAAQ	11,053	MS	5.0	5.9	80	BA	120	5	11	20	1	14	1	99.5	B	100.0	100.0	6.0
CAUT-CAAQ	CAUT-CAAQ	10,163	GM	2.0	4.9	30	BA	40	2	3	7	3	0	2	150	A	100.0	100.0	5.4
	CAUT-CAAQ	10,610	GM	0.0	4.8	90	SD	30	3	47	11	8	6.7	5	90.5	B	77.9	89.0	5.6
	CAUT-CAAQ	10,158	GM	0.0	5.7	40	TS	40	4	11	12	0	0	2	187	A	100.0	100.0	5.5
	CAUT-CAAQ	9,943	GM	3.0	5.8	100	TS	120	3	3	2	0	1.5	3	180	E	100.0	100.0	5.5
	CAUT-CAAQ	9,913	GM	3.0	6.1	120	TS	40	4	9	3	0	0	3	187	D	100.0	100.0	5.5
	CAUT-CAAQ	10,049	GM	2.0	6	0	SL	60	5	7	2	10	3.5	2	160	D	100.0	100.0	5.4
	CAUT-CAAQ	10,206	GM	1.0	6.2	130	TS	40	6	8	3	0	0.5	4	188	B	99.7	99.9	5.5
	CAUT-CAAQ	10,513	GM	0.0	5.1	90	SL	50	4	19	1	0	0	4	257	A	92.2	100.0	5.7
	CAUT-CAAQ	10,194	MS	4.0	4.9	652	SD	150	4	9	11	0	0	4	241	D	99.8	100.0	5.6
	CAUT-CAAQ	11,058	ES	0.0	5.2	40	SD	40	2	1	0	4	0	2	110	A	100.0	100.0	5.1
	CAUT-CAAQ-CAVE6	10,824	SA	1.0	6	80	SL	41	5	24	25	0	0	3	200	B	100.0	100.0	5.6
	CAUT-CAAQ-ELAC	9,752	GM	1.0	5.6	100	TS	40	5	16	11	0	1.5	9	221	B	86.6	95.3	5.7
CAPE42	CAPE42-CAAQ	9,487	MU	0.0	5.8	51	SD	110	4	6	0	0	0	2	100	B	100.0	100.0	7.6
	CAPE42-CAAQ	11,743	ES	5.0	6	160	SL	40	4	48	23	6	2	3	120	B	99.6	99.8	7.6
CAPH2?	CAAQ-CAPH2	10,156	MS	2.0	5.7	95	TS	150	5	11	4	14	0.6	7	205	B	47.1	49.8	7.5
CAPR22?	CAAQ-CAPR22	11,014	MS	2.0	6.5	230	BA	150	3	23	11	1	8	2	99.5	B	100.0	83.3	6.5
CABU6	CABU6-CAUT	9,810	SA	0.0	5.7	70	VS	40	5	18	13	0	3	2	110	D	100.0	100.0	5.4
	CABU6-CAUT-CAAQ	10,231	GM	0.0	5.2	50	BA	50	3	2	0	0	0	7	191	C	100.0	99.6	5.5

VIII. Beaked sedge and water sedge, high bryophyte cover (CAUT-CAAQ-BRY), 14 samples. Dominance by beaked sedge or water sedge and bryophytes. Bryophyte cover >30%, often >50%. Number of vascular species low, <11, often <5. pH variable, ranging 4.1 – 7.0. Total live cover low, averaging about 155%. Communities meeting this definition were also observed in the San Juan Mountains (26) by Chimner and others 2008, and on the Grand Mesa (15) by Austin 2008. There are probably also a few from the Upper Gunnison Basin (Johnston and others 2001). Tentative associations shown in Table 4-14.

Table 4-14. Tentative associations for Cluster VIII. Beaked sedge & water sedge, high bryophyte cover. (*n* = 14)

Series	Association	Elevation, ft	Landscape Area	Slope, %	pH	EC	Fen Landform	Peat depth, cm	Von Post Value	Disturbance In Fen	Disturbance In Buffer	Total Bryophyte Cover	Bare soil/peat, %	No. vascular species	Total live cover	Groundwater diagram	Pct. Peat-forming spp.	Pct. wetland species	Floristic quality index
CAUT	CAUT-BRY	10,164	GM	0.0	5.1	20	SD	50	4	13	17	87	0	1	99.5	A	100.0	100.0	5.0
	CAUT-BRY	9,994	GM	0.0	5.4	90	BA	150	1	107	78	40	62.6	3	170	E	88.2	100.0	6.9
	CAUT-BRY	12,031	ES	8.0	5.9	80	VS	45	4	2	2	61	0	2	97.5	A	99.5	99.7	5.0
	CAUT-BRY	7,927	WE	0.0	5.8	120	VS	45	4	9	21	87	0.1	3	100	A	99.5	99.5	5.0
CAUT-CAAQ	CAAQ-CAUT-BRY-FORBS	11,853	ES	3.0	5.9	80	TS	50	2	3	4	90	0	6	209	B	47.2	95.1	6.0
	CAAQ-CAUT-BRY-FORBS	10,487	GM	1.0	5.6	80	SL	55	3	4	3	60	0	9	150	B	89.3	93.5	6.1
	CAAQ-CAUT-BRY-FORBS	10,297	GM	2.0	5.6	620	TS	45	3	9	11	90	0.5	7	201	D	58.2	91.5	6.7
	CAAQ-CAUT-BRY-FORBS	11,081	ES	4.0	5.3	30	VS	45	3	5	4	30	3.5	6	181	A	95.0	57.6	5.1
CAAQ	CAAQ-BRY	11,928	EL	1.0	7	260	BA	135	3	4	1	46	0	1	97	D	100.0	100.0	6.0
	CAAQ-BRY	10,482	GM	0.0	5.2	30	BA	40	5	0	1	40	1.5	2	97.5	B	100.0	100.0	6.0
	CAAQ-BRY	11,755	MS	8.0	4.1	130	VS	135	3	12	5	84	2.1	1	97	B	100.0	100.0	6.0
	CAAQ-BRY	11,991	SA	2.0	5.4	70	SL	42	4	7	4	83	0	1	90	D	100.0	100.0	6.0
	CAAQ-BRY-DECE-PSLE	10,480	SA	13.0	6.1	24	SL	97	3	56	39	89	0.8	11	261	B	38.8	81.9	6.7
	CAAQ-BRY-DECE-PSLE	11,496	ES	2.0	5.9	70	SL	45	5	32	1	44	46	6	181	B	55.2	94.3	6.1

IX. Smaller sedges (CASA10-CAJO-CASC12-ELQU2-CASI2-CACA11-CAIL-CALI7), 31 samples. Dominance by smaller sedges or spike-rushes, sometimes with water sedge also. Sedges include cliff sedge (*Carex saxatilis*), Jones' sedge (*Carex jonesii*), short-beaked sedge, few-flowered spike-rush, pale sedge, sheep sedge, and mud sedge. Bryophyte cover various. Number of vascular species moderately low, averaging about 8. Communities meeting this definition were also observed in the San Juan Mountains (65) by Chimner and others 2008, and on the Grand Mesa (162) by Austin 2008. Tentative associations shown in Table 4-15.

Table 4-15. Tentative associations for Cluster IX. Smaller sedges. (*n* = 31)

Series	Association	Elevation, ft	Landscape Area	Slope, %	pH	EC	Fen Landform	Peat depth, cm	Von Post Value	Disturbance In Fen	Disturbance In Buffer	Total Bryophyte Cover	Bare soil/peat, %	No. of vascular species	Total live cover	Groundwater diagram	Pct. Peat-forming spp.	Pct. wetland species	Floristic quality index
CAJO	CAJO-FORBS	10,033	WE	15.0	5.5	470	SL	40	5	1	2	6	0.5	12	211	B	53.5	70.3	7.9
	CAJO-CAAQ-CAUT-BRY	10,190	GM	2.0	5.8	110	TS	60	3	28	22	20	0	9	322	C	59.3	80.9	6.6
	CAJO-CAAQ-CAUT-BRY	10,183	ES	2.0	4.8	80	VS	45	5	21	3	4	0	9	200	A	50.4	70.2	5.1
	CAJO-CAAQ-CACA4-BRY	10,548	WE	0.0	5.6	70	SD	40	5	30	0	71	0	8	271	D	62.7	83.2	7.1
CASI2	CASI2-CAAQ	10,871	CN	1.0	5.1	30	TS	150	1	16	2	8	0	2	177	A	100.0	100.0	6.0
	CASI2-CAAQ	10,803	CN	2.0	5.4	50	TS	150	2	19	19	50	0	2	197	A	100.0	100.0	6.0
	CASI2-CAAQ-BRY-FORBS	10,475	GM	1.0	6.1	90	TS	40	5	24	5	60	0	9	239	D	66.0	99.5	6.7
	CASI2-CAAQ-BRY-FORBS	10,404	GM	3.0	5.8	100	TS	45	3	24	5	30	0	7	271	B	66.6	96.1	6.4
	CASI2-CAAQ-CAUT	10,103	GM	1.0	6.2	80	TS	45	5	2	1	0	0	7	308	E	77.2	99.9	6.4
	CASI2-CAAQ-CAUT	9,352	SA	2.5	6.3	105	VS	30	3	20	34	94	4.3	4	161	D	99.7	99.8	5.9
	CASI2-CAAQ-CAUT-ELAC	10,012	GM	0.0	5.4	0	BA	40	5	3	10	96	0	9	301	A	78.2	79.6	5.6
	CASI2-CAAQ-CAUT-ELAC	10,518	GM	0.0	5.8	80	TS	40	6	24	16	30	0	6	238	B	62.1	100.0	5.9
CASC12	CASC12	10,750	GM	0.0	5.2	50	SL	40	4	11	5	0	0	2	100	B	100.0	50.0	7.0
	CASC12-ELQU2	11,260	SA	12.0	5.1	30	TS	40	4	12	3	0	0	2	117	A	100.0	91.5	7.8
	CASC12-ELQU2-CAAQ-FORBS	11,480	SA	5.0	5.1	50	TS	54	4	11	2	44	0	14	356	B	69.6	78.4	7.1
	CASC12-CAUT-CANI2-FORBS	11,225	MS	2.0	4.4	50	SD	75	3	5	4	69	0.1	14	213	A	28.7	61.6	6.1
	CASC12-CADIG-BRY-FORBS	11,917	ES	2.0	5.5	50	BA	40	4	4	1	98	0	10	212	D	52.2	64.2	8.7
	CASC12-DECE-CACA4-FORBS	11,835	SA	4.0	6.3	30	TS	50	4	2	4	44	8	16	252	A	47.1	43.9	6.4
CACA11	CACA11-CAIL-CAAQ-BRY-PEGR2	11,345	MS	2.0	5.7	60	VS	40	4	2	0	93	0	8	381	D	60.5	90.7	7.6
	CACA11-CAIL-CAAQ-BRY-PEGR2	11,459	SA	5.0	5.1	30	VS	43	3	21	14	47	8.6	16	345	A	74.5	83.6	7.8
	CACA11-CASA10-CAJO-CASI2	10,480	GM	0.0	5	7	BA	45	0	31	8	62	0	8	281		92.7	87.5	7.8
	CACA11-CAAQ-LUSU9-BRY	11,452	MS	6.0	5.1	140	VS	55	5	12	30	100	0	7	138	D	92.1	92.2	6.5
	CACA11-CAAQ-CASA10-DECE-BRY	11,993	ES	2.0	5	60	SL	40	4	16	9	60	0	11	342	B	76.2	76.2	6.7
	CACA11-CAAQ-CASA10-DECE-BRY	10,789	SA	1.0	5.2	50	TS	54	3	4	2	23	0	14	252	B	76.2	78.3	6.9
	CACA11-BRY-FORBS	10,515	MS	4.0	5.3	370	VS	50	4	38	5	97	0.2	10	173	D	69.9	73.1	6.8
	CACA11-CAAQ-CACA13	10,033	WE	0.0	6.8	35	SD	100	3	2	19	6	0	5	180	D	81.8	63.6	7.5
	CACA11-CAUT-BRY	10,525	GM	1.0	5	50	VS	65	5	36	29	26	62.3	2	110	E	100.0	100.0	5.5
	CACA11-CAUT-CAAQ	10,511	SA	2.0	4.6	20	BA	61	2	1	5	0	0	3	200	C	100.0	100.0	6.6
CALI7	CALI7-CAA1-COPA28-BRY	10,155	GM	0.0	4.9	30	BA	150	1	69	10	90	8.7	3	140	E	92.9	92.9	7.5
	CASI2-CALI7-CAAQ-BRY	10,120	GM	0.0	5.7	100	TS	150	1	0	1	100	0	6	180	A	100.0	100.0	6.7
	CALI7-CASA10-CAPH2-ELAC-BRY	11,159	ES	1.0	5.4	40	VS	40	5	5	6	80	0.5	15	360	A	44.7	89.6	7.3

X. Spike-rushes (ELAC-ELQU2-ELMA5), 15 samples. Dominance by spike-rushes, one or more of them, including needle spike-rush, few-flowered spike-rush, and pale spike rush (*Eleocharis macrostachya*). Sometimes water sedge, pale sedge, or rock sedge is present also. Bryophyte cover various. Number of vascular species low, <10, often <6. pH variable, ranging 4.7 – 8.0. EC low, ranging 20 – 140 $\mu S/cm^2$, averaging 60 $\mu S/cm^2$. Total live cover low, averaging about 180%. Communities meeting this definition were also observed in the San Juan Mountains (13) by Chimner and others 2008, and on the Grand Mesa (13) by Austin 2008. Tentative associations shown in Table 4-16.

Table 4-16. Tentative associations for Cluster X. Spike-rushes. (*n* = 15)

Series	Association	Elevation, ft	Landscape Area	Slope, %	pH	EC	Fen Landform	Peat depth, cm	Von Post Value	Disturbance In Fen	Disturbance In Buffer	Total Bryophyte Cover	Bare soil/peat, %	No. of vascular species	Total live cover	Groundwater diagram	Pct. Peat-forming spp.	Pct. wetland species	Floristic quality index
ELQU2	ELQU2-CASA10-DECE-BRY	11,258	SA	1.0	5.2	50	SL	42	3	11	4	77	0	10	162	B	79.0	92.0	7.4
	ELQU2-CAPH2-CANI2	11,180	EL	0.0	5.3	50	BA	60	6	6	2	12	0	5	160	D	50.0	68.8	8.1
	ELQU2-CAAQ-BRY	11,536	SA	1.0	5.5	40	TS	64	5	34	4	21	48	2	170	B	100.0	100.0	7.1
	ELQU2-CAAQ-BRY	11,760	SA	1.0	5	20	SL	35	5	24	10	79	0	2	157	A	100.0	100.0	7.2
	ELQU2-CAAQ-BRY	11,180	SA	7.0	5.1	50	SL	48	3	17	8	52	0	6	125	A	98.8	97.8	7.5
ELMA5	ELMA5	9,964	GM	0.0	5.4	50	BA	40	6	2	1	0	0	1	70	B	100.0	100.0	3.0
	ELMA5-CAAQ	10,066	GM	1.0	7.6	90	BA	55	6	1	0	0	0	4	160	E	80.0	100.0	4.4
	ELMA5-CAAQ	10,640	WE	0.0	4.7	20	SD	150	1	0	0	0	0	3	127	B	100.0	100.0	3.7
	ELMA5-CAAQ-BRY-FORBS	10,552	GM	2.0	5.2	20	TS	100	6	27	5	80	0	6	290	B	58.5	89.6	5.8
	ELMA5-CASA10-CACA12-BRY	11,728	SA	5.0	8	60	TS	40	3	14	2	65	18	12	258	D	72.6	67.7	5.8
	ELMA5-BRY-FORBS	11,609	SA	6.0	6.8	40	TS	55	4	7	2	90	0	8	208	B	51.8	80.0	4.9
ELAC	ELAC-CAAQ-CACA4-BRY	10,098	GM	1.0	5	40	TS	45	2	2	0	60	3	8	201	A	61.2	98.6	6.2
	ELAC-CAAQ-CACA4-BRY	10,285	GM	3.0	5.7	100	TS	45	4	30	16	80	0	7	208	A	9.9	71.0	5.9
	ELAC-CAAQ-CACA4-BRY	10,314	GM	0.0	6	140	BA	50	2	1	0	93	0	7	188	D	21.6	75.9	5.8
	ELAC-CACA12-BRY	10,486	GM	2.0	6	120	TS	40	3	13	13	80	0	2	137	B	29.2	85.4	6.2

9. Geology and Hydrology

Geology

For the purposes of relating fen occurrence and characteristics with geology, locations of the verified fens were overlaid with available spatial geologic data (Day and others 1999) to assess the various geologic settings where fens occur. Due to the available scale of geologic mapping, in some cases a fen overlapped with more than one geologic unit. In these cases, the fen was reviewed on both the geologic map and aerial photograph, and a professional judgment made on which geologic unit was present.

Nearly one-third (32%) of the fens occur in areas where glacial drift is mapped as the surficial deposit (Table 4-17). This occurred principally in the Grand Mesa, Sawatch Mountains, and the Middle San Juan landscape areas. The glacial drift includes unsorted materials as well as gravel and alluvial outwash deposits from Pinedale and Bull Lake glacial episodes that occurred between 10,000 and 200,000 years ago. An additional 21% of the fens occur within areas mapped as mass wasting deposits derived from landslide activity or other colluvial deposits. These were most commonly observed in the Grand Mesa and Eastern San Juan landscape areas. Collectively, the glacial and mass wasting classes account for over half (53%) of the fens observed; and on an areal basis, account for 82 % of the total fen acreage confirmed during the inventory. Forest-wide these two classes represent only about 18% of the total land base of the National Forests (Figure 4-23). The disproportionate frequency and extent of fens on these unconsolidated material classes may be attributable to topographic and or stratigraphic factors conducive to groundwater flows.

The frequency of occurrence of fens on intrusive and extrusive igneous and metamorphic bedrock types is roughly similar to their proportional extent across the National Forests. However, the areal extent of fens found on these bedrock types, was slightly but consistently less than the proportion across the National Forests (Table 4-17 and Figure 4-23). Fens occurring on granitic rocks types were found in the Sawatch Mountains landscape area, almost exclusively associated with granites of Precambrian age (1.7 billion years and older). Fens occurring where extrusive and intrusive igneous rocks are present were found in the Sawatch Mountains and Eastern San Juan landscape areas. In the Sawatch Mountains, the specific rock types are mapped as granodiorites (intrusive igneous rocks about 30 million years old). In the Eastern San Juans, these intermediate composition extrusive igneous rocks (that is, volcanics) are mapped as andesitic lavas.

Both the frequency and extent of fens on sedimentary bedrock types is extremely under-represented relative to the extent across the National Forests (Table 4-17 and Figure 4-23). Roughly 43% of the Grand Mesa, Uncompahgre, and Gunnison National Forests is mapped as sedimentary materials, predominantly clastic types, yet only 6% of the documented fen acreage occurred on them. Those associated with clastic rocks were found in the Northern Plateau, Grand Mesa, Sawatch Mountains and Cones landscape areas. The specific lithologies mapped included shales, siltstones and gravel conglomerates.

Table 4-17. Frequency and acreage of 147 fens by Lithology class. (Day and others 1999)

Lithology Class		Fen Count	Fen Acreage	Percent of Total Fens	Percent of Total Fen Acreage	Percent of National Forest*
MEGN	Metamorphic Gneiss	1	2	0.7%	0.1%	0.4%
MEME	Metamorphic Metavolcanic	4	19	2.7%	1.2%	2.2%
PLGR	Plutonic Granitoid	13	59	8.8%	3.6%	8.1%
PLIN	Plutonic Intermediate	10	26	6.8%	1.6%	4.3%
SECA	Sedimentary Carbonate	2	11	1.4%	0.7%	1.4%
SECL	Sedimentary Clastic	22	100	15.0%	6.2%	41.4%
UNGL	Unconsolidated Glacial Drift	47	1,019	32.0%	62.9%	8.7%
UNMA	Unconsolidated Mass Wasting	31	304	21.1%	18.8%	9.0%
VOIN	Volcanic Intermediate	15	57	10.2%	3.5%	15.3%
VOMA	Volcanic Mafic	1	19	0.7%	1.1%	1.2%
VOPY	Volcanic Pyroclastic	1	3	0.7%	0.2%	1.1%

*. Totals less than 100% due to 6 minor lithologic classes having no fens observed.

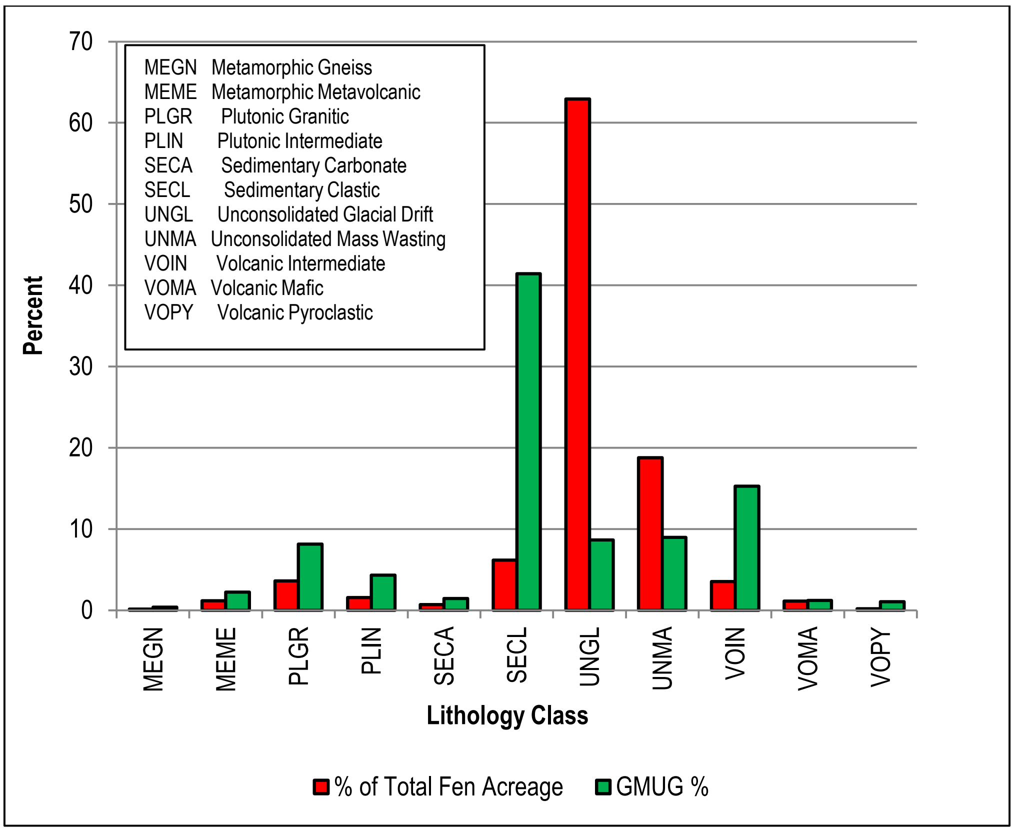


Figure 4-23. Percentage by lithology class for 147 fens.

Hydrology

The hydrologic setting of fens was assessed in the field inventory through visual observation of the general water flow pattern as compared to a set of diagrams developed for flow in and out of wetlands (including fens) adapted from Fetter (2001); see Appendix C for explanation. Six options were available, and included situations where the fen is:

A. groundwater dominated (both inflow and outflow were in the subsurface)
B. groundwater inflow dominated (no surface channel in, a surface channel flows out),
C. surface water inflow (no evidence of outflow channel),
D. surface water dominated,
E. impoundment (either natural or manmade),
F. topographically closed basin with surface water inflow and no outflow.

Fens are considered by the Forest Service to be ground-water dependent ecosystems; hence the expectation is that fens would be in a hydrologic setting reflective of a ground-water dominated system. Based on the field results, 34% of the fens were characterized as being completely groundwater dominated, and 42% were characterized as being groundwater inflow dominated. About 6% occurred in areas where there is surface inflow and no outflow, and 15% were assessed to be surface water dominated. Impoundments and closed basins were rarely observed in the field, and account for only 3% of the overall observations. These results confirm the strong linkage of fens to ground-water flows in this area.

10. Fen Landform Classification

Fen Landform classification for fens is based on topographic or landform characteristics, that have been used in previous inventories (Lemly 2007, Chimner and others 2008). Each site was assigned to one of five general landform types used during the field inventory: Depression, Basin, Toeslope, Slope, and Valley Slope. However, there were many sites where the landform seemed intermediate between two or more of the classes, and others where different portions of the site belonged to different landforms. Thus there were difficulties trying to assign a site to one class.

When samples are grouped by the five landforms, a few patterns emerge (Table 4-18).

- The sloping landforms have higher total live cover and greater slope angle.
- The valley slope landform has greatest bryophyte cover and number of species.
- The small depression landform averages deeper peat, lowest slope angle and bryophyte cover.

To facilitate using these data, the five landforms that we used were grouped into two more general hydrologic classes (Sjörs 1950, Gore and Goodall 1983, Bridgham and others 1996, Mitsch and Gosselink 2000, Wheeler and Proctor 2000, Vitt 2006):

- *Topogenous Peatlands*. Develop from water accumulating in topographic depressions with predominantly groundwater inflow. This includes our Depression and Basin classes.
- *Soligenous Peatlands*. Develop on slopes with groundwater inflow and outflow. This includes our Toeslope, Slope, and Valley Slope classes.

These more generalized types are analogous to the 'Basin' and 'Sloping' fens previously characterized in the San Juan Mountains by Chimner and others (2008). Topogenous types were the most commonly encountered during this inventory, representing 74% of the fens examined in the field. This is similar to the 67% reported by Chimner and others.

When samples are grouped into those two classes, there are some clearer trends and patterns (Table 4-19).

Topogenous Hydrologic Class

- Lower average and maximum slope angle
- Lower bryophyte cover, number of species, and total live cover
- 59% Ground Water patterns A and B; 24% D
- 55% of fens with channels

Soligenous Hydrologic Class

- Higher average and maximum slope
- Higher bryophyte cover, number of species, and total live cover
- 72% Ground Water patterns A and B; 20% D
- 81% of fens with channels

Specific trends or patterns for various variables are illustrated in the following graphs (Figures 4-25 through 4-33).

Table 4-18. Summary of selected variables by Fen Landform Class. Where three numbers are shown, they are minimum–average–maximum.

Fen Landform	No. Fens	Elevation, ft Aspect X Aspect Y Slope, %	pH EC Von Post	Max. Probe Peat Depth	Disturb. Wetland Disturb. Buffer	Bryophyte Cover Bare Soil No. Species	Total Live Cover	Floating Mat	Chan-nels	Gully Freq	Hydrologic Alteration	Ground Water Diagram	Peat-forming Wetland FQI
Basin	23	8,287–10,303–11,928 5.0–19.4–29.9 5.0–18.1–30.0 0– 1.2– 6	4.60–5.66–7.60 7–84.2–280 1– 3.8– 6	35–82–150 35–67.1–150	0–11.0–69 0–10.2–52	0–36.4–98 0– 4.3–63 1– 4.3–12	70–176–388	Yes 6 No 17	Yes 15 No 8	None 19 Low 3 Mod. 0 High 1	None 18 Low 2 Mod. 1 High 2	A 5 B 7 C 3 D 4 E 3 F 0	22–84–100 64–90–100 3.0– 6.1– 8.7
Small Depression	15	9,487–10,406–11,373 5.0–14.5–26.7 5.0–19.1–21.6 0– 0.6– 4	4.40–5.33–6.80 20–90.9–652 1– 3.7– 6	30–48–85 30–86.0–150	0– 9.7–31 0– 4.9–16	0–16.6–87 0– 4.2–46 1– 3.7–11	30–150–289	Yes 2 No 13	Yes 6 No 9	None 14 Low 1 Mod. 0 High 0	None 13 Low 1 Mod. 1 High 0	A 6 B 4 C 0 D 5 E 0 F 0	29–83–100 62–91–100 3.7– 5.8– 7.6
Slope	34	9,443–10,821–11,993 5.0–18.8–29.5 5.0–21.1–30.0 0– 4.0–15	4.80–5.61–6.40 20–107.3–470 2– 4.0– 8	35–60–150 35–61.1–150	1–12.3–38 0– 8.3–26	0–46.1–100 0– 2.8–46 1– 6.1–12	90–209–414	Yes 0 No 34	Yes 27 No 7	None 32 Low 1 Mod. 0 High 1	None 30 Low 1 Mod. 1 High 1	A 10 B 17 C 0 D 5 E 1 F 0	39–82–100 50–89–100 5.4– 6.5– 7.9
Toeslope	38	9,752–10,838–12,007 5.0–20.2–29.8 5.0–19.7–30.0 0– 2.6–12	4.80–5.78–8.00 20–94.9–620 1– 3.6– 7	40–84–150 30–67.3–150	0–10.5–26 0– 6.0–19	0–46.5–100 0– 3.2–48 2– 6.9–14	117–242–433	Yes 2 No 36	Yes 30 No 8	None 30 Low 5 Mod. 1 High 1	None 28 Low 2 Mod. 6 High 2	A 15 B 15 C 1 D 5 E 2 F 0	10–73–100 44–88–100 4.9– 6.4– 7.8
Valley Slope	37	7,927–10,372–12,184 5.0–18.8–30.0 5.0–19.8–29.8 0– 3.8–12	4.00–5.71–7.10 20–146.2–635 2– 4.4– 7	30–68–150 30–62.5–150	1–12.3–33 0–10.8–34	0–64.1–100 0– 4.9–62 1– 7.6–16	97–244–488	Yes 0 No 37	Yes 32 No 5	None 34 Low 3 Mod. 0 High 0	None 26 Low 3 Mod. 6 High 1	A 9 B 13 C 2 D 11 E 1 F 1	23–74–100 36–83–100 4.9– 6.4– 7.8

High Low Different

Table 4-19. Summary of selected variables by Hydrologic Class.

Hydrologic Class	No. Fens	Fen Type	Elevation, ft Aspect X Aspect Y Slope, %	pH EC Von Post	Max. Probe Peat Depth	Disturb. Wetland Disturb. Buffer	Bryophyte Cover Bare Soil NSpecies	Total Live Cover	Floating Mat	Chan-nels	Gully Freq	Hydrologic Alteration	Ground Water Diagram	Peat-forming Wetland FQI
Topogenous	38	BA 23 SD 15 SL 0 TS 0 VS 0	8,287–10,343–11,928 5.0–17.5–29.9 5.0–18.5–30.0 0– 0.9– 6	4.40–5.53–7.60 7–86.9–652 1– 3.7– 6	30–69–150 30–74.6–150	0–10.5–69 0– 8.1–52	0–28.6–98 0– 4.3–63 1– 4.0–12	30–166–388	Yes 8 No 30	Yes 21 No 17	None 33 Low 4 Mod. 0 High 1	None 31 Low 3 Mod. 2 High 2	A 11 B 11 C 3 D 9 E 3 F 0	22–84–100 62–91–100 3.0– 6.0– 8.7
Soligenous	109	BA 0 SD 0 SL 34 TS 38 VS 37	7,927–10,674–12,184 5.0–19.3–30.0 5.0–20.2–30.0 0– 3.5–15	4.00–5.70–8.00 20–116.2–635 1– 4.0– 8	30–71–150 30–63.7–150	0–11.7–38 0– 8.3–34	0–52.4–100 0– 3.7–62 1– 6.9–16	90–233–488	Yes 2 No 107	Yes 89 No 20	None 96 Low 9 Mod. 1 High 2	None 84 Low 6 Mod. 13 High 4	A 34 B 45 C 3 D 22 E 4 F 1	10–76–100 36–87–100 4.9– 6.5– 7.9

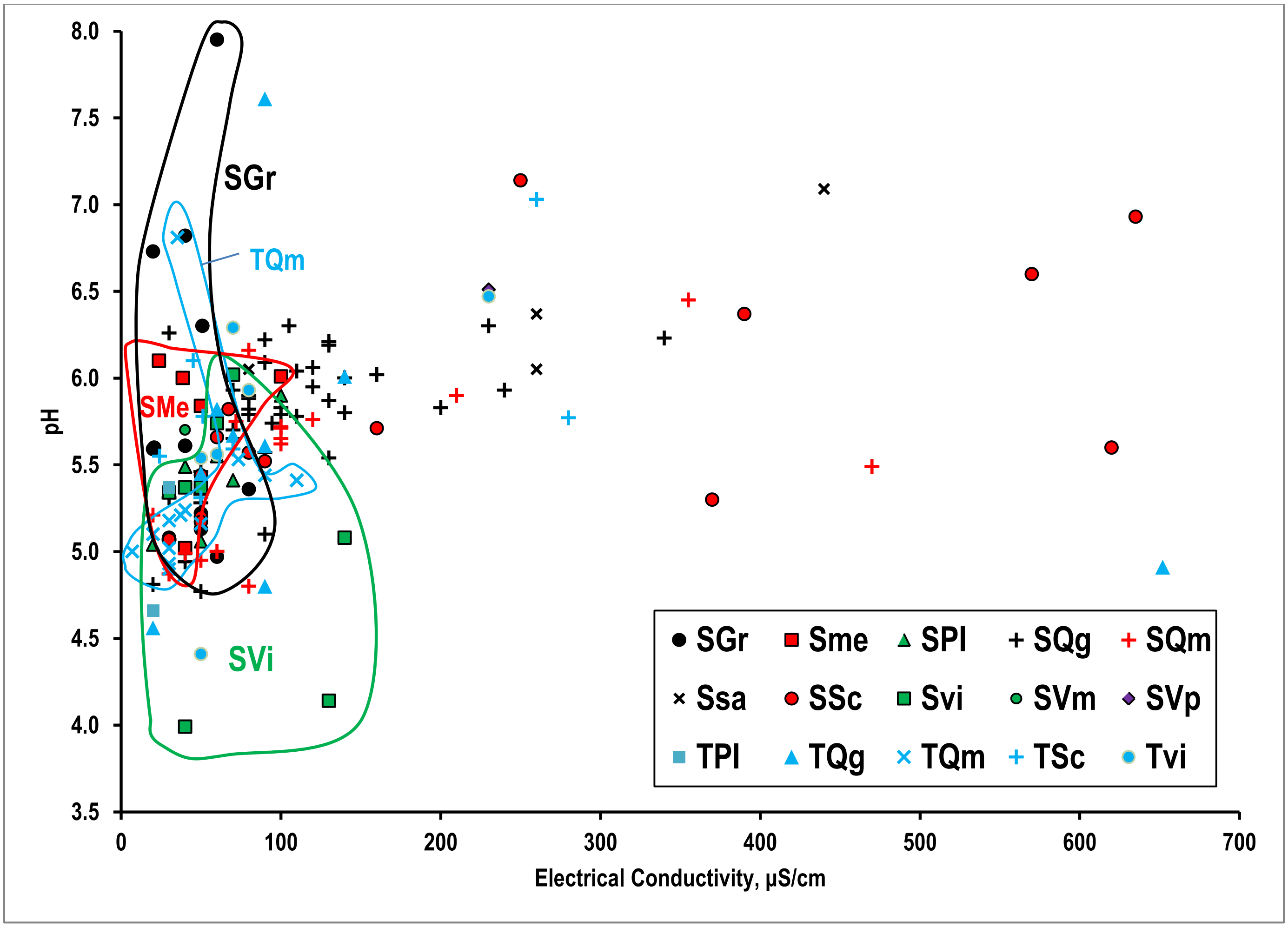


Figure 4-24. pH as a function of EC, with lithology and hydrologic class as labels. Codes shown in Table 4-20.

A graph of pH as a function of electrical conductivity (EC) is shown in Figure 4-24, after a similar graph in a recent publication (Lemly and Cooper 2011). Soligenous fens on volcanic intermediate lithology occupies a position on the graph with low pH and relatively low EC, whereas Soligenous fens on granitic lithology has higher pH and low EC. Soligenous fens on metamorphic lithology has medial pH (4.8 – 6.2) and low EC. Generally the glacial drift lithologies are scattered over the graph. Fens on mass wasting lithology generally have medial pH and wide-ranging EC values if they are soligenous, but topogenous ones are more restricted.

Table 4-20. Explanation of labeling in Figure 4-24.

Code	Lithology	Hydrologic Class
SGr	Plutonic Granitoid	Soligenous
SMe	Metamorphic Gneiss	Soligenous
SPI	Plutonic Intermediate	Soligenous
SQg	Unconsolidated Glacial Drift	Soligenous
SQm	Unconsolidated Mass Wasting	Soligenous
SSa	Sedimentary Carbonate	Soligenous
SSc	Sedimentary Clastic	Soligenous
SVi	Volcanic Intermediate	Soligenous
SVm	Volcanic Mafic	Soligenous
SVp	Volcanic Pyroclastic	Soligenous
TPI	Plutonic Intermediate	Topogenous
TQg	Unconsolidated Glacial Drift	Topogenous
TQm	Unconsolidated Mass Wasting	Topogenous
TSc	Sedimentary Clastic	Topogenous
TVi	Volcanic Intermediate	Topogenous

Figure 4-25 illustrates the proportion of fens in each of the topogenous and soligenous hydrologic classes across all geologic units (Day et al, 1999). Vertical axis in this and subsequent graphs represents percent of each hydrologic class. Soligenous fens were found over a wider variety of geologic materials, although some were in very minor amounts. As previously discussed, 53% of all fens and 82% of the total fen acreage occur on glacial or mass wasting deposits. Topogenous fens occur with greatest frequency on mass wasting units (37%), in contrast to soligenous fens which are most common on glacial terrain (35%).

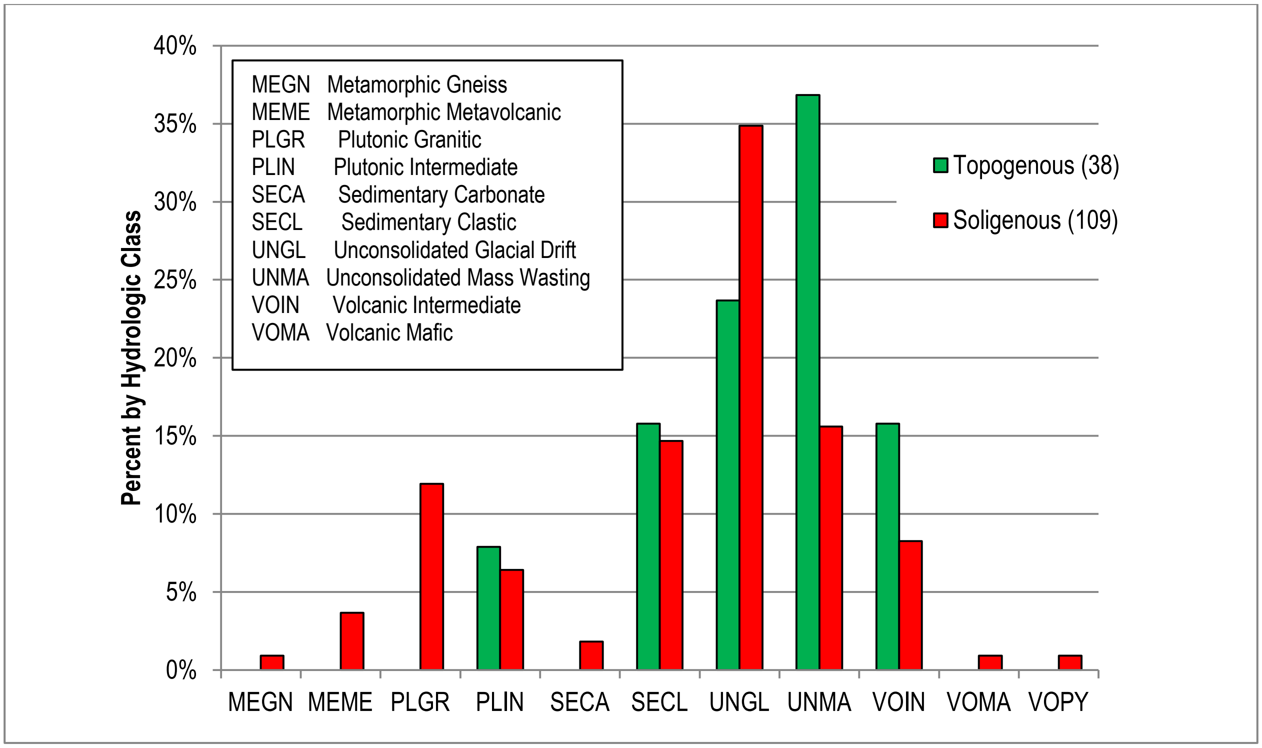


Figure 4-25. Frequency distribution of geologic unit by hydrologic class.

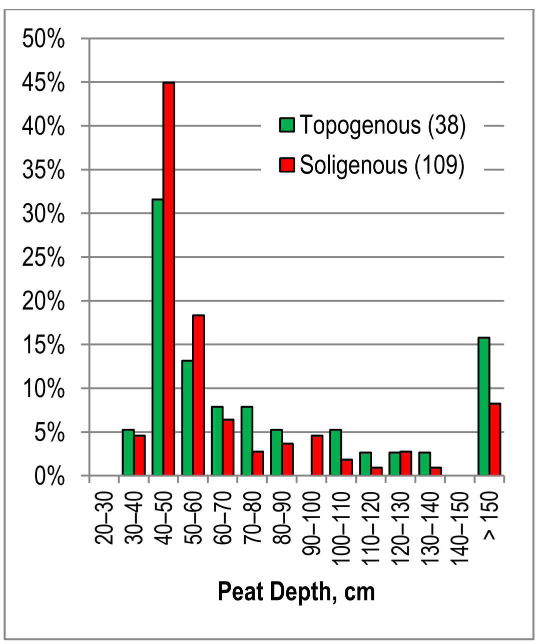


Figure 4-26. Measured peat depth by hydrologic class. Topogenous sites ($n = 38$, $\overline{x} = 74.6$ cm, $sd = 41.4$ cm) tended to have deeper peat, and two-thirds of soligenous sites ($n = 109$, $\overline{x} = 63.7$ cm, $sd = 33.8$ cm) had peat 40-60 cm deep.

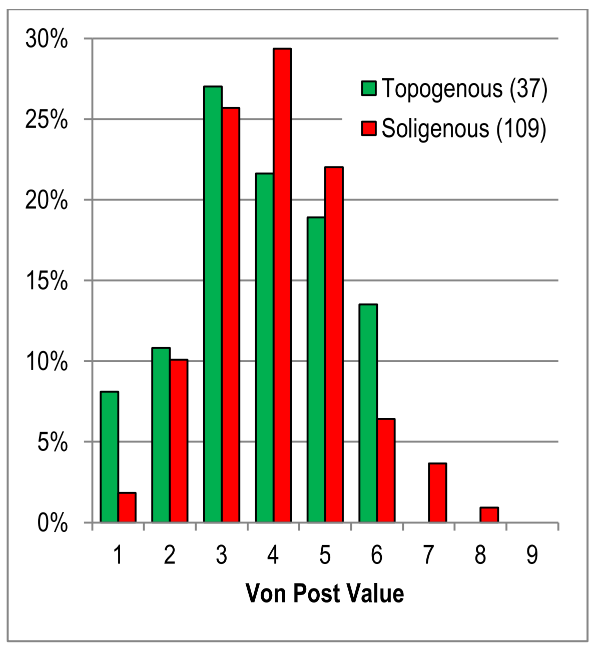


Figure 4-27. Von Post value by hydrologic class. Soligenous fens ($n = 109$, $\overline{x} = 4.0$, $sd = 1.3$) were somewhat more decomposed, having higher Von Post scores than Topogenous fens ($n = 37$, $\overline{x} = 3.7$, $sd = 1.5$).

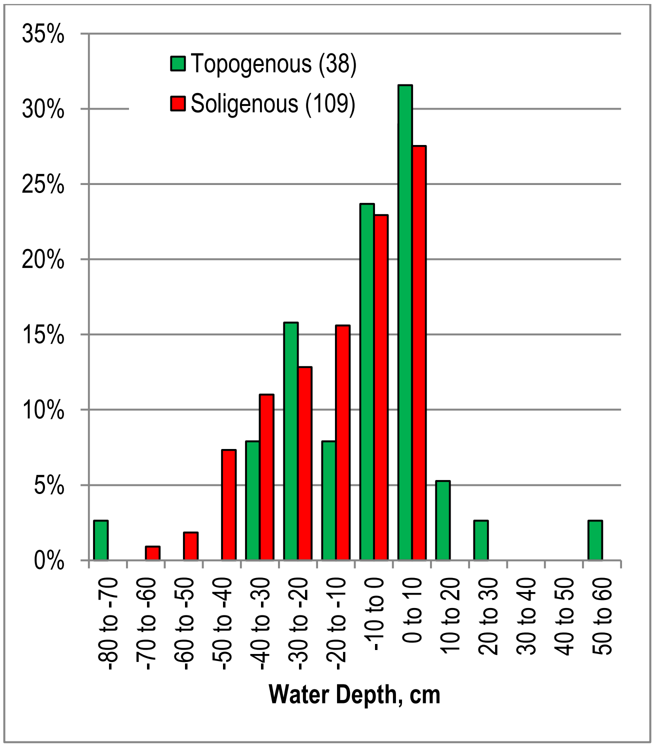


Figure 4-28. Observed water depth by hydrologic class. The sites with surface water were all Topogenous (n = 38, $\overline{x}$ = -9.2 cm, sd = 21.1 cm). Soligenous (n = 109, $\overline{x}$ = -16.0 cm, sd = 17.4 cm) sites more often had deeper water tables.

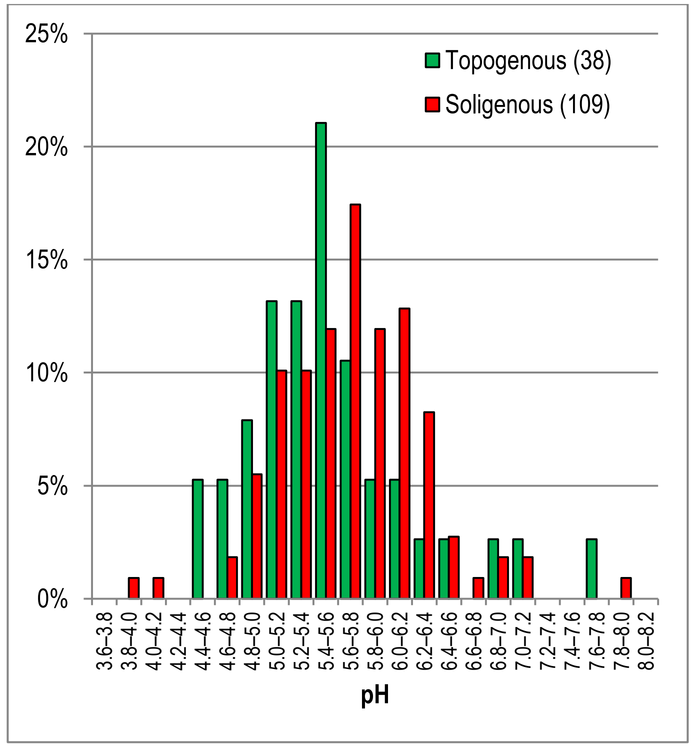


Figure 4-29. Frequency distribution of pH by hydrologic class. Soligenous (n = 109, $\overline{x}$ = 5.7, sd = 0.6) samples have higher pH in general, peak around pH 6.0. Topogenous (n = 38, $\overline{x}$ = 5.5, sd = 0.7) samples peak around pH 5.1.

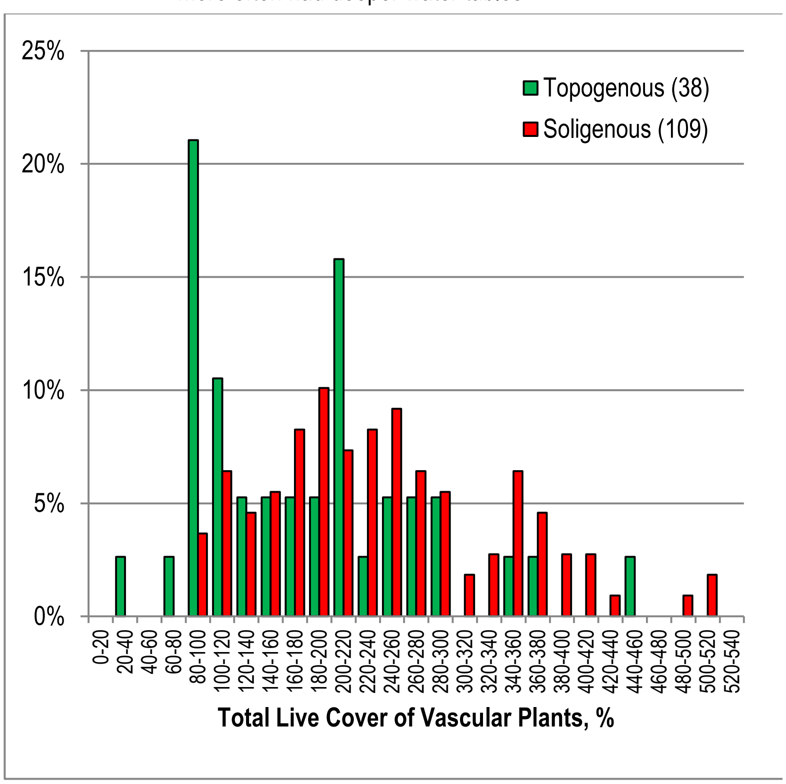


Figure 4-30. Total live cover by hydrologic class. Soligenous samples (n = 109, $\overline{x}$ = 232.0%, sd = 91.1%) tend to have higher TLC. Topogenous samples (n = 37, $\overline{x}$ = 167.2%, sd = 77.6%) have lower TLC.

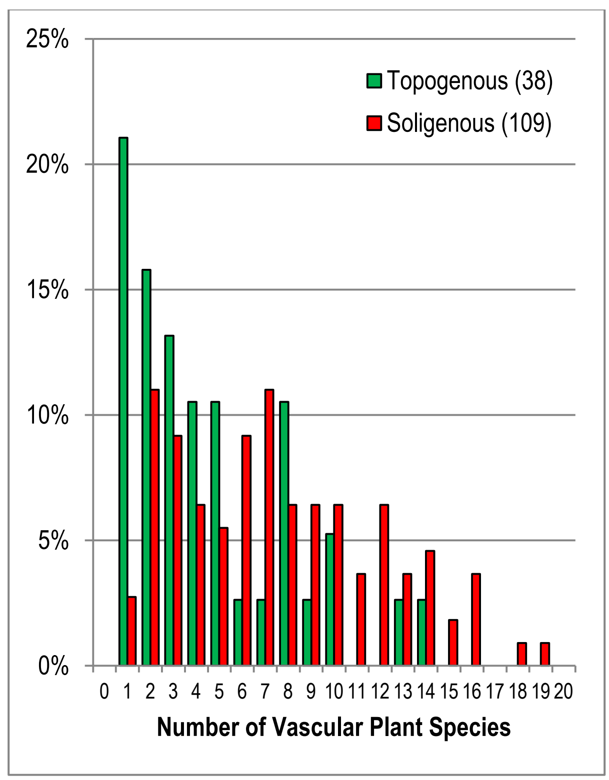


Figure 4-31. Number of species by hydrologic class. Soligenous samples (n = 109, $\overline{x}$ = 7.6, sd = 4.4) tend to have more vascular plant diversity. Topogenous samples (n = 38, $\overline{x}$ = 4.6, sd = 3.5) have fewer species.

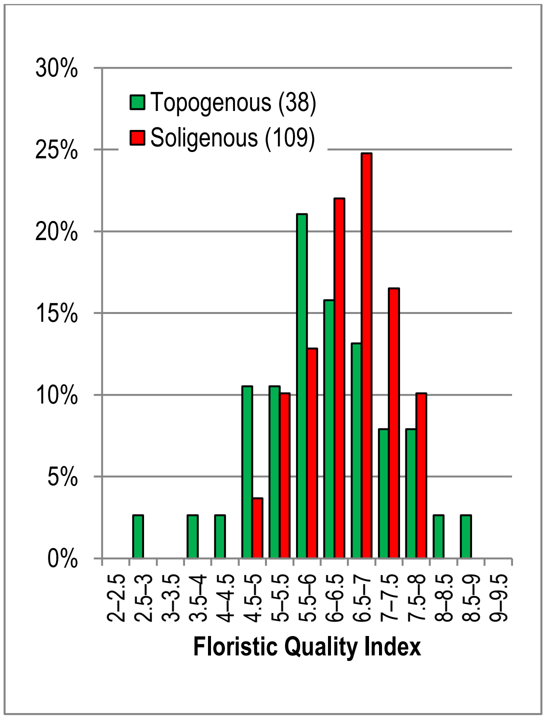


Figure 4-32. Floristic Quality Index by hydrologic class. Soligenous sites ($n = 109$, $\bar{x} = 6.4$, $sd = 0.8$) have somewhat higher FQI, and topogenous ($n = 38$, $\bar{x} = 6.0$, $sd = 1.2$) sites are more variable in FQI.

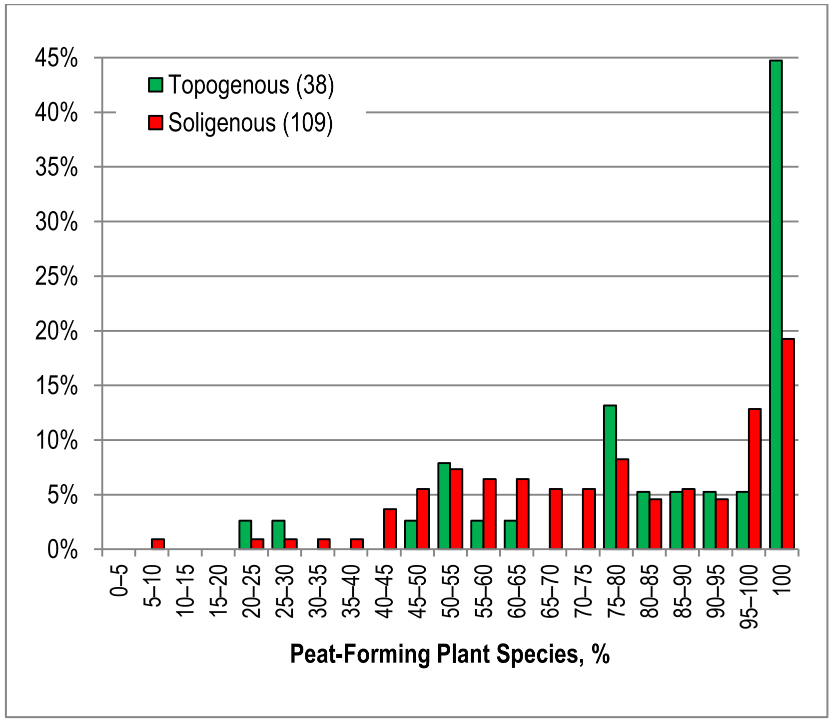


Figure 4-33. Percent peat-forming plant species (PFP) by hydrologic class. Almost 45% of Topogenous ($n = 38$, $\bar{x} = 83.7\%$, $sd = 21.9\%$) sites have 100% PFP. Almost 20% of soligenous sites ($n = 109$, $\bar{x} = 76\%$, $sd = 22.1\%$) have 100% PFP. Both distributions are spread across a wide range.

11. Hydrologic Alteration

Modifications such as ditching or groundwater flow interception can lead to lowered groundwater levels which increases aeration thus promoting peat loss due to oxidation. On the other hand, inundation of fens through reservoir regulation of water levels may prolong submergence of native communities to a degree that limits or prohibits the growth of peat-forming plant species, leading to death of the native fen species.

In this inventory, a potential fen site was selected for sampling only if it met the criteria defined for a fen. This excluded a number of sites where extreme hydrologic alterations had taken place. In the field the degree to which hydrologic processes have been altered was recorded at each site, based on the degree and extent of land uses and activities in the fen, as well as the adjacent buffer. The class definitions of Rocchio (2006) were used to characterize each site (Appendix C). The presence and size of ditches, dikes, roads, and reservoirs were used to assign a scalar value from none (0) to high (3) at each site. The distribution of the hydrologic alteration scalar is notably skewed (Figure 4-34). A large majority, 115 or 78%, of the sites sampled had no evidence of alteration.

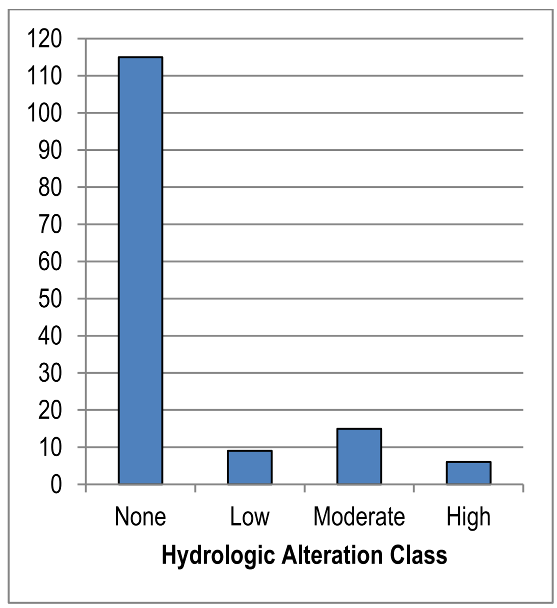


Figure 4-34. Frequency distribution of hydrologic alteration. Class 0 = no hydrologic alteration, class 1 = low, class 2 = moderate, class 3 = high ($n = 147$).

12. Disturbances in the Wetland

Natural and human disturbances were evaluated within the fen-wetland complex itself (disturbances in the 100 meter buffer are discussed in the following section). Disturbances were characterized based upon the type, intensity, areal extent, and causal agent if known. Up to five separate disturbances could be described in the fen-wetland complex (and an additional five in the adjacent buffer). Intensity of each disturbance type observed was rated from low (1) to very high (5). To facilitate consistency, a tabular summary of field indicators of intensity for typical disturbance types was provided as a reference to each crew (Appendix H).

Disturbance (or lack of) was characterized at all 147 fen-wetland complexes. A measure of total disturbance, total extent times intensity (TEXI) was calculated for each fen-wetland complex by multiplying the areal extent of each disturbance by its intensity and summing in each fen (up to five disturbances). Figure 4-35 summarizes the distribution of TEXI scores for all sampled fens.

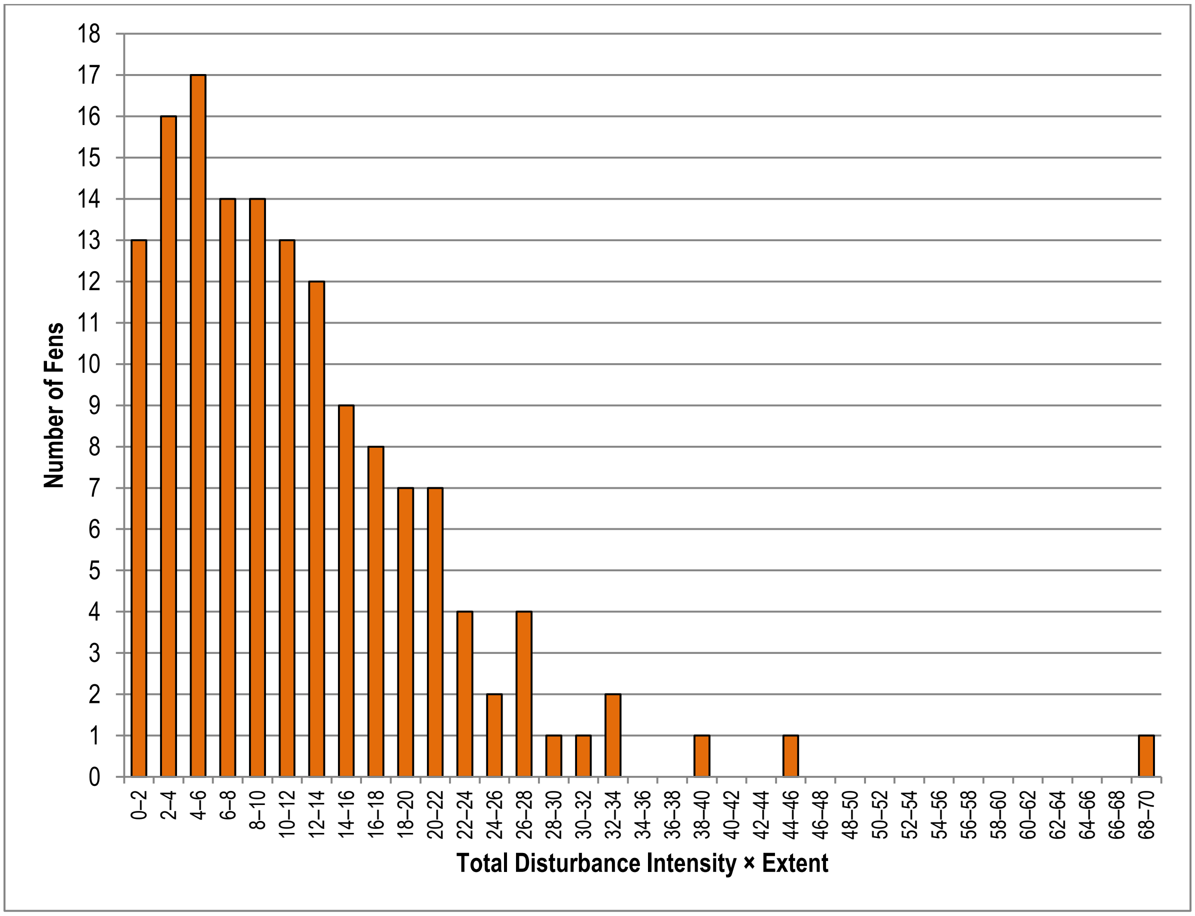


Figure 4-35. Frequency distribution of disturbance index (TEXI), sum of intensity × extent. (n = 147, $\bar{x}$ = 14.6, sd = 15.0)

TEXI was also examined by disturbance type by summing TEXI across all observations of each disturbance type. The frequency distribution of the number of occurrences by disturbance is shown in Figure 4-36 along with its corresponding cumulative TEXI score. As an example browsing occurred on 121 fens with a cumulative TEXI score of 609. Six fens had no evidence of disturbance. Evidence of 19 disturbance types was observed. The frequency of occurrence and average intensity by type are summarized in the table below (Table 4-21).

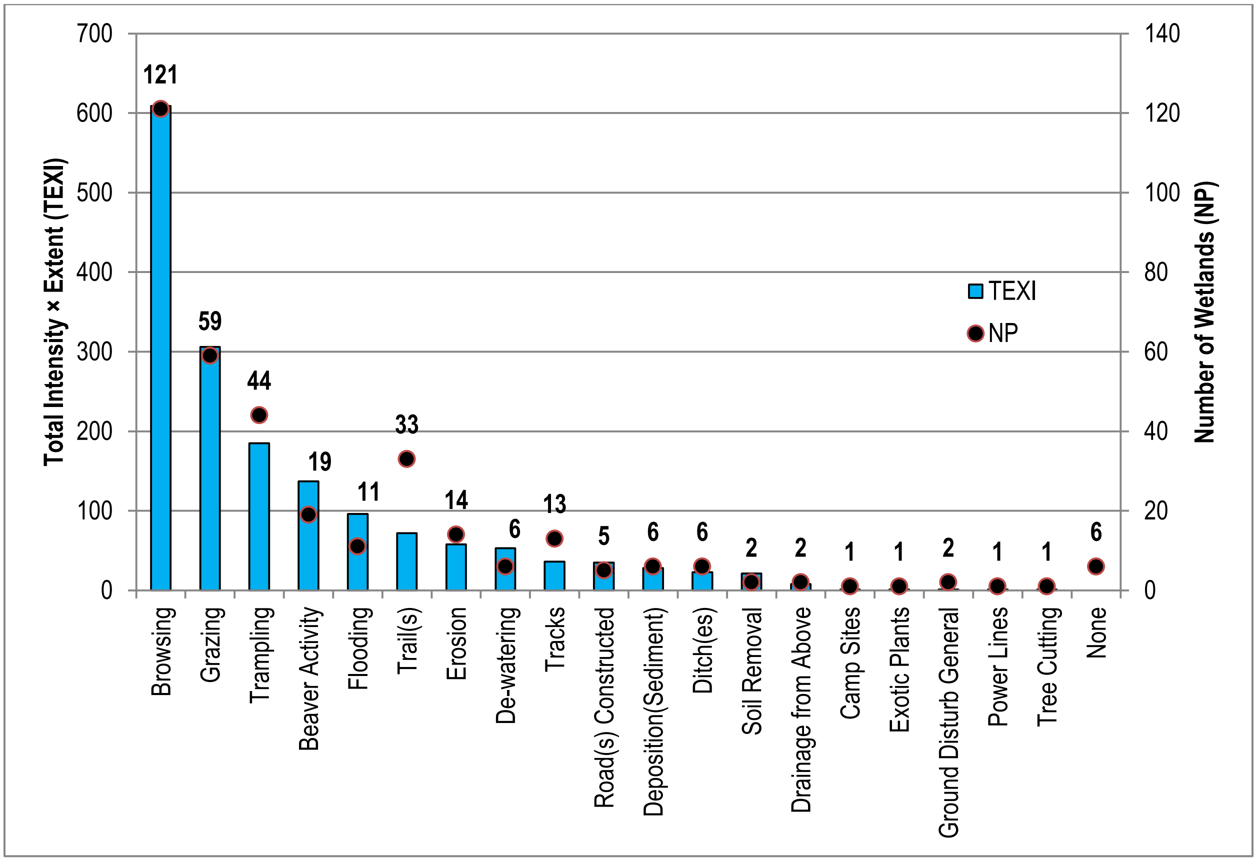


Figure 4-36. Number of disturbances recorded in 147 fen-wetland complexes. Some fens had more than one disturbance.

Table 4-21. Frequency of occurrence of specific disturbance types in 147 fen-wetland complexes. Total fen-wetland complex acreage is 1,614 ac.

Disturbance	Agent	Total* INT × EXT	No. Fens	Total Acres
Browsing	Wildlife	488	92	1,070
Beaver Activity		137	19	221
Trampling	Wildlife	130	32	372
Grazing	Livestock	127	18	209
Flooding		96	11	128
Grazing	Wildlife	91	22	256
Browsing		87	26	302
Grazing		83	18	209
Trampling		41	8	93
Browsing	Livestock	34	3	35
Trail(s)	Wildlife	30	15	174
Deposition(Sediment)		28	6	70
De-watering		26	3	35
Soil Removal	Mineral Exploration	21	2	23
Trail(s)	Recreation	21	8	93
De-watering	Water Diversion	19	2	23
Erosion		17	6	70
Erosion	Mineral Exploration	15	2	23
Erosion	Wildlife	15	3	35
Road(s) Constructed		15	3	35
Tracks	ATV	15	6	70
Trampling	Livestock	14	4	47
Ditch(es)	Mineral Exploration	12	1	12
Road(s) Constructed	Mineral Exploration	12	1	12
Tracks	Mineral Exploration	9	1	12
Trail(s)		9	7	81
De-watering	Wildlife	8	1	12
Drainage from Above		8	2	23
Road(s) Constructed	Recreation	8	1	12
Erosion	Roads	7	2	23
Trail(s)	ATV	6	2	23
Trail(s)	Livestock	6	1	12
Ditch(es)		5	3	35
Tracks	Wildlife	5	2	23
Ditch(es)	Water Diversion	4	1	12
Erosion	Water Diversion	4	1	12
Tracks	Roads	4	1	12
Tracks		3	3	35
Ditch(es)	Recreation	2	1	12
Camp Sites		1	1	12
Exotic Plants	Recreation	1	1	12
Ground Disturb Gen		1	1	12
Power Lines		1	1	12
Tree Cutting	Recreation	1	1	12
None		0	6	13

*. Intensity × Extent, totaled across all the fens in which this disturbance occurs.

In terms of prevalence and extent (TEXI), the ten most significant agent-specific disturbances are:

1. Browsing by wildlife
2. Beaver activity
3. Trampling by wildlife
4. Grazing by livestock
5. Flooding
6. Grazing by wildlife
7. Browsing by unknown animals
8. Grazing by unknown animals
9. Trampling by unknown animals
10. Browsing by livestock

Eight of the ten most common disturbances are related to the presence of wildlife and or livestock, and were often described as present at relatively low intensity levels; they are of consequence mostly because of their greater prevalence and extent. In terms of direct human impacts, the three most common disturbances are flooding, de-watering, and ATV tracks which were also recorded at rather modest levels of intensity.

Summary of disturbances by landscape area (from the 2009-2010 inventory) is shown in Figure 4-37. Animal-induced disturbances (browsing, grazing, trampling, and beaver activity) were much more common in the Sawatch Mountains Area. Water development disturbances (flooding, de-watering, soil removal) were common in the Grand Mesa Area.

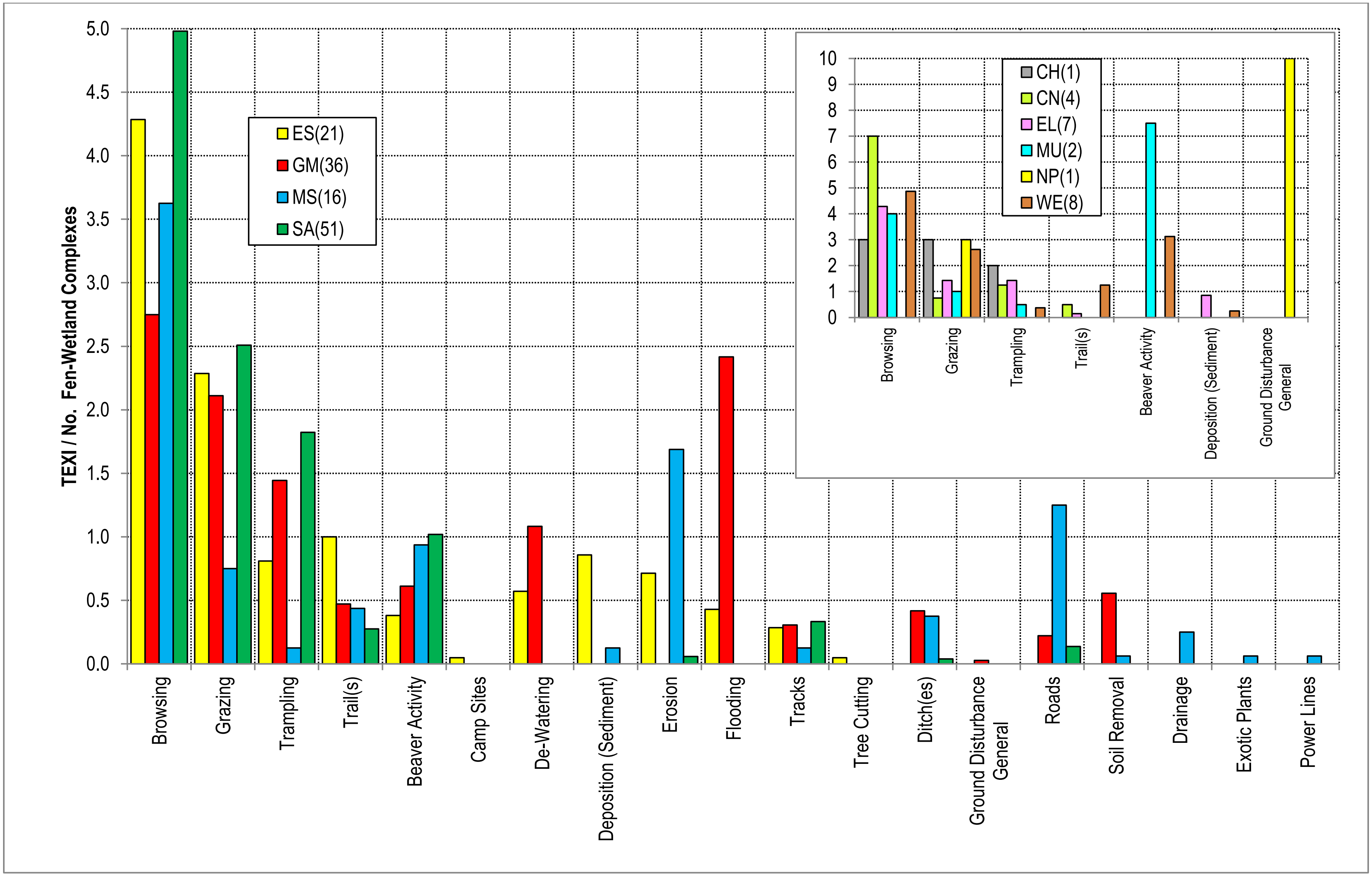


Figure 4-37. Total disturbance by landscape area, where fen samples were taken in 2009-2010. The main graph shows the four areas where the number of samples was > 10. Numbers in parenthesis are the number of fen-wetland complexes in each area. Inset shows total disturbance for the six other landscape areas where data were collected in 2009-2010, that had < 5 fens (there were no fens found in the BA and SP areas). The vertical axis was calculated for each site as Extent (scale 1-5) × Intensity (scale 1-5), then summed over all sites with that disturbance in that landscape area, then divided by the number of fen-wetland complexes in that landscape area.
Disturbance types with I×E < 4 for all areas were omitted (campsites, tree cutting, exotic plants, and power lines).

13. Disturbances in the Buffer

Disturbances were also estimated in a 100 meter buffer, measured from the edge of the fen-wetland complex. Methods were the same as for the fen-wetland complex, discussed above. For two fen-wetland complexes, there were no disturbances in the buffer; for the other 145 fen-wetland complexes, the five leading general disturbance factors were browsing, grazing, trails, roads, and erosion. Results are shown in Figure 4-38 and Table 4-22.

Table 4-22. Frequency of occurrence of specific disturbance types in the buffers around 147 wetland-fen complexes.

Disturbance	Agent	Total* INT × EXT	No. Fens
Browsing	Wildlife	202	51
Grazing	Livestock	145	17
Road(s) Constructed		126	27
Trail(s)	Recreation	94	31
Grazing		93	19
Browsing		61	20
Ground Disturb Gen	Mineral Exploration	41	5
Erosion		32	11
Trampling	Wildlife	31	6
Trail(s)	Wildlife	29	15
Road(s) Constructed	Recreation	28	6
Deposition(Sediment)		26	5
Tree Cutting	Timber Harvest	26	5
Browsing	Livestock	21	2
Flooding	.ALL	21	4
Grazing	Wildlife	21	7
Camp Sites	.ALL	19	9
Ground Disturb Gen		16	4
Soil Removal	Mineral Exploration	16	1
Trail(s)		16	10
Trail(s)	ATV	15	5
Tree Mortality	.ALL	15	1

Disturbance	Agent	Total* INT × EXT	No. Fens
Beaver Activity	.ALL	14	3
Exotic Plants	Livestock	12	2
Road(s) Constructed	ATV	12	3
Trail(s)	Livestock	12	2
Erosion	Mineral Exploration	10	2
Erosion	Roads	7	3
Trampling		7	2
Erosion	Water Diversion	6	1
Grazing	Recreation	6	1
Tree Cutting	Wildlife	6	1
Ditch(es)	Water Diversion	4	2
Road(s) Constructed	Timber Harvest	4	1
Tracks	ATV	4	1
Tracks	Recreation	4	1
Tree Cutting		4	2
Tree Cutting	Recreation	3	3
Fire	.ALL	2	1
Power Lines	.ALL	2	1
Road(s) Constructed	Mineral Exploration	2	1
Ditch(es)	Recreation	1	1
Exotic Plants	Recreation	1	1
None		0	2

*. Intensity × Extent, totaled across all the fen-wetland complexes in which this disturbance occurs.

In terms of prevalence and extent, the ten most significant types of agent-specific disturbance in the buffer are:

1. Browsing by wildlife
2. Grazing by livestock
3. Constructed roads
4. Grazing
5. Recreational trails
6. Ground disturbance
7. Browsing
8. Erosion
9. Trampling by wildlife
10. Trails attributed to wildlife

In the buffer, the effects of humans are much more evident than in the wetlands. It is reasonable to assume that disturbances attributed to humans such as roads, recreational trails, and erosion may have an effect on the wetlands, since the wetlands are usually down slope of the land in the buffer.

A measure of total disturbance was calculated for each buffer area. This total or 'cumulative' disturbance was determined by multiplying the intensity and extent of each disturbance; and then summing across all the disturbances observed (up to five). Frequency results are given in Figure 4-38.

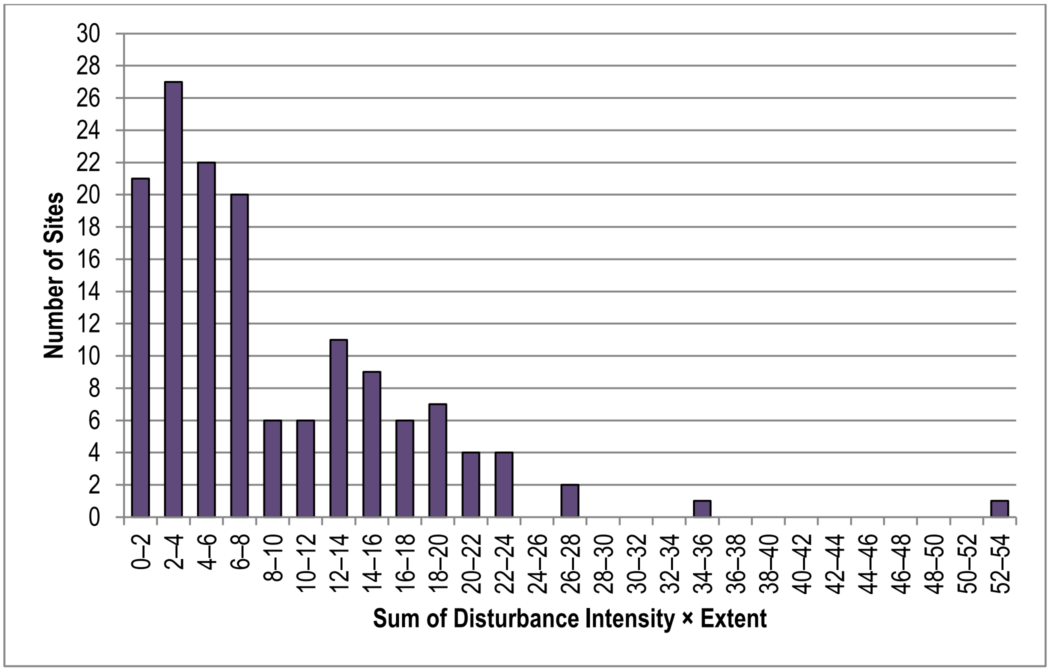


Figure 4-38. Frequency distribution of sum of Intensity × extent in the 100 m buffer. (n = 147, $\bar{x}$ = 9.1, sd = 11.1)

B. Fen Condition

Currently there is no regionally accepted assessment method specifically intended for use on fens. A standardized assessment method would be preferred, such as the Hydrogeomorphic (HGM) approach (for example, Hauer and others 2002) – those are considerably beyond the scope of this inventory.

Methods used to evaluate ecological conditions commonly utilize a combination of indirect measures or indicators to infer an overall condition. Several aspects in the development of those rating methods influence the final results. Relevant factors or variables believed to contribute to ecological condition must be identified, the number of classes to use to break up the range of values from "good to poor" must be established for each, the break points or thresholds between those classes defined, and finally the individual factors may be weighted based on their perceived importance to an overall result. This process is not exact, but iterative, continuing until the fens we know to be fully functional are rated high, and those that are nonfunctional are rated low. The method devised represents a best effort to meet the task of evaluating the degree of impact and condition of fens across the Grand Mesa, Uncompahgre, and Gunnison National Forests.

A number of recent methods for evaluating fens were reviewed and considered during development of the condition assessment used in this inventory (Chimner and others 2008, Rocchio 2006a, and Weixelman and Cooper 2009). All of these systems measure or rate several individual factors, and then combine them to determine an overall condition class. Factors considered in those evaluations range from subjective conclusions regarding the degree of disturbance, to field measurements of depth to water, to laboratory determination of the % soil carbon. Although details vary among the approaches, a number of factors and concepts are common among them; and include the following: water table depth and fluctuation, plant composition, peat quality, and field observation of detrimental disturbance. Our selection of factors emphasized objective quantitative variables that can be efficiently and reliably obtained in the field. Ultimately seven factors were incorporated in this inventory to evaluate the condition of fens. Table 4-23 briefly summarizes the seven factors and the various class breaks used by the authors cited above.

Table 4-23. Commonly used factors and condition class breaks from other authors.

Factor	Weixelman and Cooper[1]	Rocchio[2]	Chimner and others[3]
Percent Cover of Bare Soil	10%	Comparison to a Reference	<1, 1-5, 5-15, >15
Depth to water (cm)	20	30	<20, 20-30, 30-50, >50
Disturbance	Not used	Sum [(intensity) x (extent)]	(only noted)
Floristic Quality Index	Not used	>4.5, 3.5-4.5, 3-3.5, <3	Not used
Percent Peat-forming species	≥75	Not used	Not used
Hydrologic Alteration[4]	Yes or No	0, 1, 2, 3	<1, 1-5, 5-15, >15
Von Post Index	N/A	Comparison to a Reference	1-5, 6-7, 8, 9-10

1. Weixelman and Cooper 2009. 2. Rocchio 2006a. 3. Chimner and others 2008
4. Narrative definitions to characterize hydrologic alteration are provided in each reference.

1. Individual Factors

Results in the original units of measure for each factor are discussed in the "General Results" section of this report. This study used four classes (from very low to high) with associated numerical values (or scores) of 0 to 3, and relied on the previously cited work to help define the class breaks for each factor. Table 4-24 shows each factor and class breaks that were used in the evaluation.

Table 4-24. Factors and class breaks.

No.	FACTOR — CLASS → / SCORE →	Very Low 0	Low 1	Moderate 2	High 3
1	Bare Soil or Bare Peat (Microplots), %	≥ 10	5 – 10	1 – 5	< 1
2	Depth From Surface To Water, cm	≥ 40	30 – 40	20 – 30	< 20
3	Sum Disturbances: (extent) x (intensity)	≥ 36	22 – 36	10 – 22	< 10
4	Floristic Quality Index	≤ 3	3 – 3.5	3.5 – 4.5	> 4.5
5	Peat-forming Species, %	≤ 30	30 – 60	60 – 90	> 90
6	Hydrologic Alteration – Class	3	2	1	0
7	Von Post Index	9 – 10	8	6 – 7	1 – 5

1. Bare soil as measured in 5-10 microplots along a tape line. 2. Depth to water in soil pit after 1 – 2 hours. 3. For each disturbance in the wetland, multiply intensity (1 – 4) by extent (1 – 5); sum across all disturbances in the wetland. 4. Floristic quality index. 5. Percentage of vascular plant cover comprised of peat-forming species. 6. Subjective assessment of degree of hydrologic alteration, from 0 (none) to 3 (High). 7. Von Post index, an assessment of the decomposition of a peat sample

A tabular form of the frequency distribution of scores for all seven factors is presented in Table 4-25. The distribution for each of the factors is noticeably skewed toward moderate and high scores. This is especially dramatic for Floristic Quality Index and von Post, where 98% and 88% of sites respectively, scored a value of high. They both proved inconsequential in assessing conditions; which is reflected by their non-significant correlation to the ultimate score. Although less skewed, depth to water was likewise non-significant. Nonetheless we retained each of them in our analysis.

Table 4-25. Distribution of scores by factor.

Factor	Sample Size	- - - - - - S c o r e - - - - - - Very Low 0	Low 1	Moderate 2	High 3	Correlation With Final Score
Bare Soil Cover	147	10	14	15	108	– 0.5245***
Water Depth	147	12	15	20	100	NS
Disturbance in Wetland	147	3	13	49	82	– 0.1655*
Floristic Quality Index	147	1	0	2	144	NS
Percent Peat Forming Species	147	5	32	49	61	+ 0.2647**
Hydrologic Alteration	146	6	16	9	115	– 0.2817**
Von Post	146	0	1	16	129	NS

***. Highly Significant. **. Significant at 0.01. *. Significant at 0.05. NS = Not Significant.

2. Assessment of Condition

The individual scores of certain factors were weighted (Table 4-26) based on the importance given to them by Rocchio as well as data and experience from sites visited during the inventory. The final score was the calculated sum across all seven weighted factors. A total of 145 sites had complete information to allow calculation of a final score. The possible range for the final score varies from 0 to 36. The frequency distribution of the final scores is provided in Figure 4-39.

Table 4-26. Score sheet for rating condition of fen.

No.	FACTOR SCORE →	V. Low 0	Low 1	Moderate 2	High 3	SCORE	× Weight	**WEIGHTED SCORE**
1	Bare Soil or Bare Peat (Microplots), %	≥ 10	5 – 10	1 – 5	< 1	_____	1	_____
2	Depth From Surface To Water, cm	≥ 40	30 – 40	20 – 30	< 20	_____	1	_____
3	Sum Disturbances: (extent) x (intensity)	≥ 36	22 – 36	10 – 22	< 10	_____	2	_____
4	Floristic Quality Index	≤ 3	3 – 3.5	3.5 – 4.5	> 4.5	_____	1	_____
5	Peat-forming Species, %	≤ 30	30 – 60	60 – 90	> 90	_____	3	_____
6	Hydrologic Alteration – Class	3	2	1	0	_____	2	_____
7	Von Post Index	9 – 10	8	6 – 7	1 – 5	_____	2	_____
				TOTAL SCORES		_____		_____

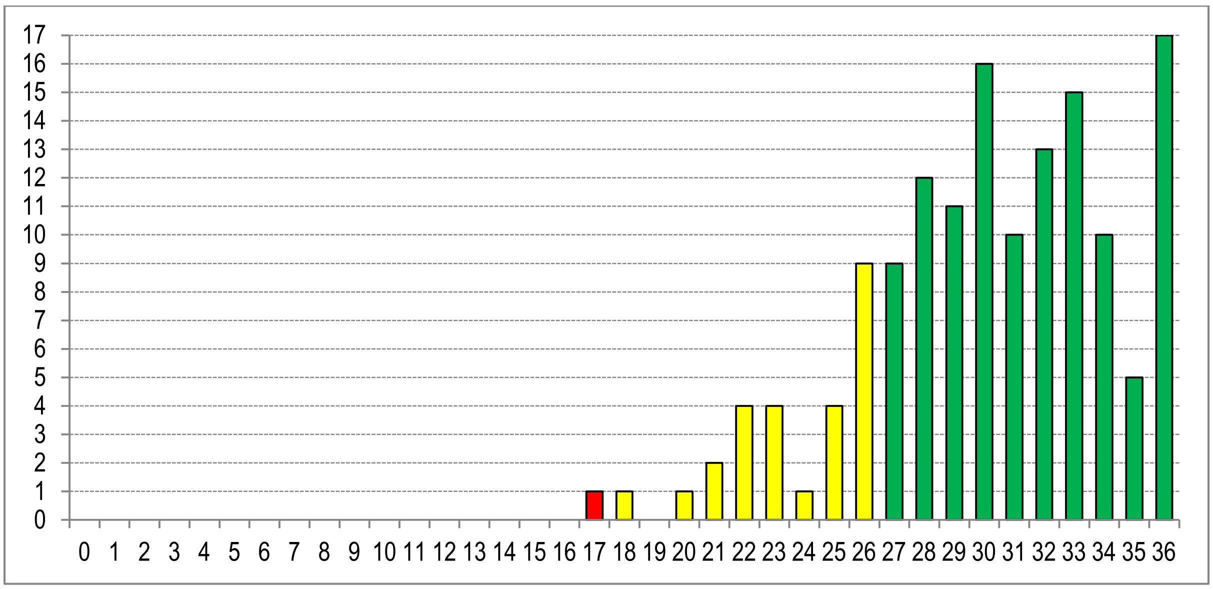


Figure 4-39. Frequency distribution of condition scores for 145 fens. High condition in green, moderate in yellow, low in red.

The lowest final score among the 2009-2010 sample set is 17. It is likely that a wetland with a weighted score of less than that would not have met the criteria for sampling, and so it would not have been included in the inventory. Dividing the weighted scores (0-36) into four equal classes (Table 4-27), indicates that most of the fens in the inventory (81%) were in High condition; with an additional 18 % Moderate; 1 % in Low, and none in Very Low Condition. These results are similar to those of Chimner and others (2008), who also found that the majority of fens examined in the field were in good condition.

Table 4-27. Condition classes for scores in Figure 4-39.

Final Score	Fen Count	Fen Percent	Condition Class
27 – 36	118	81	High
18 – 26	26	18	Moderate
9 – 17	1	1	Low
0 – 8	0	0	Very Low

3. Low-Condition Sites Not In the GRTS Inventory

Only 27 sites from the GRTS based sample set (19%) had final condition rating scores below the high class (upper quartile, see table 4-27), therefore the team purposely attempted to test the rating method on other known sites suspected to be impaired or degraded to a detectable degree. Condition ratings were made on 25 additional sites that are independent of the inventory set of 147. The supplemental set includes 15 sites sampled using the field sampling protocol and ten sites from the Grand Mesa (selected from Austin 2008) that had comparable data. Most of these lesser quality sites in this group are influenced by water development activities, and a few by historic mining.

The results are portrayed in Figure 4-40 which incorporates the original 147 plus the 25 supplemental sites, distinguished by color. The three highest scoring sites were actually acquired solely due to convenience and were not expected to have low scores. The remaining sites were intentionally chosen because of varying degrees of impact, and received lower condition scores. The sites with lowest scores have all been altered by reservoir development. Other sites with reservoirs, as well as those in close association with mining activities have conditions rated as moderate. These independent results suggest that the rating system is sensitive to or can detect degraded site conditions.

Somewhat surprisingly the individual floristic quality index factor got mostly high scores, even on many sites with low overall scores. Only three scored a zero (the lowest possible), and one received a score of one. By contrast, the bare soil factor scored poorly for all sites except the four highest overall scoring sites (green). The von Post scores varied according to the data source. The added Grand Mesa sites had uniformly poor Von Post ratings, while those from the inventory were all rated highly. This may reflect real impacts as the added Grand Mesa sites have undergone many years of water regulation.

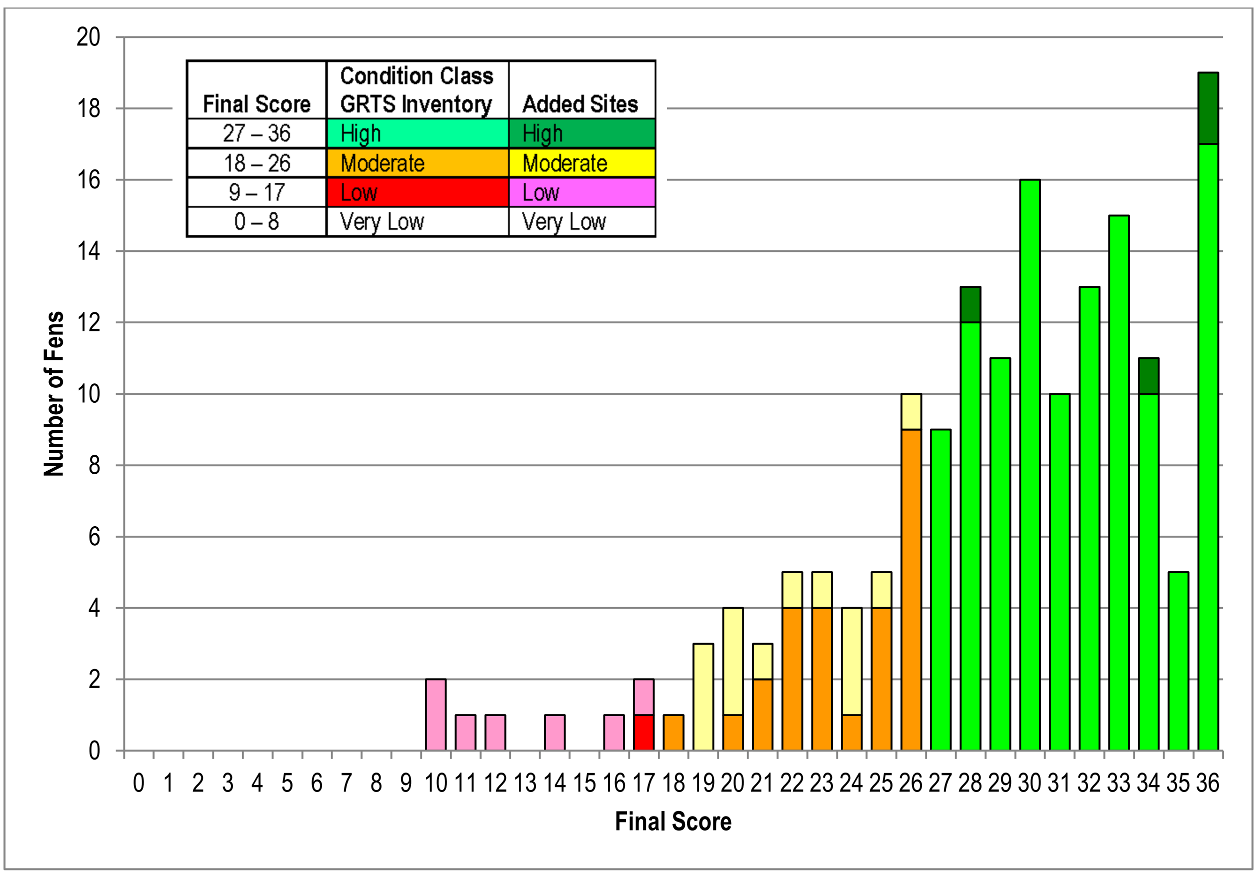
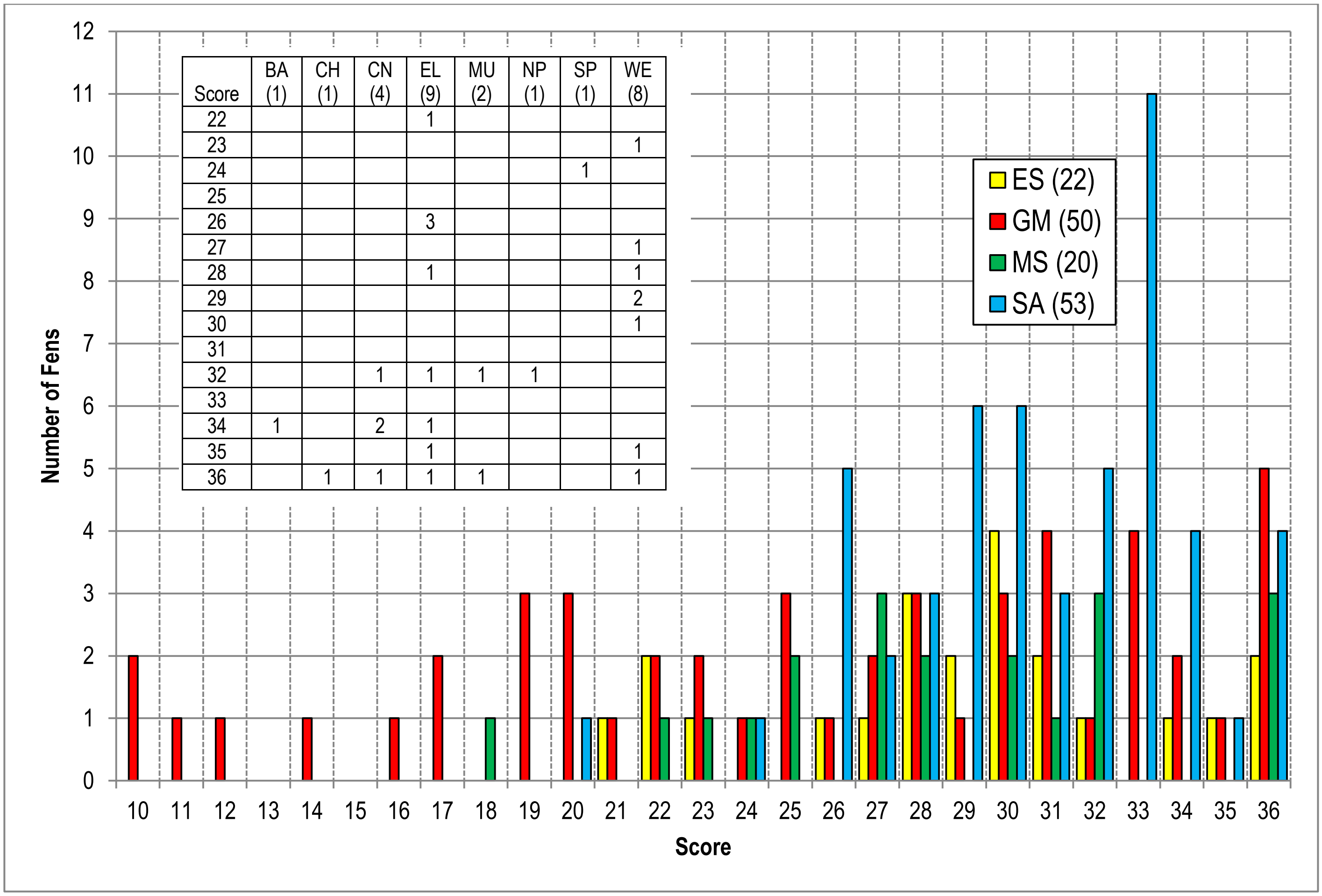


Figure 4-40. Condition scores of all fens and degraded fens that were scored. $n = 172$, including 25 fens outside the GRTS inventory (top bars). Compare Figure 4-39.

Final condition scores vary widely across landscape areas. Figure 4-41 shows the distribution of all fens rated according to the above system across four landscape areas with 20 or more sites available (Grand Mesa, Eastern San Juans, Middle San Juans, and Sawatch Mountains). It includes the 10 impaired fens sampled by Austin (2008) all of which occur on the Grand Mesa. The results might suggest that low scoring fens are limited to the Grand Mesa. However, the results are biased by the intentional focus on impacted sites in the supplemental data set; which in the area of the inventory are best known on the Grand Mesa. Low-scoring fens probably exist in the other areas as well.

The lowest-scoring fen in the random-based inventory had a score of 17. The 2009-2010 crews would have rated lower-scoring sites as not qualifying for a fen, probably because the sites no longer qualify as wetlands (U. S. Army Corps of Engineers 1987), and they would have not been sampled.



Score	BA (1)	CH (1)	CN (4)	EL (9)	MU (2)	NP (1)	SP (1)	WE (8)
22				1				
23								1
24							1	
25								
26				3				
27								1
28				1				1
29								2
30								1
31								
32			1	1	1	1		
33								
34	1		2	1				
35				1				1
36		1	1	1	1			1

Figure 4-41. Distribution of scores across the four landscape areas with the most occurrences of fens. Numbers in parenthesis are numbers of fens in each area. Inset shows scores by landscape areas for the eight areas with few samples (<10).

4. Examples of Fen Condition Rating

In order to illustrate the condition class rating system and results, we provide a detailed discussion of the five worst sites in the statistical inventory, those with score ≤ 21 (Table 4-28). For contrast, two of the best sites were included that both scored the highest score (36) and had no disturbances in the wetland.

Table 4-28. Selected sites to illustrate condition rating. The columns on the right show the seven factors in Table 4-26.

																					Factors Used in Scoring							Scores							
No.	PFS*	Landscape Area	Beaver	Fen Type	Slope	Rock Cover	Sediment Cover	Peat Depth	pH	EC	Open Water	Floating Mat	Water Develop.	Channels	Gully Freq	Gully Size	Acres	Total Live Cover	No. Species	Wetland Pct.	Disturbance in Buffer	**1. Bare Soil Cover**	**2. Water Depth**	**3. Disturbance in Wetland**	**4. Floristic Quality Index**	**5. Peat-Forming Pct.**	**6. Hydrologic Alteration**	**7. Von Post Index**	Score For Factor 1	Score For Factor 2	Score For Factor 3	Score For Factor 4	Score For Factor 5	Score For Factor 6	Score For Factor 7	**Final Score**
1	WFG046	GM	None	BA	0	20	>15%	150	5.44	90.0	Y	Y	Y	Y	H	Lg	70.90	170.0	3	100.0	52	62.6	-30	69	6.9	88.2	H	1	0	2	0	3	2	0	3	**17**
2	WFS236	MS	None	VS	9	5	2-5%	120	3.99	40.0	Y	N	N	Y	L	Lg	0.59	350.5	6	35.8	18	0.3	-50	10	7.2	23.0	H	4	3	0	3	3	0	0	3	**18**
3	WFG011	GM	None	TS	2	1	0%	100	5.21	20.0	Y	N	Y	N	0		21.99	289.5	6	89.6	6	0.0	-5	16	5.8	58.5	H	6	3	3	2	3	1	0	2	**20**
4	WFS134	MS	None	TS	2	0	0-2%	150	5.74	94.5	Y	N	Y	Y	H	Lg	4.86	206.0	7	49.8	5	0.6	-30	13	7.5	47.1	H	5	3	2	2	3	1	0	3	**21**
5	WFS345	ES	Present	VS	0		0%	70	5.93	240.0	Y	N	Y	Y	0		25.22	120.0	3	91.3	18	6.0	-40	23	5.1	82.9	M	5	1	1	1	3	2	1	3	**21**
6	WFS148	MS	None	SD	0	0	0	150	5.21	37.2	Y	N	N	N	0		1.94	97.0	1	100.0	5	0.0	-5	0	5.0	100.0	0	3	3	3	3	3	3	3	3	**36**
7	WFG042	GM	None	TS	0	0	0	150	5.72	100.0	Y	Y	N	N	0		6.15	180.0	5	100.0	1	0.0	-1	0	6.7	100.0	0	1	3	3	3	3	3	3	3	**36**

HIGH	LOW	CONTRIBUTING FACTOR TO LOW CONDITION

*. Potential fen site number.

1. Kennecott Slough (WFG046) on Grand Mesa (Score 17 out of 36)

This is now a 70 acre reservoir, in a basin. The reservoir is alternately filled and drained on a regular basis. At one time the site was nearly covered with a floating peat mat (Figures 4-42 and 4-43). "The 1936 and 1956 photographs indicate that the primary peat mass is still intact. The 1978 photograph shows flooding (dark color) and the peat mass breaking apart. In the 2007 photograph the peat mass has sunken to the bottom of the reservoir and any remaining plant communities are drowning" (Austin 2008). From the mid-1960s through about 2001, this was the site of an active peat mine, which systematically removed the floating mat. By 2007, at a time when the reservoir was full, the once-extensive floating mat is represented by only a few floating pieces of peat.

Figure 4-42. The upper end of Kennecott, at a time when the reservoir was drawn down. Photo by Steven Jay, August 24, 2010.

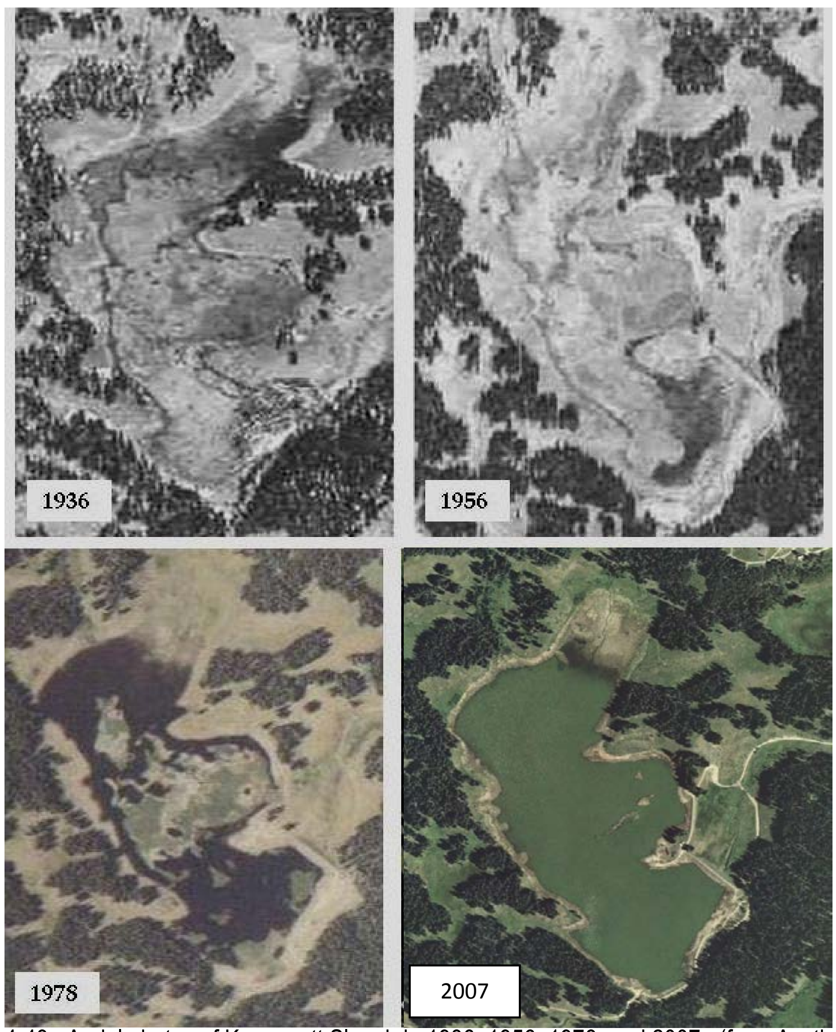


Figure 4-43. Aerial photos of Kennecott Slough in 1936, 1956, 1978, and 2007. (from Austin 2008)

This site was visited in 2009, but at that time the reservoir was full and the remnant floating mat could not be reached; the site was revisited in 2010 at a time when the reservoir had been drawn down (Figure 4-44).

The site's score is 17, the lowest-scoring site in the 2009-2010 inventory. Bare soil cover and disturbance sum were very high (Table 4-29), and there were a number of gullies, channels, ditches, and vehicle tracks. The site had obviously been considerably altered. Very low (zero) scores were tallied in the condition assessment for bare soil, disturbance, and hydrologic alteration. Disturbances in the wetland include peat mining, flooding, roads, ditches, and ATV tracks.

Figure 4-44. A remnant of the floating mat at Kennecott Slough, looking 270°mag. When the reservoir is filled, this site is probably submerged, judging from aerial photos and the high sediment cover. Photo by Steven Jay, August 24, 2010.

Vegetation at the best site available in 2010 (Figure 4-44) is dominated by beaked sedge, marsh-marigold, and purple cinquefoil; total bryophyte cover is 40% (Table 4-29). Peat is deep (> 150 cm), of very good quality (Von Post 1). Electrical conductivity is somewhat elevated, probably normal for the Grand Mesa landscape. Total live cover is 170% with only three species present, both low for a site of this quality. It seems likely that these are the only plants that will survive the yearly cycle of flooding and drainage.

Table 4-29. Vegetation cover at a site within Kennecott Slough. Site shown in Figure 4-44.

L	GF	Code	Cover	Name	Common
1	G	CAUT	80.0 %	Carex utriculata	beaked sedge, Northwest Territory sedge
2	F	PSLE	20.0 %	Psychrophila leptosepala	elkslip marsh-marigold, elkslip, white marsh-marigold
3	F	COPA28	70.0 %	Comarum palustre	purple cinquefoil
4	B	.BRY	40.0 %	Total bryophyte cover	Total bryophyte cover
5	Z	.BARE	62.6 %	bare soil	bare soil
6	Z	.LITT	27.4 %	litter and duff	litter and duff
7	Z	.BAVE	10.1 %	live plant bases	live plant bases

2. Upper Gray Copper Gulch (WFS236) in the Middle San Juans Area (Score 18 out of 36)

This 0. 6 acre fen is on a valley slope in upper Gray Copper Gulch, a tributary of Red Mountain Creek. The site (Figures 4-45 and 4-46) appears to have been fairly heavily impacted in the past by mining activities, livestock grazing, or both. This was part of a sheep grazing allotment until the mid-1980s; the allotment has been vacant since then. Before that it was likely grazed fairly heavily, though old range management records state that the wet meadows were improving because the sheep didn't use them much. The site has also apparently seen hydrologic alteration through past dams and weirs, and there is a gully on the site now.

Figure 4-45. View of WFS236 in Gray Copper Gulch. Photo by Steven Jay, July 14, 2010.

Figure 4-46. Photo of the 4 m × 4 m relevé in Gray Copper Gulch. Photo by Janna Simonsen, July 14, 2010.

This is the second lowest-scoring site in the inventory, scoring 18. In this case, zero scores in the condition rating were tallied for water depth (–50 cm), peat-forming plants (23%, very low), and hydrologic alteration. Wetland plant percent is also low (36%), and there were channels present. Slope angle is 9%, fairly high for a fen.

The vegetation is dominated by dwarf bilberry, black alpine sedge, *Aulacomnium palustre*, blackroot sedge, *Sphagnum* moss, and water sedge. Bilberry and the first two sedges are not peat-forming species, sometimes dominant in alpine sites and in cold pockets in the high subalpine, such as this valley. Vegetation cover is shown in Table 4-30. Total live cover is 351%, fairly high, on six species.

Table 4-30. Vegetation and ground cover at site WFS237 in Gray Copper Gulch. Site shown in Figure 4-45

L	GF	Code	Cover	Name	Common
1	S	VACE	90.0 %	Vaccinium cespitosum	dwarf bilberry
2	G	CAAQ	80.0 %	Carex aquatilis	water sedge
3	G	CAEL3	70.0 %	Carex elynoides	blackroot sedge
4	G	CANI2	90.0 %	Carex nigricans	black alpine sedge
5	G	LUSU9	0.5 %	Luzula subcapitata	Colorado woodrush
6	F	BIBI5	20.0 %	Bistorta bistortoides	American bistort
7	B	AULAC2	90.0 %	Aulacomnium sp.	
8	B	SPHAG2	30.0 %	Sphagnum sp.	
9	Z	.BARE	0.3 %	bare soil	bare soil
10	Z	.LITT	94.7 %	litter and duff	litter and duff
11	Z	.BAVE	5.8 %	live plant bases	live plant bases
12	Z	.BRY	42.0 %	Total bryophyte cover	Total bryophyte cover

3. Bullfinch Reservoir No. 1 (WFG011) on the Grand Mesa (Score 20 out of 36)

This 22 acre site contains a reservoir, with a fen above it. When the reservoir is completely full, the fen is inundated. According to Austin 2008, two-thirds of the site is regularly flooded and used as a reservoir. In terms of the factors used in the condition assessment the site has water developments and open water, and the hydrology has been altered (Figure 4-47).

Figure 4-47. Looking southwest towards Bullfinch Reservoir No. 1. Photo by Janna Simonsen, July 11, 2009.

Vegetation is dominated by pale spikerush, water sedge, and a wide variety of forbs (Table 4-31, Figure 4-48), mostly indicating the frequent flooding of the site.

Table 4-31. Vegetation and ground cover at site WFG011 in Bullfinch Reservoir No. 1.

L	GF	Code	Cover	Name	Common
1	G	CAAQ	40.0 %	Carex aquatilis	water sedge
2	G	ELMA5	99.5 %	Eleocharis macrostachya	pale spikerush
3	F	CLRH2	50.0 %	Clementsia rhodantha	rose crown, redpod stonecrop
4	F	PSLE	60.0 %	Psychrophila leptosepala	elkslip marsh-marigold, elkslip, white marsh-marigold
5	F	PEGR2	30.0 %	Pedicularis groenlandica	elephantella, elephant-head pedicularis, elephanthead
6	F	VIMA2	10.0 %	Viola macloskeyi	small white violet, smooth white violet
7	Z	.BARE	00.0 %	bare soil	bare soil
8	Z	.LITT	97.0 %	litter and duff	litter and duff
9	Z	.BAVE	3.0 %	live plant bases	live plant bases
10	Z	.BRY	80.0 %	Total bryophyte cover	Total bryophyte cover

This site scored fairly low, 20; there is a zero for hydrologic alteration, and a one for peat-forming plants (59%, low). The peat is moderately highly decomposed (Von Post 6), and floristic quality is low (5. 8). The site slopes at 2% to the northeast. Peat is 100 cm deep and water –5 cm, both good; the peat is 55% organic matter.

Figure 4-48. Looking at the 4 m × 4 m relevé at Bullfinch Reservoir No. 1. Photo by Janna Simonsen, July 11, 2009.

4. Lateral Moraine Fen (WFS134) in the Middle San Juans Area (Score 21 out of 36)

This site is a toeslope fen above Trout Lake in the Middle San Juans (Figure 4-49). The site was fairly heavily grazed in the past (before about 1980), and there are also signs of beaver activity. There are several deep channels that bisect the site. This site is now part of an active restoration project, with graduate students from Colorado State University doing research. In addition to this research, a vegetation transect and full soil pit have been documented at this site by Barry Johnston and Jacqueline Foss, respectively.

Figure 4-49. A view of Lateral Moraine Fen. Photo by Janna Simonsen, June 30, 2010.

The rating for this site is 21. One zero is for high degree of hydrologic alteration. A one is for the low percentage of peat-forming plants (47%). The site also has water channels, and relatively deep water depth (-30 cm) (Figures 4-50, 4-51, 4-52). Vegetation and ground cover is shown in Table 4-32.

Table 4-32. Vegetation and soil cover at Lateral Moraine Fen.

L	GF	Code	Cover	Name	Common
1	G	CASI2	20.0 %	Carex simulata	short-beaked sedge
2	G	CACA11	70.0 %	Carex canescens	pale sedge, gray sedge, silvery sedge
3	G	CASA10	80.0 %	Carex saxatilis	rock sedge, russet sedge
4	G	CAAQ	20.0 %	Carex aquatilis	water sedge
5	G	CAJO	30.0 %	Carex jonesii	Jones's sedge
6	F	PEGR2	40.0 %	Pedicularis groenlandica	elephantella, elephant-head pedicularis, elephanthead
7	F	PSLE	0.5 %	Psychrophila leptosepala	elkslip marsh-marigold, elkslip, white marsh-marigold
8	F	GATR2	20.0 %	Galium trifidum	small bedstraw, small cleavers, threepetal bedstraw
9	Z	.BARE	00.0 %	bare soil	bare soil
10	Z	.LITT	50.0 %	litter and duff	litter and duff
11	Z	.BAVE	10.0 %	live plant bases	live plant bases
12	Z	.COWPIE	10.0 %	droppings cattle	droppings cattle
13	Z	.BRY	62.0 %	Total bryophyte cover	Total bryophyte cover

Figure 4-50. The soil from the pit at WFS134 in Lateral Moraine Fen. Photo by Janna Simonsen, June 30, 2010.


Figure 4-51. The soil pit dug in 2008 at Lateral Moraine Fen. Photo by Jacqueline Foss, Sept. 11, 2008.


Figure 4-52. The relevé at the sample point, in Lateral Moraine Fen. Photo by Janna Simonsen, June 30, 2010.

5. Bottom of Cimarron River above Silver Jack Reservoir (WFS345), Eastern San Juans Area (Score 20 out of 36)

Fen WFS345 is in the Eastern San Juan Mountains Area, in cell 4ES026. This fen is given a moderate rating (20), with four ones, a two and two threes; it is rated low in water depth, bare soil, hydrologic alteration, and disturbance (Figures 4-53 and 4-54). Vegetation is dominated by mountain willow (20% cover) and beaked sedge (100%), with a little bit of the exotic black medic (Table 4-33). Bare soil is 6% cover. Water table is at 40 cm below the surface. Back water flooding from the Silver Jack reservoir occurs at moderate intensity across 35-50% of the wetland, and browsing by wildlife at high intensity across 25-50% of the area. There is grazing by wildlife and beaver activity as well. A road occurs in the buffer. A pit was dug to 70 cm, which is the extent of the peat. The soil sample from approximately 65 cm showed 20% organic carbon and 43% organic matter.

Figure 4-53. Panorama of WFS345, near Silver Jack Reservoir. The inlet can just be seen on the right. Photo by Janna Simonsen, Aug. 5, 2009.

Figure 4-54. The relevé at site WFS345, near Silver Jack reservoir. Photo by Janna Simonsen, Aug. 5, 2009.

Table 4-33. Vegetation and ground cover at site WFS345, near Silver Jack Reservoir.

L	GF	Code	Cover	Name	Common
1	S	SAMO2	20.0 %	Salix monticola	serviceberry willow, mountain willow, park willow
2	G	CAUT	99.5 %	Carex utriculata	beaked sedge, Northwest Territory sedge
3	F	MELU	0.5 %	Medicago lupulina	black medic
4	Z	.BARE	6.0 %	bare soil	bare soil
5	Z	.LITT	91.6 %	litter and duff	litter and duff
6	Z	.BAVE	3.0 %	live plant bases	live plant bases
7	Z	.BRY	3.2 %	Total bryophyte cover	Total bryophyte cover
8	B	ALAC4	10.0 %	Allium acuminatum	tapertip onion
9	Z	.ALGAE	20.0 %	Algae	algae

6. Hidden Basin Fen (WFS148) in the Middle San Juans Area (Score 36 out of 36)

Hidden Basin Fen is given the highest rating (36), because it has all threes for the seven rating criteria. It is a two-acre site in a basin, dominated entirely by beaked sedge (Figures 4-55 and 4-56). Water depth is shallow (–5 cm), and peat is >150 cm deep. No disturbances were noted in the wetland. There is a small amount of open water, and no gullies, ditches, or hydrologic alteration. Von Post rating is 3, good, and organic matter and organic carbon are both high. Vegetation and ground cover are shown in Table 4-34.

Figure 4-55. Panorama of Hidden Basin Fen. Photo by Janna Simonsen, June 29, 2010.

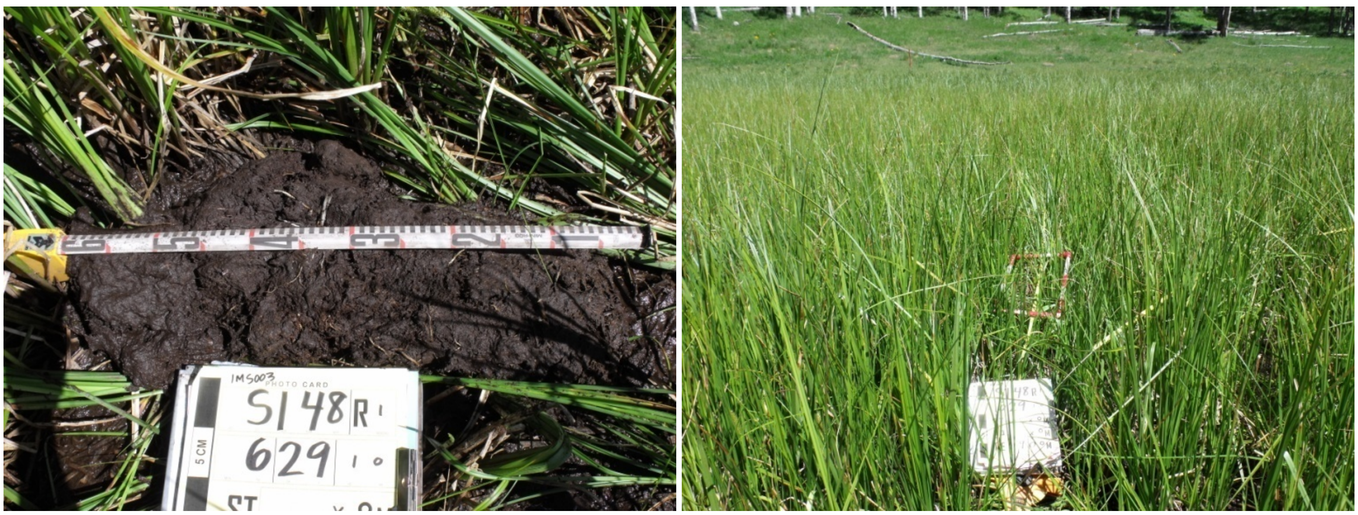


Figure 4-56. Left, soil plug, right, relevé; at Hidden Basin Fen. Photos by Janna Simonsen, June 29, 2010. Vegetation is dominated by beaked sedge (Table 4-34), with no bare soil and no bryophytes.

Table 4-34. Vegetation and ground cover at site WFS148, Hidden Basin Fen.

L	GF	Code	Cover	Name	Common
1	G	CAUT	97.0 %	Carex utriculata	beaked sedge, Northwest Territory sedge
2	Z	.BARE	00.0 %	bare soil	bare soil
3	Z	.LITT	99.5 %	litter and duff	litter and duff
4	Z	.BAVE	3.0 %	live plant bases	live plant bases
5	Z	.WATER	34.0 %	water open	water open
6	Z	.BRY	00.0 %	Total bryophyte cover	Total bryophyte cover

7. Horse Fen (WFG042) on the Grand Mesa (Score 36 out of 36)

Horse Fen is a high-quality fen on the Grand Mesa, where there has been vegetation, hydrologic, and soil monitoring for over three years (Johnston and others 2007, Johnston and others 2010). It earned the highest score in the inventory (36), with threes in all seven categories. No disturbances were recorded in the wetland (Figures 4-57 and 4-58).

Figure 4-57. Panorama of Horse Fen. Photo by Janna Simonsen, July 17, 2009.

Figure 4-58. Left, soil plug, right, relevé; at Horse Fen. Photos by Janna Simonsen, July 17, 2009.

Vegetation at the sample site for this inventory is dominated by short-beaked sedge, water sedge, mud sedge, lakeshore sedge, and purple cinquefoil (Table 4-35). Bryophyte cover is complete, and there is no bare soil.

Table 4-35. Vegetation and ground cover at site WFG042, Horse Fen.

L	GF	Code	Cover	Name	Common
1	G	CASI2	99.5 %	Carex simulata	short-beaked sedge
2	G	CAAQ	40.0 %	Carex aquatilis	water sedge
3	G	CALI7	10.0 %	Carex limosa	mud sedge
4	G	CALE8	10.0 %	Carex lenticularis	lakeshore sedge
5	F	PEGR2	0.5 %	Pedicularis groenlandica	elephantella, elephant-head pedicularis, elephanthead
6	F	COPA28	30.0 %	Comarum palustre	purple cinquefoil
7	Z	.WATER	90.0 %	water open	water open
8	Z	.LITT	97.0 %	litter and duff	litter and duff
9	Z	.BAVE	3.0 %	live plant bases	live plant bases
10	Z	.BRY	99.5 %	Total bryophyte cover	Total bryophyte cover
11	Z	.BARE	00.0 %	bare soil	bare soil

An example of what might have been formerly a fen is shown in Figure 4-59, a site not in the random-based inventory. The soil in the moist opening in the bottom is peaty loam, apparently not accumulating peat; mottles and gleying are very evident. The water table is very low, below –60 cm. Vegetation is dominated by shrubby cinquefoil (*Dasiphora floribunda*) and moist sedges, so the site no longer qualifies as a wetland (U. S. Army Corps of Engineers 1987). An estimate of its rating would be in the range of 4 to 6, mostly because there is no evidence of hydrologic alteration.

Figure 4-59. Ignacio Park in the Cochetopa Area. August 22, 2008. The boundaries of the possible former fen have been drawn in white.

V. Summary of All Known Fens on the National Forests

A. All Known Fens on the Grand Mesa, Uncompahgre, and Gunnison National Forests

This section is a discussion of all known fens on the Grand Mesa, Uncompahgre, and Gunnison National Forests, including fens identified by the 2009-2010 inventory and all other sources.

The total number of potential fen sites and fens known from the Forest is shown in Table 5-1. Some areas have been better studied than others. The fact that the Northern Plateau, Southern Plateau, and Muddy Areas are not well studied is not of great consequence, because the random-based sample shows that fens are not very likely to be found in those areas. However, the low percentages of areas and acres studied for the Elk Mountains and West Elks shows that exploration for fens remains to be done there. These are areas that have not been intensively surveyed for fens.

Table 5-1. Total number and acreage of potential fen sites relative to other land cover types by landscape area, on the Grand Mesa, Uncompahgre, and Gunnison National Forests.

Landscape Area Name	Area Acres	All PFS*		Fens		Not Fens		Not Studied		Pct. Studied		Fen Acres
		No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	
Battlement Mesa	47,291	9	61.2	1	4.9	4	8.9	4	47.5	55.6%	22.4%	0.01%
Cochetopa	294,756	42	161.0	2	42.5	5	16.6	35	101.8	16.7%	36.7%	0.01%
Cones	59,238	51	232.6	16	93.4	9	27.5	26	111.6	49.0%	52.0%	0.16%
Eastern San Juans	369,618	330	2,353.4	45	664.0	33	313.9	252	1,375.4	23.6%	41.6%	0.18%
Elk Mountains	290,781	263	1,335.4	12	62.2	21	124.1	230	1,149.1	12.5%	14.0%	0.02%
Grand Mesa	354,197	700	5,626.1	122	1,318.8	69	891.7	509	3,415.5	27.3%	39.3%	0.37%
Middle San Juans	187,861	213	831.5	70	330.4	9	50.1	134	451.0	37.1%	45.8%	0.18%
Muddy	121,468	88	353.7	2	0.9	6	21.6	80	331.1	9.1%	6.4%	0.00%
Northern Plateau	292,473	159	253.3	1	1.9	12	15.9	146	235.5	8.2%	7.0%	0.00%
Sawatch Mountains	419,742	869	4,791.8	96	1,796.2	214	1,011.1	559	1,984.5	35.7%	58.6%	0.43%
Southern Plateau	322,428	225	304.7	1	0.2	27	31.2	197	273.4	12.4%	10.3%	0.00%
West Elks	389,971	335	1,190.3	11	22.1	30	71.3	294	1,096.8	12.2%	7.9%	0.01%
	3,149,824	3,284	17,494.8	379	4,337.6	439	2,584.0	2,466	10,573.3	24.9%	39.6%	0.14%

*. Potential fen sites.

Percentages of the landscape areas that are fens, shown in the last column of Table 5-1, reflects only those fens that are currently known. The 2009-2010 inventory only sampled 8.5% of the cells containing potential fen sites on the National Forests. It is certain that most of these areas will contain more fens than Table 5-1 shows.

The percentage of acres that are known to be fens varies widely from area to area, from less than 0.001% in the Southern Plateau to at least 0.43% in the Sawatch Mountains Area (Table 5-1, Figure 5-1). Note that *all* of these percentages are less than 1%. The Forest-wide average is at least 0.14%.

The columns entitled "not studied" in Table 5-1 refer to those potential fen sites identified in the photointerpretation phase of the 2009-2010 inventory, that have not been visited to determine whether they are fens.

Fens are much more common (and have been more extensively studied) in the Sawatch Mountains and Grand Mesa Areas, and moderately common in the Eastern San Juans, Middle San Juans, and Cones areas. The West Elks and Elk Mountains have not been as well explored, so those areas may have more fens than are known at present. In all the other areas, fens are rare to very rare: Cochetopa, Battlement Mesa, and the Uncompahgre Plateau (Figure 5-1).

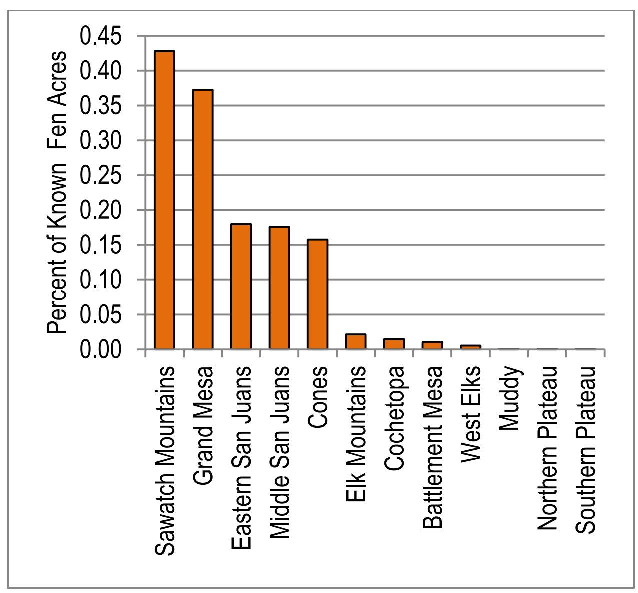


Figure 5-1. Percentage of all known fens in each landscape area.

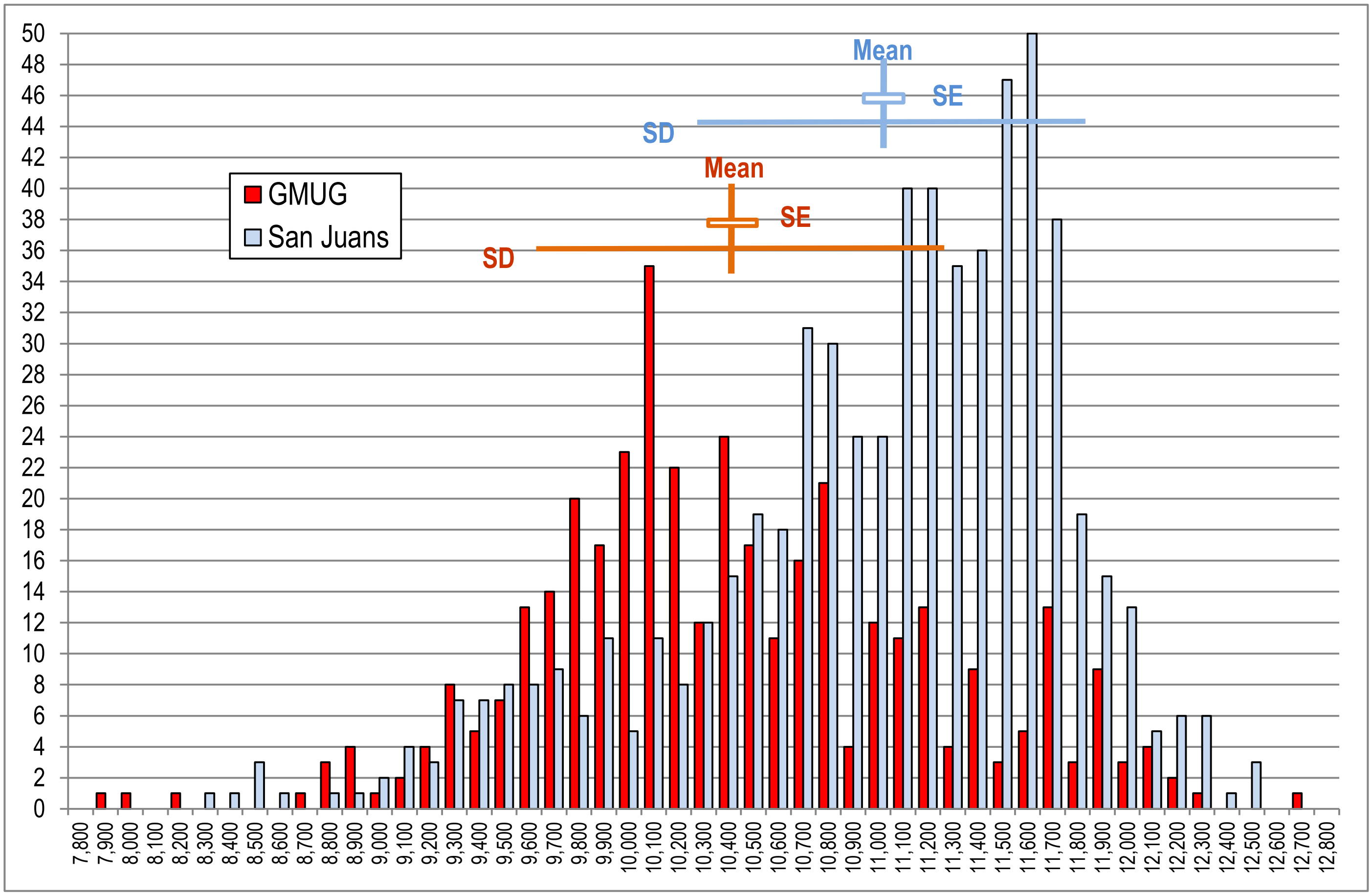


Figure 5-2. Frequency distribution of elevation for all fens known on the Grand Mesa, Uncompahgre, and Gunnison National Forests. For Grand Mesa, Uncompahgre, and Gunnison National Forests fens, mean elevation is 10,466 ft, with standard deviation 783.2 ft, and standard error 40.2 ft.
For San Juans fens, mean elevation is 11,046 ft, with standard deviation 762.6 ft, and standard error 30.5 ft.

Elevation of all known fens is shown in Figure 5-2. On this Forest, 95% of fens occur between 9,000 ft and 12,000 ft, and 82% between 9,200 ft and 11,300 ft. About three-quarters of fens occur within the standard deviation about the mean, that is, between 9,600 ft and 11,300 ft. In the San Juan mountains, elevations are significantly higher; the mean is 580 ft higher (Chimner and others 2006). To some extent this difference in average elevations can be explained by the lower latitudes in the San Juan Mountains, about 37° to 37° 30' as compared with 38° 30' to 39° in the leading fen areas on the Grand Mesa-Uncompahgre-Gunnison. This latitude difference corresponds to 400 – 500 ft elevation difference (Johnston and others 2001, after Daubenmire 1954, Gregg 1963, Cronquist and others 1972). The peaks in the two data sets probably correspond to flat landforms where fens are more likely in the different areas: the San Juan Peneplain (elevation 11,000 to 12,000 ft) for the San Juans data set, and Grand Mesa (average elevation 9,519 ft) and Taylor Park (10,658 ft) for the Grand Mesa, Uncompahgre, and Gunnison data set.

A summary of selected fen characteristics by landscape area is shown in Table 5-2.

Table 5-2. Selected characteristics by landscape area, 2009-2010 inventory. Battlement Mesa (BA) and Southern Plateau (SP) had no fens sampled as part of this inventory. Low – High

Area Code	Landscape Area Name	NF[a]	pH EC Von Post	PROBEX[b] Peat Depth	TLC[c] TLCB[d] NS[e]	BRY[f] BARE[g] SLOPE	ASPX[h] ASPY[h] Elevation	TEXI[i] TEXIB[j]	PEATFOX[k] WETPLX[m] FQI[n]	Fen Type	GULLY FREQ	HYDRO ALTER	Ground Water Diagram[o]	Fen Lithology	Hydrologic Class
CH	Cochetopa	1	6.30 70 5	35 35	207 266 5	59 0 1	11.9 19.8 10,648	8 8	95 93 6.2	Basin 1 Depression 0 Slope 0 Toeslope 0 Valley Slope 0	None 1 Low 0 Mod. 0 High 0	None 1 Low 0 Mod. 0 High 0	A 1 D 0 B 0 E 0 C 0 F 0	VOIN 1	Soligenous 0 Topogenous 1
CN	Cones	4	5.10–5.65–6.40 30–132.5–390 1–3.3–8	45–98–150 70–123.8–150	177–202–237 185–225–258 2–3.0–5	8–22.8–50 0–0.0–0 1–1.8–2	5.0–15.9–19.3 0.6–10.8–19.3 10,679–10,827–10,953	5–9.5–13 2–5.8–12	99–100–100 100–100–100 5.6–6.0–6.3	Basin 0 Depression 0 Slope 1 Toeslope 3 Valley Slope 0	None 3 Low 0 Mod. 0 High 0	None 4 Low 0 Mod. 0 High 0	A 4 D 0 B 0 E 0 C 0 F 0	SECL 4	Soligenous 4 Topogenous 0
EL	Elk Mountains	7	5.30–5.99–7.10 30–146.7–280 3–4.3–6	40–62–150 40–76.3–135	97–167–311 98–199–339 1–5.4–11	1–32.4–70 0–6.4–37 0–2.4–10	0.0–7.0–19.1 1.3–9.0–19.7 8,876–10,802–11,928	1–8.7–24 0–5.4–15	50–81–100 69–89–100 4.8–6.5–8.1	Basin 3 Depression 1 Slope 1 Toeslope 1 Valley Slope 1	None 7 Low 0 Mod. 0 High 0	None 7 Low 0 Mod. 0 High 0	A 2 D 4 B 1 E 0 C 0 F 0	PLIN 2 SECL 6	Soligenous 2 Topogenous 5
ES	Eastern San Juans	21	4.80–5.63–6.50 30–106.2–340 2–4.4–7	35–70–150 32–48.7–85	98–231–433 114–273–509 2–7.1–14	3–42.3–98 0–4.9–46 0–3.3–13	1.3–9.4–19.5 0.3–13.5–20.0 8,959–11,068–12,184	1–11.7–38 0–6.9–23	31–69–100 58–83–100 4.9–6.2–8.7	Basin 1 Depression 1 Slope 6 Toeslope 3 Valley Slope 10	None 21 Low 0 Mod. 0 High 0	None 17 Low 2 Mod. 2 High 0	A 9 D 4 B 6 E 0 C 2 F 0	UNGL 9 UNMA 9 VOIN 8 VOPY 3	Soligenous 20 Topogenous 1
GM	Grand Mesa	36	4.80–5.60–7.60 7–95.2–620 1–3.8–6	30–80–150 30–57.5–150	70–193–322 70–229–397 1–4.5–9	0–35.7–100 0–4.4–63 0–1.1–3	0.0–10.8–19.9 0.2–8.8–20.0 9,752–10,261–10,750	0–12.6–69 0–8.3–52	10–81–100 50–93–100 3.0–5.9–7.8	Basin 11 Depression 2 Slope 6 Toeslope 16 Valley Slope 1	None 30 Low 4 Mod. 1 High 1	None 20 Low 4 Mod. 9 High 3	A 10 D 6 B 11 E 6 C 2 F 0	UNGL 16 UNMA 16 VOMA 2 SECL 7	Soligenous 24 Topogenous 12
MS	Middle San Juans	16	4.00–5.49–6.90 37–223.6–652 3–4.1–6	35–50–85 40–108.5–150	97–177–381 97–222–474 1–5.0–11	0–45.1–100 0–2.8–14 0–4.3–11	0.0–10.4–19.8 0.0–9.9–20.0 9,656–10,771–11,755	0–9.9–24 0–9.1–23	23–72–100 36–81–100 5.0–6.4–7.6	Basin 2 Depression 5 Slope 1 Toeslope 1 Valley Slope 7	None 10 Low 5 Mod. 0 High 1	None 11 Low 1 Mod. 2 High 2	A 3 D 6 B 7 E 0 C 0 F 0	UNGL 2 UNMA 3 VOIN 8 SECL 3	Soligenous 9 Topogenous 7
MU	Muddy	2	5.60–5.70–5.80 24–37.6–51 4–4.5–5	40–40–40 80–95.0–110	30–65–100 30–65–100 1–1.5–2	0–0.0–0 0–0.0–0 0–0.0–0	0.1–0.1–0.1 5.0–11.6–11.6 9,487–9,492–9,496	7–13.0–19 0–0.0–0	100–100–100 100–100–100 5.0–6.3–7.6	Basin 0 Depression 2 Slope 0 Toeslope 0 Valley Slope 0	None 2 Low 0 Mod. 0 High 0	None 1 Low 1 Mod. 0 High 0	A 0 D 0 B 2 E 0 C 0 F 0	SECL 2	Soligenous 0 Topogenous 2
NP	Northern Plateau	1	6.10 45 6	40 40	100 100 1	0 0 1	12.4 0.3 8,287	13 21	100 100 5.0	Basin 1 Depression 0 Slope 0 Toeslope 0 Valley Slope 0	None 1 Low 0 Mod. 0 High 0	None 1 Low 0 Mod. 0 High 0	A 0 D 0 B 1 E 0 C 0 F 0	SECL 1	Soligenous 0 Topogenous 1
SA	Sawatch Mountains	51	4.60–5.69–8.00 20–76.8–440 2–3.8–7	30–76–150 30–59.1–150	90–259–488 100–324–587 1–8.2–16	0–65.7–100 0–2.2–48 0–3.8–13	0.0–6.8–19.6 0.0–8.6–20.0 9,352–10,724–12,007	1–11.2–33 1–9.2–34	39–77–100 44–86–100 4.9–6.7–7.8	Basin 4 Depression 0 Slope 17 Toeslope 14 Valley Slope 16	None 48 Low 3 Mod. 0 High 0	None 46 Low 1 Mod. 2 High 0	A 15 D 7 B 25 E 0 C 2 F 1	MEGN 1 UNGL 26 MEME 5 PLGR 16 VOFE 2 PLIN 8 SECA 4 SECL 2	Soligenous 47 Topogenous 4
WE	West Elks	8	4.70–5.66–6.80 20–132.2–470 1–3.1–5	40–45–65 40–80.6–150	100–176–289 100–197–342 1–4.5–8	0–21.5–87 0–12.6–54 0–2.4–15	0.1–7.4–20.0 2.3–10.3–18.2 7,927–9,831–10,640	0–12.5–26 0–9.1–20	48–81–100 64–86–100 3.7–6.0–7.9	Basin 0 Depression 4 Slope 2 Toeslope 0 Valley Slope 2	None 6 Low 1 Mod. 0 High 1	None 7 Low 0 Mod. 0 High 1	A 1 D 3 B 3 E 1 C 0 F 0	UNMA 5 PLIN 1 SECL 2	Soligenous 4 Topogenous 4

When one value is given, there is only one sample. When three values are given, they are Minimum – Average – Maximum.
a. NS – Number of fens. b. Maximum tile probe depth, cm. c. Total Live Cover of vascular plants, %.
d. Total live cover of vascular plants plus total bryophyte cover. e. Number of vascular plant species. f. Total bryophyte cover, %. g. Cover of bare soil and bare peat.
h. Aspect coordinates range 0-20; X-coordinate is the easterliness of the aspect bearing; Y-coordinate is the northerliness. i. TEXI – weighted sum of disturbance intensities in the wetland.
j. TEXIB – weighted sum of disturbance intensities in the 100 m buffer. k. Percent peat-forming plants (see Appendix F). m. Percent wetland plants (see Appendix F).
n. FQI – Floristic Quality Index (see Appendix F). o. Ground water pattern, see diagrams in Appendix C (Fetter 2001). p. General Fen Landform and Lithology. See Table 4-17 for codes.

Lithology by landscape area is shown in Figure 5-3 and Table 5-3. The unconsolidated glacial drift class is prominent in the Sawatch Mountains, Grand Mesa, and Eastern San Juans Areas.

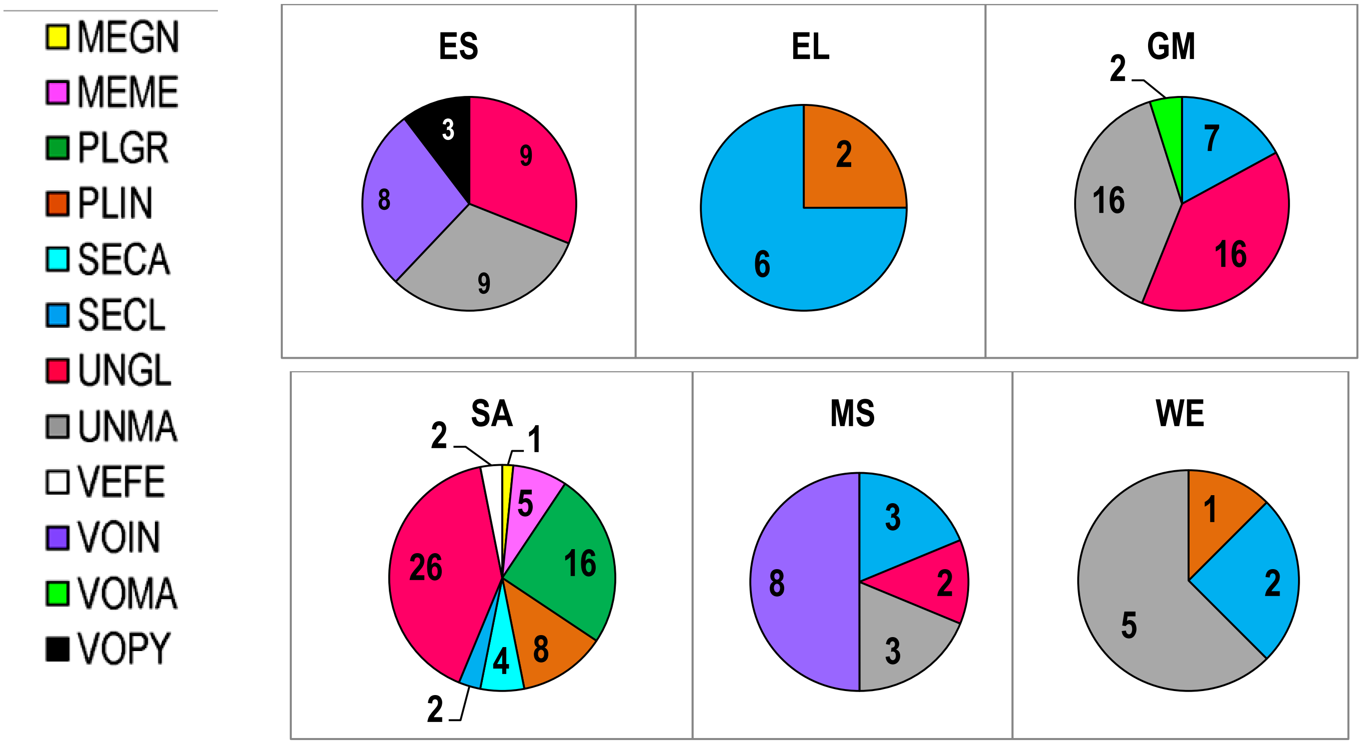


Figure 5-3. Lithology by landscape area. Labels are number of fens. BA, NP, SP have no fens. CH has one (VOIN), CN has four (SECL), and MU has two (SECL). Data in Table 4-4.

Table 5-3. Lithology class by landscape area.

Lithology		CH		CN		ES		EL		GM		MS		MU		SA		WE	
Code	Class	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres
MEGN	Metamorphic Gneiss															1	2.4		
MEME	Metamorphic Metavolcanic															5	21.0		
PLGR	Plutonic Granitic															16	71.2		
PLIN	Plutonic Intermediate							2	7.3							8	23.4	1	0.8
SECA	Sedimentary Carbonate															4	6.8		
SECL	Sedimentary Clastic			4	11.5			6	23.9	7	69.6	3	5.3	2	0.9	2	6.4	2	3.4
UNGL	Unconsolidated Glacial Drift					9	68.3			16	207.1	2	8.6			26	683.5		
UNMA	Unconsolidated Mass Wasting					9	94.5			16	186.8	3	3.7					5	11.4
VEFE	Volcanic Felsite															2	3.8		
VOIN	Volcanic Intermediate	1	0.4			8	53.1					8	13.1						
VOMA	Volcanic Mafic									2	19.6								
VOPY	Volcanic Pyroclastic					3	10.4												

Acreage of all fens known from the Grand Mesa, Uncompahgre, and Gunnison National Forests is shown in Figure 5-4 on the next page. Half of the fens are less than 3½ acres, and about 25% of the fens are less than one acre. Data from the San Juan Mountains (Chimner and others 2006) indicates a similar pattern, with smaller acreages.

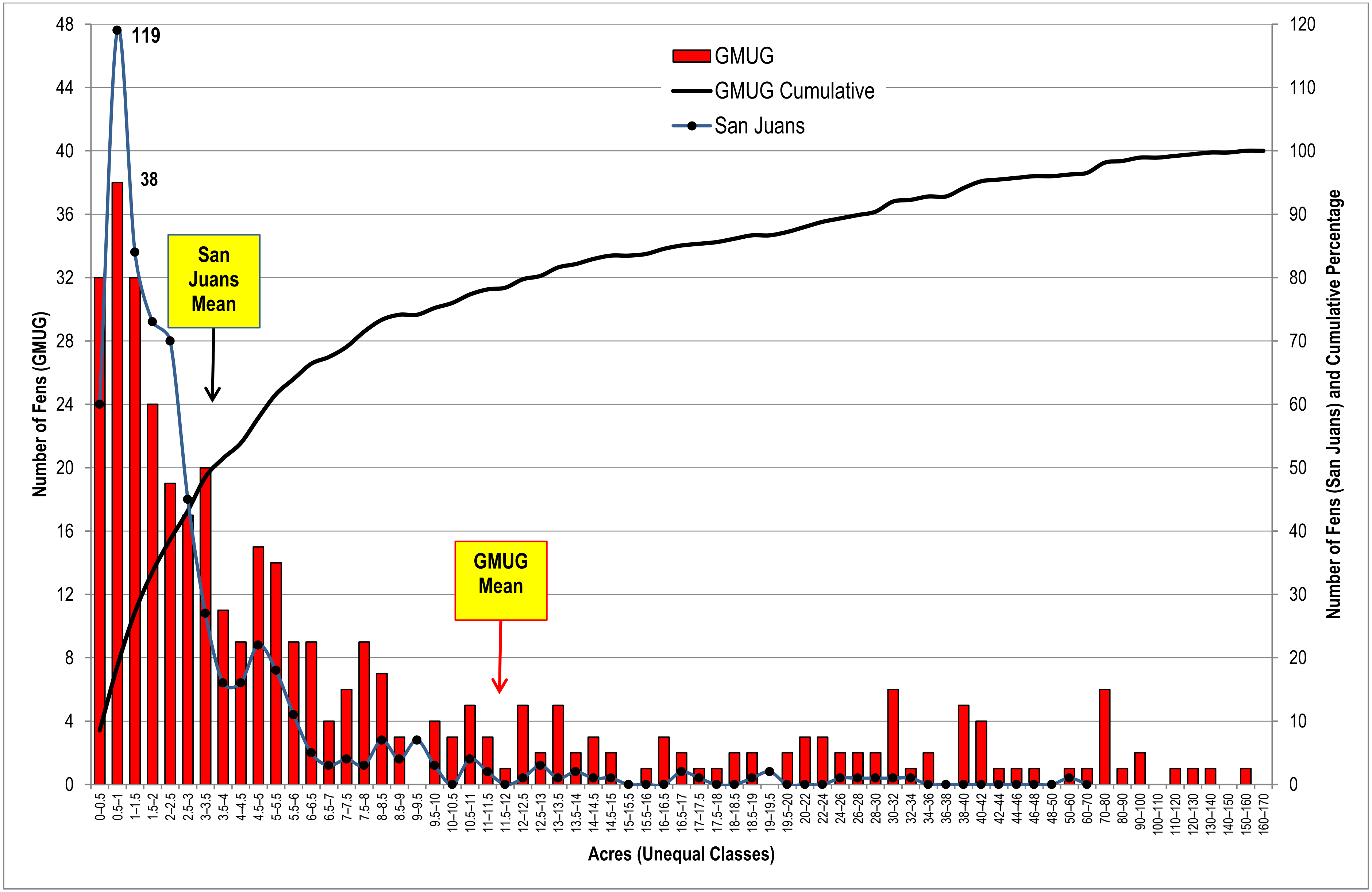


Figure 5-4. Acreages of all fens documented on the Grand Mesa, Uncompahgre, and Gunnison National Forests. Note unequal classes on the horizontal axis. (Bathke 2000-2001-2003, Lemly 2007, Austin 2008, Austin 2009). San Juan fen data from Chimner and others 2006.

B. Summary by Landscape Area

1. Summary for Sawatch Mountains Area (SA)

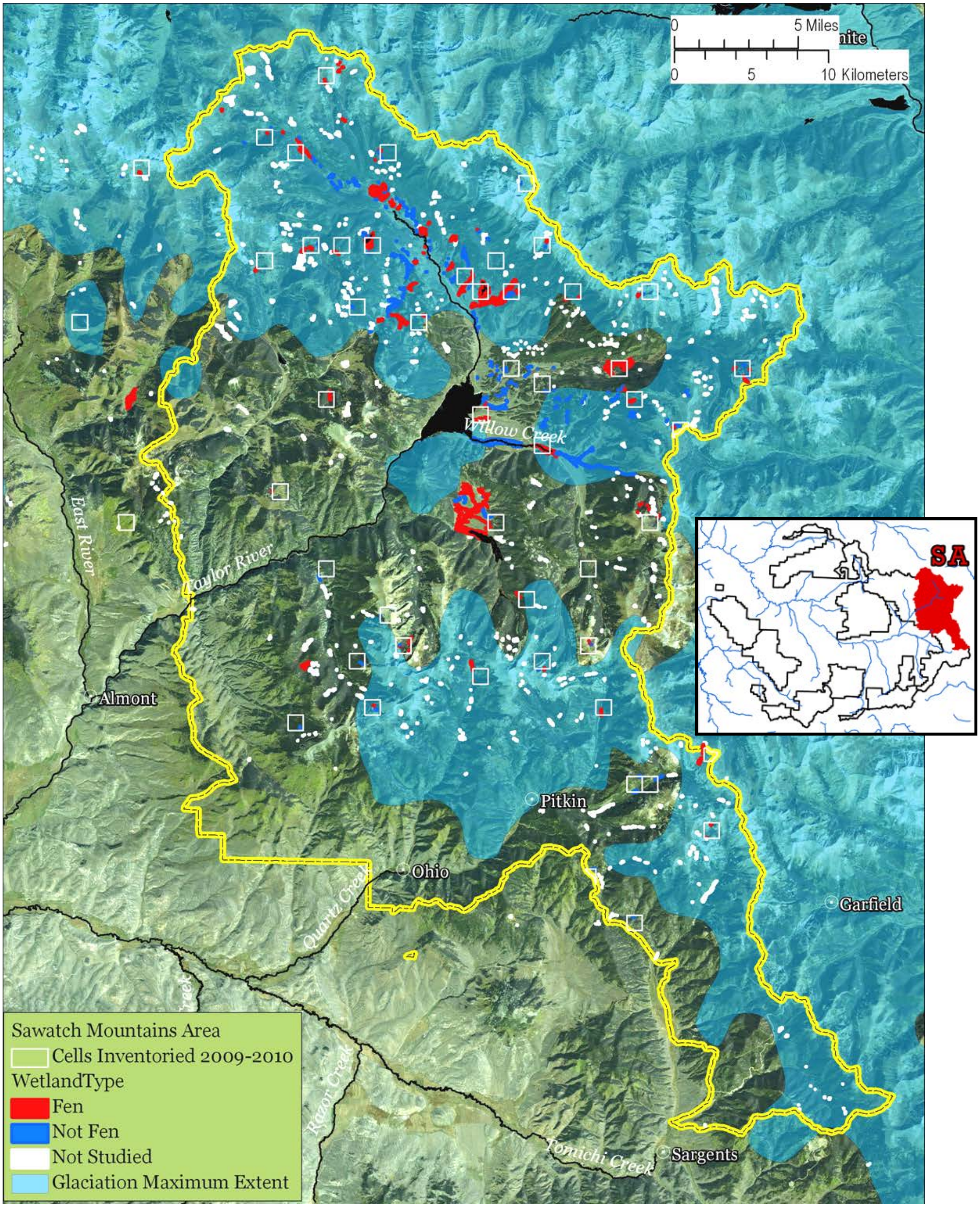


Figure 5-5. The Sawatch Mountains Area (SA). Inset shows area SA in relation to the rest of the Grand Mesa, Uncompahgre, and Gunnison National Forests.

The Sawatch Mountains Area is almost 420,000 acres and comprises the upper portions of the Taylor River, Quartz Creek, and Tomichi Creek watersheds (Figure 5-5). Figure 5-5 also shows fens inventoried by David Bathke in 2000-2003 (Bathke 2000-2001-2003) and ongoing fen inventories by Gay Austin, Paula Lehr, and several others. The Sawatch Mountains Area has the highest density of wetlands and fens on the National Forests. Based on the inventory results there are approximately 596 (± 167) fens within this area (Table 4-2). The wetlands and fens in this area sometimes are larger and more linear in shape than in other areas.

The Sawatch Mountains area is mainly Precambrian granite and gneiss; much of this area is glaciated (Matthews and others 2003). Over three-quarters of the fen acres are on Unconsolidated Glacial Drift, with less than one-tenth of the fen acres on Plutonic Granitic lithologies (Figure 5-3, Table 5-3). Fen landforms are dominated (92%) by soligenous types on slopes, toeslopes, and valley slopes (Table 5-2).

Electrical conductivity of water in the pit is on average lower in this area, as compared with most other areas, and the Muddy area is lowest. Ground water diagrams A and B dominate (ground water input, stream or ground water output). Most disturbances are related to animals: browsing, grazing, trampling, beaver activity (Figure 4-37). Condition scores range moderate to high (20 – 36), with an average of high (30.5); 70% of sites are rated high (27 – 36).

Fen vegetation is the most diverse on the Forest, with every large cluster represented. General vegetation types for this area are shown in Table 5-4. There are a lot more shrub-dominated fens in the Sawatch Mountains area than in other areas. Cluster V – Bog birch-planeleaf willow is only found in this area on these National Forests (Appendix J). Proportion of peat-forming plants averages low in this area. Fens dominated by planeleaf willow and other short willows are especially common in the Sawatch Mountains Area (Appendix J).

Table 5-4. General fen vegetation types in the Sawatch Mountains Area. (*n* = 53)

Cluster Name	No. Samples	Acres	Elevation	Bryophyte Cover
I. Tall willows-large sedges	1	47.7	9,644	0
II. Planeleaf willow–water sedge–beaked sedge, BRY < 60, usually < 30	5	62.8	9,814–10,477–11,068	0
III. Planeleaf willow–water sedge–beaked sedge, BRY > 60, often > 80	9	271.3	9,683–10,325–11,359	0–167–250
IV. Planeleaf willow–short sedges or spike-rushes, BRY > 50	12	72.8	9,381–11,049–12,009	0–7–40
V. Bog birch–planeleaf willow	6	225.3	9,368–9,996–10,777	0–67–101
VI. Barrenground willow	1	9.6	10,540	0
VII. Beaked sedge–water sedge, BRY < 25, often < 10	3	12.5	9,724–10,120–10,826	0
VIII. Beaked sedge–water sedge, BRY > 35, often > 50	2	0.5	10,487–11,241–11,994	0
IX. Short sedges	8	108.5	9,352–11,067–11,847	0–19–155
X. Spike-rushes	6	12.5	11,181–11,512–11,760	0–90–90
	53	823.5		

2. Summary for Grand Mesa (GM)

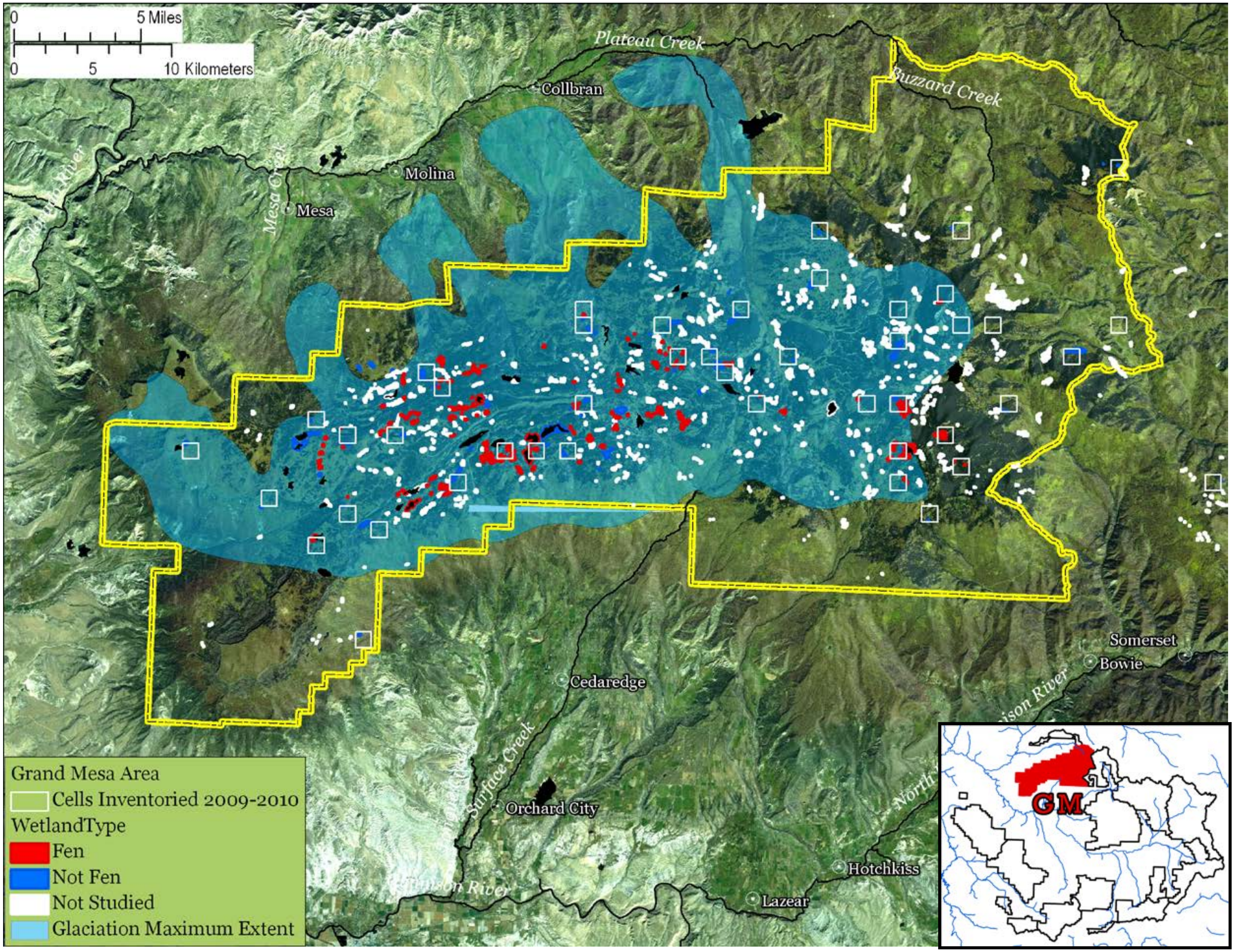


Figure 5-6. The Grand Mesa Area (GM). Inset shows area GM in relation to the rest of the Grand Mesa, Uncompahgre, and Gunnison National Forests.

Grand Mesa comprises over 350,000 acres, parts of the upper portions of Plateau Creek, Muddy Creek, Kannah Creek, and Surface Creek watersheds (Figure 5-6). Figure 5-6 also shows fens inventoried by Gay Austin from 2002 to present (Austin 2008) and ongoing fen inventories by WestWater Engineering and several others.

The Grand Mesa area has the second highest density of wetlands and fens on the National Forests. The northeast part of this area has few fens; yet the Grand Mesa landform has many fens, especially the area shown as glaciated in Figure 5-6. Based on the inventory results there are approximately 426 (± 213) fens within this area (Table 4-2). The wetlands and fens in this area are usually rounder in shape than in the Sawatch Mountains Area.

Grand Mesa is made of Tertiary basalt layers that have been uplifted. When these surfaces were uplifted the sides were subject to much slumping, which created many holes and crevices where water collected and peat accumulated (Yeend 1969, Austin 2008). Much of the Grand Mesa was subsequently glaciated (Yeend 1969). Over three-quarters of the fen acres are on Unconsolidated Glacial Drift or Unconsolidated Mass Wasting, with perhaps one-fifth of the fen acres on Sedimentary Clastic lithologies (Figure 5-3). Fen landforms are two-thirds soligenous and one-third topogenous types, a higher percentage of topogenous (basins and depressions) than elsewhere on the National Forests (Table 5-2).

Disturbances in fens on the Grand Mesa tend to be related to water development, for example flooding, de-watering, ditches, and soil removal (Figure 4-37). There are also disturbances from animals, such as browsing, grazing, and trampling. Condition ratings widely range from low to high (10 – 36), averaging moderate (25.8); about half are high, 10% low, and 35% moderate condition.

Herbaceous fen vegetation types are much more common on the Grand Mesa than elsewhere on the National Forests, and shrub-dominated fens much less likely (Table 5-5, Appendix J). Fens with significant bryophyte cover are common, and there is a large variety of different dominant sedge species.

Table 5-5. General fen vegetation types in the Grand Mesa Area. (*n* = 346)

Cluster Name	No. Samples	Acres	Elevation	Bryophyte Cover
I. Tall willows-large sedges	1	29.5	9,652	11
II. Planeleaf willow–water sedge–beaked sedge, BRY < 60, usually < 30	23	153.8	9,678–10,358–10,855	0–57–71
III. Planeleaf willow–water sedge–beaked sedge, BRY > 60, often > 80	3	19.0	10,282–10,642–10,833	76–81–91
VII. Beaked sedge–water sedge, BRY < 25, often < 10	97	1,067.1	9,652–10,341–10,869	0–12–21
VIII. Beaked sedge–water sedge, BRY > 35, often > 50	27	246.1	9,994–10,417–10,864	0–98–101
IX. Short sedges	145	1,731.6	9,912–10,382–10,869	0–98–106
X. Spike-rushes	29	798.1	9,913–10,282–10,867	0–78–102
XI. Semi-Aquatic	21	145.7	10,015–10,450–10,869	0–1–2
	346	4,190.9		

3. Summary for Eastern San Juan Mountains Area (ES)

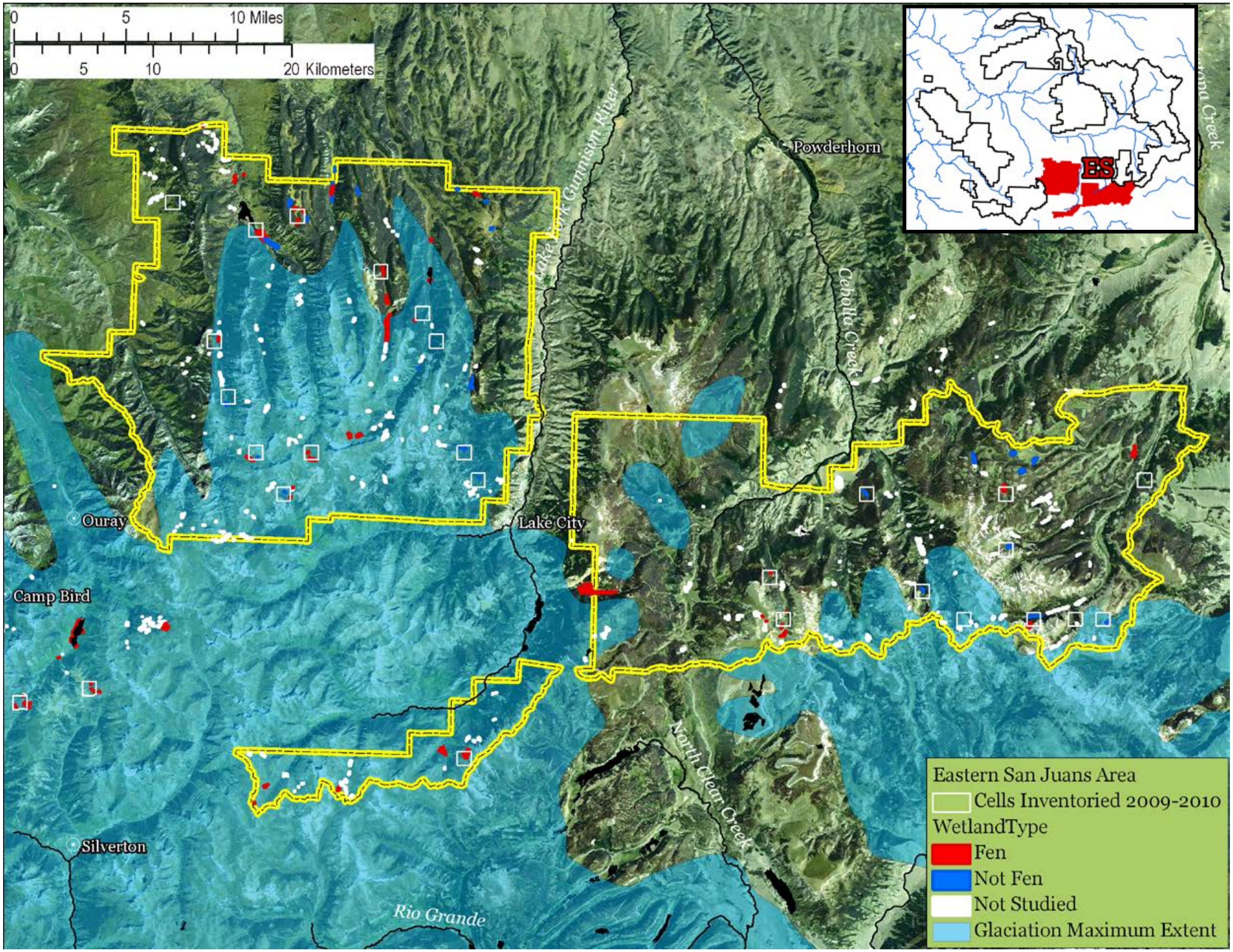


Figure 5-7. The Eastern San Juan Mountains Area (ES). Inset shows area ES in relation to the rest of the Grand Mesa, Uncompahgre, and Gunnison National Forests.

The Eastern San Juan Mountains area comprises almost 370,000 acres, parts of the upper portions of the Rock Creek, Cochetopa Creek, Cimarron River, Lake Fork of the Gunnison River, and Cow Creek watersheds (Figure 5-7). Figure 5-7 also shows fens inventoried by Gay Austin and several others. One-quarter (25%) of the potential fen sites have been studied (Table 5-1). Based on the inventory results there are approximately 248 (± 117) fens within this area (Table 4-2).

The Eastern San Juan Mountains Area is almost all Tertiary volcanic rocks. Much of this area has been glaciated. About three-quarters of the fen acres are on Unconsolidated Glacial Drift or Unconsolidated Mass Wasting, with perhaps one-quarter of the fen acres on Volcanic Intermediate lithologies (Table 5-3, Figure 5-3). Fen landforms are 90% soligenous type (Table 5-2).

Most of the disturbances in this area are animal-related: browsing, grazing, and trampling; there are also significant other disturbances, such as trails, erosion, and sediment deposition (Figure 4-37). Condition classes range from moderate to high (21 – 36), averaging high (28.9); about three-quarters of sites are rated high. A wide variety of fen vegetation types is found in this area, with shrub-dominated fen vegetation more common than areas to the north. General vegetation types for this area are shown in Table 5-6.

Table 5-6. General fen vegetation types in the Eastern San Juan Mountains Area. (*n* = 21)

Cluster Name	No. Samples	Acres	Elevation	Bryophyte Cover
I. Tall willows-large sedges	2	65.0	8,959–8,972–8,984	0–5–10
II. Planeleaf willow–water sedge–beaked sedge, BRY < 60, usually < 30	4	37.8	10,211–11,017–11,735	0–20–20
III. Planeleaf willow–water sedge–beaked sedge, BRY > 60, often > 80	1	3.9	11,970	0
IV. Planeleaf willow–short sedges or spike-rushes, BRY > 50	2	12.1	11,059–11,618–12,177	71–90–90
VI. Barrenground willow	1	3.1	11,257	0
VII. Beaked sedge–water sedge, BRY < 25, often < 10	3	7.5	9,443–10,747–11,740	0–20–20
VIII. Beaked sedge–water sedge, BRY > 35, often > 50	4	29.6	11,081–11,615–12,031	0–90–90
IX. Short sedges	4	67.2	10,184–11,313–11,993	0–73–97
	21	226.2		

4. Summary for Middle San Juan Mountains Area (MS)

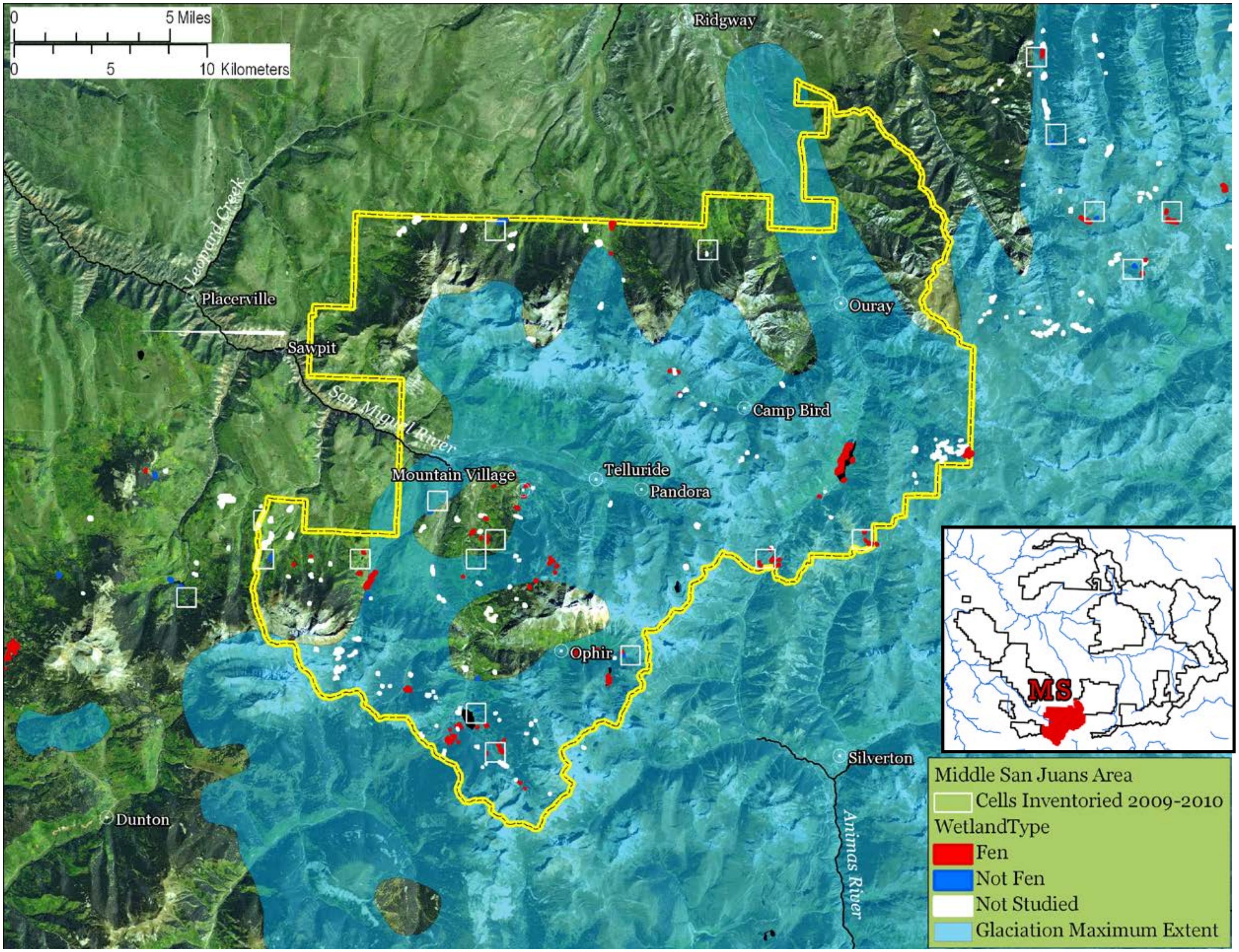


Figure 5-8. The Middle San Juans Area(MS). Inset shows area MS in relation to the rest of the Grand Mesa, Uncompahgre, and Gunnison National Forests..

The Middle San Juan Mountains area comprises almost 188,000 acres, parts of the upper portions of the Uncompahgre River, Rio San Miguel, Fall Creek, Alder Creek, and Dallas Creek watersheds (Figure 5-8). The Middle San Juan Area has been explored for fens. An extensive survey of fens for restoration was conducted in this area (Chimner and others 2008). Over a third (37. 1%) of the potential fen sites in this area have been studied (Table 5-1). Based on the inventory results there are approximately 193 (± 129) fens in this area (Table 4-2).

Electrical conductivity of water in the pit averages higher in this area than any other on this Forest (Table 5-2). The eastern and southeastern portion of this area is formed of Tertiary volcanic rocks, yet the central portion is highly varied, and the eastern and northeastern parts have Tertiary sedimentary rocks. Almost all of this area has been glaciated. About 40% of the fen acres are on Unconsolidated Mass Wasting and Unconsolidated Glacial Drift lithology, yet almost half is on Volcanic Intermediate (Table 5-3). Fen landforms are about equally divided between soligenous and topogenous types (Table 5-2).

Browsing and beaver activity account for most of the disturbances observed in this area, however human disturbances are also significant, such as erosion, roads, and trails (Figure 4-37). Condition ratings range from moderate to high (21 – 36), averaging high (28.4); about 70% of sites are rated high condition.

A wide variety of fen vegetation types is found in this area, with shrub-dominated fen vegetation fairly common. General vegetation types for this area are shown in Table 5-7. One of these fens is dominated by alpine vegetation, not included in the classification (community type O1 in Appendix G). Total live cover and percent peat-forming plants average relatively low in this area (Table 5-2).

Table 5-7. General fen vegetation types in the Middle San Juan Mountains Area. (*n* = 71)

Cluster Name	No. Samples	Acres	Elevation	Bryophyte Cover
I. Tall willows-large sedges	6	26.9	9,181–9,698–10,570	0–70–70
II. Planeleaf willow–water sedge–beaked sedge, BRY < 60, usually < 30	6	71.5	9,237–10,024–10,574	12–48–70
III. Planeleaf willow–water sedge–beaked sedge, BRY > 60, often > 80	18	76.3	9,181–10,595–11,735	0–85–130
V. Bog birch–planeleaf willow	2	9.6	9,693–9,764–9,834	60–85–85
VI. Barrenground willow	1	2.4	9,656	100
VII. Beaked sedge–water sedge, BRY < 25, often < 10	10	36.3	9,877–10,499–11,289	0–7–20
VIII. Beaked sedge–water sedge, BRY > 35, often > 50	13	80.3	10,031–10,977–11,755	10–74–108
IX. Short sedges	14	27.9	9,419–11,075–11,626	0–91–120
X. Spike-rushes	1	25.0	11,735	91
	71	356.2		

5. Summary for West Elks (WE)

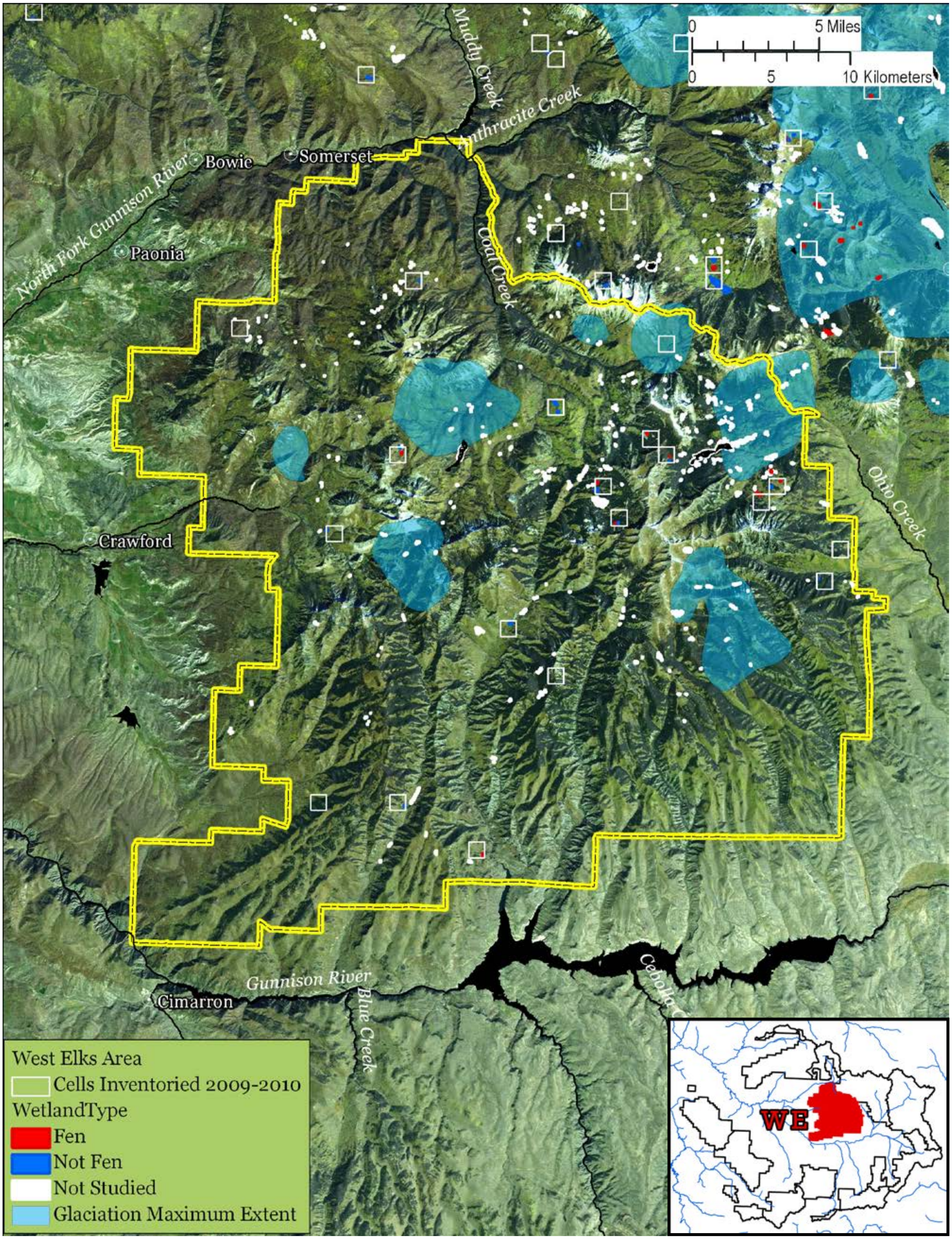


Figure 5-9. The West Elks Area (WE). Inset shows area WE in relation to the rest of the Grand Mesa, Uncompahgre, and Gunnison National Forests.

The West Elks Area comprises almost 390,000 acres, parts of the upper portions of the Coal Creek, Soap Creek, Smith Fork, and Minnesota Creek watersheds (Figure 5-9). Based on the inventory results there are approximately 102 (± 63) fens in the West Elks Area (Table 4-2).

The West Elk Mountains are almost all Tertiary volcanic rocks. The West Elks had a number of smaller glaciers (Figure 5-9, Matthews and others 2003). Most of the fens were on Unconsolidated Mass Wasting lithology (Table 5-3). Fen landforms are about equally divided between soligenous and topogenous types (Table 5-2).

Most of the disturbances to fens in this area are animal-related: browsing grazing, and beaver activity (Figure 4-37). Condition ratings range from moderate to high (23 – 36), averaging high (29.6); over 85% of the fen sites are rated high.

A variety of fen vegetation types is found, with shrub-dominated fen vegetation fairly common. General vegetation types are shown in Table 5-8. Total live cover averages relatively low in these areas (Table 5-2).

Table 5-8. General fen vegetation types in the West Elks Area. (n = 8)

Cluster Name	No. Samples	Acres	Elevation	Bryophyte Cover
I. Tall willows-large sedges	1	2.6	10,190	0
II. Planeleaf willow–water sedge–beaked sedge, BRY < 60, usually < 30	1	4.3	9,915	0
VII. Beaked sedge–water sedge, BRY < 25, often < 10	1	1.8	9,358	0
VIII. Beaked sedge–water sedge, BRY > 35, often > 50	1	3.3	7,926	90
IX. Short sedges	3	2.8	10,033–10,205–10,548	0–23–70
X. Spike-rushes	1	0.8	10,640	0
	8	15.6		

6. Summary for Elk Mountains (EL)

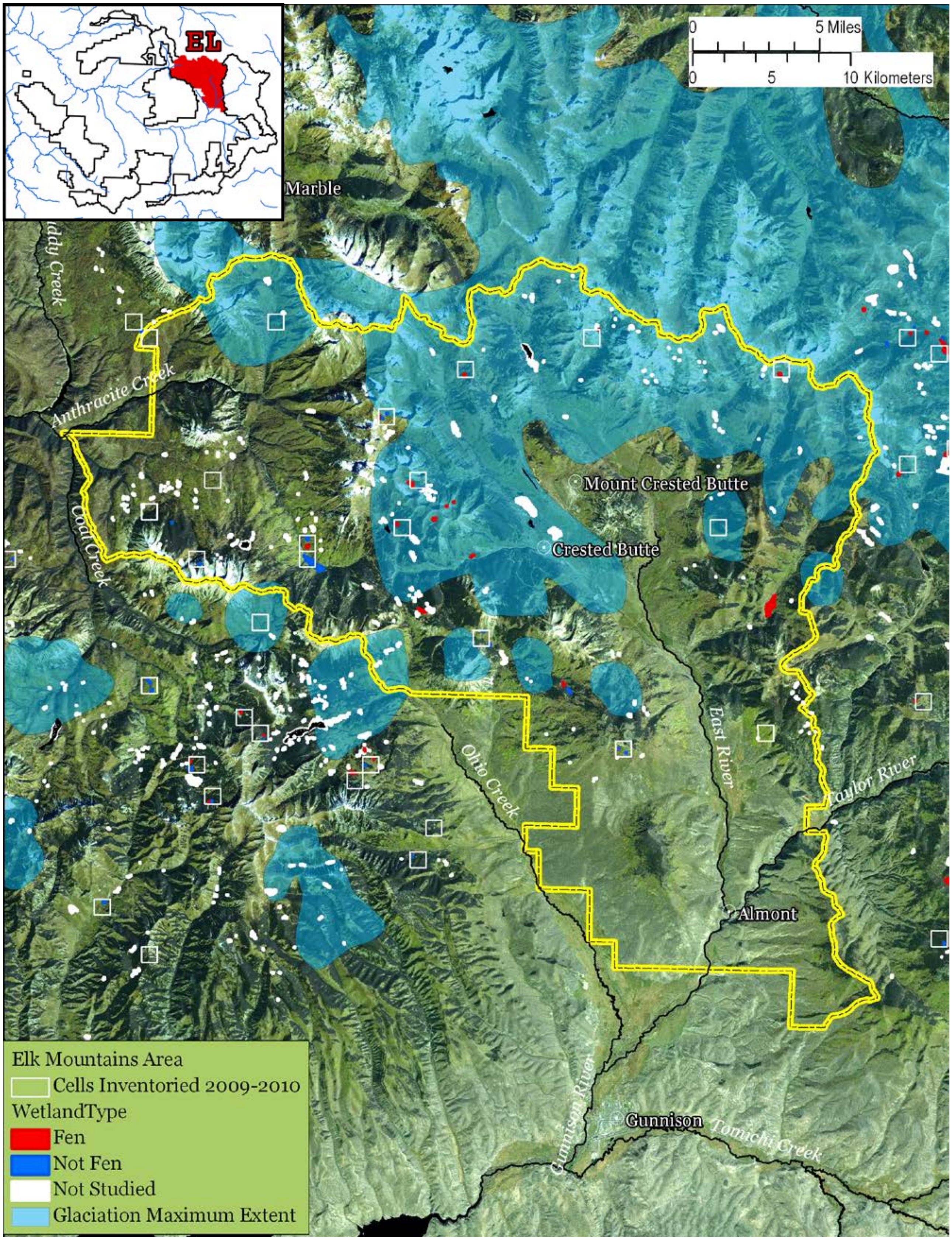


Figure 5-10. The Elk Mountains Area (EL). Inset shows area EL in relation to the rest of the Grand Mesa, Uncompahgre, and Gunnison National Forests.

The Elk Mountains area comprises over 290,000 acres, parts of the upper portions of the Slate River, Ohio Creek, and Coal Creek watersheds (Figure 5-10). Based on the inventory results there are approximately 82 (± 47) fens in the Elk Mountains Areas (Table 4-2).

The Elk Mountains are geologically varied, with Cretaceous sedimentary rocks prominent at high elevations. Most of the Elk Mountains have been glaciated by large glaciers, especially in the eastern part (Matthews and others 2003), and most of the fens were on Unconsolidated Mass Wasting lithology (Table 5-3). Fen landforms are about equally divided between soligenous and topogenous types (Table 5-2).

Most of the fen disturbances in this area are animal-related: browsing, grazing, and trampling (Figure 4-37). Condition scores range from moderate to high (22 – 36), averaging high (29.4); over half the fen sites are rated high.

A variety of fen vegetation types exists, with shrub-dominated fen vegetation fairly common. General vegetation types are shown in Table 5-9.

Table 5-9. General fen vegetation types in the Elk Mountains Area. (*n* = 9)

Cluster Name	No. Samples	Acres	Elevation	Bryophyte Cover
II. Planeleaf willow–water sedge–beaked sedge, BRY < 60, usually < 30	2	5.4	10,591–10,611–10,631	0
IV. Planeleaf willow–short sedges or spike-rushes, BRY > 50	1	10.1	11,034	50
VII. Beaked sedge–water sedge, BRY < 25, often < 10	2	6.7	8,877–10,125–11,373	0–1–1
VIII. Beaked sedge–water sedge, BRY > 35, often > 50	2	7.2	11,217–11,573–11,928	50
IX. Short sedges	1	3.0	9,552	60
X. Spike-rushes	1	2.7	11,180	20
	9	35.1		

7. Summary for Cones Area (CN)

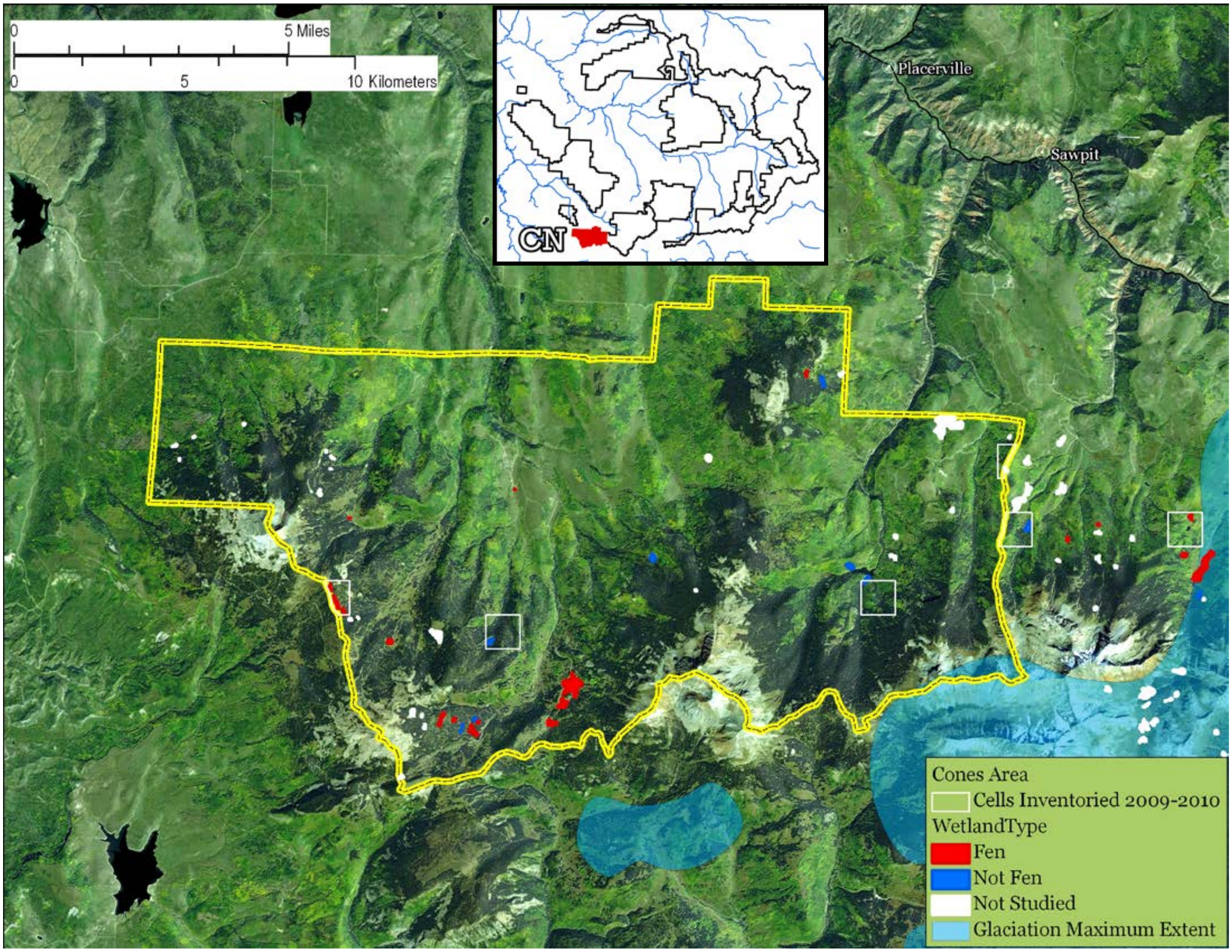


Figure 5-11. The Cones Area(CN). Inset shows area CN in relation to the rest of the Grand Mesa, Uncompahgre, and Gunnison National Forests.

The Cones area comprises almost 60,000 acres, parts of the upper portions of the Beaver Creek and Fall Creek watersheds (Figure 5-11). The Cones area has been somewhat explored for fens; an extensive survey of fens for restoration was conducted in the southern portion (Chimner and others 2008). About one half (49%) of the potential fen sites in this area have been studied (Table 5-1). Based on the inventory results there are approximately 42 (± 57) fens in this area (Table 4-2).

Almost all of the area is on Tertiary sedimentary rocks. None of the area has been glaciated. All of the fens are on Sedimentary Clastic lithology (Table 5-3), and are all soligenous type (Table 5-2).

Disturbances in the fens were all animal-related: browsing, grazing, trampling (Figure 4-37). Condition scores were high (32 – 36) for all four fens investigated. General vegetation types are shown in Table 5-10.

Table 5-10. General fen vegetation types in the Cones Area. (*n* = 6)

Cluster Name	No. Samples	Acres	Elevation	Bryophyte Cover
II. Planeleaf willow–water sedge–beaked sedge, BRY < 60, usually < 30	2	1.8	8,962–9,820–10,678	50–80–80
IV. Planeleaf willow–short sedges or spike-rushes, BRY > 50	1	2.5	10,952	0
VIII. Beaked sedge–water sedge, BRY > 35, often > 50	1	0.2	10,343	77
IX. Short sedges	2	7.4	10,804–10,838–10,871	0
	6	11.9		

8. Summary for Muddy Area (MU)

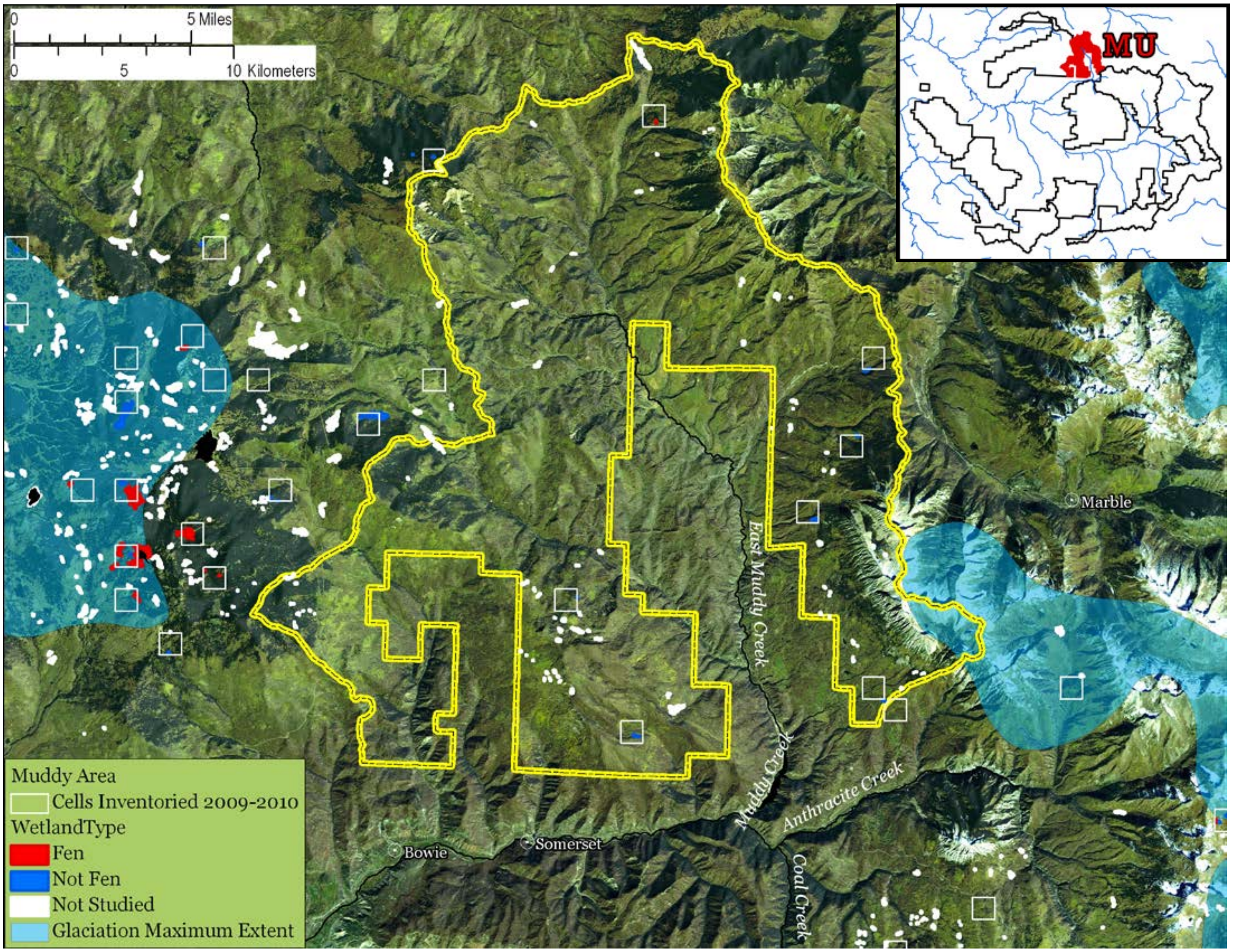


Figure 5-12. The Muddy Area(MU). Inset shows area MU in relation to the rest of the Grand Mesa, Uncompahgre, and Gunnison National Forests.

The Muddy area comprises about 121,000 acres, parts of the upper portions of East and West Muddy Creek and Hubbard Creek watersheds (Figure 5-12). A few more fens may be found in this area. Based on the inventory results there are approximately 23 (± 44) fens in this area (Table 4-2).

Almost all of this area is on Tertiary sedimentary rocks. None of this area has been glaciated. Both of the fens are on Sedimentary Clastic lithology (Table 5-3) and are all topogenous type (Table 5-2).

Disturbances in the two fens investigated in this area were all animal-related: browsing and grazing. Condition scores were both high (32 – 36). The one vegetation type sampled is shown in Table 5-11.

Table 5-11. General vegetation types in the Muddy Area. (n = 2)

Cluster Name	No. Samples	Acres	Elevation	Bryophyte Cover
VII. Beaked sedge–water sedge, BRY < 25, often < 10	2	0.9	9,487–9,492–9,496	0

9. Summary for Northern Plateau (NP)

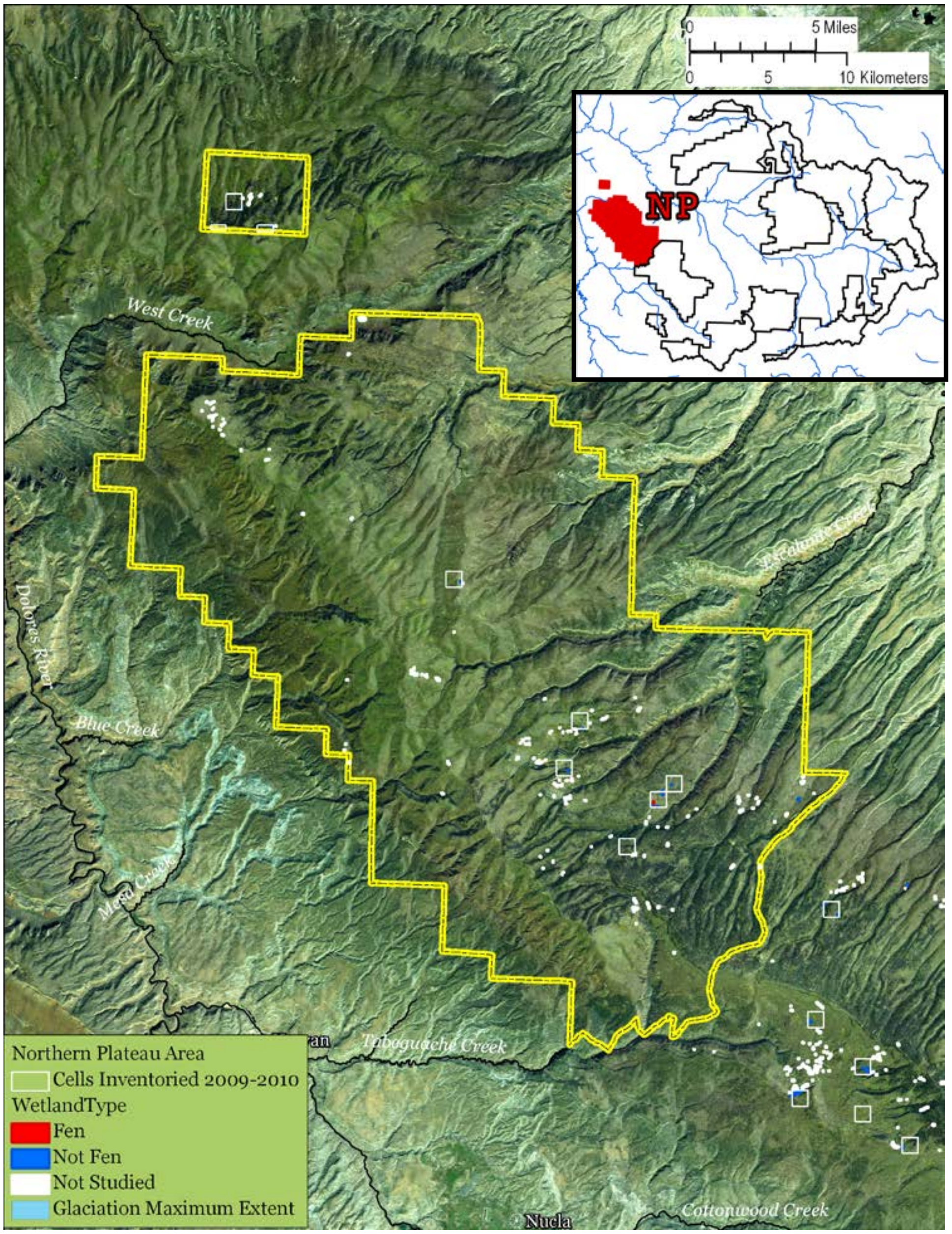


Figure 5-13. The Northern Plateau Area (NP). Inset shows area NP in relation to the rest of the Grand Mesa, Uncompahgre, and Gunnison National Forests.

The Northern Plateau area comprises over 292,000 acres, with several creeks draining northeast into the Uncompahgre and Gunnison Rivers, and several creeks draining southwest into the Rio San Miguel and Rio Dolores (Figure 5-13). A few more fens will be found on the plateau. Based on the inventory results there are approximately 12 (± 23) fens in the Northern Plateau (Table 4-2).

Jurassic sedimentary rocks are prominent in the southern part of this area, and Triassic sedimentary rocks in the northern two-thirds. None of the area has been glaciated. The fen is on Sedimentary Clastic lithology (Table 5-3), of topogenous type (Table 5-2). The one fen investigated had been disturbed by browsing, and rated high (32). The one vegetation type is shown in Table 5-12.

Table 5-12. General fen vegetation types in the Northern Plateau Area. (*n* = 1)

Cluster Name	No. Samples	Acres	Elevation	Bryophyte Cover
VII. Beaked sedge–water sedge, BRY < 25, often < 10	1	1.9	8,288	0

10. Summary for Cochetopa Area (CH)

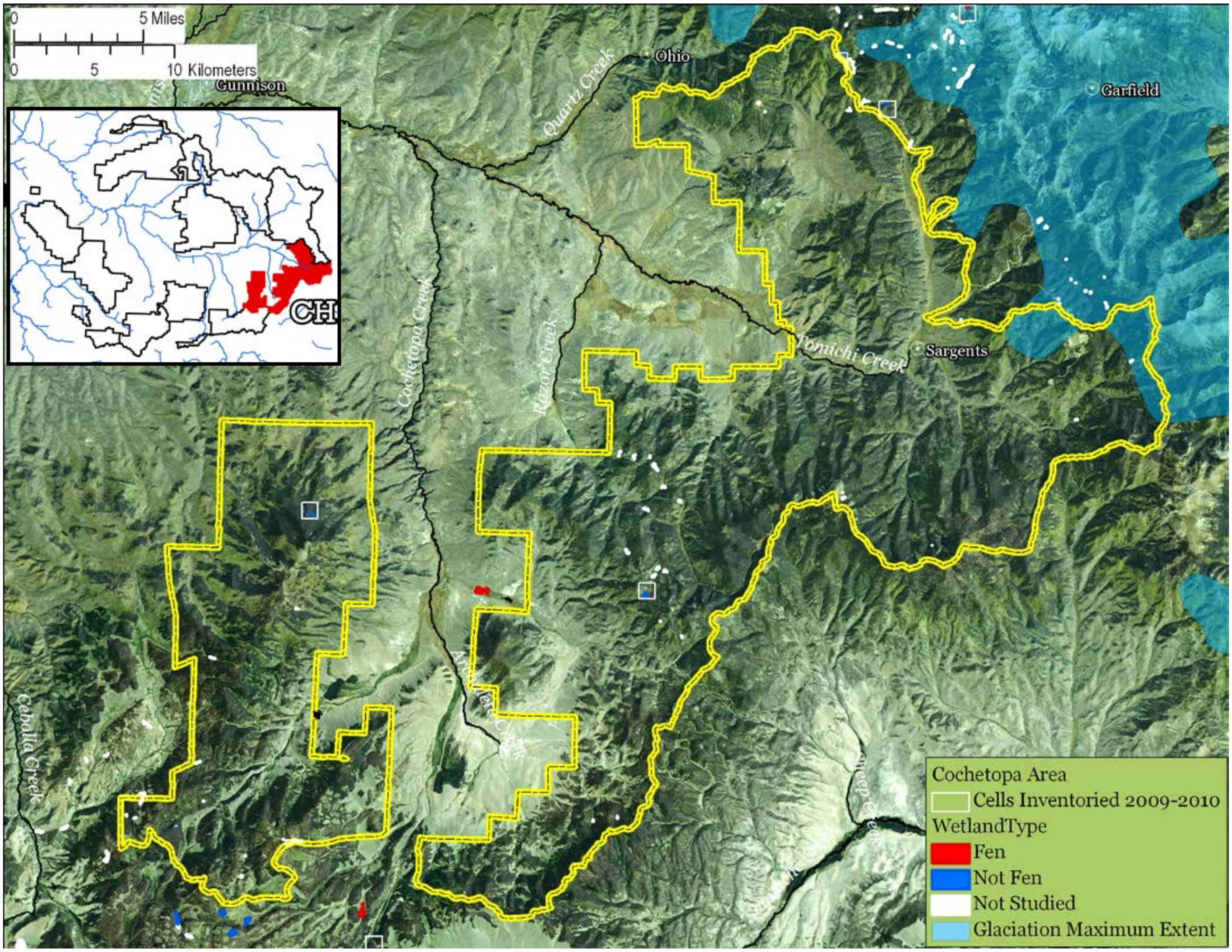


Figure 5-14. The Cochetopa Area (CH). Inset shows area CH in relation to the rest of the Grand Mesa, Uncompahgre, and Gunnison National Forests.

The Cochetopa area comprises almost 295,000 acres, with upper portions of the Tomichi Creek, Razor Creek, West Pass Creek, Los Pinos Creek, and West Beaver Creek watersheds (Figure 5-14). Based on the inventory results there are approximately 13 (± 25) fens in this area (Table 4-2).

The Cochetopa area is almost all Tertiary volcanic rocks, and very little of this area has been glaciated. The fen is on Volcanic Intermediate lithology (Table 5-3), of topogenous type (Table 5-2).

The one fen found in this area had been disturbed by browsing and trampling, and rated high (36). The one vegetation type sampled in this area is shown in Table 5-13.

Table 5-13. General fen vegetation types in the Cochetopa Area. (*n* = 1)

Cluster Name	No. Samples	Acres	Elevation	Bryophyte Cover
II. Planeleaf willow–water sedge–beaked sedge, BRY < 60, usually < 30	1	0.4	10,647	0

11. Summary for Battlement Mesa (BA)

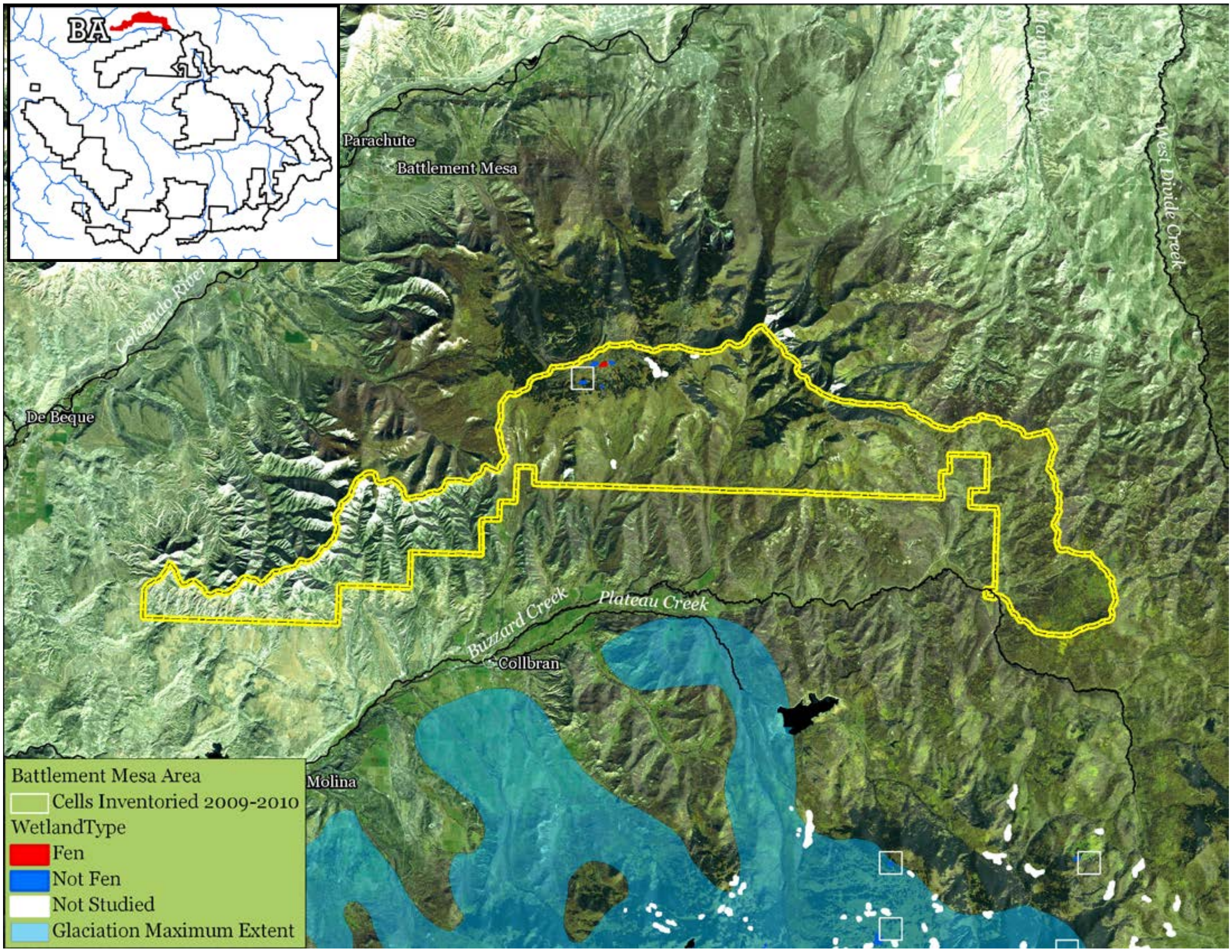


Figure 5-15. The Battlement Mesa Area (BA). Inset shows area BA in relation to the rest of the Grand Mesa, Uncompahgre, and Gunnison National Forests.

The Battlement Mesa area comprises over 47,000 acres, parts of the upper portions of Plateau Creek watershed (Figure 5-15). There has been little exploration for fens in this area; few fens will be found here in the future. Battlement Mesa is made of Tertiary sedimentary layers that have been uplifted.

The one fen inventoried had been disturbed by grazing and trails, and rated high (34). The one vegetation type sampled is shown in Table 5-14.

Table 5-14. General fen vegetation types for the Battlement Mesa Area. (*n* = 1)

Cluster Name	No. Samples	Acres	Elevation	Bryophyte Cover
VII. Beaked sedge–water sedge, BRY < 25, often < 10	1	4.9	10,478	0

12. Summary for Southern Plateau (SP)

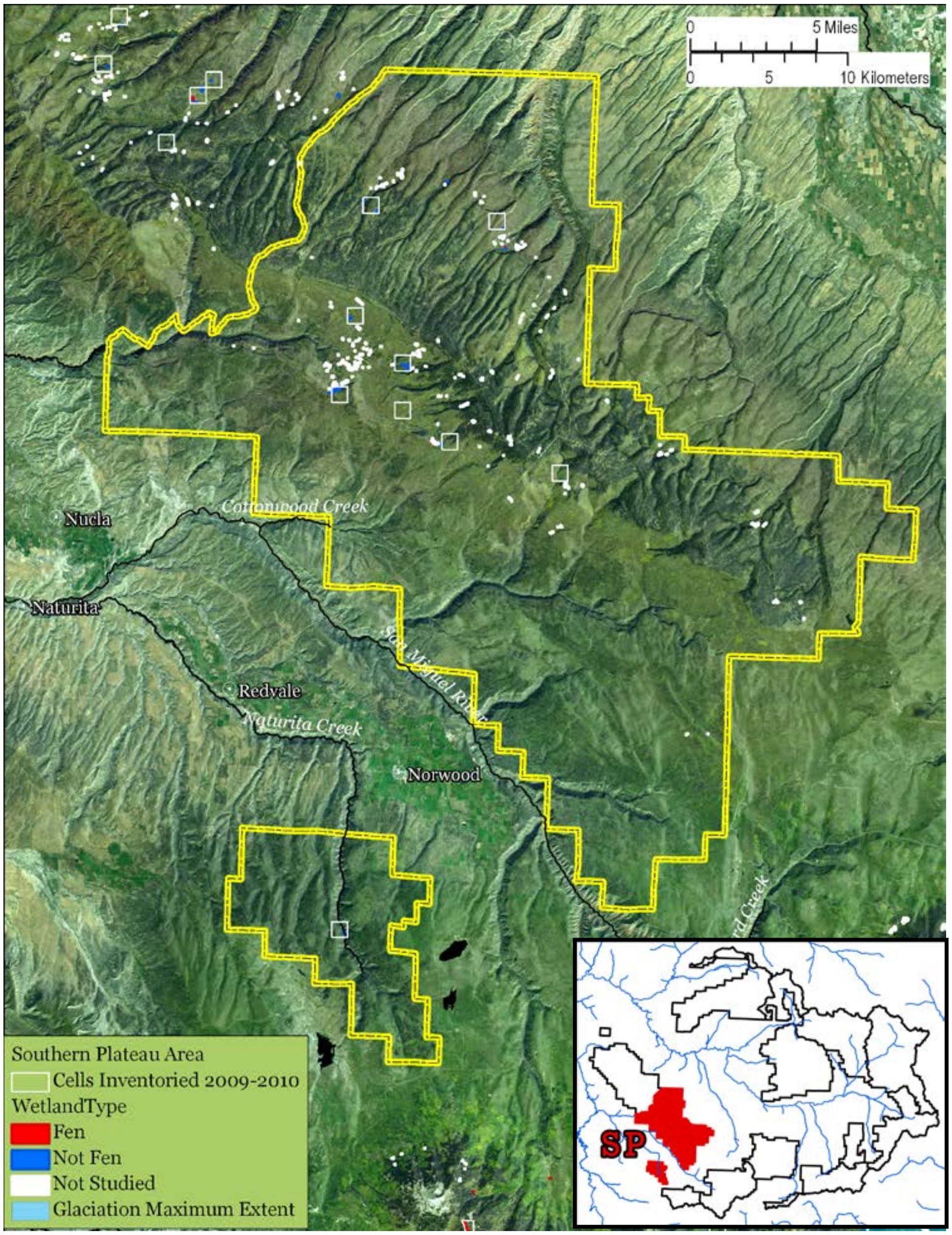


Figure 5-16. The Southern Plateau Area (SP). Inset shows area SP in relation to the rest of the Grand Mesa, Uncompahgre, and Gunnison National Forests.

The Uncompahgre Plateau comprises over 322,000 acres, with several creek draining northeast into the Uncompahgre River, and several creeks draining southwest into the Rio San Miguel and Rio Dolores (Figure 5-16). Close to zero fens will be found in the Southern Plateau (Table 4-2).

Most of this area is Tertiary sedimentary rocks, with Jurassic sedimentary rocks becoming prominent in the northern third. None of the area has been glaciated.

The one fen known is on Sedimentary Clastic lithology (Table 5-3), of topogenous type (Table 5-2). The one fen known has been disturbed by animal browsing and grazing, and is rated moderate (24). The one vegetation type sampled is shown in Table 5-15.

Table 5-15. General fen vegetation types in the Southern Plateau Area. (n = 1)

Cluster Name	No. Samples	Acres	Elevation	Bryophyte Cover
VII. Beaked sedge–water sedge, BRY < 25, often < 10	1	0.2	7,999	0

VI. Discussion and Conclusions

A combination of photointerpretation and spatially-balanced field sampling was employed to assess fen resources over the large and complex area encompassed by the Grand Mesa, Uncompahgre, and Gunnison National Forests. The results allow predictions to be made regarding the total number and acreage of fens both forest-wide and by landscape area. On these National Forests, fens are generally concentrated in the Subalpine Zone in areas where past glaciation has occurred and are most abundant on the Grand Mesa, and within the Sawatch and San Juan Mountains.

This landscape scale inventory was not designed to inventory or assess rare fen types. Rare fen types that represent a very small portion of the total population on the Forest (such as iron fens or calcareous fens) are poorly represented in the sample, and consequently the results are inevitably skewed toward the more common types. Since one purpose of this investigation was to characterize the nature of the entire population of fens on the National Forests, additional efforts would be necessary to locate and investigate these rare fen types.

A number of vegetation, water, soil, and disturbance characteristics were measured or estimated at each fen. A rating system was devised to assess current fen condition based on the intensity and extent of disturbances and a number of the measured site factors. The system worked reasonably well for the inventory sample set as well as a supplemental set of fens known to be of poor quality. The majority (81%) of the inventoried sites scored in the highest of four condition classes. Two of the factors used, floristic quality index and Von Post rating, did not appear to influence the scores; while a single measure of water table depth was problematic because of seasonal and yearly variation. Further use and refinement of the method on additional sites is needed.

Restoration potential was not addressed during the inventory or in the condition rating process. However, our data and condition rating system provide a basis for managers evaluating restoration opportunities during project planning. Active restoration needs as well as protective measures to reduce the risk of impacts should be considered, for example re-locating dispersed camp sites, managing motorized and mechanized recreation (such as ATVs and snowmobiles), or addressing user created routes.

There is a broader regional need for a properly-referenced formal condition class rating system, such as the Hydrogeomorphic Approach (Hauer and Smith 1998, Hauer and others 2002a). This system is based on a number of reference fens that can be used for comparative purposes. The results of this inventory have identified a number of fen-wetland complexes that could serve as reference sites in such a system.

A spatial GIS geodatabase of fens, wetlands, and potential fen sites has been developed covering these National Forests. It represents the best available information regarding the location of wetlands on the Grand Mesa, Uncompahgre, and Gunnison National Forests, especially non-riverine wetlands.

Recommendations

- Activities within watersheds containing fens should be carefully managed to protect the water related resources and linkages associated with fens, especially ground water.
- The spatial GIS layer should be routinely used during project planning and analysis of riparian and aquatic related resources.
- There is a need for careful range and wildlife management given that the most common disturbances were related to animal uses.
- The Forests should engage in internal and public outreach to broaden awareness of the value and unique qualities of fens.
- Coordinate this effort and future examinations of wetlands and fens with other National Forests and agencies, and take advantage of emerging technology such as remote sensing approaches (Werstak and others 2010).

Lessons Learned

- Having an interdisciplinary team overseeing the effort was very valuable. Yet we could have had better coordination with other disciplines including the fisheries, range, and wildlife specialists.
- Our search image applied during the photointerpretation step identified wetlands reasonably well (81% accuracy), but less so for fens (36%). The characterization of fens could be improved with an initial field season focused solely on developing and refining a fen search image. Improved photointerpretation could then facilitate a second more efficient and intensive field season with more specific objectives, and a more highly skilled crew.
- Field crew skills need to be matched with the questions that need to be addressed. This means focusing on defining questions that are appropriate. Critical skills include botany, hydrology, and wetland determination.
- Spend time and energy getting experienced crew leaders, who have back-country skills, have commitment and energy to cover a lot of ground, and have skill in wetland plant identification

Research Needs

The 2009-2010 inventory began to answer some questions regarding fens; however, questions still remain that need documentation in more formal research. The team identified five important research categories coming from this inventory.

1. Water Management
    - What are the effects of large artificial fluctuations in water levels on fen characteristics?
    - What are the limits, beyond which water level fluctuations result in loss of fen functionality?
2. Resource Management
    - What effects do some current observed impacts have on fens, such as vehicle use (ATV's), over-snow recreation (vehicles and skis), human trails, livestock grazing. What are the effects of these activities in the buffer around the site?
    - How would a water influence zone be delineated for a fen and what are appropriate best management practices for this zone to provide protection to fens?
    - Are certain fens on the Grand Mesa, Uncompahgre, and Gunnison more vulnerable than others to hydrological impacts, vehicles, big game use, fire and fuels management, or livestock grazing?
3. Restoration and Mitigation
    - What characteristics would best qualify a fen for restoration? What restoration procedures should be used, and how should they be adapted for different fen conditions and histories?
    - What evaluation method(s) should be used to determine suitability of a site for mitigation, and used for monitoring the site?
4. Condition Assessment
    - What are the thresholds in condition indicators, beyond which fen functionality is lost? When would the loss be temporary or irretrievable?
    - What plant species or other indicators indicate highly disturbed, poorly functioning fen conditions?
5. Climate Change
    - What changes can we expect from climate change on the extent and functioning of fens?

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Left, J. Simonsen, July 12, 2010. Center, S. Jay, June 28, 2010.
Right, B. Ogata, N. Kashi, S. Louis-Prescott, J. Simonsen. Training day in Taylor Park, June 9, 2009

Thank you all!