Beckwourth Fen Report for 2007 & 2008

Catie & Jim Bishop, February 2009

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INTRODUCTION

The Sierra Nevada Framework has identified riparian and other water-dependent habitats as places of interest and concern on National Forest land, due to their uniqueness and vulnerability to disturbance. Fens are one type of wetland habitat, and the Plumas National Forest initiated surveys in 2003 to identify, characterize, and map the fens on the Forest. Fen surveys were conducted by Catie and Jim Bishop between July and October in both 2003 and 2004 on the Feather River Ranger District (FRRD), in the Bucks Lake Wilderness (BLW) area in 2005 & 2006, and on the Beckwourth District in 2007 & 2008.

Fens on the Beckwourth District of the Plumas National Forest occur primarily in 2 areas: Grizzly Valley (GV) and Lakes Basin (LB), see (Figure 1). This report describes the Beckwourth fens, and makes some comparisons with the FRRD & BLW fens. The FRRD fens are described in the 2004 report (cumulatively 2003 & 2004 field work); the BLW fens are described in the 2006 report (cumulatively 2005 & 2006 field work).

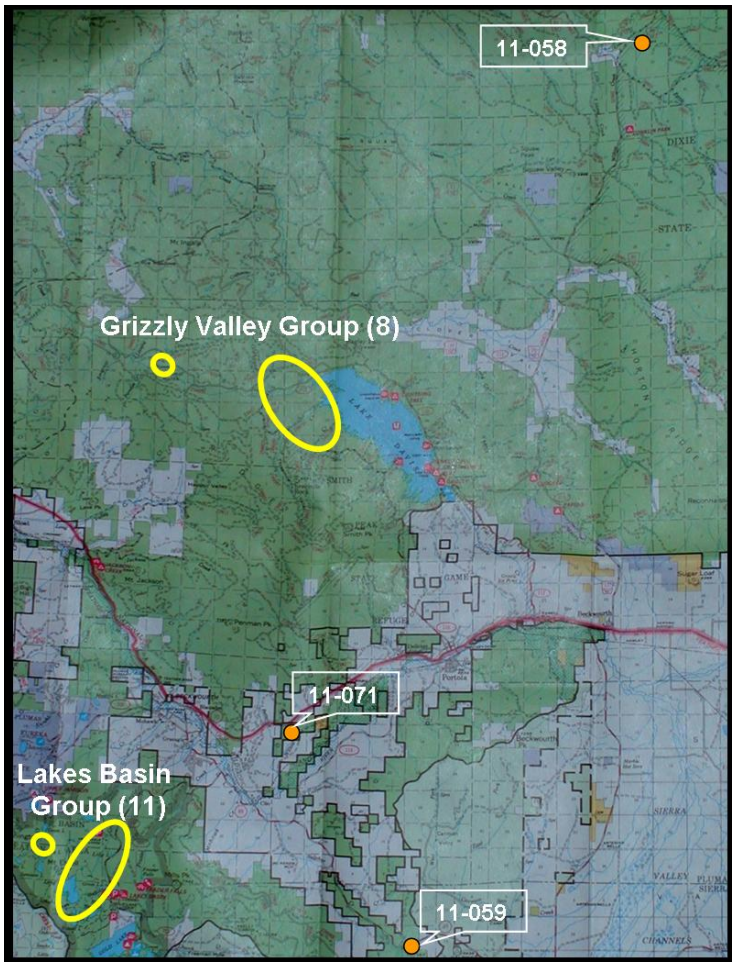

Figure 1. General location of Beckwourth District fens. The two main fen groups are named and the number of fens in each group shown. Three fens that did not fall into either fen group are shown with their identifications (a used on maps and plant lists)

Fen Definition

There are three currently accepted criteria for defining a fen:

First of all it must be saturated, and dry only minimally or not at all during the dry season. The continuous wetness, and cool temperature of the water, encourages the formation of peat. Peat is incompletely decayed vegetation, the decay being retarded by water-saturated, cool, oxygen-deficient conditions.

Second, the peat depth must be 40 centimeters or greater—actually, what must be 40cm or greater is the vertical extent of "organic soil" (or histosol), according to the definition for a histosol, at least 40 cm having sufficient organic carbon within the top 80 cm of soil, Hurt & Vasilas 2006 (see Glossary). Peat forms exceedingly slowly, accumulating from each year's growth, and deep peat layers indicate a stable environment lasting perhaps thousands of years. Living plant roots are contained within the peat layer and are not in direct contact with mineral soil.

Third, the vegetation in a fen receives essentially all of its mineral nutrients from ground water (as it is not rooted in mineral soil), in contrast to a "bog" which receives its mineral input from precipitation.

"In summary, fens are ground water fed peat-accumulating ecosystems that have perennially saturated soils, and whose hydrologic regime, geochemistry, and potential ecological characteristics are produced by the landscape that supplies its groundwater, as well as long-term issues of site history, and land and water management", Cooper & Wolf, 2006.

The fens encompass both wetter and drier areas, as well as various depths of peat. So, not every square foot is technically a fen with 40 cm of peat. However, the entire "fen", as a saturated peatland, is a functional ecosystem worthy on the whole of scientific description and management consideration. An analogy might be a "riparian zone", in which some locations are not as wet as others and have patches where the vegetation is not dependent on the stream water...the whole thing is still an ecologically relevant "riparian zone".

In this survey, the entire open area of perennially-saturated peatland, excluding forest and shrub border and larger/deeper ponds, is considered to be the fen for defining the perimeter. The fen perimeter follows the edge of the fen opening, and is shown on sketch maps in the Survey Forms in Appendix C, and on the Geo-database.

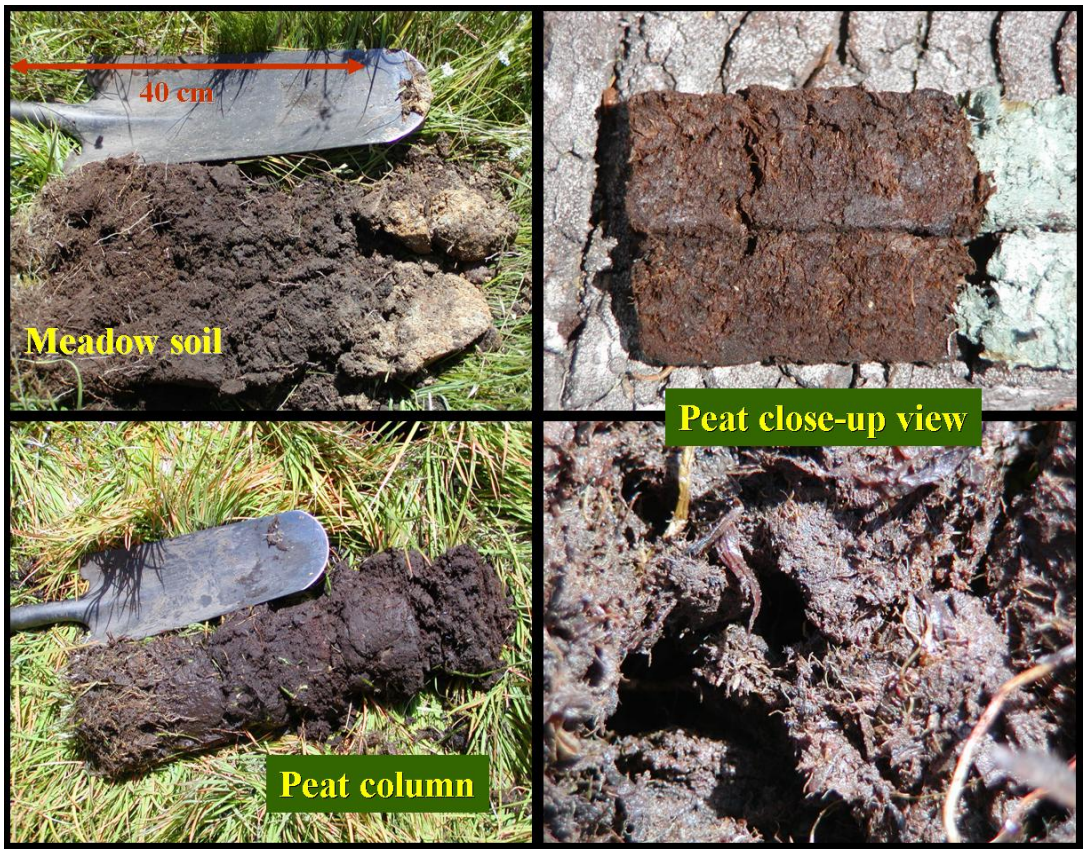

Figure 2. Peat, undecomposed vegetation, is an inherent feature of fens. Shown here are examples of peat, and a meadow soil for comparison. In many areas peat is underlain by clay, and in some areas by soil containing some gravel or sand (clay shown with peat in the upper right photo).

Fens are unique and important in that they:

- Contain a higher diversity, and a much higher diversity per unit area, of plant species than the surrounding forest.
- Include rare vegetation alliances, and special-interest plants.
- Usually lack non-native plant species, except in some fens where long-term human use has occurred.
- Impose varied habitat structure, with open water accessible, which supports a higher diversity of wildlife than in the adjacent forest.
- Embody a biostratigraphic record that preserves plant and climate data over millennia.
- Are relatively rare on the landscape and represent outlying examples of higher-latitude ecosystems.

Further studies of the fens could provide important insights:

- Some of the fens may have begun to form at the end of the last ice age, and studying peat cores will help us understand the ecological history of the fen through post-glacial time.

- Pollen cores will enable us to know about changing plant community composition and abundance, both within and outside the fen.

- Isotope studies of the water in the fen could reveal when that water fell as rain, and how long it has been traveling underground. This will give us insight into the hydrologic framework that has formed and maintains the fens.

- Plant and water chemistry studies will show us how vegetation, especially mosses, interacts with water chemistry and influences nutrient availability.

- Peatlands are important carbon reservoirs, and offer opportunities to study carbon flows to/from the atmosphere

- Studies of outside influences, such as cattle grazing and human impact, will help us better manage these unique wetland ecosystems.

REGIONAL SETTING

An overview of the climate, geology, elevation, geography, and vegetation of the fens surveyed portrays their natural setting. The climate in which these fens exist reflects the typical Mediterranean pattern that dominates in California. There is a predictably hot and dry summer period and an unpredictably wet winter period. The heaviest rain and snow falls during the winter months, with only occasional summer thunderstorms that deliver little if any water overall. Precipitation in the Grizzly Valley totals about 62 cm (25 inches) annually, with up to about 100 cm (40 inches) on the surrounding slopes and ridges. Precipitation in the Lakes Basin is in the range of 120 to 150 cm (50 or 60 inches). Both areas are typically covered with a snowpack much of the winter and early spring.

The GV fens are underlain predominantly by Pleistocene lakebed sediments in a silicic-volcanic bedrock setting. The LB fens occur mostly on metavolcanic rocks of predominantly intermediate geochemical composition.

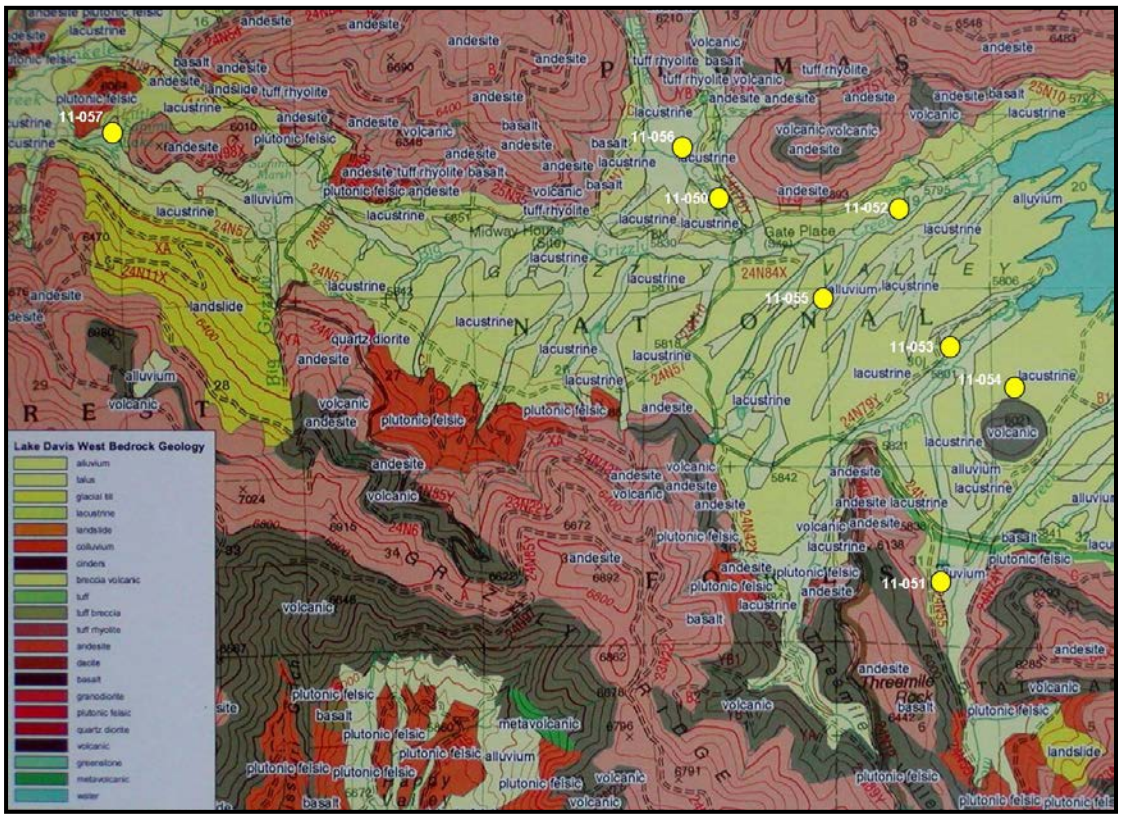

Figure 3. Geologic map for Grizzly Valley fens. The darker yellow denotes "lacustrine" deposits, Pleistocene lakebeds, and those deposits probably also underlie the paler yellow "alluvial" deposits. Waters traversing those lakebeds tend to gain dissolved minerals and a higher pH.

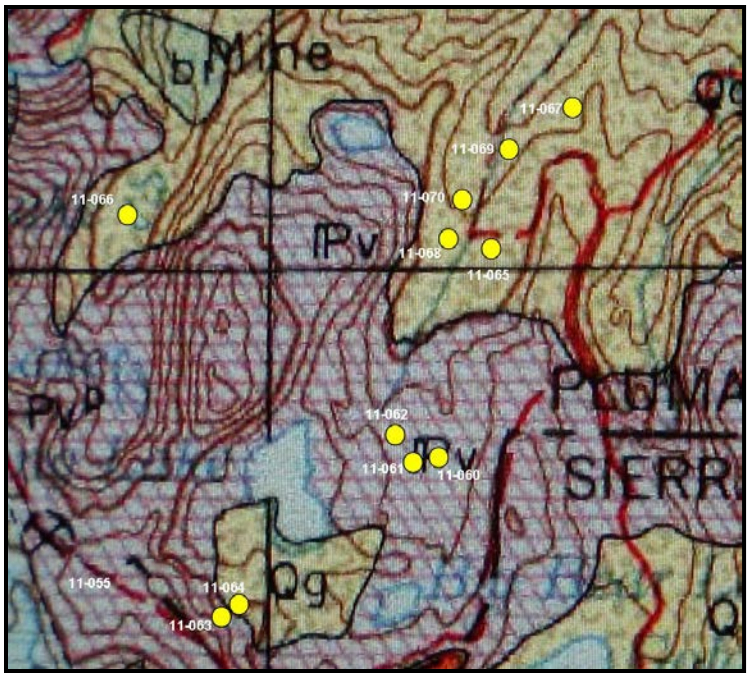

Figure 4. Geologic map for Lakes Basin fens. "IPv" denotes metavolcanic rocks, and "Qg" denotes glacial deposits. The general geochemistry of the substrate rocks and deposits is intermediate, and the groundwaters tend to have low dissolved mineral contents and moderate pH values.

The fens in GV (and one in the Last Chance Creek valley, a valley similar to Grizzly Valley but drier, which for discussion purposes is included in the GV group) occur mostly as limited areas within larger meadows, including narrow linear meadows of tributary streams. The LB fens don't occur within large meadows, but instead the fen occupies most of the opening in the surrounding forest or shrubs, or in some cases next to bounding shallow lakes or ponds (Figure 5). The adjacent forest in both GV and LB is primarily lodgepole and Jeffrey pine, Douglas fir, and white fir, though in different relative amounts.

Figure 5. Overall fen settings. Left, typical of Lakes Basin, fens occupy essentially all of the wet opening and are surrounded by forest or shrubs. Right, typical of Grizzly and Last Chance Valleys, fens lie in large meadows and usually occupy only a small fraction of the total meadow area.

The fens surveyed in the Grizzly Valley group lie between 5750 and 5860 feet in elevation; in the Lakes Basin between 5580 and 6950 feet. Topographically most of the fens occur in the bottoms of drainages, where there are springs emerging and/or subsurface inflow at the toe of the adjacent slope. Smaller fens commonly lie within the smaller drainages, and often where the stream gradient is slightly sloping. Larger fens occupy larger/broader drainages where the stream gradient is nearly flat. Several GV fens are isolated well out in very large meadows where springs emerge.

SCOPE AND METHODOLOGY

Locating the Fens

The goal of this project was to identify, characterize and map the fens within the Beckwourth District. Our survey area focused initially on grazing allotments in and around Grizzly Valley and Last Chance Creek Valley, totaling about 83,000 acres. The next target area was the Lakes Basin, totaling about 30,000 acres. And we looked within a general area of about 20,000 acres in which a couple of likely fens were known. Two strategies were used to locate possible fens: aerial-photo reconnaissance (primarily), and in a few cases previous visits recorded by botanists to what were thought at the time might be fens. We visited about 50 sites and found 22 of them to fit our working definition of a fen as outlined in the INTRODUCTION. There are 22 numbered fens, one of which has 2 peatland areas separated by drier meadow soils.

The survey probably identified most of the open fens that would show on the aerial photographs. It is quite possible that the survey missed wooded fens, especially those lacking a significant associated open area, because they are very hard to see from above. Finding small wooded fens usually requires walking into them, and we did not have the opportunity to walk over all of the surveyed areas.

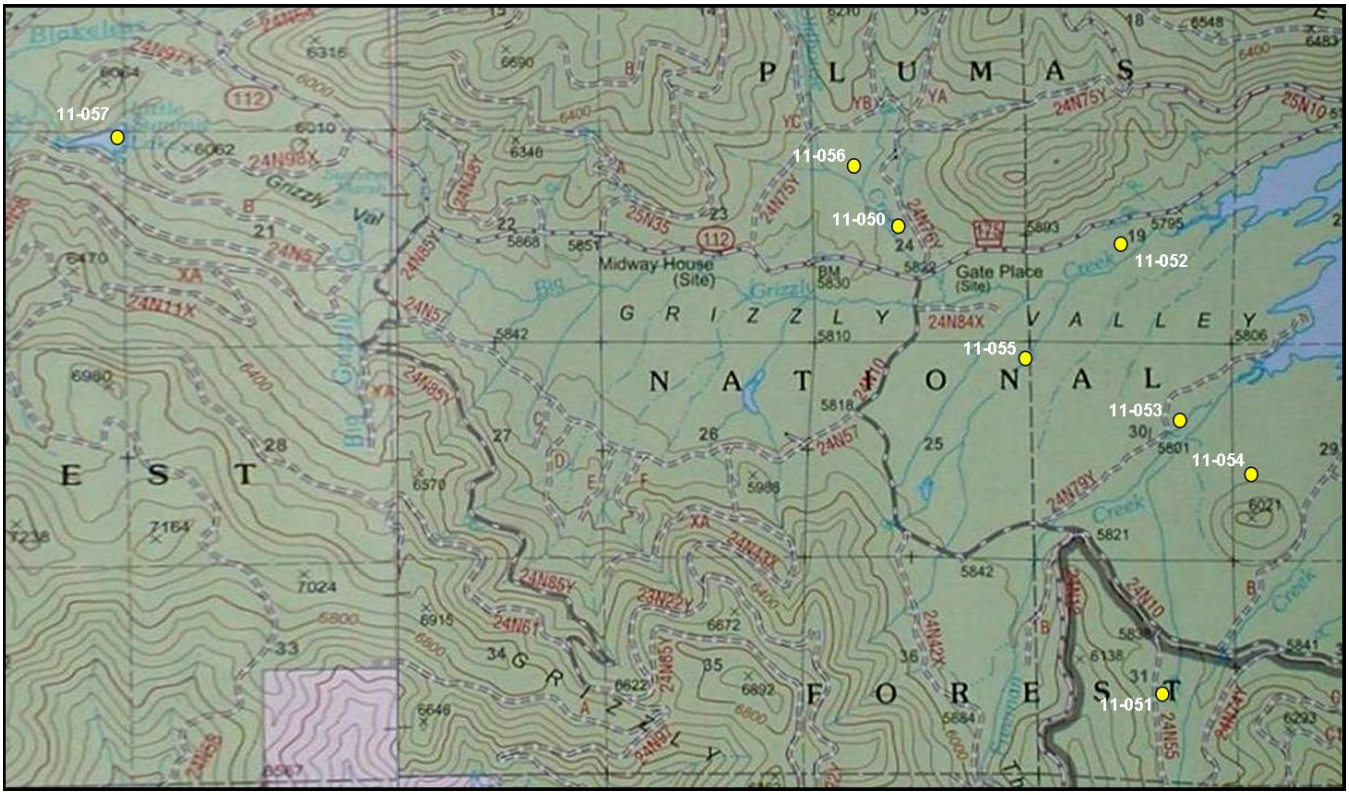

Figure 6. Locations of the Grizzly Valley Group of fens, with identifying numbers. Dots show general location.

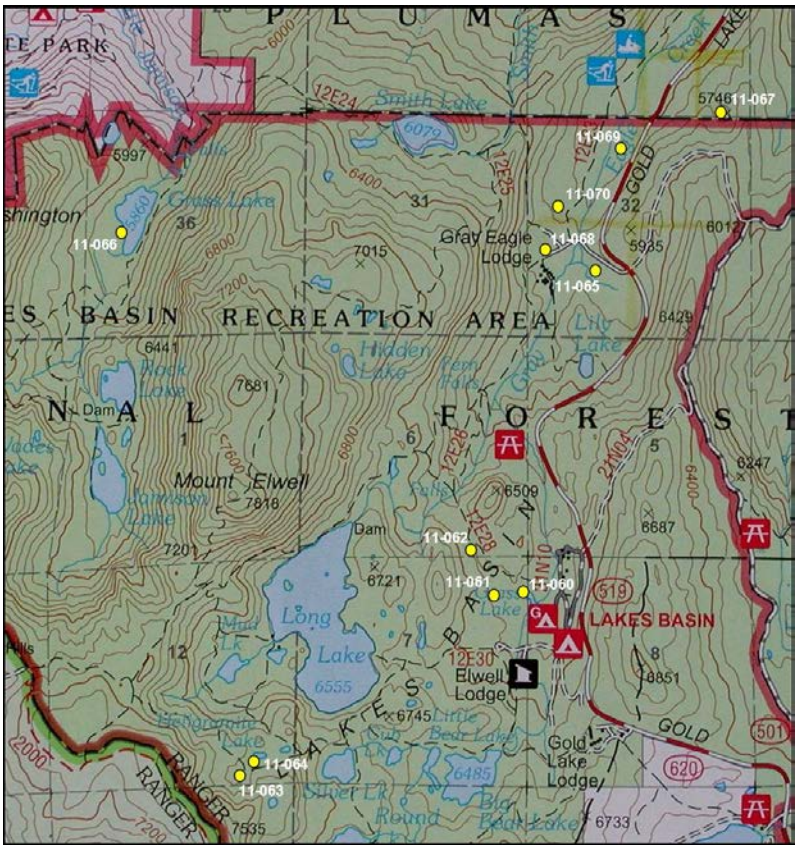

Figure 7. Locations of the Lakes Basin Group of fens, with identifying numbers. Dots show general location

At each targeted site surface wetness was checked, and sample holes were dug to evaluate subsurface wetness and the peat depth. Where the profile was wet and the peat depth at least 40 cm the area was considered a fen. We spent very little time in wet areas that we determined were not fens. The "non-qualifying" areas usually turned out to be meadows that were not saturated, or shallow wet areas. In either case they did not have sufficient peat depth. A common finding was that areas that are "surface wetted", rather than infused by subsurface spring flows, tended to be underlain by a shallow clay layer, rather than peat even though they supported some of the same kinds of vegetation.

Fen Survey Strategy

At each fen an initial reconnaissance was conducted to identify discernible plant communities that were distinct from the others and of fairly uniform character. A representative of each of the major plant communities (also referred to as "stands" on the Region 5 Fen Survey Form) became a numbered survey "plot". A sample hole was dug in each plot, in a location that was clearly representative of that vegetation type, not in a transition zone. The peat column was described and physical measurements made. The plants characteristic of each plot were identified. In addition, plants that occurred within the fen but not necessarily within a defined plot were also recorded.

Physical Measurement Methodology

At each sample hole the following observations/measurements were made, and the location of the hole determined by GPS and also noted on the sketch map.

1. The peat cores removed from the holes were examined and described with regard to peat characteristics, and any special features such as gravel/sand layers. Peat is readily identified when it is made up of partially-decomposed plant parts. Those peat cores tend to be fibrous and brown or light brown in color. Especially in the lower parts of the profile, the peat is often more decomposed, and is darker and not very fibrous. As a "field characteristic" such organic soil material tends to rub clean when rubbed between finger and thumb, in contrast to dark clay which tends to spread like grease and to remain on the fingers. The definition of adequate "peat" is based on the definition of a histic soil, and the organic component need not be strictly peat, Hurt & Vasilas (2006), see Glossary.

2. Root-zone temperature (an ecologically relevant parameter which is the root-environment temperature of the soil and the water that saturates it) was measured with a soil thermometer inserted so the sensor was at a depth of 15 to 20 cm. The temperature of the water in the hole was not used, because there is often not enough standing water accumulated in the hole, sometimes water runs in from a surface pond which is warmer than the saturating water, and sometimes it flows up from the bottom and is cooler than the saturating water. The thermometer was accurate to +/- 1 ^{o}F.

3. pH of water that accumulated in the hole was measured with a pH meter. For the most part such water represents the waters that saturate the root zone of the fen plants, and the effort was made to avoid sampling surface waters that flowed into the hole from shallow pools (the pH of surface waters is affected by the diurnal variation of photosynthesis, which removes CO_2 and thereby influences pH). The rated accuracy of the pH meter is +/- 0.01 pH unit. It was calibrated to a pH 7.00 standard buffer each field day. pH measurements are rounded to the nearest 0.1 pH unit and are assumed representative and accurate to that level.

4. Electrical conductivity is a measure of the dissolved-ion concentration of the fen waters. The unit of measure is "microsiemens/cm", abbreviated throughout this report as "µS". The rated accuracy of the meter is +/- 2% of full-scale, and it was calibrated to a 447 µS standard each field day. The overall accuracy of the field measurements is about +/- 2% of the observed measurement.

5. Saturation depth was determined by measuring from the ground surface to a level on the side of the hole where water appeared to be seeping out (Figure 8). Where standing water eventually accumulated in the hole (which can take a couple of hours in some columns that are not very permeable) the depth of that water surface below the ground surface was measured. "Ground surface" is the average level of the low-vegetation mat (often moss) at the rim of the hole. Not all of the holes had obvious seepage, and some holes refilled too slowly to give a final depth to water.

In each fen an effort was made to locate one or more points that were clearly water sources supplying the fen, to get an idea of the nature of the source water. These could often be

recognized by their cold temperature (40-48 ^{o}F), having come directly from underground and not yet exposed to much solar heating. Many springs arise underneath the vegetation in the fen opening and cannot be directly sampled, and in some fens an accessible water source was not found. The temperature, pH, and electrical conductivity were taken at each defined water source.

Limited re-sampling of some of these fens and some on the Feather River District suggests that the pH measurements are generally consistent to within about +/- 0.2 pH units (usually no more than +/- 0.1 pH units for the Beckwourth fens), the root-zone temperatures to within about +/- 5 ^{o}F, and the water-source temperatures to within about +/- 1°F. The greater variability in root-zone water temperatures is expected, given the varying degrees of solar heating that influence it. However, even though individual root-zone temperatures varied by several ^{o}F, in comparing repeated temperature observations in these and other fens, the variations were not systematic and comparisons between the average temperatures for groups of fens is considered to be significant.

Data were recorded the old fashioned way, in a field notebook. A sketch map was made of the fen, along with its notable features, and source and sample locations. With the aid of stereo-pair aerial photos and the sketch map, the fen perimeter was delineated on 4X-enlarged copies of aerial photos, and those perimeters and features are incorporated in the sketch map page of each Fen Survey Form. Those perimeters are transcribed onto digital orthophotos for incorporation into the Geo Data Base.

Botanical Observation Methodology

Catie conducted the plant surveys (Plant lists are in Appendix A). An attempt was made to identify all flowering plants in the fen opening and the major plants bordering the fen opening. Special interest plants were actively looked for. In fens that were impacted by cattle grazing many plants, especially gramminoids, had lost the reproductive structures needed for specific identification. In the case of bryophytes, samples were collected and submitted for expert identification (see bryophyte plant list, Appendix A). For most of the fens only a few hours were available for data collection, most were visited only once, so inevitably there were plants that were missed.

In the current Manual of California Vegetation, fens are given only one designation: “sedge series”, “fen habitat”. Cooper and Wolf (2006) provide a “preliminary fen community classification”. But given the lack of formally defined and standardized fen vegetation types we have not designated specific types for these fens. The new Manual of California Vegetation, when it is published, will contain many more defined alliances for fen vegetation than were available to us during our current surveys.

Supplementary Information

All supplementary information was recorded on a Fen Survey Form. Along with plant species data, the fen features are described in a qualitative way. That descriptive information, with sketch maps, is displayed on the survey forms. The geologic substrate under the fen area was also recorded on the survey forms.

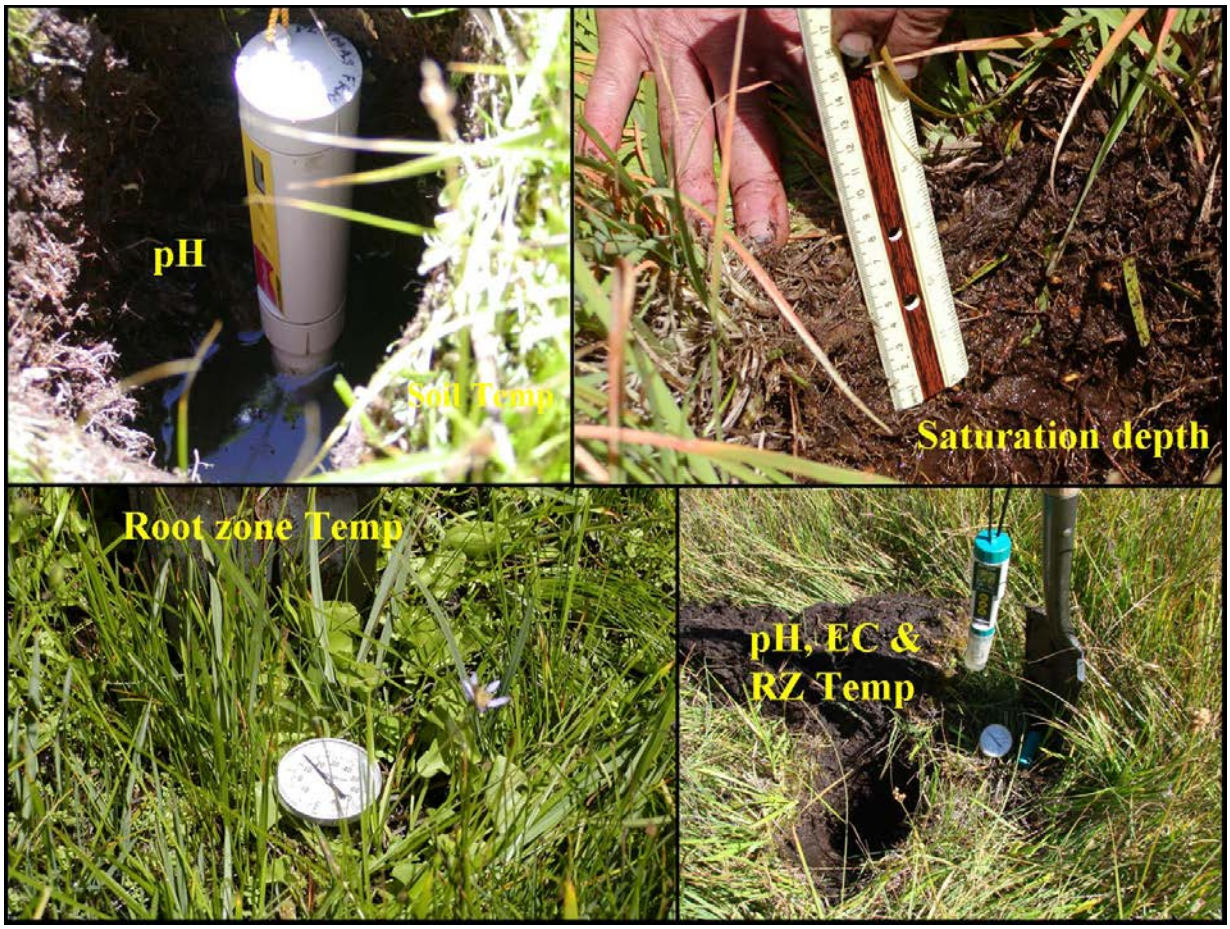

Figure 8. Measurement methodology. A sample hole was dug and allowed to fill with water at least to sufficient depth to allow a water sample. Saturation depth is the distance from the surface to the level where water seeps from the sidewall. Depth-to-water is the distance from the surface to the standing water. Temperature of the rooting zone (essentially the temperature of the saturating water at that level) was measured at 15 to 20 cm depth next to the hole. pH and electrical conductivity (EC) measurements were made of the fen-saturating water accumulated in the sample hole. Lower right photograph shows how all three observations can be made "hands free" while the pH/EC meter equilibrates (water sample is in a small vial on the bottom of the meter).Peat depth was measured, to at least 40 cm depth.

DESCRIPTION OF OVERALL FEN CHARACTERISTICS

Physical & Geographic Characteristics

The observed physical features of the fens are tabulated in the individual Fen Survey Forms, Draft 2006 (Appendix C) and summarized here in Table 1.

For all Beckwourth Fens:

- Source-water pH ranged from 5.7 to 9.0, and averaged 7.0 over all fens
- Source water electrical conductivity (EC) ranged from 18 μS to 210 μS and averaged 151 μS
- Fen root-zone-saturating water pH ranged from 5.1 to 7.0 and the average of all fens was 6.2, about 0.8 pH units more acidic than the source water (presumably due to dissolved atmospheric CO_2 and organic acids).
- Fen root-zone-saturating water EC ranged from 28 μS to 347 μS and averaged 194 μS, with the fen-water EC being higher than the source-water EC due to accumulation of dissolved ions.
- Source-water temperature ranged from 44°F to 61°F and averaged 49°F.
- Root-zone temperature (at 15 to 20 cm depth) ranged from 53°F to 62°F and averaged 58 °F.

Table 1. Beckwourth fen physical characteristics. Shown for each fen is the average value of all observations within that fen of: saturation depth, pH and electrical conductivity (of fen root-zone water and of source-water) and temperature (of root-zone soil and of source-water). NA means insufficient water for fen pH/EC measurement, no good source-water location found, or "average aspect" not computed. Aspect and slope refer to the overall orientation of the fen. A range of slopes indicates that major portions of the fen had significantly different slopes. Averages within each major fen group (GV = Grizzly Valley group; LB = Lakes Basin group) and over all Beckwourth fens are rounded off to the same level of precision as in the individual fen averages. Saturation depths are in centimeters, temperatures in °F, slopes in per-cent, conductivities in micro-Siemens, and elevations in feet.

FEN # and NAME	FEN SAT DEP	ROOT ZONE T	FEN pH	FEN EC	FEN H_2O T	SRCE H_2O pH	SRCE H_2O EC	ASPCT	SLPE	ELEV (feet)
11-050 Oldhouse	13 cm	56 °F	6.5	188 μS	48 °F	7.3	178 μS	S	3 %	5800
11-051 Woodsy	8 cm	60 °F	6.4	256 μS	44 °F	6.8	162 μS	NNE	2 %	5860
11-052 Waterbed	4 cm	62 °F	6.4	258 μS	48 °F	6.8	170 μS	SSE	1 %	5780
11-053 Sulfur	1 cm	59 °F	6.4	218 μS	54 °F	8.1	178 μS	NE	1 %	5800

FEN # and NAME	FEN SAT DEP	ROOT ZONE T	FEN pH	FEN EC	FEN H_2O T	SRCE H_2O pH	SRCE H_2O EC	ASPCT	SLPE	ELEV (feet)
11-054 Two-mound	9 cm	55 ºF	6.9	197 µS	NA	NA	NA	NE	2 %	5830
11-055 Mudhole	7 cm	60 ºF	6.6	150 µS	48 ºF	6.8	132 µS	NE	1 %	5820
11-056 Upper Oldhouse	5 cm	56 ºF	6.3	209 µS	44 ºF	7.0	210 µS	S	3 %	5860
11-057 Summit	35 cm	54 ºF	NA	NA	NA	NA	NA	W	<1 %	5860
11-058 Alkali Flat	5 cm	58 ºF	7.0	286 µS	61 ºF	9.0	152 µS	NW	2 %	5750
AVG OF GV FENS	**10 cm**	**58 ºF**	**6.6**	**220 µS**	**50 ºF**	**7.4**	**169 µS**	**NA**	**2 %**	**5820**
11-059 McNair	11 cm	58 ºF	6.5	238 µS	46 ºF	6.7	155 µS	N	2 %	5420
11-060 Crescent	6 cm	60 ºF	6.0	NA	61 ºF	6.2	NA	flat	0	6300
11-061 Slender Sedge	9 cm	60 ºF	5,8	110 µS	46 ºF	6.3	91 µS	SE	2 %	6300
11-062 Narthecium	6 cm	61 ºF	5.7	224 µS	50 ºF	7.3	152 µS	S	2 %	6320
11-063 Helgramite	1 cm	57 ºF	5.5	28 µS	46 ºF	6.2	18 µS	N	1 %	6950
11-064 Shorebird	4 cm	62 ºF	5.1	NA	49 ºF	5.7	NA	flat	0	6940
11-065 Graeagle	16 cm	56 ºF	6.2	226 µS	44 ºF	7.3	208 µS	NW	2 %	5790
11-066 Fringe	7 cm	53 ºF	6.2	118 µS	NA	NA	NA	flat	0	5860
11-067 Sundew	15 cm	61 ºF	5.9	137 µS	53 ºF	6.7	98 µS	flat	0	5750
11-068 Parnassia	5 cm	54 ºF	6.2	161 µS	48 ºF	7.8	151 µS	E	4	5830
11-069 New Trail	9 cm	58 ºF	6.3	148 µS	48 ºF	6.5	171 µS	WNW	6	5580
11-070 Madia	10 cm	55 ºF	6.5	196 µS	49 ºF	6.9	191 µS	N	6	5740
AVG OF LB FENS	**8 cm**	**58 ºF**	**5.9**	**150 µS**	**50 ºF**	**6.7**	**135 µS**	**NA**	**2 %**	**6120**
11-071 Leopard Lily	25 cm	57 ºF	6.5	347 µS	NA	NA	NA	SE	27 %	4700
AVG OF BECKWOURTH FENS	**10 cm**	**58 ºF**	**6.2**	**194 µS**	**49 ºF**	**7.0**	**151 µS**	**NA**	**3 %**	**5900**

The geomorphic setting of all of the GV fens and most of the LB fens can be described as "sloping" (see Glossary for definition of terms, Appendix B). Several "basin" fens occur in the Lakes Basin group. There are "spring mound" forms in many of the Beckwourth fens, often within the larger sloping fen, and in a couple of cases in the GV group spring mounds make up most the fen (Figure 11 for spring mound illustration)

Fen slopes are 0% to 6%, averaging 2%, with one exceptional fen (11-071) having 27% slope. Overall tendencies in slope-aspect direction simply reflect the regional slope direction of the landscape, and individual fen slopes are controlled by the local topographic setting. The fens range in size from less than a tenth of an acre to about 10 acres.

Figure 9. Slope vs. basin fens. Left is a slope fen (11-062), maintained by infusion of water from spring flows. Right is a basin fen (11-061), saturated by water retained in a shallow lake.

Fen Biotopography and Vegetation Patterns

Topographic features of fen openings (Figure 10&11) with relief of order centimeters to decimeters are commonly observed raised above, or sunk below, the general level of the fen. Although the reasons behind their formation are not all known, they are apparently the result of biological processes such as the differential growth and accumulation, and/or subsidence, of vegetation and are termed 'biotopography'. The variations in height and saturation greatly influence the small-scale patterning of vegetation. These interesting features certainly deserve more study to explain their origins.

One observation is that this small-scale patterning depends on having a water table near the surface, and on surface stability. With a high water table small-scale variations in height result in large relative distances above/below the water level. But if the water is many decimeters deep height variations of centimeters will make little relative difference ecologically. And surface disturbance such as hoof punching can destroy that small-scale patterning. Fens with desaturated peat and/or excessive surface damage tend to lose that small-scale biotopographic patterning.

Figure 10. Patterning of vegetation into distinct biotopgraphic features at the centimeter to decimeter-scale. Berms flank small channels and impound shallow pools, each area having its unique plant community. Even smaller-scale variations, on the order of decimeters horizontally, are created by centimeter-scale variations in surface height relative to saturation depth.

Where flows are high, springs emerging from beneath the fen vegetation can create spring holes or support floating vegetation mats, thick mats capable of supporting our weight (though with wet feet). Lower flow rates create spring mounds and berms (relief of order decimeters to a meter) nourishing greater plant productivity over them. Sample holes dug in the berms and mounds typically produce peat that is deep and fibrous.

Pools are another feature typical in fens, and sometimes form behind berms. The peat column underlying these pools, although sufficiently deep, is typically less solid and less competent than that under the berms, and would tend to settle and to form a shallow basin. As summer turns to fall, and in dry years, the surface may remain wet, but standing water is often gone. Oddly enough, sample holes in shallow pool areas often refill very slowly from subsurface lateral water flows. In shallow pools, the characteristic plants are typically a much more sparsely-distributed water-emergent species. The root biomass is often many times greater than the above-ground biomass, but because of the sparse distribution of photosynthetic tissue they probably support a lower rate of peat accumulation, given the limited overall productivity. That in turn contributes to, and perpetuates, the depressed topography of basins and ponds.

Different plant communities inhabit these microtopographic sites (spring mounds, basins, berms, and low-relief uplands) which illustrates how sensitive many plants are to small changes in the water regime.

Figure 11. Biotopographic landforms typical of fens. Raised mounds and berms develop where extra water nourishes greater biomass productivity. Shallow pools are commonly retained by low berms. Top left, spring mound (fen 11-050). Top right, spring hole on top of spring mound (fen 11-050). Bottom right, shallow pond (now drying), with sparse emergent vegetation (fen 11-067). Bottom left, berm composed largely of Narthecium and Allium flanking an open channel (fen 11-062).

Botanical Characteristics

There are distinct plant communities within the fens, often with quite sharp boundaries, and clearly associated with height variation and with saturation (Figure 11). Biotopography helps to partition the fen into loose groupings of plants that prefer different microsites. The largest plant communities inhabit the broadest uniform biotopographic zones. These are usually graminoid-dominated, and thickly vegetated, with a mix of sedges, grasses, and herbs.

Mounds that form over springs usually have thick vegetation consisting of plants such as bog saxifrage (Saxifraga oregana). Berms which were raised above their surroundings (typically on the order of decimeters) contain low (<1m) shrubs of blueberry (Vaccinium uliginosum), alpine laurel (Kalmia polifolia var microphylla), bog onion Allium validum, and sometimes stunted lodgepole pine (Pinus contorta ssp. murrayana). In the shrub border at the edge of the fen grow alders (Alnus incana var. tenuifolia) and willows (Salix eastwoodiae) which typically exceeded 2 meters in height, along with herbs such as ragwort (Senecio triangularis), and Bigelow's sneezeweed (Helenium bigelovii).

The generally flatter, lower-relief areas contain a mix of low-stature plants. This is where the various mosses and, in one fen, the tiny sundew (Drosera rotundifolia) found a sunny patch away from the shrubby berms and the shallow pools. Small herbs such as primrose monkeyflower (Mimulus primuloides) and tinker's penny (Hypericum anagalloides) are commonly found here.

The shallow pools are of various depths, mostly a few centimeters. The actual bottom of the pool is often covered by a layer of algae. In the shallowest pools the spike rush (Eleocharis sp.), bulrush (Scirpus sp.), or sedge,(Carex sp.) is dominant. With greater pool depth these give way to the mostly submerged buck-bean (Menyanthes trifoliata), and marsh cinquefoil (Potentilla palustris), and finally to the pond lily (Nuphar luteum ssp.polysepalum) in the deepest pools. (Figure 12)

Bryophytes can make up a large fraction of the biomass in some habitats. We collected samples of mosses in several fens, representing different habitats.*Sphagnum* mosses were found only in small patches in some fens of the Lakes Basin group. None were found in the Grizzly Valley area, possibly due to pH values that were not acidic enough and possibly to relatively high ion concentrations (EC).

We found uncommon species of mosses in our surveys, including two sensitive mosses: *Meesia triquetra* and *Meesia uliginosa.*Some of these sensitive and special-interest moss species are rare and may constitute a patch of a few square centimeters in an entire fen. Notable is the occurrence of some 6 species of moss in Alkali Flat fen (11-058), the most alkaline fen, which were not observed in any other fens. Mosses are especially susceptible to hydrologic changes or trampling.

Most of the mosses were identified by David Toren, a moss expert working seasonally for the Plumas National Forest. In several fens David Toren collected his own samples. The *Sphagnum* mosses were sent to specialists at eastern universities for their identification, and we have not received those identifications before this document went to print. A list of the other bryophyte species is included with the plant list in Appendix A.

It has been noted from other regions that wetlands contain a high number of endemic plant species. We noticed this to be true in our early fen surveys as well. One thing we were surprised to find in the earlier CWW and BLW fen surveys was that the fens there had no non-native or invasive plants. Healthy and uniquely demanding ecosystems tend to resist invasion. However, during the Beckwourth District fen surveys we did encounter several non-native and invasive plants. The Beckwourth area fens have a long history of human habitation, livestock grazing (both cattle and pack stock), manipulation to enhance grazing and hunting of waterfowl, and

almost all of them are adjacent to currently utilized roads or trails. We believe there is a correlation between higher human-animal impact and greater numbers of non-native plants.

Figure 12. Some plants typical of the different biotopographic zones in the fen. Clockwise from top left is Bigelow's sneezeweed Helenium bigelovii from the dryer fen border, Marsh cinquefoil Potentilla palustris in shallow pools, a*lpine laurel Kalmia polifolia on the low berms, and yellow pond lily Nuphar lutea* ssp. *polysepala from the deeper pools.*

Some Interesting Species

Sphagnum moss is the bryophyte that is typically thought of when one thinks about fens or bogs. In our earlier surveys in the BLW fens it was observed widely (in contrast to occurring in only a couple of fens on the CWW area). Several samples of sphagnum were collected in 4 of the Beckwourth fens. Samples were sent to experts to identify the species. Due to the fact that sphagnum moss has not been well studied in the western US, identifications may not be firm. See Bryophyte list in Appendix A. Sphagnum requires a sufficiently low pH to colonize an area. It can have a profound effect on the other plants in the fen ecosystem due to its ability to sequester nitrogen and lower the pH of the surrounding water. It also prefers water with low levels of dissolved ions. Few of the fens in the Beckwourth district had sufficiently low pH's (probably due to the geological substrate) to support much Sphagnum. Average pH in the four fens with Sphagnum is 5.2 (see Plant List, Appendix A), and in fens without *Sphagnum* it averages 5.9.

The Sundew (*Drosera rotundifolia*) is an insectivorous plant that grows rooted in saturated substrates and is on the Plumas National Forest Special Interest plant list. Although it has been found occasionally in small numbers in wet areas not strictly considered fens (primarily because of their lack of 40 cm of peat), it is found in large numbers in the undisturbed fens in the BLW and CWW fens. Only one fen on the Beckwourth District contained *Drosera*, and that is the only occurrence of that plant on the District.

Another Special Interest plant (CNPS List 2) found growing in the Beckwourth fens is *Carex lasiocarpa*. Called Slender Sedge, this sedge has grass-like foliage, and grows in standing water mostly around lake margins. *Carex lasiocarpa* was found in 4 LB fens.

Narthecium californicum is very common and a main peat-forming plant in the CWW fens, but it was completely absent in BLW and LaPorte fens, and occurred in only a few sites in Lakes Basin. Commonly seen in California's Northern Coast Range and Klamath Mountains, it is unknown why it has such a restricted population in the Sierras.

Eriophorum gracile or Cotton grass is a sedge common in cold, high-latitude wetlands, as are other fen plants, but uncommon in lower latitudes.

The moss *Meesia triquetra* and *Meesia uliginosa* are considered Special Interest plants due to their rarity and restricted habitat. There were several uncommon mosses found in the Beckwourth fens.

Figure 13. Uncommon species of particular interest: Center Narthecium californicum; upper left Meesia triquetra;, upper right Eriophorum gracile; lower right Carex lasiocarpa; lower left Drosera rotundifolia.

OBSERVED ALTERATIONS OF FENS: HYDROLOGY, PEAT & PLANT OCCURENCE

Peat accumulates under perennially saturated, cool, and anaerobic conditions. The top of the "peat body" coincides closely with the top of the saturated zone. Sediment lenses can occur within the peat column, and represent depositional events. The fen is the embodiment of processes of accumulation. The surface-water flow regime across the fen would be characterized as "sheet flow" (vs. channeled flow).

If water cuts a channel down into the peat it will lower the water table and halt peat accumulation, and the peat will start to decompose. The fen plant community becomes less diverse, and our observations suggest it commonly transitions to a different suite of plants. Peat will be oxidized and broken down. In some instances the dewatered area has become dry, dusty ground. Burrowing animals such as pocket gophers will move in, contributing to the decomposition process. The reason for dewatering in the Beckwourth fens is typically channels incised into the peat. The banks of channels incised in the peat body will be made of peat. The new water level will slope upward and away from the water level in the channel bottom (stream)

to eventually reach the surface.In a peat body, stream incision and channeled flows (vs. sheet flow) represents a departure from normal fen processes of accumulation, and a transition from accumulation to erosion.

Many fens we surveyed in the Beckwourth district contain incised channels or rivulets that flow through the fen area, usually originating at the spring source or from a gap in a collapsed spring mound. Examples include Fens 11-051, 11-052, 11-056, 11-058, 11-065, 11-068 (Figure 14).

Figure 14. Channels in fens. Through-flowing channels are usually the result of downcutting caused or initiated by cattle. They lower the water table and lead to desaturation of the peat body. Top left, incipient channel (fen 11-058). Remaining three photographs show channels in Fen 11-056, the upper right example being about 1 meter deep. In the lower left and upper right examples the banks next to the channel were heavily damaged by cattle trampling.

Figure 15. Once-saturated peat drying out or disintegrating. Left, small pine trees growing on a desaturated spring mound (Fen 11-056). Right, exposed tree roots previously rooted in peat that has decomposed under dry aerobic conditions (Fen 11-065). Red line indicates approximate upper surface of peat/soil (inferred from remaining in-situ peat chunks) and is behind the shovel (blade is 40 cm long). Approximately 20 cm of peat, perhaps more, had decomposed.

The amount of exposed peat is recognized as a gauge of the degree of degradation a fen has suffered, and areas with 15% or more of exposed peat/soil are considered to be degrading/oxidizing, Weixelman & Cooper 2008. We noted various levels of peat exposure, sometimes exceeding 30%, some grazed fens (Figures 16 & 17).

Figure 16. Exposed peat on the surface of a spring mound, in an area of heavy use by cattle (Fen 11-055). Exposed peat is vulnerable to oxidation, and when the surface area of exposed peat exceeds 15% it is considered to be degrading, Weixelman and Cooper (2008).

Most of the fens within the Grizzly Valley area are currently grazed, and grazing has occurred in the general area for at least a century. Most of the fens in the Lakes Basin area are not currently grazed, though historically they did experience livestock grazing. The association of impacts to the fen surface, channel formation, trampling of spring holes, and desaturation with cattle grazing is widespread and consistent. However, the full picture of processes operating, and their timing, to produce the current observations is not complete.

A lack of plant diversity and invasion by non-native plants are associated with degraded fen ecosystems. There was only one fen on the Beckwourth District (11-067) that contained a diverse suite of plants as we normally see in ungrazed or low-impacted fens. It is the least impacted fen by virtue of its isolation and difficult access. Sundew (*Drosera rotundifolia*) is here, and is known from only one other location in the Lakes Basin area, and that is in Plumas Eureka State Park. The sensitive moss (*Meesia triquetra)* and fen-loving cotton grass (*Eriophorum gracile*) growing here were also not seen in any other fens. These plants were absent in other Lakes Basin fens even though this fen has a pH and conductivity that was right in the middle of the range for Lakes Basin fens, suggesting that the environmental conditions in other fens would be conducive to those plants.

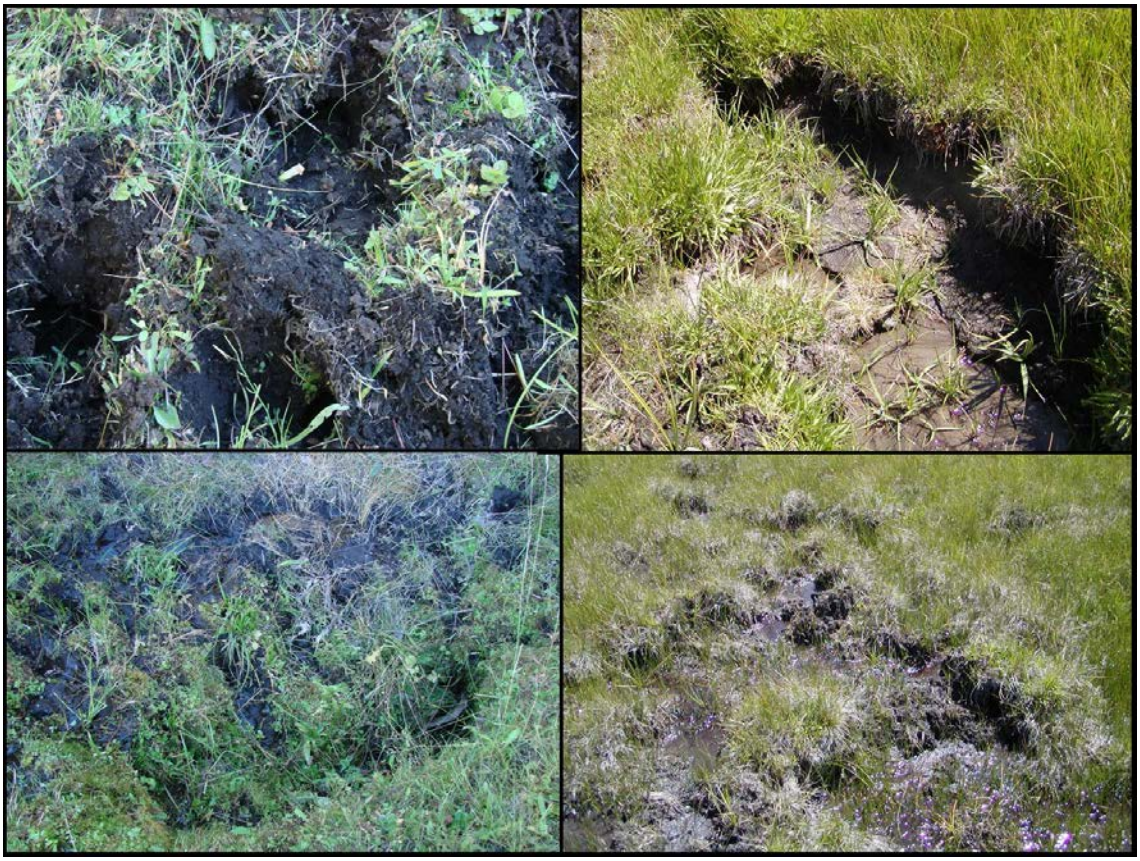

Figure 17. Hoof damage to fen surface. Top left and lower right (Fen 11-051), deep hoof imprints up to approximately 28 cm (11 inches) deep, on a spring mound. Upper and lower right (Fen 11-058), hoof prints and bank shaving. In both lower photographs water can be seen seeping into the hoof prints. Hoof prints can expose peat to oxidation, initiate channeled water flows, damage peat-forming plant root systems, and directly destroy small plants.

Currently the Lakes Basin fens have lodges, campgrounds, trails and other human-impact sources nearby, and nearly all of the Beckwourth fens are adjacent to or not far from roads. Those human influences have probably contributed to the introduction of non-native plants into the fens. The road embankment leading to Graeagle Lodge cuts across a fen and evidently has channeled and restricted the water, turning the water-restricted part of it into a meadow and reducing the overall size of the fen. Exposed roots of a tree once rooted in the fen show graphically how much peat has been oxidized since the drying (Figure 15).

Figure 18. Road embankment across a fen near Graeagle Lodge, aerial view. The upstream portion of the fen is on the left side (west and north) of the road. Water to the large area to the SE (lower right) of the road has been cut off, leaving a dry meadow, and channeled waters only feed a small extension of the fen below a culvert near the NE end of the embankment.

FEN-GROUP COMPARISONS & CONTRASTS

There were significant geographic/physical and biological differences between the GV-group fens and the LB-group fens. The Beckwourth fens show both similarities and differences with those in the Bucks Lake Wilderness (BLW, Mt. Hough District) and those in the Coldwater-Willow (CWW, Feather River District). Basic geographic and physical data on which the comparisons described below are based is contained in Table 1 and in Bishop (2006) and Bishop (2004).

Between Grizzly Valley and Lakes Basin Fens (Beckwourth District)

Geographic/physical Contrasts

These two groups of fens, GV vs. LB, occupy geographically and geologically different settings. The GV fens are mostly on lakebed sediments overlying siliceous volcanic rocks, while the LB fens are primarily on glacial till overlying metamorphic rocks of intermediate to silicic

geochemical character. 'Silicic' rocks are relatively high in silica (SiO_2), Na, & K; 'Intermediate' rocks have slightly less silica, and relatively a little more Ca, Fe, and Mg.

Quantifiable contrasts are as follows.

- Average elevation: GV fens 5820 feet (with a narrow elevation range from 5750 to 5860 feet)
- LB fens 6120 feet (range from 5740 to 6950 feet)
- Source-water pH: GV is 0.7 pH units higher than LB (pH 7.4 vs. pH 6.7)
- Root-zone-water pH: GV is 0.7 pH units higher than LB (pH 6.6 vs. pH 5.9)
- For both areas the root-zone pH is 0.8 units lower than the source pH
- Source-water electrical conductivity (EC): GV is 34 μS higher than for LB (169 μS vs. 135 μS).
- Root-zone-water EC: GV is 70 μS higher than LB (220 μS vs. 150 μS)
- Source-water temperature (50°F) is the same in GV and LB
- Root-zone temperature (58°F) is the same in GV and LB

The higher pH and EC of both root-zone waters and source waters in the GV fens probably reflects the influence of lakebed sediments on the permeating groundwater in increasing the pH and also the dissolved ion concentration as it passes through those sediments.Metamorphic geologic substrates in the Lakes Basin provide lower dissolved-ion concentrations and therefore less buffering against lower pHs than do more alkaline substrates. In both areas the fen plant root-zone pH is more acidic than the source-water pH by about 0.8 pH-points, due to the contribution of atmospheric dissolved CO_2 and organic acids in fen waters. The temperature averages cited here that characterize the GV and LB fens represent several dozen observations each and the comparison is considered to be significant.

In summary, the GV fens vs. the LB fens are lower in elevation by about 300 feet, on more alkaline and finer-grained substrates, higher in pH by about 0.7 pH-units, and containing about 50% more dissolved ions.

Botanical comparisons

The geographic setting for the fens in the Grizzly Valley area was different than that of Lakes Basin, in addition to the physical characteristics noted above. GV fens tended to be situated within a broader meadow, while LB fens were either on lake margins, or surrounded by dry forest. This difference was evident in the suite of plants each supported. It's hard to know exactly why a species is present or absent in any two given habitats, so the following is largely descriptive. See Plant List in Appendix A for more detail on botanical comparisons (#50-#57 GV fens; #60-#70 LB fens).

- Overall species richness in Grizzly Valley fens was half that of Lakes Basin fens (Table 2)
- Sphagnum moss was found in some LB fens but in none of the GV fens
- Shooting star *Dodecatheon* sp. was only seen in GV

The substrate of the GV fens was that of old lake-bed sediments, which affected water chemistry (higher pH and electrical conductivity) and likely contributed to plant and moss differences. Another difference in the plant species was probably reflective of the grazing regime. The GV fens are currently grazed, and the LB fens are not. In general there was much greater plant diversity in the LB fens than in the GV fens.

Between major fen-groups of Beckwourth, Feather River, and Mount Hough Districts

Geographic/physical contrasts

The four major groups of fens on the Plumas N. F. (GV, LB, CWW, and BLW) occupy generally different settings in terms of geography and geology. However, the LB and CWW areas are very similar in geology (both mostly on metamorphic rocks of silicic or intermediate composition), and in botanical character. The BLW fens lie on granitic substrates and at the highest average elevations. In decreasing order of average precipitation: BLW, CWW, LB, GV.

Quantifiable contrasts are as follows, listed in decreasing order for that parameter.

- Average elevation (feet): BLW 6200, LB 6120, GV 5820, CWW 5560
- Source-water pH: GV 7.4, LB 6.7, CWW 6.6, BLW 5.9
- Root-zone-water pH: GV 6.6, LB = CWW 5.9, BLW 5.4
- Source-water temperature (^{o}F): GV = LB 50, CWW 47, BLW 46
- Root-zone temperature (^{o}F): GV = LB = CWW 58, BLW 53

Botanical comparisons

As with the comparisons of GV and LB, grazing plays a role in the types of species that inhabit a fen. The CWW and LB fens are currently ungrazed, while the BLW and GV fens are grazed. It's hard to speculate about species between such diverse landscapes, but there are a few things we noticed consistently.

Drosera rotundifolia had habitat and elevation requirements that seemed to be met by all of our fen locations, yet in many places it was absent or barely present. Where grazing is heavy and ongoing, a tiny plant that tends to grow in the open and requires its sticky leaves to snare nitrogen-rich insects, is vulnerable to trampling. By the end of a season of grazing, there is barely an area of the fen which has not been stepped on. In some fens the sundew held on in

small patches by growing on vertical banks or partially submerged logs, in locations protected from hooves. But in the ungrazed fens, it could be seen in large patches throughout the fen opening.

Likewise, grassy plants such as the Special Interest sedges *Carex limosa*, and *C. lasiocarpa*, are probably preferentially eaten by the cattle, keeping their numbers low. Also, cattle hoof punches tend to damage the underground rhizomes of long-rhizomed sedges, which then make them less competitive with, and may be replaced by, the shorter-rhizomed or cespitose sedges. In the proper habitat in less impacted fens, the numbers of individual Special Interest sedges was higher.

Where water channels had formed, lowering the water table, sometimes a single species of sedge might dominate, perhaps making for good cattle feed, but reducing the overall diversity of species. Where draining was severe, the peat itself was decomposing, and those areas ceased to be a functioning fen system. Through-flowing incised water channels are not a natural feature in a fen, and are often caused by cattle trails or purposeful ditching to drain a very wet area for enhancement of forage species.

Species richness comparisons are below (Table 2). Three of the areas show consistent species counts, while the fourth (GV) is much lower. A couple of reasons for the lower species counts in a given area are as follows. The shrub border was missing in most GV fens since they typically were surrounded by meadow (which would account for no more than about 10 species), and the plant lists represent only a snapshot of what is identifiable on the day we took inventory (though each fen group includes many fens seen over the course of a season). Some fens we visited in cattle allotments had cows present, and others did not have cows yet that season.

Table 2. Species richness for each of the major fen-groups on the Plumas N.F., the total number of species identified in that fen group

Fen Group	Dicots	Monocots	Bryophytes	Total
CWW	63	27	20	110
BLW	49	28	37	114
GV	30	15	8	53
LB	56	41	9	106

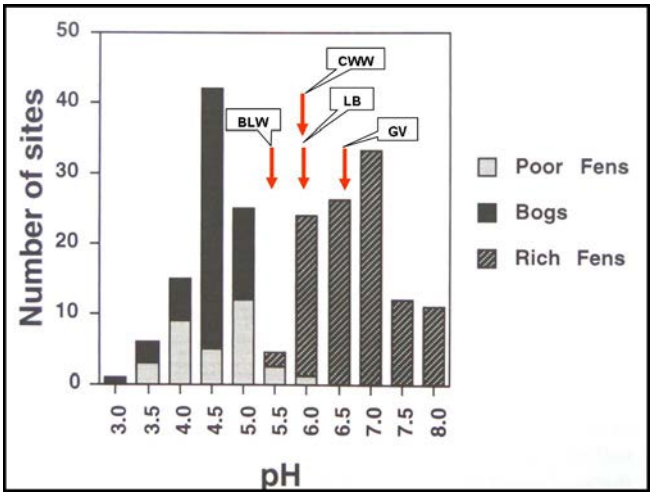

Figure 19. Fen pH for 100 western Canadian fens from Shaw & Goffinet (2000). Fen pH for each of the four major groups on the Plumas N.F. shown with arrows.

DISCUSSION AND CONCLUSIONS

Some generalizations can be drawn from our reconnaissance regarding the likely habitat for fens on the Beckwourth. In the Grizzly Valley area they tend to occur on the edges of, or associated with, large meadows. The substrate is old lakebed sediments overlying volcanic bedrock of intermediate geochemical composition. In the Lakes Basin area the fens occupy lake margins or small openings in the drier forest. This area is glacially sculpted in a metavolcanic substrate. Most of the fens in both areas are spring-fed. A steady-state equilibrium is established wherein the water flow infuses and maintains the fen, and the vegetation/peat blanket retards the water flow. There is a balance between inflow and drainage, and altering either could damage the fen.

Some plants, while they may not be strict "fen endemics", at least showed an occurrence strongly correlated with fens. Such fen plants include *Drosera rotundifolia, Carex lasiocarpa, Menyanthes trifoliata, Eriophorum gracile,* and *Sphagnum sp.* mosses. Where they occur outside of fens it is in very wet portions of meadows that were not fens only in lacking the full 40 cm of peat, but were fairly saturated and may have had sufficient peat to effectively contain the root zone.

Because of the continuous wetness, stability, and extreme age of the fens, plants which require these conditions have colonized and maintain the stable fen ecosystem. We hope to date some of our fens in the future; other fens in the Sierra Nevada have been dated to between 4000 and 8500 years old (personal communication, Sagehen Field Station staff). Fen pools are used by wildlife (such as frogs and toads for nurseries), and are often the only open water in an area. The shrub-dominated fen border provides good cover, diversity of structure, and is utilized by higher densities of wildlife, than in either the fen opening or the surrounding forest. This survey does not include invertebrates, however tiny clams (0.5-2mm), hydra, worms, shrimp, and other water dependent animals were observed under the dissecting microscope during plant identification.

Wetlands of all kinds have been drained for agriculture, road building, grazing, OHV use and other uses, or polluted by agriculture or mining and logging runoff. This makes the remaining intact wetlands even rarer. And protecting the fens is important for reasons going beyond those associated with plant and wildlife habitat. These ecosystems have been stable for thousands of years and have been used as windows on the past. Their core samples can reveal the changes in plant types and abundances, and can suggest paleoclimates. It is well known that wetlands are excellent natural filters of water-born impurities, and they moderate peak water flows.

During this survey we noticed clear correlations between on-going cattle grazing and alteration/degradation of the fens. Also, historically higher stocking levels may have triggered progressively-amplifying hydrologic changes that are manifested today. It will take more study to quantify the effects of livestock grazing on the hydrology and biology of fens, but it is clear that livestock hooves impact the surface and water flows, and cattle preferentially eat certain plants and trample others. This question will need more study in the future.

Another question to be investigated in the future is if, or how much, the "fertilization" of a fen by cattle changes the nutrient input, and therefore the species composition, of an ecosystem that is defined in part by the special circumstance of the separation of its root system (and therefore its nutrition source) from mineral soil. It remains to be learned from further studies whether another impact of livestock waste products, "urine burning" of fen mosses, is a problem.

Fens appear to be very unique, stable, and relatively pristine ecosystems...far outliers of boreal ecosystems far to the north. On the Plumas NF they occur on a wide variety of geologic substrates (a potentially important determinant of a fen's character), and that geologic diversity is unique compared to the widespread granitic substrate that is characteristic if most of the areas in the Sierra Nevada, or the dominantly volcanic character of NE California. They merit further study for many reasons: to locate fens in new areas; to add quantitative plant-frequency data; to characterize the chemistry of their groundwater; to get some absolute ages; to evaluate carbon-loss processes in a warming climate, and to analyze the embedded paleoecological and paleoclimate records. They have much to can tell us, once we know how to read them, and should be protected from direct impacts and from any impacts to the hydrologic systems on which they depend.

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Appendix A - Plant Lists

Plant List for Beckwourth - Fen Number 11-0#

Dicots * = plants of interest

Species / FENS 2007-2008	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Abies concolor												X	X	X				X			X	
Abies magnifica														X								
Achillea millefolium	X				X		X					X				X						X
Aconitum columbianum																			X		X	
Alnus incana											X	X					X	X		X	X	X
Calocedrus decurrens												X						X			X	X
Camassia quamash	X																					
Cirsium douglasii var. breweri																						X
Cornus sericea												X	X				X	X	X	X	X	X
Dodecatheon hendersonii	X		X			X	X			X												
Drosera rotundifolia *										X								X				
Epilobium sp.			X		X		X		X	X	X		X	X		X	X	X	X			
Equisetum arvense									X				X						X	X	X	X
Equisetum laevigatum												X					X					X
Galium trifidum								X									X					
Gentianopsis simplex										X						X		X	X		X	
Geum macrophyllum																X			X			
Helenium bigelovii																X			X	X	X	
Heracleum lanatum																				X		
Hippurus vulgaris																	X					
Hypericum anagaloides	X						X				X	X	X	X		X		X	X			

Species / FENS 2007-2008	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Hypericum perforatum																		X	X	X	X	
Kalmia polifolia														X	X							
Lotus oblongifolia																		X	X	X	X	X
Madia bolanderi																			X	X	X	
Menyanthes trifoliata											X	X	X		X			X	X			
Mimulus guttatus	X	X			X		X					X					X	X	X	X	X	
Mimulus primuloides	X	X	X	X	X	X	X			X		X	X	X	X	X	X	X	X	X		
Montia chamissoi	X																					
Montia linearis	X																					
Muhlenbergia filiformis												X										
Nemophila pedunculata	X																					
Nuphar leuteum ssp. polysepalum											X							X				
Oreostema alpigenum	X						X			X		X	X	X	X	X		X	X	X	X	
Oxypolis occidentalis																				X	X	
Parnassia californica																			X	X	X	
Pedicularis attolens												X		X								
Pedicularis groenlandica														X	X				X			
Perideridia parishii	X												X			X		X	X	X	X	
Phlox gracilis	X																					
Pinus contorta ssp. murrayana							X					X	X	X		X		X		X	X	
Pinus jeffreyi											X		X					X			X	X
Pinus lambertiana																		X				
Pinus monticola																						
Polemonium occidentale		X																				
Polygonum bistortoides	X	X								X												

Species / FENS 2007-2008	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Potentilla gracilis	X						X		X							X		X				
Potentilla palustris																X			X			
Prunella vulgaris																				X	X	
Pseudotsuga menziesii																		X				
Pycnanthemum californicum																						X
Pyrola asarifolia		X									X	X							X			
Ranunculus alismafolius	X	X	X		X					X		X										
Ranunculus aquatilus																	X					
Ranunculus flamula	X																					
Rorippa curvisiliqua							X															
Salix eastwoodiae					X						X	X	X	X			X		X	X	X	
Salix sp.	X																	X		X		X
Saxifraga oregana	X	X			X	X	X															
Senecio hydrophyloides	X															X						
Senecio triangularis												X	X				X	X	X	X	X	
Sidalcea oregana																						X
Solidago spectbilis									X								X		X			X
Sphenosciadium capitellatum																	X		X	X	X	X
Spiraea densiflora												X	X	X								
Stellaria longipes	X				X		X		X													
Taraxicum officianale																X			X			
Trifolium longipes	X		X						X			X										
Trifolium wormskioldii																			X	X		
Tsuga heterophylla																						
Vaccinium uliginosum																		X				

Species / FENS 2007-2008	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Veronica americana							X										X					
Viola macloskeyi												X				X	X	X				

MONOCOTS

Species / Fen	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Allium validum					X			X				X	X					X	X		X	
Carex alma																		X	X	X		X
Carex aquatilis																		X				
Carex aurea	X	X							X			X				X		X	X			
Carex canescens																	X					
Carex capitata	X				X					X												
Carex echinata												X	X		X			X				
Carex hassei																		X				X
Carex lanuginosa																						X
Carex lasiocarpa *											X	X										
Carex lenticularis									X										X	X		
Carex luzulifolia													X					X				
Carex luzulina													X									
Carex nebrascensis	X		X	X	X	X	X		X	X				X				X	X			
Carex nigricans														X								
Carex praeceptorum														X								
Carex simulata	X		X		X					X						X						
Carex subfusca			X				X															
Carex utriculata	X	X	X		X		X	X		X	X	X	X	X	X			X	X			
Carex vesicaria												X		X		X	X					

Species / Fen	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Danthonia californica																X		X			X	
Deschampsia cespitosa	X						X		X					X	X	X		X	X			
Dulichium arundinaceum											X							X				
Eleocharis macrostachya												X					X	X				
Eleocharis pauciflora	X	X	X	X		X	X				X		X	X				X	X			
Eleocharis quinquiflora											X											
Epipactis gigantea																						X
Eriophorum gracile																		X				
Glyceria elata																	X			X		
Hordeum brachyantherum																						
Juncus balticus																						
Juncus mexicanus	X	X		X	X	X	X		X	X	X					X						X
Juncus nevadensis				X						X			X			X				X	X	
Juncus oxymeris													X						X			X
Lilium pardelinum																						
Lilium parvum																			X			
Luzula subcongesta												X				X			X	X		
Muhlenbergia filiformis	X	X	X		X		X					X	X	X	X				X			
Narthecium californicum													X						X		X	
Phleum pratense	X	X																				X
Platenthera leucostachys												X	X				X	X	X	X	X	
Platenthera sparsiflora													X						X	X		
Poa palustris	X						X				X											
Scirpus americanus																		X				X
Scirpus congdonii														X								

Species / Fen	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Scirpus microcarpus													X				X	X				
Spiranthes romanzoffiana		X					X												X	X	X	
Tofieldia occidentalis ssp.occident.												X	X					X	X	X	X	
Veratrum californicum												X	X					X	X	X	X	

BRYOPHYTES

Species / Fen	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Amblystegium radicale																	X					
Brachythecium frigidum	X																					
Bryum sp																		X				
Bryum lisae							X															
Bryum pallens									X													
Bryum pseudotriquetrum	X								X													
Bryum sp. (undescribed)												X						X				
Campylium polygamum												X										
Campylium stellatum									X													
Drepanocladus sp	X	X	X	X	X		X		X	X					X							
Drepanocladus sordidus	X								X													
Drepanocladus aduncus									X													
Fontianalis antipyretica												X										
Funaria hygrometrica									X													
Hennediella heimii									X													
Marchantia polymorpha				X			X						X									X
Meesia triquetra *																		X				
Philonotis fontana	X																					

Species / Fen	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Philonotis sp.						X	X			X												
Pohlia wahlenbergii									X													
Sphagnum											X		X	X	X							

Appendix B - Glossary

Fen Type and Landform definitions are based on Cooper & Wolf (2006)

Basin: basin fen types occur in natural depressions and where dikes, moraines or other obstructions result in water ponding, fens form as a pond fills with partially decomposed vegetation.

Lava-discontinuity: lava-discontinuity fens are a special case of slope fens. They occur in lava-flow terrain where very large springs flows discharge from permeable volcanic rocks that overly an impervious surface that was developed on an earlier flow.

Slope: slope fen types occur most commonly at the base of a slope, but also further up on a slope, where springs discharge and the water is retained by the fen vegetation.

Spring Mounds: spring mounds form over localized points of ground water discharge, due to the higher productivity and/or reduced decomposition of plant material. They can occur as essentially isolated fens, or within larger fens of either slope or basin type. They are typically of order a meter in height and several meters or 10s of meters in horizontal extent.

Histic soil or Histosol: Organic soils that vary from 12% to 18% organic carbon depending on clay content, at least 40 cm having sufficient organic carbon within the top 80 cm of soil

Poor Fen: Water saturating the root zone of the fen has a pH of less than 5.4. "Poor" is used to suggest the typically lower nutrient levels. They tend to have *Sphagnum* and lower primary productivity.

Rich Fen: Water saturating the root zone of the fen has a pH of greater than 7 (or 7.5 for "extreme rich" fens). "Rich" is used to suggest the typically higher nutrient levels of such fens. They tend to have brown-moss dominated bryophyte flora and to lack *Sphagnum*.

Species Richness: A term to indicate the number of species found in an area. The higher the number of species, the more "rich" the area.