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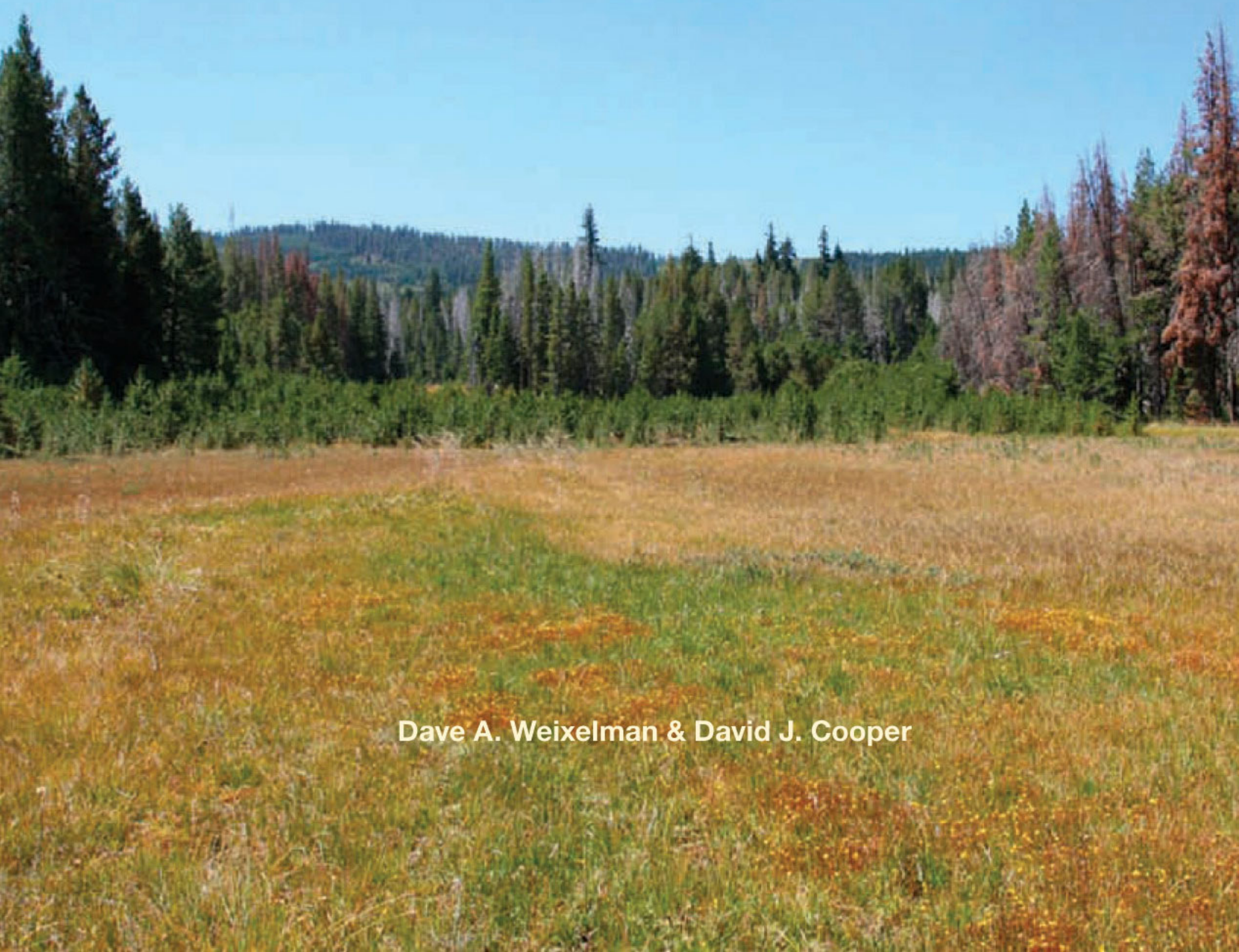
Assessing Proper Functioning Condition for Fen Areas in the Sierra Nevada and Southern Cascade Ranges in California

A User Guide



Dave A. Weixelman & David J. Cooper

Abstract

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Fens are an important and unique wetland type. Fens are peat-forming wetlands that rely on groundwater input and require thousands of years to develop and cannot easily be restored once destroyed. Fens are also hotspots of biodiversity. They often are home to rare plants, insects, and small mammals. Larger animals like deer and livestock graze in this type of wetland. Fens are valuable to humans as well. They are important as sites of groundwater discharge and are good indicators of shallow aquifers. Vegetation in all wetlands plays an important role in recycling nutrients, trapping eroding soil, and filtering out polluting chemicals such as nitrates. In addition, fens figure prominently in nearly all scenarios of CO_2-induced global change because they are a major sink for atmospheric carbon.

The purpose of this document is to provide a checklist and supporting science to help rate the condition of fens in the Sierra Nevada and Southern Cascades of California. The field assessment is designed to be done by an interdisciplinary (ID) team composed of botany, range, and soils/hydrology expertise. The items in the checklist are factors that can be estimated or measured directly in the field with a minimum of equipment. The checklist has been adapted from the Bureau of Land Management Proper Functioning Condition (PFC) checklist for lentic areas (Prichard et al. 1999).

Keywords: fen, peatland, wetland, proper functioning condition, PFC

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A User Guide to Assessing Proper Functioning Condition for Fen Areas in the Sierra Nevada and Southern Cascade Ranges in California

I. Introduction

The purpose of this document is to provide a checklist and supporting science for rating the physical functioning of fens in the Sierra Nevada and Southern Cascades in California. This document uses the Proper Functioning Condition method, or PFC method. The term PFC is used to describe both the assessment process, and a defined, on-the-ground condition for fens. See Figure 1 for a map of the area where this document can be used. The intended audience includes hydrologists, soil scientists, biologists, and range personnel. The field assessment is designed to be done by an interdisciplinary (ID) team with journey level expertise expertise in botany, range, and soils (or hydrology). Journey level experience requires at least one year of field experience in the appropriate discipline.

The items in the checklist are factors that can be estimated or measured directly in the field with a minimum of equipment. The checklist can be found in Appendix A of this document. The checklist has been adapted from the Bureau of Land Management Proper Functioning Condition (PFC) checklist for lentic areas (standing water wetlands) (Prichard et al. 1999) -- but is tailored to fens. The ID team should read through and be familiar with the PFC lentic checklist document (Prichard et al. 1999) before beginning the fen assessment. Many of the concepts in this document are taken from the PFC lentic document. Plant nomenclature in this document follows the Jepson Manual (Hickman 1993). All photos are by the authors unless otherwise noted.

A. The PFC (Proper Functioning Condition) Method: What It Is and What It Isn't

PFC is: A methodology for assessing the physical functioning of fen areas. The term PFC is used to describe both the **assessment** process, and a defined, on-the-ground **condition** of a fen area (National Riparian Service Team, BLM, Prineville, OR, pers. comm.). In either case, PFC defines a minimum or starting point. PFC is a tool we can use to discuss, better understand, and begin to assess the condition of an area and should not be used as the sole source of information on the condition of an area or replace quantitative protocols to assess condition. This PFC protocol does describe quantitative measurements which could be part of a quantitative fen assessment.

The PFC **assessment** provides a consistent approach for assessing the physical functioning of fens through consideration of hydrology, vegetation, and soil/landform attributes. The PFC assessment synthesizes information that is foundational to determining the overall health of a fen.

The on-the ground **condition** termed PFC refers to *how well* the physical processes are functioning. PFC is a state of resiliency that will allow continued development of the fen, sustaining that system's ability to produce values related to both physical and biological attributes.

PFC isn't*:* The sole methodology for assessing the health of the aquatic or terrestrial components of a fen.

PFC isn't*:* A replacement for inventory or monitoring protocols designed to yield information on the "biology" of the plants and animals dependent on the fen.

PFC can: Provide information on whether a fen area is physically functioning in a manner which will allow the maintenance or recovery of desired values over time.

PFC can*:* help determine if a fen is meeting or moving towards a desired future condition. The US Forest Service 2004 Sierra Nevada Forest Plan Amendment Record of Decision (SNFPA) states that a desired future condition of fens is Proper Functioning Condition.

PFC can't*:* Provide more than strong clues as to the actual condition of habitat for plants and animals. Generally a fen in a physically non-functioning condition will not provide quality habitat conditions. A fen that has recovered to a *proper functioning condition*, would either be providing quality habitat conditions, or would be moving in that direction if recovery is allowed to continue.

II. Background

A. Definition of a fen

Fens are ecosystems with hydric soils with an aquic soil moisture regime, and an accumulation of peat in the histic epipedon. Organic soils are commonly referred to as peat or muck. These organic soils contain a minimum of 40 cm of organic horizons within the upper 80 cm of the soil profile (Soil Survey Staff 1999-2006). The organic horizons contain at least 12 – 18% organic-carbon content by dry weight, depending upon the percent of clay in the mineral fraction. For this document, we are adopting the NRCS definition of organic soil, however future research may help clarify the peat thickness or composition criteria that are most useful for defining a fen. Many or most fens have areas of thinner peat soils. This could be on the margins of a basin, or the edges of a spring complex. However, all wetland areas connected to the main peat body should be considered to be part of the fen complex.

Fens have formed where the long-term rate of organic matter production by plants exceeds the rate of decomposition due to waterlogging (Vitt 2000). Peat accumulates very slowly, from 11 to 41 cm (4.3 to 16.2 inches) per thousand years in the Rocky Mountains (Cooper 1990, Chimner and Cooper 2002). Compared to other habitats, fens support a disproportionately large number of rare vascular and nonvascular plants species in the Sierra Nevada underscoring the importance of these habitats for regional biological diversity. In addition, fens figure prominently in nearly all scenarios of CO_2-induced global change because they are a major sink for atmospheric carbon.

B. Major types of fens in the Sierra Nevada and Southern Cascades in California

Fens can be categorized both in terms of hydrochemistry and hydrogeomorphic settings. The vegetation of fens varies widely and appears to be controlled by the hydrologic regime (water depth, water inflow rates), as well as water chemistry (pH, cation, anion, and nutrient concentrations) (Cooper et al. 2005a). In California, fens that are acidic (i.e. low pH values) are termed poor fens, while fens that are basic, circumneutral or slightly acid, have higher pH values, and are termed rich fens.

- Poor fens have water pH of 4.5 – 5.4 (Vitt 1994, Cooper & Andrus 1994, Halsey et al. 1997, Vitt 2000), are poor in base cations and have no or little alkalinity. They are dominated by mostly oligotrophic species of the mosses *Sphagnum* and *Drepanocladus*.
- Moderate-rich fens have slightly acid to neutral pH (5.5-6.9) and have low to moderate alkalinity with a ground layer of brown mosses often including *Drepanocladus, Philonotis*, and low abundances of mesotrophic species of *Sphagnum*. Moderate-rich fens may be dominated by a dense cover of sedges.
- Extreme-rich fens have basic pH (above 6.9), high concentrations of base cations, and high alkalinity. They are characterized by sedges (*Carex*) and moss species such as *Drepanocladus* and *Philonotis*, and may contain marl deposits.

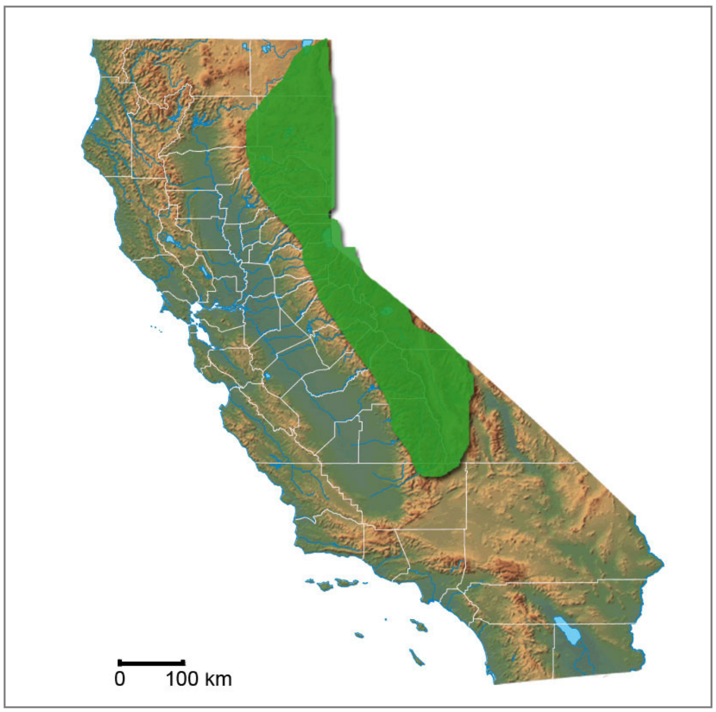

Figure 1. The study area (shaded green) in the Sierra Nevada and Southern Cascade ranges of California.

Fens have formed in four major geomorphic settings based on studies of fens in the Sierra Nevada and Southern Cascades of California (Cooper et al. 2005a , USFS 2006): hill slopes, basins, mound, and lava bedrock discontinuities. This study area is shown in Figure 1. It is important to note that some fens occur on more than one geomorphic setting, for example slope and basin fens.

Sloping fens

Sloping fens, also called soligeneous peatlands (Mitsch and Gosselink 2000), occur on or at the base of slopes where groundwater discharges to the surface due to a break in the topography, or change in geology, or in valley bottoms where alluvial groundwater supports peat formation (Cooper 1990, Woods 2001, Rocchio 2005). This fen type is usually underlain by springs, or a complex of ground water discharge points (see Figure 2). This is the most common type of fen in the Sierra Nevada (Cooper et al. 2005a).

Basin fens

Basin fens, also called topogeneous peatlands, develop in topographic depressions that typically have no perennial surface water inlet or outlet (Rocchio 2005). Their water source includes upwelling groundwater or surface runoff from the basin edges (see Figure 3). Some basin fens develop a unique fen feature-- a floating mat on the margins of open water.

Mound fens

Mound fens are raised areas where peat has accumulated due to single strong source of upwelling of water (see Figure 4). This type often occurs at the base of slopes associated with sloping fens. There typically is a surface water outlet so they are not classified as basin fens.

Lava fens

Lava fens have been described by Cooper et al. (2005a). Lava fens appear to be restricted to the southern Cascades, primarily on the Lassen and Modoc National Forests. Lava fens are created when a lava discontinuity creates hillside groundwater flow systems (see Figure 5). These fens are similar to the sloping fen type and differ due to their unique geology, flow rates, and water chemistry.

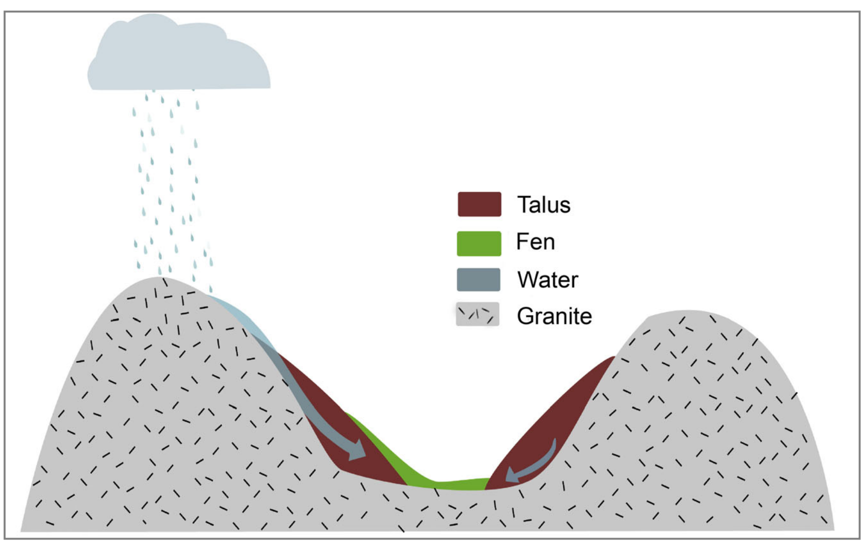

Figure 2. Illustration of a sloping fen complex (green areas) on hillslopes and at toe of slopes.

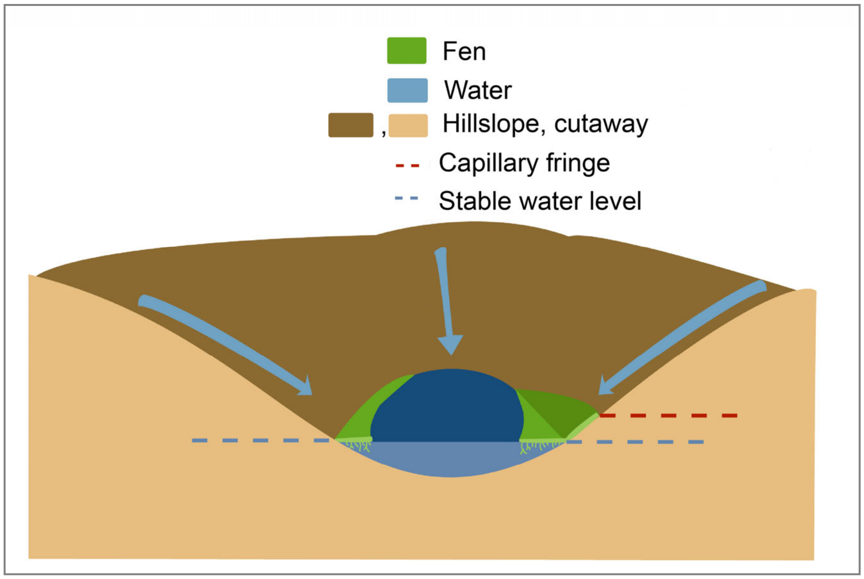

Figure 3. Illustration of basin type fen, which is supported by both surface and ground water inflow. Water levels in the basins tend to be very stable, and floating peat mats are common.

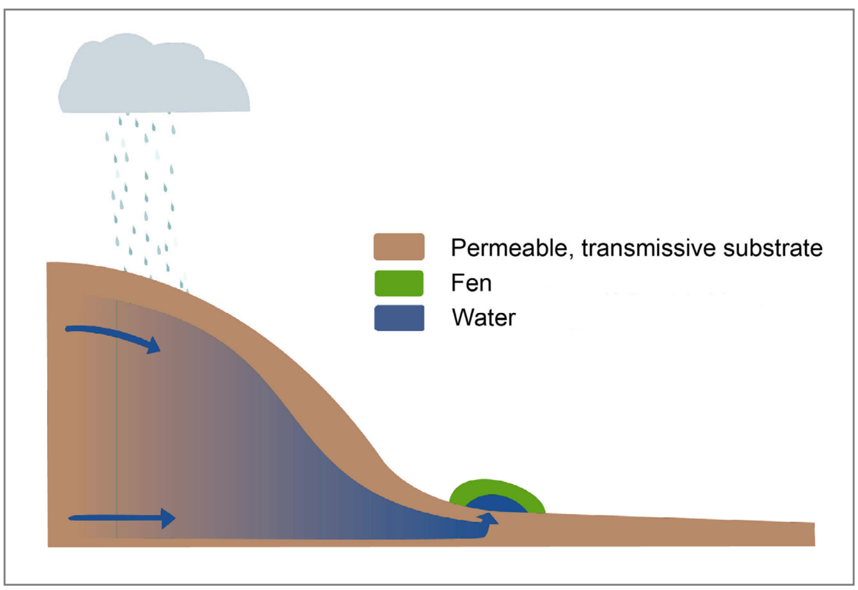

Figure 4. Illustration of a spring mound fen.

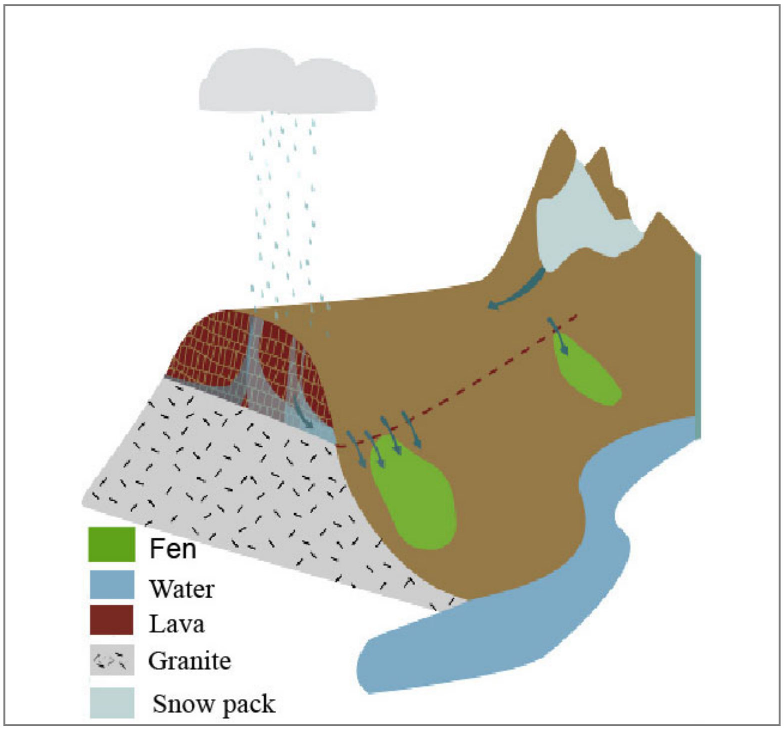

Figure 5. Illustration of a lava discontinuity fen formed where ground water discharges at a lava bed discontinuity. Fens of this type are common in the southern Cascade Range on the Lassen National Forest.

III. Threats to Fens

A. Groundwater alteration

The integrity of peatland ecosystems is inherently tied to the hydrologic conditions that supported peat accumulation. Water diversions, ditches, and roads can have a substantial impact on the hydrologic regime and the biotic integrity of fens (Johnson 1996, Woods 2001, Cooper et al. 1998, Austin 2008).

In addition, roads can act as sources of sediment input into fens. Roads placed above fens may divert runoff away from the fen and the result is a de-watering of the fen (Patterson and Cooper 2007). Once the water table is lowered, peat subsidence and subsequent decomposition occurs in a few years thereby reducing the peat thickness altering hydrologic patterns, and resulting in a change in plant species composition (Cooper 1990). As areas dry out, dominant plant species often change to non peat-forming species such as herbaceous dicots. Since fens are groundwater-reliant, any disturbance that significantly impacts water quantity or quality is a threat. These threats include groundwater pumping, mining of peat or minerals, improper placement of roads, water diversions, ditching, and ponds excavated for livestock watering sources. Fens can also be permanently altered by flooding (often from filling of a reservoir behind a new or reconstructed dam) for several years (Austin 2008).

B. Land use

The land uses occurring on or adjacent to fens can threaten fens. Livestock management can impact peatlands by trampling, compacting peat, creating bare areas in the fen or in adjacent uplands, altering hydrologic conditions, and initiating erosion and gully formation (headcutting). Cooper et al. (2005b) found that when as little as 15% of the soil surface is bare of vegetation, it can result in a negative carbon budget and therefore a loss of peat. In some cases, cattle trails can form head cuts or channelization that alters fen hydrologic regimes, lowering the water table, and drying out areas of the fen. As areas dry out or are overgrazed, plant species composition often changes to non peat-forming species, particularly herbaceous dicots, and moss cover diminishes leaving exposed dry peat.

Off highway vehicle (OHV) use can negatively impact fens by exposing soil and bare peat, creating channels in fens which act as a water diversion, and compacting soil. Recent research indicates that over-snow vehicle use can have detrimental impacts to fens, by eliminating the insulating function of snow cover and causing the fens to freeze (Cooper unpublished data).

As noted above, construction of roads and water management activities (such as dams, ditches, and diversions) can have significant negative effects on fen extent and condition. Timber harvest activities can result in negative effects such as adding sediment to fen areas and affecting the quality of water entering fens. Timber harvest activities can also result in increased water supply to watersheds by reducing water losses due to evapotranspiration and potentially increase water supply to fen areas.

B. Exotic plant species and native increasers

Invasion by exotic species (nonnative plant species) is apparent in some peatlands in the Sierra Nevada. Such species include timothy (*Phleum pratense*) as well as exotic species common to other wetland types such as Canada thistle (*Cirsium arvense*) and dandelion (*Taraxacum officinale*). Native increasers (plants that increase after disturbance) such as Bolander's mock dandelion (*Phalacroseris bolanderi)*, primrose monkeyflower (*Mimulus primuloides)*, and tinker's penny (*Hypericum anagalloides*) often invade a fen that has been overgrazed or artificially drained. Although these species are native and commonly absent or found in low abundance in undisturbed fens, they can be indicative of disturbance if they dominate areas previously occupied by sedges (Ratliffe 1985, Rocchio 2005).

IV. Proper Functioning Condition (PFC)

Proper functioning condition (PFC) is a qualitative assessment method for rating the condition of lotic and lentic sites (Prichard et al. 1999). This document describes a PFC assessment specifically for fens. The term PFC is used to describe both the assessment process, and a defined, on-the-ground rating of condition of a fen area.

This PFC assessment is based upon a consistent approach balancing hydrology, vegetation, and soil and erosion attributes and processes to assess the condition of a fen. A checklist is used (Appendix A of this document), which synthesizes information that is fundamental to determining the overall health of an area of fen. Some of the checklist items may be quantitatively measured to further support the PFC condition rating.

A. Consideration of Capability and Potential

Each fen area has to be judged against its capability and potential (from Prichard et al. 1999). The capability and potential of natural fen-wetland areas are characterized by the interaction of three components: 1) hydrologic regime; 2) vegetation and 3) soil and erosion components.

Potential is defined as the highest ecological status a fen area can attain "without interferences by man under the present environmental conditions" (Pritchard et al. 1976, Range Inventory Standardization Committee 1983).

Capability is defined as the highest ecological status a fen area can attain given political, social, or economic constraints. These constraints are often referred to as limiting factors. A constraint in this case is something that is determined to be beyond the control of the land manager.

If the capability of a site is determined to be less than potential, then the checklist items are answered according to the areas capability. In this case, the question on page two of the checklist "Are factors contributing to conditions outside the control of the manager?" is answered "yes," and the factor involved is checked to show that the new capability is beyond the control of the land manager to change.

B. Determination of Potential for fen sites

When beginning the PFC process on a fen area, it is important for the ID team to discuss and determine the type of fen being evaluated, and compare this fen with descriptions of reference fens from published literature, established reference wetlands (Brinson and Rheinhardt 1996), and inventory results from the general area.

The ID team must identify the fen landform setting (basin, sloping, mound, or lava) and determine the fen pH category (poor, moderate rich, or extreme rich from Cooper et al. [2005a]). A single fen may occur on more than one landform setting. This information is recorded on the first page of the fen checklist (see Appendix A). Determining the landform setting and pH category is important because of the different potential to support vegetation. For example, poor fens (low pH value) with a water table near the surface, generally have an extensive moss cover and a patchy, open cover of sedges and rushes. Sites with more dynamic water tables experience saturation at the surface early in the season followed by late-season drawdown (MacKenzie and Moran. 2004). These types of sites usually have a low cover of bryophytes because most fen mosses are intolerant of consistently dry conditions. Intermediate and extreme rich fens can have an extensive moss cover or very little moss cover depending on the stability of the water table and tend to have a higher cover of sedges and rushes.

Intact, fully functioning fens vary in plant species composition (potential vegetation). Fens that are functioning properly have the following characteristics in common:

- Perennially high water table and saturated soils that limit decomposition rates,
- Natural surface and subsurface flow patterns that are not significantly affected by disturbance,
- Sufficiently low soil temperatures that limit microbial activity and low organic matter decomposition rates resulting in low CO_2 emissions,
- Good cover of native, non-invader vegetation over the peat body with little exposed peat,
- High proportion of peat-forming plant species,
- Fen is in balance with the water and sediment being supplied by the watershed (i.e. no excessive erosion or deposition).

Further, fens in the Sierra Nevada have in general been greatly impacted by grazing, water diversions, and management. These disturbances have significantly altered the appearance and vegetation composition of many fens.

It is important for the ID team to address the potential of a fen using vegetation, hydrologic, and soil characteristics given the capability of the site. When discussing the potential of a site use the following points to guide the discussion process. This approach, adapted from Prichard et al. (1999), requires the team to:

- Look for relict areas (exclosures, preserves, established reference wetlands, literature descriptions of high-quality fens, etc.),
- Seek out historic photos and documentation that may indicate the historic condition. Historical photos are nearly always valuable, but some caution is necessary, for a photo may have been taken after intense disturbance,
- Search out species lists and descriptions from reference or high-quality fens (animals and plants – historic and present),
- Determine species habitat needs (animals and plants) related to species that are/were present,
- Examine the soils, particularly at the margins of fens for alterations in drainage and soil moisture regime and oxidation or erosion of organic soil.
- Examine the hydrologic regime; determine the source of the water for the fen, establish the likely water table depths and its variation through the summer in different parts of the fen. Try to determine whether the hydrological regime has changed over historical time, and what were the causes of such change

- Correctly identify the vegetation that currently exists. Are they the same species that occurred historically and likely formed the peat layers?
- Determine the general condition of the watershed and the general area adjacent to the fen, and
- Look for limiting factors, both human-caused and natural, and determine if they can be corrected.

Once the team has discussed the vegetation, hydrologic regime, and soil and water characteristics, identified the landform setting and the fen type (rich, intermediate, or poor), and followed the approach above, the team should be able to describe in general terms the potential of the site given the site capability. Having a general picture, or idea of site potential will be important for answering the questions on site functionality.

The checklist should be used on areas that are already identified as fens by using the USFS R5 Fen Survey Form. This checklist is not designed to determine if a site meets the criteria of a fen.

Figures 6 through 11 contain photos showing poor, moderate rich, and extreme rich fens. They are intended to illustrate the range of variability between these fen types and their natural vegetation. Fens vary in vegetation composition even within the poor, moderate rich, and extreme rich fen categories and will not always follow the patterns shown here.

Figure 6. A poor fen (pH = 5.2). The vegetation is dominated by graminoids and shrubs that are obligate wetland species. The water table is near the surface with very little exposed peat. Note alder (Alnus sp.) in the foreground. Silver Lake fen, Plumas National Forest, July 2, 2002.

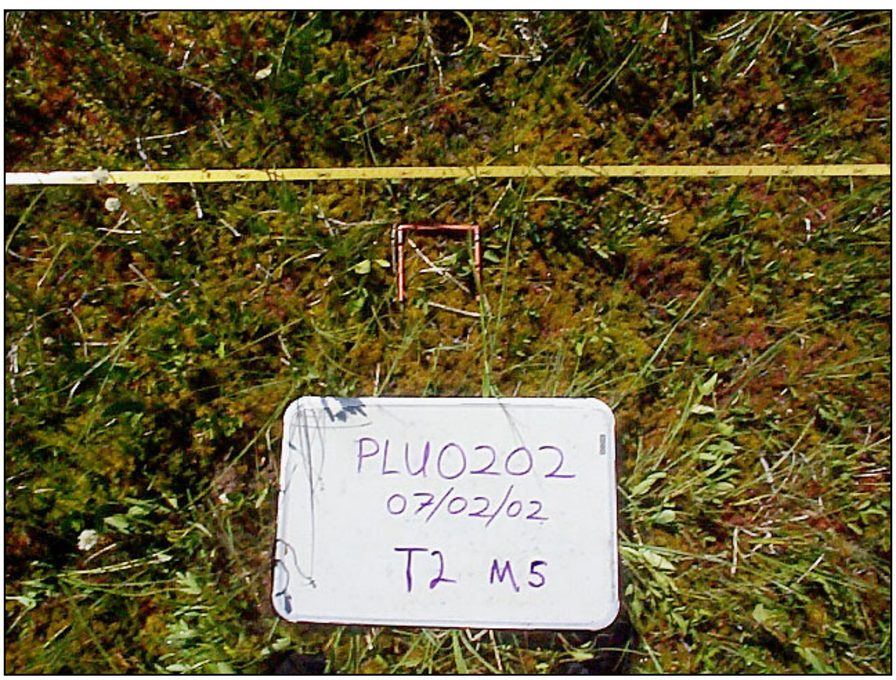

Figure 7. Close-up of a poor fen (pH = 5.2). Note extensive moss cover.

Figure 8. A moderate-rich fen (pH = 6.2). The sedges that are present are obligate wetland species. The water table is near the surface and there is very little exposed peat. Mason fen, Tahoe National Forest, August 24, 2007.

Figure 9. Close-up of a moderate-rich fen (pH = 6.2) Note the mix of moss, litter, and vascular plant cover. Mason fen, Tahoe National Forest.

Figure 10. Hanging Fen, an extreme rich fen (pH = 7.9) in the Convict Creek Basin, California. The sedges that are present are obligate wetland species.

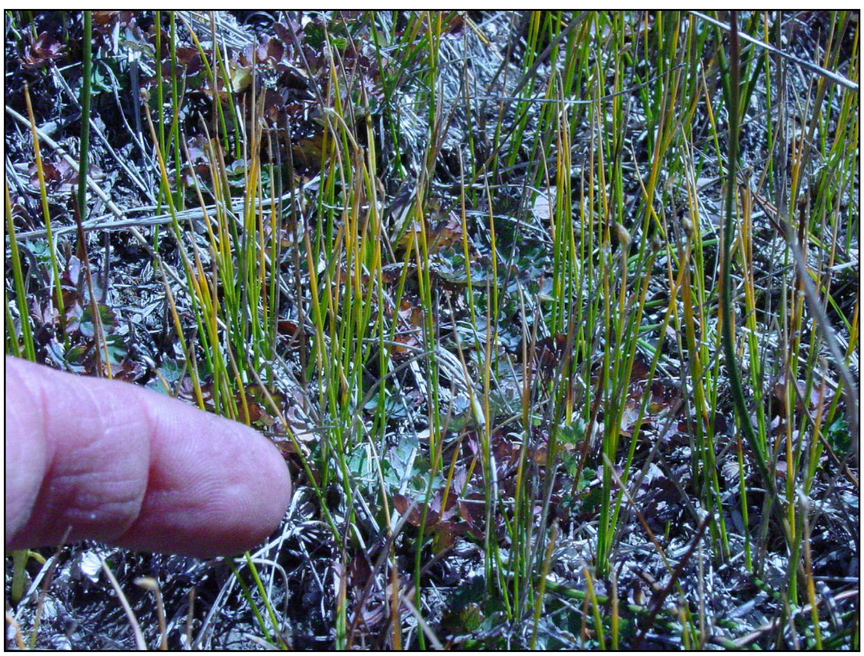

Figure 11. Close-up of *Scirpus pumilus* an extreme rich fen indicator in Hanging Fen (pH = 7.9).

C. Functional Rating

The condition checklist has ten items for assessing the functionality of the site. Previous inventories of Sierra Nevada fens and wetlands (Erman 1973, Erman 1976, Erman and Chouteau 1979, Ratliffe 1985, Bartolomne et al. 1990, Allen-Diaz 1991, Chadde et al. 1998, Cooper et al. 1998, Prichard et al. 1999, Mitsch and Gosselink 2000. Cooper 2005). Cooper et al. (2005a, 2005b), Rocchio (2005), Patterson and Cooper (2007) suggest that the items in the checklist are important measures of the functional status of Sierra Nevada montane and subalpine fens and fens in general. These items were chosen because they can be observed in the field and do not require complex equipment. The checklist items can be broadly classified under: 1) hydrologic regime; 2) vegetation; and 3) and soil and erosion characteristics.

The checklist items are designed to address the common attributes and processes that are necessary for a fen to function properly. Each item on the checklist is answered with a "yes" meaning that the attribute or process is working, a "no" meaning that it is not working, or an "N/A" meaning the item is not applicable to that particular area. For any item marked "no", the severity of the condition must be explained in the "Remarks" section and must be discussed by the ID team in determining the fen functionality.

There is no set number of "no" answers that dictate whether an area is at-risk or nonfunctional. This is due to the variability in kinds of fen-wetland areas (based on differences in climate, geology, landform, vegetation, and substrate) and the variability in the severity of individual factors relative to an area's ability to maintain a functioning peat body.

Following completion of the checklist, a "functional rating", either PFC, functional-at-risk, or nonfunctional is determined based on an ID team's discussion (Prichard et al. 1999). When determining the functional rating, it is important for the ID team to understand the type of fen being assessed. The ID team must review the "yes" and "no" answers on the checklist and their respective comments about the severity of the situation, then collectively agree on a rating of proper functioning condition, functional-at- risk, or nonfunctional. If an ID team agrees on a functional-at-risk rating, a determination of trend is then made whenever possible.

If a fen area possesses the characteristics of a healthy fen described above, then it has a high probability of maintaining its peat accumulation functions. If all the answers on the checklist are "yes", this area is in proper functioning condition. However, if some answers on the checklist are "no", the area may still meet the definition of PFC. The ID team reviews the "no" answers and determines if any of these answers make this fen area susceptible and cause a degradation of the peat body. If they do, the ID team would rate the area and explain why it is something less than PFC.

If a fen area is not at PFC, it is placed into one of three other categories:

- **Functional- at-risk** – fen areas that are at least partially functioning, but that have an existing soil, water, or vegetation attribute that makes them susceptible to degradation.
- **Nonfunctional** – fen areas that clearly are not providing adequate vegetation, soil and water characteristics, to maintain a healthy peat ecosystem.

- **Unknown** – fen areas for which sufficient information is lacking to make a determination. This category should only be chosen when the ID team agrees that the checklist items cannot be answered. This is not a fall-back determination in situations where the team cannot decide or agree on the answers to the checklist items.

A functional-at-risk fen area will have some or even most of the elements in the checklist, but have at least one item that gives it a high probability of degradation for any elements of the definition given above (Prichard et al. 1999). Most of the time, several "no" answers will be evident because of the interrelationships between items in the checklist. If the ID team thinks that these "no" answers collectively provide the probability for degradation from the definition elements above, then the rating is functional-at-risk. If there is disagreement among the team members after all the comments have been discussed, it is probably advisable to be conservative in the rating (i.e. if the discussion is between PFC and functional-at-risk, then the rating should be functional-at-risk).

Nonfunctional fen areas clearly lack the elements of a functional fen. Usually nonfunctional fen areas translate to a preponderance of "no" answers" on the checklist, but not necessarily all "no" answers. A fen area may still be dominated by peat-forming plant species but be clearly nonfunctional because of a water diversion that is clearly lowering the water table and causing establishment of plant species that indicate drying conditions.

Trend must be determined, if possible, when a rating of functional-at-risk is given. Preferably, trend is determined by comparing the present situation with previous photos (Prichard et al. 1996), trend studies, inventories, and any other documentation or personal knowledge. In the absence of information prior to the assessment, indicators of "apparent trend" may be deduced during the assessment process. Recruitment and establishment of wetland species (or absence thereof) that indicate an increase or decline in soil moisture characteristics can be especially useful. However, care must be taken to relate these indicators to recent climatic conditions as well as to management. If there is insufficient evidence to make a determination that there is a trend toward PFC (upward) or away from PFC (downward), then the trend is not apparent.

V. Checklist Items (the checklist can be found in Appendix A)

A. Hydrology characteristics (Items 1 – 3)

Item 1. Fen water table is within 20 cm of the soil surface for most of the summer.

Purpose

The integrity of peatland systems is inherently tied to hydrologic conditions. The purpose of item 1 is to document that the water table is high enough for most of the summer to maintain a peatland ecosystem. Studies of fens in the Southern Rocky Mountains (Cooper

1990, Chimner and Cooper 2003), and in Sweden (Silvola et al. 1996), reported that only those areas with soil saturation or a water table within 20 cm of the soil surface through July and August accumulated peat. In many fens, the water table can drop in late-July and August so careful interpretation of this metric needs to be implemented (Cooper 1990).

Examples

This item is measured by augering several holes in the wetland. A useful first step in this hydrologic assessment is to walk the whole fen and identify flow paths, channels, ditches, pools, standing or sheet-flowing surface water, dry patches, and ensure that placement of the auger holes is done to represent all of these visible hydrologic differences on-site. There is no need to auger a hole where there is water above the surface or where the water table is close to the surface as evidenced by water pooling around an observer's feet while standing in the fen.

Auger several holes in the wetland, allowing water in the holes to equilibrate, and determining the average depth to the water table. A 3-inch diameter auger is recommended, smaller diameter augers can make it difficult to see the water level. The distance between the soil surface and the water level equals the depth to the water table. This metric is best used during site visits made in mid-July through August. Allow at least 30 minutes to pass before measuring the water level in the soil auger holes. Examine the sides of the hole and determine the shallowest depth at which water is entering the hole. Record the depth at which water is entering (seeping) into the hole or the level of the water, whichever is the shallowest. This will be the depth to water table.

When applying this indicator, both the season of the year and preceding weather conditions *must be considered*. When making these measurements, disturb the fen as minimally as possible. Consideration of annual precipitation and annual snowpack are needed to assess the reliability of this metric (Rocchio 2005). During years of average precipitation (or average snowpack) this metric, taken together with the other metrics, is a reliable rapid method of assessing the integrity of the groundwater levels in the wetland.

In order to make a determination of "yes" or "no" on this item, the ID team uses the average depth to water table as a general guideline considering the potential and capability of the site. As a general guideline, if the average water table depth in the fen is greater than (>)20 cm during the site visit the answer to item 1 would be "no".

Item 2. There is no evidence of hydrologic alteration in the watershed that could affect the fen

Purpose

The condition of the surrounding uplands and surrounding wetland area (if any) can greatly affect the condition of a fen area. Changes in the surrounding upland or wetland area can influence the magnitude, timing, or duration of overland flow events as well as groundwater, which in turn can affect a fen area. The purpose of item 2 is to determine if there has been a change in the water or sediments being supplied to a fen-wetland area, and whether it is resulting in *degradation*. This item pertains to whether uplands are contributing to the degradation of a fen–wetland area; it does not pertain to the condition of the uplands.

Examples

Evidence that a wetland area is being degraded may include upslope road ditches and cross drainage structures installed in a manner that concentrates overland flows or groundwater inflows away from the fen-wetland area, causing desiccation of the fen-wetland area. Additional evidence may be fan deposits showing excess sediment being deposited into the wetland. If any of these items are present, the answer to item 2 would be “no”. If flow has been added from a diversion, and excessive erosion or deposition is taking place as a result of this increased flow, the answer to item 2 would be “no.” Item 2 will never be answered “N/A”; it will always have a “yes” or “no” answer. It is possible to have disturbances in the uplands and still not see major changes in the magnitude, timing, or duration of overland flows having a negative impact on fen-wetland areas. If there is no evidence of hydrologic alteration in the watershed that could affect the fen, the answer to item 2 is “yes”, even if the uplands are not in good condition.

Item 3. Natural surface or subsurface flow patterns are unaltered within the fen (i.e., no flow pattern disturbance by dams, dikes, trails, hoof action, hummocking, roads, rills, gullies, ditches, drilling activities etc.)

Purpose

Alteration of surface of subsurface flow patterns may affect the functionality of the fen. Land uses within the fen-wetland allow oxygen flux into the peat body, increase decomposition, can reduce soil permeability, affect surface water inflows, impede subsurface flow, and lower water tables. The purpose of this item is to determine if surface or subsurface flow patterns are being maintained (Prichard et al. 1999).

Examples

Evidence that the natural surface or subsurface flow patterns have been altered may include hummocking from hoof action of grazing animals, dams, dikes, trails, roads, gullies, ditches or any disturbance that impedes or alters surface or groundwater flows and (in the judgment of the team) is causing degradation to the fen. If any of these items are present, and in the judgment of the team are causing an alteration of surface or subsurface flow patterns that are degrading the fen, then the answer to item 3 would be “no.” An answer of “no” would be given for item 3 for the example shown in Figure 12. In this example, a ditch was dug near the middle of the fen and was draining a portion of the fen. If hoof action or trailing from livestock is causing water channels or visible erosion then the answer to item 3 would be “no.”

Damage to the fen surface can occur when large herbivores or people walk through fens and by motorized vehicles driving on the fen. In the case of livestock, the animal’s weight can cause shearing that in turn results in direct exposure of the peat layer. Animals walking through the fen may increase the amount of peat exposed to the air or cutting through the moss or litter layers and exposing peat and/or soil. Excessive trampling can cause increased exposure of the peat layer, which in turn results in oxidation of the organic layers and decomposition of the peat. Trampling and/or hoof punching is considered damage when there are hoof prints, tire tracks, or human prints that cause shearing and expose bare peat or bare soil and are causing water channels to form or are causing visible signs of erosion.

In the case of Basin fens with a floating peat mat, item 3 pertains to the edges of the floating peat mat that is in contact with a water body. These types of fens often develop adjacent to shallow lakes and ponds and a floating peat mat forms over water. Saturation of the floating mat depends on close contact with the surrounding water. Situations where a floating mat would be removed from contact with the water include: 1) drainage of the lake/pond stranding the floating mat above the water table (this would certainly expose peat on the side of the floating mat); 2) wave action from boats could break apart the edge of the floating mat, exposing “old” peat at the margin, and 3) trampling or trailing could sever all or part of the floating mat and cause it to become free floating. This would leave a broken edge of peat, and possibly free floating peat islands as evidence. If any of these situations are present on floating mats, the answer to item 3 would be “no.”

Figure 12. Ditch that has been dug in a fen on the Tahoe National Forest. This ditch is approximately 6 inches (15 cm) deep and is dewatering the area around the ditch.

B. Vegetation Characteristics (Items 4 – 8)

Item 4. The vegetation is comprised largely of known peat-forming plant species

Purpose

An intact hydrologic regime and the presence of peat forming vegetation are critical for the persistence of fen wetlands (Patterson and Cooper 2007). Peat-forming vegetation in fens is both adapted to its physical and chemical environment and helps to stabilize these conditions. Peat-forming plants have adapted to waterlogged anaerobic environments, acidification of external interstitial water, and nutrient deficiency. The percentage of peat-forming plants on a site is an indicator of the degree to which peat formation is being maintained. The purpose of item 4 is to determine if the site is dominated by short-lived, shallow rooted pioneering species or long-lived perennial, deep-rooted hydrophytes. The long-term productivity and sustainability of the peat body is, in part, determined by the amount of these short-lived pioneering species versus the amount of long-lived perennial, deep-rooted plant species contributing organic matter as compared with the amount contributed by short-lived pioneering species.

Examples

With increasing disturbance, long-lived native graminoid cover decreases relative to the cover of forbs. The presence of species such as *Mimulus primuloides, Hypericum anagalloides, Phalacroseris bolanderi*, and other short-lived, pioneering species indicates that disturbance of the surface layer is occurring or has occurred in the past. These changes are typically the result of a change in hydrology due to soil compaction, physical disturbance, or upstream alterations.

Appendix B lists many of the species that are commonly found in fens in California including vascular and nonvascular plants. Species that are known peat-forming plants are noted. Using the field form in Appendix C, record the amount of canopy cover (Daubenmire 1959) for the dominant species on the site and note whether the species is a known peat former or not. Remember to tally mosses and liverworts as well as vascular plant species. A field form for this exercise can be found in Appendix C.

The answer to item 4 requires you walk the extent of the fen and determine if the site is generally dominated by peat-forming plants. If the fen is clearly dominated by peat-forming plant species and the percent cover of non peat forming plants is insignificant, then the answer to item 4, would be “yes.” A general rule of thumb is if 75% or greater of the cover is by peat-forming species then the answer to item 4 would be “yes.” If the team decides that relative cover of peat forming species is less than 75%, then the answer to item 4 would be “no.”

Land management practices such as dams, dikes, and roads can result in excess surface water inundating peatlands. This surface water if present for extended periods, may result in a loss of peat forming species and an increase in aquatic or marsh species. In basin fens where excess surface water is present, and the excess surface water is due to land management practices, and the surface water is causing fen species, e.g. peat forming species, to become less abundant, then the answer to item 4 would be "no."

Item 5. Plant species present generally indicate maintenance of fen-wetland soil moisture characteristics

Purpose

Accumulation of peat occurs under yearlong or seasonally saturated conditions where the rate of organic matter deposition is greater than the rate of microbial decomposition. Peat soils are uniquely composed largely of plant remains in various stages of decomposition. The presence of obligate wetland and facultatative wetland plant species is a reliable indicator for assessing whether peat is being maintained in those areas that already have peat. The intent of this item is to look for those species that indicate the presence of a persistent high water table, which maintains fen-wetland species over time (Prichard et al. 1999). This water table condition is essential to the maintenance and recovery of a fen-wetland area. This characteristic does not necessitate quantifying species cover, but rather if the presence of these species indicate the maintenance of fen moisture conditions. Even species which can increase with disturbance, such as needle spikerush (*Eleocharis acicularis*), an obligate wetland species (OBL), may indicate maintenance of the water table in the absence of deep-rooted perennial plant species. This depends on how degraded the area appears and the types of species present. The amount of wetland plant species is an indicator of water levels and the amount of water level fluctuation in fens and wetland areas in general (Prichard et al. 1999). For lists of obligate (OBL) and facultative wetland (FACW) plant species, see Appendix B.

Examples

The entire area of the fen should be walked and the presence of obligate wetland plants (OBL) and facultative wetland plants (FACW) should be noted (see Appendix B for lists of plant species and wetland ratings). If the site is dominated (greater than 75% of the total canopy cover) by OBL and FACW species, the answer to item 5 would be "yes." If facultative (FAC), facultative upland (FACU), or upland (UPL) species are present in significant amounts (greater than 25% of the total canopy cover), item 5 would be answered "no" since these species typically occur in drier settings. Lowering of the water table as indicated by the hydrologic attributes will often lead to establishment of drier adapted species on the site.

Item 6: There are no significant areas within the fen where wetland plant species are being replaced by non wetland plant species

Purpose

The intent of this item is to identify any areas in the fen where plants species indicative of drying conditions are present. Lowering of the water table as indicated by the hydrologic attributes will often lead to establishment of these species on the site. A persistent, high water table is essential to the maintenance and recovery of a fen-wetland area. This characteristic is not asking the amount of the species, but rather if the presence of these species indicate that drying is occurring in significant areas of the fen.

Examples

The entire area of the fen should be walked and the presence of species that have a wetland status rating of FAC, FACU, or UPL should be noted (see Appendix B for wetland ratings of fen plant species). If facultative (FAC), facultative upland (FACU), or upland (UPL) species are present in significant amounts in parts of the fen, item 6 would be answered "no" since these species typically occur in drier settings. This can happen at the edges of a fen, near areas of downcut streams or watercourses, or in areas heavily impacted. Lowering of the water table as indicated by the hydrologic attributes will often lead to establishment of species adapted to drier conditions. If there are none of these species present in significant areas of the fen, the answer to item 6 would be "yes." Note that item 5 addresses the overall abundance of wetland species. Whereas item 6 is asking if there are any areas where non wetland species (FAC, FACU, or UPL) are being established. Item 5 can be answered "yes", while item 6 could be answered "no" if non wetland species are being established due to hydrologic changes caused by management.

Item 7. In the sites adjacent to the fen, favorable conditions for continued development of the peat body, i.e., standing mature trees, (if applicable), and ground cover are maintained.

Purpose

Adjacent forested stands provide a source of downed wood for peatlands. While downed logs are not required for fen formation, downed trees provide microtopography for species adapted for drier conditions. In addition, trees add carbon to the peat body, and when a tree falls perpendicular to the gradient of a sloping fen, the bole can slow and disperse sheet flowing water. Intact forests adjacent to peatlands also directly influence both inflow and outlflow by buffering surface runoff. The soil surface under forested stands and rangelands adjacent to a fen will have a stable surface and not provide any sediment into the fen, but rather will filter the water flowing into the fen from adjacent uplands. The intent of this item is to determine whether adjacent site characteristics are maintaining those conditions.

Examples

In fens that have developed adjacent to a forest the presence of mature trees is important for continued functioning of the fen. As a general guideline, it is important to maintain an intact forest at a distance of one mature tree height from the fen edge. This does not preclude management of forests within one mature tree height of the edge of the fen. . The goal for maintaining favorable conditions for the peat body is to maintain some standing live mature trees or healthy rangelands next to the fen that are stable and not eroding. If this condition is met, then the answer to item 7 would be "yes."

Item 8. Conifer seedlings or saplings or upland shrubs are absent or few in any areas associated with what may be fen surface condition changes, mineral sediment deposition, or hydrologic alterations.

Purpose

The purpose of item 8 is to determine if conifer or upland shrub encroachment is occurring and is linked to hydrologic changes within or around the fen. Peatlands or fens in California's Sierra Nevada are typically small wet meadows surrounded by mixed conifer forest. Encroachment by conifers into fens can indicate changes in the fen's hydrologic regime. Lowering of water tables due to drainage can allow trees and shrubs such as shrubby cinquefoil (*Dasiphora fruticosa*) and sagebrush species (*Artemisia* spp.) to encroach into the fen and perhaps succession toward a closed canopy community.

Examples

Lowering of a peatland's water table results in increased soil aeration, soil temperature, decomposition, nutrient availability, and can result in tree invasion (Lieffers and Rothwell 1986, MacDonald and Lieffers 1990, MacDonald and Yin 1999). Increased tree growth following lowering of the water table is especially indicated by species (such as lodgepole pine, *Pinus contorta ssp. murryana*) which are often more prevalent on hummocks within the fen. Lowered water tables can also dramatically reduce the micro-scale heterogeneity that characterizes peatlands by eliminating the fine-scale gradients in pH, moisture, and nutrient availability associated with hummocks and hollows (MacDonald and Yin 1999).

Lodgepole pine occurring on hummocks or high points in an undulating surface that are not associated with disturbance resulting from management are considered naturally occurring. It is well known that certain conifers that have adaptations for growing in waterlogged soils, may invade fens in cyclical patterns, but more importantly that many fens, particularly poor fens may have an open overstory of trees. Comparison of old photographs with current condition often indicates that conifer encroachment into riparian areas and wetlands may be due to long-term fire suppression in the upland. The intent of this item is to determine if conifer encroachment is occurring due to hydrologic alteration that results from management.

To answer this question, walk the fen and note if there are conifer seedlings or saplings or upland shrubs in any areas that are associated with hydrologic alteration of the fen. If conifer seedlings or saplings establishment is associated with hydrologic alteration, then the answer to item 8 would be "no."

C. Soil and Erosion Characteristics (Items 9 – 10)

Item 9. Bare soil and/or bare peat averages less than 10% cover for the entire fen (omitting pools and other stable water features).

Purpose

The purpose of item 9 is to determine if there is adequate wetland vegetation cover present to protect the peat surface from decomposition and erosion. In a study by Cooper et al. (2005b), percent bare ground or bare peat was positively correlated with a net loss of carbon from the peatland. Decreased carbon sequestration was likely caused by lower plant production and higher ecosystem respiration. Grazing intensity decreased carbon storage due to increased bare ground from trampling. Chimner and Cooper (2002) found that when bare ground exceeded 15 to 20% cover there was a net loss of carbon, i.e. the portion of the fen where there was greater than 15% cover of bare peat was losing peat. In a study of mountain meadows in the Sierra Nevada, Weixelman and Zamudio (2001) reported that a bare soil cover of greater than 10% was positively associated with increased amounts of early successional forbs and shallower root depths. However, small amounts of bare peat covered by water occur naturally in stable pools and in small rivulets in fens.

Examples

Recording the amount of bare peat and/or bare soil requires careful examination of the site. Measure the amount of bare peat and/or soil along a transect. The procedure involves selecting 100 points along a transect through a representative part of a fen. First, a representative portion of the fen is chosen. A random starting point is chosen and a 100-foot tape is laid out in a random direction. For most fens, it may be adequate to start the transect at one end of the fen and work toward the opposite side. In order to get 100 points in a small fen, you may need to reverse direction at the opposite end. In either case, sample a representative portion of the fen. At each foot mark on the tape, the observer lowers a sampling pin to the ground (something sharp like a pencil) until the pin hits a plant or the ground. Disregard elevated parts of vascular plants because we are recording ground cover. The pin is pushed to the ground and a hit on basal vegetation, bare soil, bare peat, litter, gravel (2 mm - 2.5 cm in diameter), rock (= or > 2.5 cm in diameter), moss, liverwort, or lichen is recorded. Total percentage of bare peat and bare soil is determined by dividing the number of hits for bare peat and bare soil by the total number of points sampled. For monitoring purposes, a more detailed quantitative determination of the percent cover of bare peat and bare soil using permanently marked transect lines and quadrat frames can be used (Weixelman et al. 1996, Coulloudon et al. 1999).

Bare peat is peat that is exposed and has the consistency of peat. If litter covers the peat and the litter does not have the consistency of peat and has not been incorporated into the peat then count as litter (see Figures 13 through 17). When standing water covers bare soil or bare peat inside stable, established pools or other stable water features then do not count as bare soil or bare peat. However, water-filled hoof prints or tire tracks that expose bare peat would count as bare peat (see Figures 13 through 17). As a general guideline when laying out the transect, avoid stable water features such as established pools.

In some fens, the percent cover of bare peat will be consistent over the area. In other fens there may be higher percentages of bare peat in some parts of the fen, and lower percentages in other parts of the fen. In this situation, you may need a transect in more than one area of the fen to determine the average cover of bare peat or bare soil across the whole fen. Item 9 is asking if there is greater than 10% cover of bare peat and bare soil over the entire fen. If so, then the answer to item 9 would be "no." In situations where the overall cover of bare peat is less than 10%, but there are significant areas where bare peat exceeds 15%, the ID Team decides if the situation is causing degradation to the fen.

Figure 13. Hoof prints filled with water in fen (from Cooper et al. 2005a). These water-filled hoof prints would count as bare peat.

Figure 14. Bare peat exposed in a fen (photo by Catie Bishop).

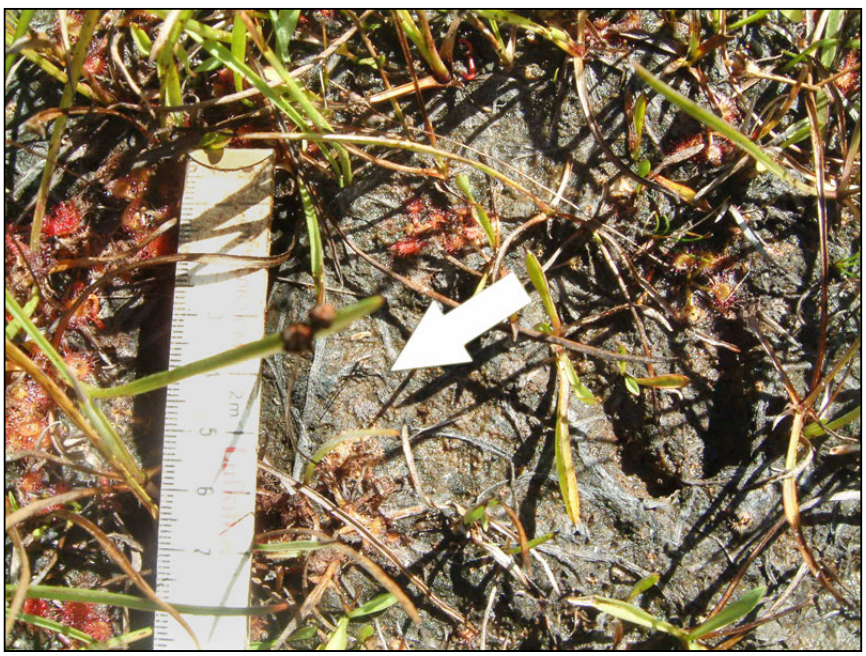

Figure 15. Close-up of bare peat in fen. Note that surface litter (arrow) is decomposing and is in the process of being incorporated into the upper peat layer and has the consistency of peat. This situation would be counted as bare peat.

Figure 16. Close-up of litter cover in fen. Note that the litter layer is laying on the surface and is not incorporated into the peat layer and does not have the consistency of peat. Count this situation as litter, not bare peat.

Figure 17. Standing water about one inch deep covering bare peat in a stand of *Eleocharis*. When standing water covers bare peat or bare soil, and occurs in a stable, established pool, do not count as bare peat.

Item 10. Fen is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)

Purpose

The intent of this item is to identify that water and sediment are being supplied at a natural rate and the fen can function properly.

Small waterways or water tracks are natural in fens. Fens are generally found in sites where they receive very little sediment influx. Increased flows and subsequent increased energy of water due to channeling water from road building, timber harvest, water diversions, grazing, or other management activities, may form headcuts, gullies, or channels in fens. This process may lead to dewatering of the entire fen or areas near the downcut. Excess sediment can change nutrient cycling, bury vegetation, suppress regeneration of plants, increase decomposition of the peat body, and carry pollutants into the fen. In addition, the type and intensity of land use in the fen and contributing watershed affects the amount of sediment that enters into a fen (Rocchio 2005).

Examples

If a fen shows evidence of noticeable sediment deposition or if flow has been added and noticeable erosion or mineral soil deposition is taking place as a result of this increased flow, the answer to item 10 would be "no". Indicators of excessive erosion or deposition can include fans of sediment being deposited over the fen, headcuts, rills, gullies, and channel formation (artificial or natural).

Figure 18. Sediment being deposited (lower left corner of photo) directly from a road. The road is located immediately to the left of the fen in this photo. Photo by Susan Marsico.

Figure 19. Channel forming in peat. Adjacent to this spot the peat was greater than one meter deep. (photo by Catie Bishop).

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Appendix A:
Fen Condition Checklist

General Instructions

- As a minimum, an interdisciplinary (ID) team will use this checklist to determine the degree of function of a fen
- An ID team must review existing documents, particularly Prichard et al. (1999), so that the team has an understanding of the concepts of the fen-wetland area they are assessing.
- An ID team should walk the fen and must determine the attributes and processes important to the fen area being assessed.
- Establish photo points where possible to document the area being assessed.
- Mark one box for each element. Elements are numbered for the purpose of cataloging comments. The numbers do not refer to importance. If the item does not pertain to the site, then mark "NA". Items where the "NA" box is grey in color must be answered with a "yes" or "no."
- For any item marked "No," the severity of the condition must be explained in the "Remarks" section and must be a subject of discussion with the ID team in determining fen functionality. Using the "Remarks" section to also explain items marked "Yes" is encouraged but not required.
- Based on the ID team's discussion, a "functional rating" will be resolved and the checklist's summary section will be completed.
- The time required to complete the survey will vary depending on the size of the fen, experience of the participants, the number of participants, and other factors. Allow at least two hours to complete the field portion of the survey.

Name of fen: ____

Observers: ____

Date: ______________________________

What type of fen is this?

Landform type (check all that apply):
Sloping ______ Basin ______ Mound ______ Lava ______

pH category:
poor fen (3.0 – 5.4), moderate rich fen (5.5 – 6.9), extreme rich fen (> 6.9)

pH value ______

Poor fen ______ Moderate-rich fen ______ Extreme rich fen ______

Yes	No	N/A	**Hydrology**
			1. Fen water table is within 20 cm of the soil surface for most of the summer. Notes:
			2. There is no evidence of hydrologic alteration in the watershed that could affect the fen. Notes:
			3. Natural surface or subsurface flow patterns are unaltered within the fen (i.e. no flow pattern disturbance by dams, dikes, trails, hoof action, hummocking, roads, rills, gullies, ditches, drilling activities, etc.). Notes:

Yes	No	N/A	**Vegetation**
			4. The vegetation is comprised largely of known peat-forming plant species. Notes:
			5. Plant species present generally indicate maintenance of fen-wetland soil moisture characteristics. Notes:
			6. There are no significant areas within the fen where wetland plant species have been replaced by non wetland plant species. Notes:
			7. In the sites adjacent to the fen, favorable conditions for continued development of the peat body, i.e., standing mature trees, (if applicable), and ground cover are maintained. Notes:
			8. Conifer seedlings or saplings or upland shrubs are absent or few in any areas associated with what may be fen surface condition changes, mineral sediment deposition or hydrological alterations. Notes:
Yes	No	N/A	**Soil and erosion**
			9. Bare soil and/or bare peat averages less than 10% cover for the entire fen (omitting pools and other stable water features). Notes:
			10. Fen is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition). Notes:

Remarks

___ Proper Functioning Condition

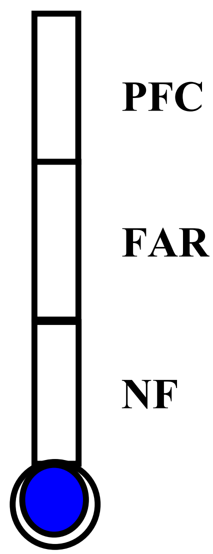
___ Functional - At Risk

___ Nonfunctional

___ Unknown

Trend for Functional - At Risk:

___ Upward
___ Downward
___ Not Apparent



Are factors contributing to unacceptable conditions outside the control of the manager?

Yes ___
No ___

If yes, what are those factors?
___ Flow regulations
___ Mining activities
___ Upstream channel conditions
___ Channelization
___ Road encroachment
___ Oil field water discharge
___ Augmented flows
___ Other (specify)

Appendix B:
Draft list of plants found in fens

Explanation of ratings:

Lifeform: indicates whether the species is a fern or fern ally, grass, grasslike (sedges and rushes), forb, woody species, or moss.

Peat-forming plants
Indicates whether the species is generally considered peat-forming or not. Considered peat-forming if they typically occur in late successional stages, i.e. stable hydrologically and with minimal surface disturbance. Nearly all woody species that are obligate or facultative wetland species were rated as peat-forming plants.

Native or introduced: species names with an asterisk (*) indicate species that are not native to North America

Indicators of disturbance: a yes means that the species generally becomes established after disturbance and/or drying conditions.

Wetland status ratings. These ratings are from the USDI, Fish and Wildlife Service, National Wetland Inventory (NWI) for the CA region.

OBL = occurs almost always in wetlands(estimated probability 99%)
FACW = usually occurs in wetlands (estimated probability 67%-99%)
FAC = equally likely to occur in wetlands or not (estimated probability 34%-66%)
FACU = usually occurs in uplands rather than wetlands
UPL = nearly always occurs in uplands

A brief note on the species list: This list was compiled from two databases. The first database is a list of all species recorded on a survey of 100 fens in the Sierra Nevada and Southern Cascades ranges in California by Dr. David Cooper during 2004-2005. The second database consists of all species recorded on permanently marked plots in fens as part of the USFS R5 range long term monitoring database. Please notify the authors if you find a species in a fen and it is not listed here. The list is grouped by fern allies, grasses, grasslikes, forb, shrub, tree, and moss.

Appendix B - 1

Plant Species	**Common Name**	**Lifeform**	**Peat forming**	**Indicator of disturbance**	**Wetland status**
Botrychium simplex	little grapefern	Fern allies	No	No	FAC
Equisestum arvense	field horsetail	Fern allies	No	Yes	FACW-
Equisetum hyemale	scouringrush horsetail	Fern allies	No	Yes	FACW
Agrostis pallens	seashore bentgrass	Grass	No	No	FAC
Agrostis scabra	rough bentgrass	Grass	No	No	FAC
Agrostis stolonifera	redtop	Grass	No	Yes	FACW
Agrostis thurberiana	Alpine bentgrass	Grass	No	No	FACW
Agrostis variabilis	mountain bentgrass	Grass	No	No	FACW
Calamagrostis canadensis	bluejoint reedgrass	Grass	No	No	FAC
Danthonia californica	California oatgrass	Grass	No	No	FACW
Deschampsia cespitosa	tufted hairgrass	Grass	No	Yes	FACW
Deschampsia elongata	slender hairgrass	Grass	No	No	FACW
Glyceria borealis	small floating mannagrass	Grass	Yes	No	OBL
Glyceria elata	mannagrass	Grass	Yes	No	OBL
Glyceria grandis	American mannagrass	Grass	Yes	No	OBL
Kobresia myosuroides	Bellardi bog sedge	Grass	Yes	No	FACW
Muhlenbergia filiformis	slender muhly	Grass	No	No	OBL
Phleum alpinum	alpine Timothy	Grass	No	Yes	FACW
Phleum pratense*	timothy	Grass	No	Yes	FACU
Poa pratensis*	Kentucky bluegrass	Grass	No	Yes	FACU
Carex alma	sturdy sedge	Grasslike	Yes	Yes	FACW
Carex amplifolia	bigleaf sedge	Grasslike	Yes	No	OBL
Carex angustata	wide fruit sedge	Grasslike	Yes	No	OBL
Carex aquatilis	aquatic sedge	Grasslike	Yes	No	OBL
Carex athrostachya	slender beak sedge	Grasslike	Yes	No	FACW
Carex aurea	golden sedge	Grasslike	Yes	No	OBL
Carex canescens	silvery sedge	Grasslike	Yes	No	OBL

Appendix B – 2

Scientific name	Common Name	Lifeform	Peat Forming	Indicator of disturbance	Wetland status
Carex capitata	capitate sedge	Grasslike	Yes	No	FACW
Carex echinata	Star sedge	Grasslike	Yes	No	OBL
Carex illota	sheep sedge	Grasslike	Yes	No	OBL
Carex jonesii	Jones’ sedge	Grasslike	Yes	No	FACW
Carex lemmonii	Lemmon’s sedge	Grasslike	Yes	No	FACW
Carex lenticularis	lakeshore sedge	Grasslike	Yes	No	OBL
Carex limosa	mud sedge	Grasslike	Yes	No	OBL
Carex luzulina	woodrush sedge	Grasslike	Yes	No	OBL
Carex microptera	smallwing sedge	Grasslike	Yes	No	FACW
Carex nebrascensis	Nebraska sedge	Grasslike	Yes	No	OBL
Carex scopulorum	mountain sedge	Grasslike	Yes	No	FACW
Carex simulata	analogue sedge	Grasslike	Yes	No	OBL
Carex subfusca	Brown sedge	Grasslike	Yes	No	FAC
Carex subnigricans	nearly black sedge	Grasslike	Yes	No	FAC
Carex utriculata	beaked sedge	Grasslike	Yes	No	OBL
Carex vernacula	native sedge	Grasslike	Yes	No	FACW
Carex vesicaria	blister sedge	Grasslike	Yes	No	OBL
Eleocharis acicularis	Needle spikerush	Grasslike	Yes	No	OBL
Eleocharis macrostachya	pale spikerush	Grasslike	Yes	No	OBL
Eleocharis paucoflora	Few-flower spikerush	Grasslike	Yes	No	OBL
Eriophorum criniger	fringed cottongrass	Grasslike	Yes	No	OBL
Eriophorum gracile	slender cottongrass	Grasslike	Yes	No	OBL
Juncus balticus	Baltic ruch	Grasslike	Yes	Yes	OBL
Juncus effuses	common rush	Grasslike	Yes	No	FACW
Juncus oxymeris	pointed rush	Grasslike	Yes	No	FACW+
Juncus ensifolius	swordleaf rush	Grasslike	Yes	No	FACW+
Juncus mertensianus	Mertens’ rush	Grasslike	Yes	No	OBL

Appendix B – 3

Scientific name	Common Name	Lifeform	Peat forming	Indicator of disturbance	Wetland status
Juncus mexicanus	Mexican rush	Grasslike	Yes	No	OBL
Juncus nevadensis	Sierra rush	Grasslike	Yes	No	FACW
Juncus orthophyllus	straightleaf rush	Grasslike	Yes	No	FACW
Juncus ensifolius	swordleaf rush	Grasslike	Yes	No	FACW+
Luzula comosa	pacific woodrush	Grasslike	Yes	No	FAC
Rhyncospora alba	white beaksedge	Grasslike	Yes	No	OBL
Rhyncospora capitellata	brownish beaksedge	Grasslike	Yes	No	OBL
Scirpus congdonii	Congdon's bulrush	Grasslike	Yes	No	OBL
Scirpus microcarpus	panicled bulrush	Grasslike	Yes	No	OBL
Achillea millefolium*	common yarrow	Forb	No	Yes	FACU
Allium validum	Pacific onion	Forb	No	No	OBL
Aquilegia formosa	western colombine	Forb	No	No	FAC
Arnica chamissonis*	Chamisso arnica	Forb	No	Yes	FACU
Arnica longifolia	spearleaf arnica	Forb	No	No	FAC
Aster alpigenus*	alpine aster	Forb	No	No	OBL
Aster occidentalis*	western aster	Forb	No	Yes	FAC
Caltha leptosepala	white marsh marigold	Forb	No	No	OBL
Camassia quamash	small camas	Forb	No	No	FACW
Darlingtonia californica	California pitcherplant	Forb	Yes	No	OBL
Dodecatheon alpinum	Alpine shootingstar	Forb	No	No	OBL
Dodecatheon jeffreyi	Sierra shootingstar	Forb	No	No	FACW
Drosera anglica	English sundew	Forb	Yes	No	OBL
Drosera rotundifolia	round-leaved sundew	Forb	Yes	No	OBL
Epilobium ciliatum	fringed willowherb	Forb	No	No	OBL
Geum macrophyllum*	largeleaf avens	Forb	No	Yes	FACW
Epilobium halleanum	glandular willowherb	Forb	No	No	FAC

Scientific name	Common Name	Lifeform	Peat forming	Indicator of disturbrance	Wetland status
Epilobium oreganum	Grants pass willowherb	Forb	No	No	OBL
Epilobium oregonense	Oregon willowherb	Forb	No	No	OBL
Erigeron peregrinus	subalpine fleabane	Forb	No	No	FACW
Galium trifidum	narrowleaf bedstraw	Forb	No	No	OBL
Gentiana newberryi	alpine gentian	Forb	No	No	FACW
Gentianopsis simplex	one-flowered gentian	Forb	No	No	OBL
Hastingia alba	white rush-lily	Forb	Yes	No	OBL
Helenium bigelovii	Bigalow's sneezeweed	Forb	No	Yes	FACW
Hypericum anagalloides*	tinker's penny	Forb	No	Yes	OBL
Hypericum formosum*	St. Johnswort	Forb	No	No	OBL
Ivesia lycopodioides	clubmoss mousetail	Forb	No	No	FAC
Lotus oblongifolius*	birds-foot trefoil	Forb	No	No	OBL
Lotus oblongifolius*	birds-foot trefoil	Forb	No	No	OBL
Lupinus polyphyllus	bigleaf lupine	Forb	No	No	FACW
Madia bolanderi*	Bolander's madia	Forb	No	No	UPL
Menyanthes trifoliata	Buckbean	Forb	Yes	No	OBL
Mimulus guttatus	Seep monkeyflower	Forb	No	No	OBL
Mimulus primuloides	primrose monkeyflower	Forb	No	Yes	OBL
Narthecium californicum	California bog asphodel	Forb	Yes	No	OBL
Nuphar lutea	yellow pond-lily	Forb	Yes	No	OBL
Oxypolis occidentalis	western cowbane	Forb	Yes	No	OBL
Parnassia californica	California grass-of-Parnassus	Forb	No	No	OBL
Pedicularis attolens	little elephantshead	Forb	Yes	No	OBL
Pedicularis groenlandica	elephanthead lousewort	Forb	Yes	No	OBL
Perideridia parishii	Parishe's yampah	Forb	No	Yes	FAC
Phalacroseris bolanderi*	Bolander's mock dandelion	Forb	No	Yes	OBL

Species	Common name	Life Form	Peat Forming	Indicator of disturbance	Wetland Status
Platanthera leucostachys	Sierra bog orchid	Forb	Yes	No	FACW
Polygonum bistortoides	American bistort	Forb	No	No	OBL
Polygonum polygaloides	milkwort knotweed	Forb	No	Yes	FACW-
Potentilla gracilis	Slender cinquefoil	Forb	No	Yes	FACW
Prunella vulgaris	Common selfheal	Forb	No	Yes	FACU
Ranunculus alismifolius	Plantainleaf buttercup	Forb	No	Yes	FACW
Rorippa nasturtium-aquaticum	watercress	Forb	No	No	OBL
Saxifraga oregano	Oregon saxifrage	Forb	Yes	No	OBL
Senecio triangularis	arrowleaf ragwort	Forb	No	No	OBL
Sidalcea oregano	Oregon checkerbloom	Forb	No	No	OBL
Sisyrinchium bellum	western blue-eyed grass	Forb	No	No	FACW-
Spiranthes romanzoffiana	hooded lady's tresses	Forb	Yes	No	OBL
Stachys albens	whitestem hedgenettle	Forb	No	No	OBL
Stellaria longipes	longstalk starwort	Forb	No	No	OBL
Taraxacum officinale*	common dandelion	Forb	No	Yes	FACW
Tofieldia occidentalis	western false asphodel	Forb	No	No	OBL
Trifolium albopurpuream	Rancheria clover	Forb	No	No	UPL
Trifolium bifidum	notchleaf clover	Forb	No	No	UPL
Trifolium longipes	longstalk clover	Forb	No	No	FACW
Trifolium monanthum	mountain carpet clover	Forb	No	No	FACW
Trifolium variegatum	whitetip clover	Forb	No	No	FACW
Trifolium wormskioldii	cows clover	Forb	No	No	FACW
Tritelia hyacinthine	white brodiaea	Forb	No	No	FACW
Veratrum californicum	California false hellebore	Forb	No	No	OBL

Appendix B – 6

Scientific name	**Common Name**	**Lifeform**	**Peat Forming**	**Indicator of disturbance**	**Wetland status**
Veronica americana	American speedwell	Forb	No	No	OBL
Viola macloskeyi	small white violet	Forb	No	No	OBL
Alnus incana	Gray alder	Shrub	Yes	No	FACW
Betula glandulosa	resin birch	Shrub	Yes	No	OBL
Cornus nuttallii	pacific dogwood	Shrub	Yes	No	FAC
Kalmia polifolia	Bog laurel	Shrub	Yes	No	FACW
Ledum glandulosum	western labrador tea	Shrub	Yes	No	OBL
Rhododendron occidentale	western azalea	Shrub	No	No	FAC
Salix eastwoodii	mountain willow	Shrub	Yes	No	OBL
Salix lemmonii	Lemmon's willow	Shrub	Yes	No	OBL
Salix orestera	Sierra willow	Shrub	Yes	No	FACW
Salix planifolia	planeleaf willow	Shrub	Yes	No	OBL
Spirea douglasii	Rose spirea	Shrub	Yes	No	OBL
Vaccinium caespitosum	dwarf bilberry	Shrub	Yes	No	FACW
Vaccinium uliginosum	Bog blueberry	Shrub	Yes	No	FACW+
Calocedrus decurens	incense cedar	Tree	Yes	No	UPL
Pinus contorta	lodgepole pine	Tree	Yes	No	FACU
Pinus jeffreyi	Jeffrey pine	Tree	Yes	No	UPL
Aulacomnium palustre	aulacomnium moss	Moss	Yes	No	OBL
Brachythecium frigidum	Cold brachytecium moss	Moss	Yes	No	OBL
Bryum pseudotriquetrum	common green Bryum moss	Moss	Yes	No	FACW
Bryum [Ptychostomum] 'robustum' sp. nov.	robust Bryum moss	Moss	Yes	No	?
Bryum weigelii	Weigel's Bryum moss	Moss	Yes	No	?
Calliergon giganteum	giant Calliergon moss	Moss	Yes	No	OBL

Scientific name	Common Name	Lifeform	Peat Forming	Indicator of disturbance	Wetland status
Campylium polygamum	campylium moss	Moss	Yes	No	OBL
Campylium stellatum	star Campylium moss	Moss	Yes	No	OBL
Campylium chrysopyllum	goldenleaf Campylium moss	Moss	Yes	No	OBL
Cratoneuron filicinum	cratoneuron moss	Moss	Yes	No	?
Drepanocladus aduncus	drepanocladus moss	Moss	Yes	No	OBL
Drepanocladus sp.	drepanocladus moss	Moss	Yes	No	OBL
Meesia triquetra	meesia moss	Moss	Yes	No	OBL
Meesia uliginosa	meesia moss	Moss	Yes	No	OBL
Philonotis Fontana sensu lato	philonotis moss	Moss	Yes	No	OBL
Plagiomnium rostratum	plagiomnium moss	Moss	?	No	OBL
Pohlia wahlenbergii	Wahlenberg's pohlia moss	Moss	?	No	?
Sphagnum angustifolium	sphagnum moss	Moss	Yes	No	OBL
Sphagnum capillifolium	sphagnum moss	Moss	Yes	No	OBL
Sphagnum sp.	sphagnum moss	Moss	Yes	No	OBL
Sphagnum squarrosum	sphagnum moss	Moss	Yes	No	OBL
Sphagnum subsecundum	sphagnum moss	Moss	Yes	No	OBL
Sphagnum teres	sphagnum moss	Moss	Yes	No	OBL
Marchantia polymorpha	liverwort	Liverwort	?	No	OBL
Sphagnum capillifolium	sphagnum moss	Moss	Yes	No	OBL

Appendix C:
Field form for recording plant species data.

Location: ____

Date: _________________ Recorders: ______________________________

Plant species	Cover class midpoint	Peat forming (yes or no)	Native species (yes or no)	Wetland status

Cover class	Cover	Midpoint
1	< 5 %	2.5
2	5 – 25%	15
3	25 – 50%	37.5
4	50 – 75%	62.5
5	75 – 95%	85
6	95 – 100%	97.5

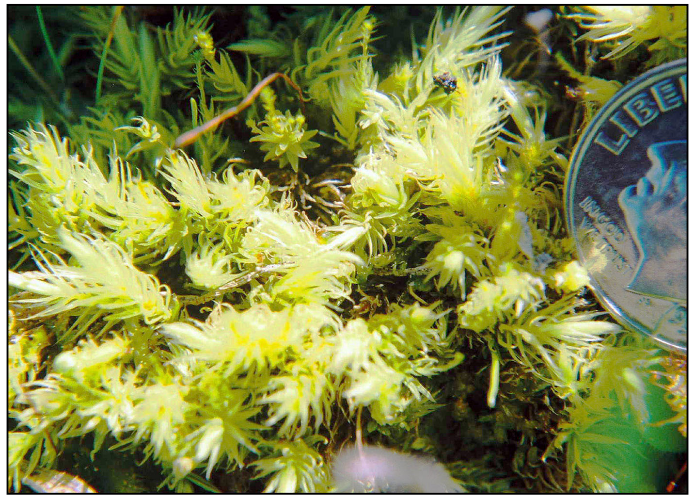
Appendix D.
Photos of common mosses and liverworts that occur in fens in the Sierra Nevada and Southern Cascade ranges, California (arranged alphabetical by genus). Special thanks to Carl Wishner, Colin Dillingam, and Cheryl Beyer for providing captions.

Note: The pictured mosses and liverworts are some of the more common species in fens in the study area. These photos should not be used for sole identification. Consult a bryologist for reliable identification. Ideally, at least one member of the interdisciplinary team will have had some form of training on mosses of fens in CA.

Aulacomnium palustre (acrocarpous moss [erect, few or no branches])

Photo credit: Dave Weixelman

This common and abundant peat-loving moss also grows up onto wood and rocks at fen margins. This species often has gemmaphores (erect continuations of the main stem with terminal, globose clusters of elliptical gemmae). The plants form yellowish-green turfs, and the stems are covered with a dense, rust-colored tomentum. This, together with the strongly papillose (tiny bumps) leaf cells, and pearly-white costa (leaf midrib) are good field characters.



Bruchia bolanderi (acrocarpous moss)

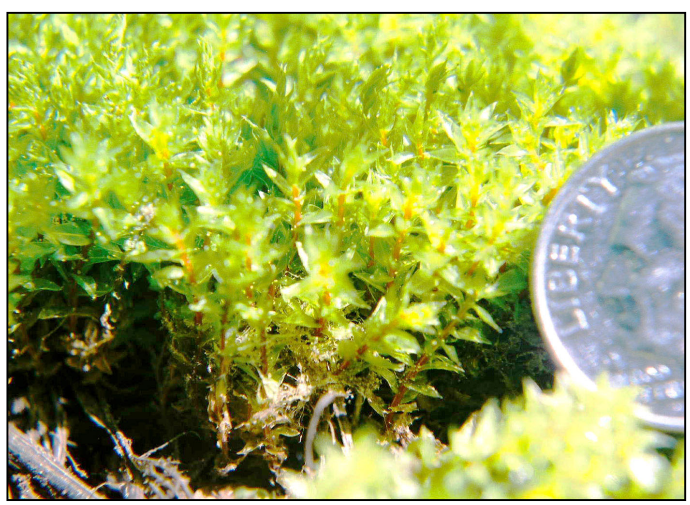
Photo credit: Carl Wishner, and inset Cheryl Beyer.

This tiny moss only about 2-3mm high has narrowly subulate (long-tipped) leaves. The plants form bright green turfs on disturbed mineral soils, often at the drying upper margin of stream channels cut through moist meadows, from montane to alpine zones. Difficult to identify without sporophytes, once one learns to recognize the the green turfs that resemble algae, this species can be reliably determined. The distinctive sporophytes with long necks equaling the spore sac appear late in the summer, around mid-August, or later. Initially very orange in color, and standing upright, they mature late fall to a purple color, lay flat, soon covered with snow, and not opening to release their spores until the spring after the capsule wall decays. The capsules are cleistocarpous (not opening by a lid).

Bryum pseudotriquetrum (acrocarpous moss)

Photo credit: Dave Weixelman

This species grows abundantly throughout western North America in peat-soils in fens, stream margins, seeps, and even rock outcrops. It is characterized by often long stems densely matted with rhizoids, and ovate leaves with decurrent (running down the stem) bases, and a short excurrent costa (leaf midrib extends just beyond tip of leaf). Although the species is dioicous (male and female plants separate), the pendant capsules with a long tapering neck are not uncommon. Compare with the other Bryum (undescribed) below.



***Bryum* sp**. (undescribed) (acrocarpous moss)

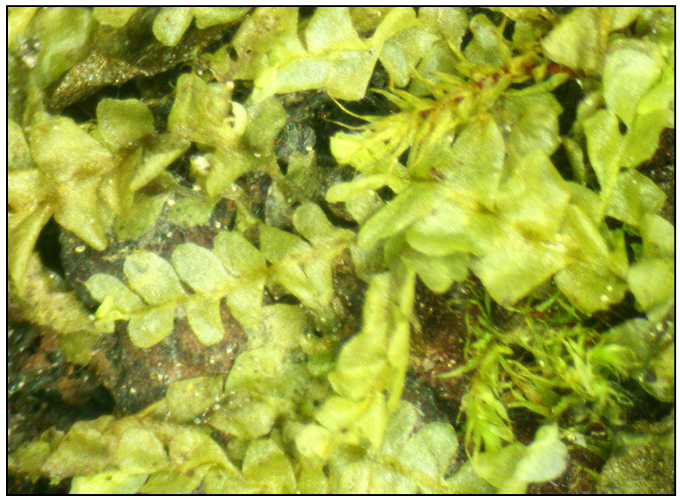
Photo credit: Carl Wishner

This relatively common *Bryum* [sensu lato] of Sierran and southern Cascade fens has not yet been described, but when it is, it will be included in the genus *Ptychostomum*. It is a robust species with large, translucent leaves, approximately 4mm long, with a distinct thickened border, and strongly contorted leaves when dry. According to John Spence, an authority on these mosses, this undescribed species is "basically a giant form of *Bryum turbinatum*, but with an elongate capsule." Capsules are rare, because the species is dioicous (male and female plants separate). Although it grows in full sun, it is also often found growing underneath the shade of vascular plant species in fens.

Chiloscyphus polyanthos (leafy liverwort)

Photo credit: Carl Wishner

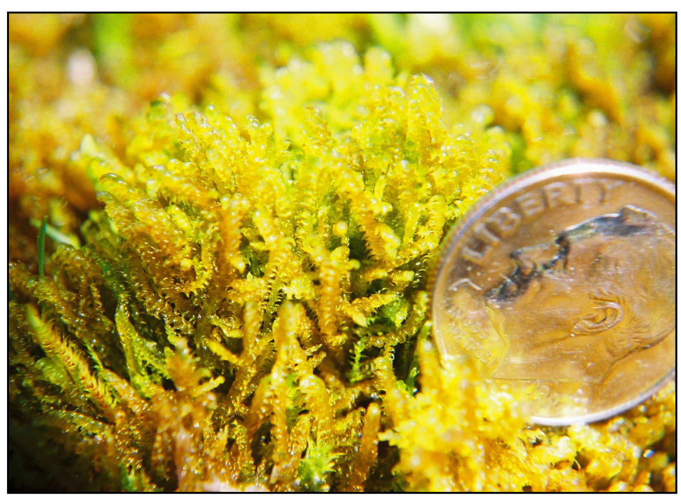
This is a common plant of wet ground, shaded rocks, soil, organic debris and decaying logs, seasonally inundated or permanently submerged. They form loose prostrate mats, pale or dull green to brownish in color, with stems 2-4cm long. The obliquely set dorsal leaves are succubous, overlapping like the shingles of a roof, with the forward edge of each leaf overlapped by the back edge of the next one closer to the stem apex. The leaf apices are rounded, truncate, or slightly emarginate (indented). On the bottom side of the stem is a single row of small, two-pronged underleaves that are much different from the dorsal leaves. Two Californian species of this genus are polymorphic and occasionally difficult to separate.



***Drepanocladus* sp**. (pleurocarpous moss [highly-branched])

Photo credit: Dave Weixelman

Five species of *Drepanocladus* are reported from California and the Sierra Nevada, and recognition of species is difficult. Members of the genus can be very abundant, growing in saturated, slow or non-moving waters, and fens. The ovate-lanceolate leaves are most often strongly falcate-secund (curved, and turned to one side), but are occasionally relatively straight, and with sharp-pointed tips. They are medium sized, green, yellow-green, yellowish or brownish (but not reddish), and pinnately branched. The leaf midrib (costa) is ½ to ¾ of the leaf, ending well below apex. The leaf margins are entire. Compare with *Warnstorfia exannulata*.



Helodium blandowii (pleurocarpous moss)

Photo Credit: Carl Wishner

This species occurs widespread in boreal areas of the northern hemisphere, but has only recently been found in California, in several sites primarily on the east side of the Sierra Nevada, in calcium-rich fens. The pale color sometimes suggests *Sphagnum* to the uninitiated, but the closely pinnate branching readily separates it from the fasciculate branching of *Sphagnum*. It is a rather robust, with erect stems and closely pinnate, nearly equal branches, forming dense, soft yellow or light-green masses.

Marchantia polymorpha (thallose liverwort)

Photo credit: Carl Wishner

This common robust liverwort is found on banks of streams, seeps, springs, and fens. The surface has a distinctive hexagonal patterning, due to the large air chambers in the thallus, and each chamber has a small pore, visible with the naked eye. Sexes are separate (dioicous), and the photo shows the female plants bearing structures called carpophores that occur as umbrella-shaped structures with finger-like rays on the end of long stalks. The male plants have similar stalked structures with a rounded disk-like terminus. These are not often seen, but the species is easily recognizable by the regular presence of small cup-shaped structures that bear small, lens-shaped asexual reproductive bodies called gemmae. The thallus also often has a darkened central band of cells along its length: a feature not seen in other local genera resembling *Marchantia*.

Meesia triquetra (acrocarpous moss)

Photo credit: Stuart Osbrack

This rare moss is sometimes locally abundant in rich fens and grows on peat soils. The wide-spreading ovate-lanceolate leaves are distinctively three-ranked (moist) when viewed from above, appearing to spiral down the stem. The dark green leaves have serrulate (finely toothed) margins. Sexes are separate (dioicous), and when present, the capsules have long necks that abruptly expand into the spore sac. The seta (stalk of the capsule) is exceptionally long, reaching to as much as 10cm.

Meesia uliginosa (acrocarpous moss)

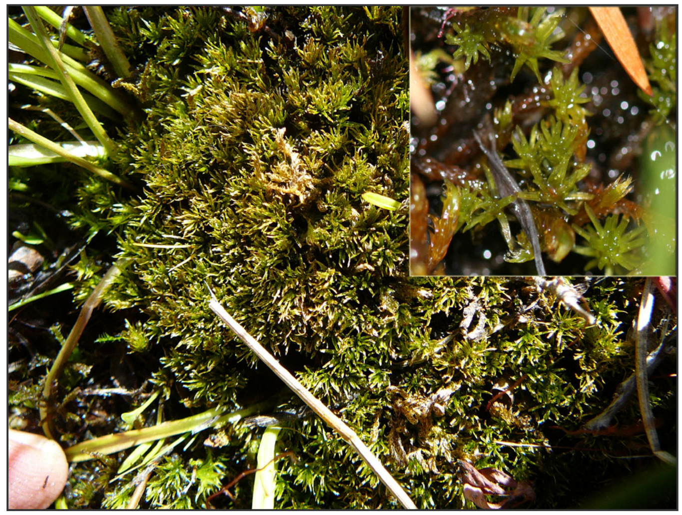


Photo credit: Carl Wishner, inset Stuart Osbrack

This rare moss is most often found on saturated wood within fens or in less saturated portions of raised peat. Unlike *Meesia triquetra*, the leaves are not three-ranked when moist, are erect, rather than wide spreading, and are ligulate (tongue-shaped) with clearly revolute margins, although they are serrulate at the apex. The leaf costa (midrib) ends just below the blunt leaf apex. Sexes are usually separate (dioicous), and when present, the capsules have long necks that abruptly expand into the spore sac. The seta is generally much shorter than *Meesia triquetra*, generally less than 5cm.

Philonotis fontana (acrocarpous moss)

Photo credit: Carl Wishner

Nine species of this genus are reported from the Cascade Ranges and Sierra Nevada of California, growing on moist soil of seeps, or in bogs and fens. Members of the fontana complex of species are most frequently encountered. These erect plants often have terminal branches terminating in whorls, with the short branches subtending antheridial (male) rosette-like buds. They are glaucous to whitish green or yellowish green, occasionally reddish, with broadly to narrowly lanceolate leaves, As with other genera of these habitats, they have a dense coating of red brown rhizoids on the lower portions of the stems. They are usually dioicous (separate sexes). Therefore the unusual globose capsules as shown in this photograph are not often seen.

***Sphagnum* sp.** (acrocarpous moss)

Photo credit: Carl Wishner

Sphagnum in California is restricted to perennially saturated soils in bogs and fens. The distribution of species seems to be relictual, and is strongly discontinuous. *Sphagnum* has never been found with sporophytes (capsules) in California. Although the genus is easily recognized by its unique system of descending and ascending branches arising in fascicles, and overall generally whitish color, often tinged with green, pink, or red, recognition of species is a difficult matter. Approximately fifteen species are reported from the Sierra Nevada. The taxonomy of Californian *Sphagnum* is not well understood, and their names can be expected to undergo substantial future revisions.

Warnstorfia exannulata (pleurocarpous moss)

Photo credit: Carl Wishner

This pleurocarpous (highly-branched) moss is less common than the widespread Drepanocladus species. Warnstorfia exannulata occurs in intermediately mineral-rich fens, and closely resembles Drepanocladus aduncus. Both species are medium sized, green, yellowish, but Drepanocladus does not develop red colorations, as does Warnstorfia. Unlike the pinnately branched Drepanocladus, Warnstorfia stems tend to be radially branched. The leaf midrib (costa) of Warnstorfia is stronger than Drepanocladus, reaching 60-95 percent of the way up the leaf. As viewed using a strong hand lens, the leaf margins are distinctly toothed (denticulate) toward the tip, or base, or both, unlike Drepanocladus, which has an entire leaf margin.