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Plant community characterization and ranking of fens in the Lake Tahoe Basin, California and Nevada

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The California Native Plant Society (CNPS) Vegetation Program worked collaboratively with the USDA Forest Service (USFS) and California Department of Parks and Recreation to produce a vegetation classification, map, and quantitative ranking of sites with fens and wet meadows in the Lake Tahoe Basin. Project goals included surveying and classifying fen sites for their vegetation type, vegetation diversity, and presence of rare species, and ranking sites for their ecological integrity and quality. CNPS staff visited 15 sites in 2010, and completed 57 vegetation stand surveys. We recorded field data using standard CNPS vegetation plot protocols in combination with an expanded USFS Region 5 Fen survey protocol developed for this project. We analyzed the field data from CNPS in 2010 with pre-existing USFS data from 2009-2010. The analysis resulted in a classification of 26 alliances and 38 associations, which are floristically and environmentally defined plant communities per the National Vegetation Classification System. We also established a system for ranking fen sites to assist land managers in recognizing high priority sites and in making long-term management decisions.

Key words: California, classification, fens, Lake Tahoe Basin, meadows, Nevada, ranking, vegetation, wetlands

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Fens are peat-forming wetlands, supported by nearly constant groundwater inflow (Bedford and Godwin 2003). Perennial saturation creates oxygen-deprived soils with very low rates of decomposition that allow the accumulation of organic matter produced by wetland plants. They differ from other wet meadows because the deep organic layer in fens means that plants rooting in the peat derive all, or almost all, of their water and nutrients from the peat body, rather than the underlying mineral layer.

Fen peat bodies accumulate very slowly and persist for thousands of years (Wood 1975). Fens also are hotspots of biological diversity. In California, fens have formed in many mountainous and north coastal areas that vary in botanical, ecological, geochemical, and hydrologic characteristics. The perennial supply of water provides refugia for plant and animal species that persist only in fens. Many of these species have their main ranges of distribution far to the north in Alaska and Canada (Chadde et al. 1998), with their southernmost ranges in California or Rocky Mountain fens. The presence of water in fens makes them an important component of surrounding forest ecosystems, providing moisture and forage for animals in drought situations (Cooper and Wolf 2006).

Most fens in California are less than a hectare in size (Sawyer et al. 2009). All peatlands in the Sierra Nevada are fens supported by groundwater flow (Benedict and Major 1982). Fens in the Sierra Nevada often occur in meadow complexes, along with areas of dry meadow or wet meadow, or both, which can be categorized by the depth and persistence of the localized water table (Allen-Diaz 1991, Cooper and Wolf 2006). Most meadows and fens are dominated by herbaceous plants, though they may also have high cover of woody vegetation or mosses (Figure 1).

Figure 1.—Variation in vegetation at Ginny Lake Fen, Washoe County, Nevada, July 2010. Photograph by Kendra Sikes.

A main criterion for fen determination is the requirement of at least 40 cm of organic soil in the upper 80 cm of the soil profile (per the U.S. Forest Service [USFS]

Region 5 Fen Protocols; USFS 2010), which is the definition of a Histosol (Soil Survey Staff 1999). Another primary criterion is soil saturation for most of the year. To measure this characteristic, surveyors try to determine whether the water table is within 20 cm of the soil surface during July and August of a normal precipitation year. This saturation criterion is based on fen studies in the Southern Rocky Mountains (Cooper 1990, Chimner and Cooper 2003) and Sweden (Silvola et al. 1996), which found that only those areas where water tables are within 20 cm of the soil surface through July and August accumulated peat (Weixelman and Cooper 2009).

California fens are rare natural communities (CDFG 2010, Sawyer et al. 2009) having unique ecological characteristics and limited range. Recent detailed surveys indicate that each fen or meadow complex may contain few to many vegetation types that are not necessarily rare. In addition, fens have been identified as one of the most sensitive habitat types in the Sierra Nevada (Sierra Nevada Ecosystem Project 1996, USFS 2004). Fens can be classified by their vegetation type, rarity, and diversity as well as by their soils, geomorphology, and hydrologic factors. By identifying vegetation of fens, we are able to better understand the patterns of plant species assemblages, as well as environmental factors that are associated with this rare wetland habitat.

Fen vegetation in the Sierra Nevada has not been well studied or inventoried except in the last decade (Cooper and Wolf 2006, Sikes et al. 2010). Fens and meadows have already been identified in the Tahoe Science Plan (Manley et al. 2009) as special communities that are small in area but have great functional importance. Specific fen sites, including Grass Lake and Hell Hole (Figure 2), have been designated by the Tahoe Regional Planning Agency

Figure 2.—Hell Hole Fen, El Dorado County, California, July 2010. Photograph by Kendra Sikes.

as unique and uncommon plant communities for which they have established standards to assure non-degradation of the natural characteristics of the community (TRPA 2011). These sites support a high diversity of species that are often restricted to these communities.

The Lake Tahoe Basin Management Unit (LTBMU) of the USFS carried out a reconnaissance of meadow sites containing fens on their lands, with 10 sites identified prior to 2009, and >35 sites identified during 2009 (S. Gross, USFS, personal communication). Sites were identified as containing fens using the USFS Region 5 criteria for peat accumulation and water table depth (USFS 2010). However, further research was needed to determine the vegetation diversity, complexity, and quality of these fens. Our project addresses current knowledge gaps by providing maps of fens and associated meadows and describing their ecological characteristics, vegetation types, and site conditions.

Materials and Methods

Study area.—The Lake Tahoe Basin (LTB) is comprised of Lake Tahoe and the lands that drain into the lake. The LTB spans three counties in California and two in Nevada, and is approximately 70 km in distance lengthwise. It ranges in elevation from 1900 m at lake level to 3300 m at Freel Peak. The LTBMU, managed by the USFS, covers over 75% of the LTB land area across >62,000 hectares (150,000 acres) (USFS 2014).

Existing fen data were provided by the LTBMU staff for our analysis. Like other Region 5 Forests, the LTBMU has been identifying and surveying their fen resources using the Region 5 (R5) fen survey protocol (USFS 2010). LTBMU staff completed an aerial imagery assessment in 2007 to identify potential fen sites across the LTB. During 2009–2010, they visited potential fen sites to collect vegetation data and soil samples to determine whether the sites contain fens. In addition to USFS data, we obtained fen plot data collected on state parks and USFS lands by Stanton et al. (2002). While previous efforts used differing protocols, they contained vegetation data adequate for our analysis.

We selected sites as a diverse subset of known, confirmed fen sites in the LTB region (see Figure 3). Sites visited in August and September 2010 by CNPS were located within three watersheds (hydrological units at the 10-digit level, HU-10; NRCS 2007), and five subwatersheds (HU-12). These sites were selected from five regions in the LTB, which we identified geographically during a larger fen conservation assessment effort for the USFS throughout the Sierra Nevada and adjacent areas, including West Basin, Incline Village, East Basin, South Basin and Meiss Country (Sikes et al. 2010).

Sampling methods.—Sampling was implemented using an Expanded Draft Protocol for USFS R5 Fen Surveys, version August 2010, which incorporated methods from previous versions, the USFS Colorado peatland protocol, and the CNPS vegetation sampling methods. This expanded survey protocol includes two parts. The first part focused on the meadow complex or site and is completed once per location (or per sampling year, if return visits are made). The second part was plot-based and focused on visibly 'homogenous' stands of vegetation within the fen-meadow complex. These surveys included ocular estimates of percent cover for all species present within 20-m^2 plots.

Soil samples were collected from a 40-cm soil column to confirm organic carbon (OC) content in some cases. When the soil column showed distinct horizons, multiple samples were taken, and the width of the portion recorded. We calculated average total carbon (TC) in columns with multiple samples according to the portion of the column that

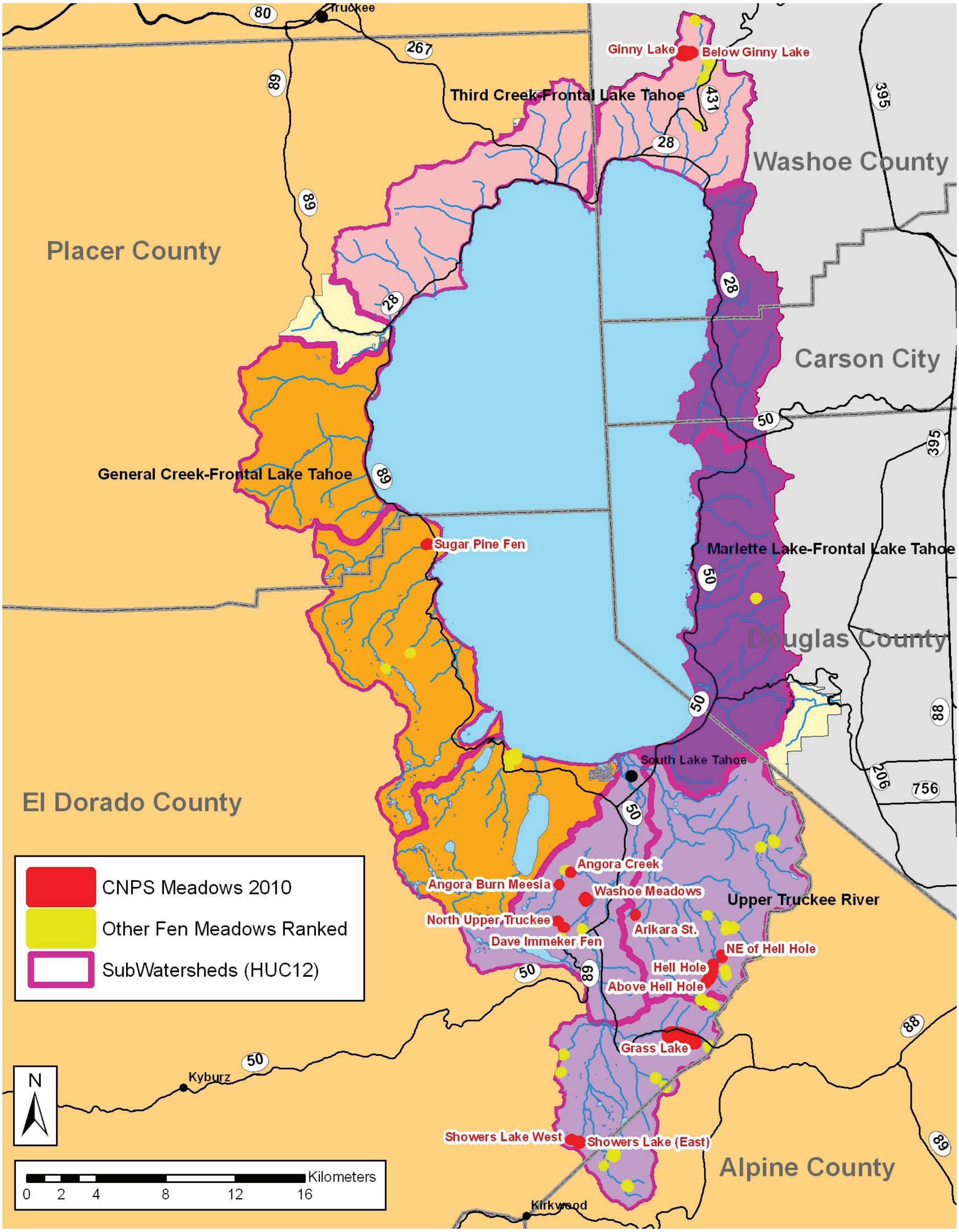

Figure 3.—Lake Tahoe Basin study area displaying HU-10 watersheds by color blocks, HU-12 subwatersheds, and ranked sites with confirmed fens including labeled sites visited by CNPS in 2010 (see Appendix I).

each sample represented. Because most sites were previously visited and fen status had already been confirmed with soil analysis, we typically took soil samples only when our vegetation stands were outside of the area previously recognized as a fen. Soils in the LTB are low in clay content (S. Gross, USFS, personal communication), so particle size was not analyzed. We stored the field data in a version of the R5 Fen Geodatabase with modifications, including additional data fields and domains. The original User's Guide (Fischer et al. 2006), our modifications, and some instructions for updating fields were provided to the LTBMU along with the geodatabase.

Vegetation classification analysis.—The vegetation classification in this report is based upon the U.S. National Vegetation Classification (Grossman et al. 1998, NatureServe 2013a). In California, the classification has been developed by the State Natural Heritage Program of the California Department of Fish and Wildlife (CDFW) and CNPS in partnership with NatureServe. In addition to sites visited by CNPS, meadows previously confirmed to have fens in the LTB were included in our analysis. Data from the LTB were combined with other novel information that had not previously been analyzed within the entire Sierra Nevada region, including fen and wet meadow surveys from Sequoia, Shasta-Trinity, Stanislaus, and Tahoe National Forests. Thus, we assembled and analyzed a total of 280 surveys, which included 3,470 plant records, integrating new data with the preliminary classification (Sikes et al. 2010) to begin describing the local variation of LTB fens.

Data quality control procedures prior to analysis included checking plant names for synonymy, reviewing consistency in the taxa at the subspecific or generic level (such that a single name was used for each taxon), lumping infrequently cited taxa to the next highest level, and removing uncommon species that occurred in less than three plots, which reduced the number of taxa from 270 to 191 and avoided potential noise associated with species that were rare in the dataset. Three plots that were statistical outliers and greater than three standard deviations away from the other plots, using Euclidean distance of species composition and abundance, were also deleted. Uncommon species and outlier plots were removed only for the cluster analysis, and are included in the species list and other descriptive information (see Sikes et al. 2011).

Cluster analysis was performed on the 277 surveys described above, using PC-ORD Version 5.05 (McCune and Mefford 2006). The Flexible Beta linkage method of Hierarchical Cluster Analysis (with a value of –0.25) was used along with the Sorensen distance measure, which is a distance measure recommended for species composition data (McCune and Grace 2002). Indicator Species Analysis (Dufrene and Legendre 1997) was used to determine the number of groups that had both a low average P-value and a high number of significant indicator species. The result was 25 groupings of samples based on their species and abundances. These groupings assist in detecting and describing the value of different species for indicating specific environmental conditions. Once samples were assigned to groups, we reviewed each sample individually to identify those that matched current vegetation alliance descriptions and keys and to determine if descriptions of new alliances were warranted.

We had difficulty separating some of the groups that were dominated by *Sphagnum, Vaccinium, Kalmia,* and *Pinus contorta* ssp. *murrayana*; thus, we performed a second analysis on those groups. We assembled data containing *Sphagnum* as a dominant component from any location in the entire region, including surveys that had been assigned to an association with *Sphagnum* in our preliminary classification (Sikes et al. 2010). This subset included 160 surveys with 184 plant taxa. All *Sphagnum* records, which were the common denominator for the selection, were removed for the cluster analysis, and uncommon species that occurred only once were deleted, with a reduction from 184 to 128 taxa. Using the same analytical process of clustering followed by indicator species analysis, the result was 10 groups.

Mapping methods.—Using a combination of field data collection and aerial photo-interpretation, we altered existing delineations of meadow and fen (or potential fen) extent provided by the USFS, and we created some polygons of new fen sites. In the field, we estimated the extent of each fen using a soil probe (identifying boundaries or areas of at least 40 cm of peat depth), drew the outline on printed aerial imagery, or used a GPS to mark the boundary. In the office, we used the field data and aerial imagery (FSA 2009) to allow computer digitizing of the information recorded in field sketches and GPS data. We also mapped the surveyed vegetation stands using plot photographs and other field data.

For each site, we created a separate map that displays vegetation stands, a fen delineation, and a meadow opening outline (see Figure 4). The meadow outlines provide general indicators for the size and extent of the fen meadow complexes, but they are not based on a specific scientific definition of a meadow. Values for the meadow areas based on those outlines were used as one of the viability factors in assessing that criterion (see below).

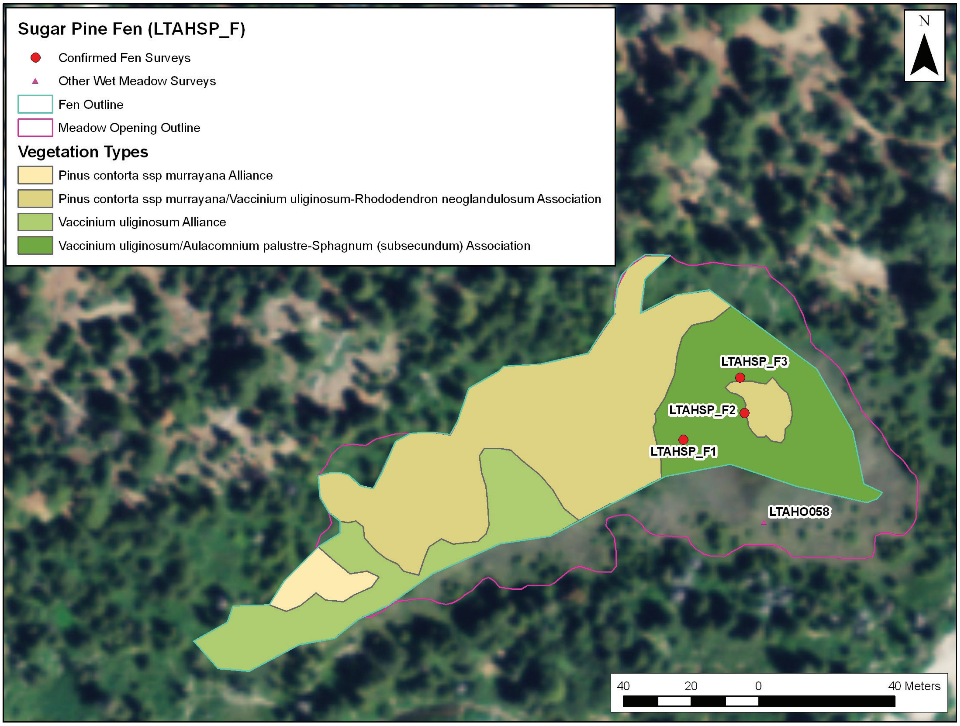

FIGURE 4.—Vegetation map and surveys at Sugar Pine Fen, General Creek – Frontal Lake Tahoe Subwatershed and Watershed, Ed Z'Berg Sugar Pine State Park, El Dorado County, California.

Ranking criteria and methods.—We ranked all sites within the LTB where wet meadows have been confirmed as containing fens, which consisted of 49 confirmed fen meadows (out of 125 individual meadows with data available) in four watersheds and seven subwatersheds in four counties (Alpine and El Dorado counties in California, and Washoe and Douglas counties in Nevada). These do not, however, represent a complete inventory of fens within the LTB. Additonal fens likely exist on private lands, or on public land, that were not detected in the initial aerial photo interpretation and follow-up field surveys.

We adapted the ranking system developed by Chadde et al. (1998) for the Rocky Mountains, which subjectively assesses each peatland using seven criteria on a 3-point scale. We modified the Chadde et al. (1998) system by including two types of within-meadow diversity, physical/topographic diversity and biological diversity (or biodiversity), making 8 criteria. We have attempted to more objectively rate each criterion, by assembling and combining various factors with quantifiable characteristics to determine ratings. Since we were able to quantify a fairly large range of variation for some criteria assessed, we have chosen a 5-point scale to score each site for each criterion. An overall "conservation significance" ranking was the sum of the eight criteria, as defined below: uniqueness, quality, rarity (of plant species and vegetation types), biological diversity (or biodiversity of plants), physical / topographical diversity, viability, defensibility, and scientific and educational value. Lower ranking values represented lower conservation significance based on comparisons across the current data using this quantitative system.

Uniqueness was represented by three environmental conditions (elevation, geology, and pH), and whether these aspects were within the normal range for the group of sites or outside of the primary distribution. Quality was represented by minimal impacts or disturbance noted, distance to the closest road, past range-allotment status, and designation within an urban defense zone. Rarity was scored according to the presence of rare plant species and rare vegetation types. Biodiversity was represented by species richness, presence of woody-dominated fen types, and number of vegetation types per site. Physical diversity was scored according to the presence of five topographical features, general topographic complexity, and the number of water sources recorded. Viability was rated according to size of the fen complex, presence of other fens within the subwatershed, and distance to nearest fens. Defensibility was based on our knowledge of each site's state of protection, and whether they were within specially designated zones. Lastly, scientific and educational value were determined by accessibility of the sites and whether they had been used in the past for research or educational purposes. Further information on these criteria can be found in Sikes et al. (2011).

For 13 of the 49 ranked meadow locations, we had complete meadow diversity data obtained after revising and expanding the USFS R5 protocol. For the other 36 fen meadows with confirmed fens, a previous version of the R5 fen meadow protocol was used; therefore, we were not able to fully assess their diversity criteria and their rank. These sites received automatic scores of 3 (intermediate) for biodiversity and physical diversity.

Results

Species and vegetation data.—We visited 15 different sites within the LTB, with 13 in the USFS-managed lands and two on lands managed by California State Parks (Figure 3). USFS staff conducted other surveys during 2009–2010 in LTB fen meadows (see Appendix

I for locations). Multiple stand or plot surveys were often conducted at each site to capture information on distinct stands of vegetation and to define the plant communities in each fen (Appendix I). In all, 243 vascular plant taxa and 44 nonvascular species were identified in the combined surveys.

CNPS staff recorded five rare plant species in the 2010 fieldwork, along with three species of *Sphagnum* which are the Special Interest List for the LTBMU. Six additional rare species and a fourth species of *Sphagnum* have been recorded in fens of the LTB, according to existing USFS and California Natural Diversity Database (CNDDB 2011) records (Appendix II). Eight of these species are CRPR 2B plants, which are rare in California but more common elsewhere. Two species are CRPR 4 plants, taxa to watch because they have such limited distribution. The last moss on the list, *Tomentypnum nitens,* was recently found in California for the first time; it is not currently ranked, but review from the CNDDB has been requested.

Soil analysis.—Thirty-five soil samples from 40-cm soil columns were analyzed for organic carbon (OC) and total nitrogen. The 35 samples came from 18 soil pits at 12 sites. One of the 18 soil pits did not meet criteria for organic soils and, thus, was not classified as a fen. Samples from three pits returned inconclusive results, since their total percentage carbon was within the histosol range (between 12 and 18%) that depends on clay content, which we did not assess. To be defined as organic, soil OC must be greater than 18% if the soil is greater than 60% clay, and it must be greater than 12% OC if the soil is without clay (Soil Survey Staff 1999).

Vegetation classification and mapping.—Our classification includes 26 alliances and 38 associations assigned to 177 stand samples from the Lake Tahoe Basin (Appendix III). Thirty-five plots were not classified to the association level due to unusual species composition or generic-level plant identifications, though most fit into definitions of existing alliances. Sixty-five additional stand samples were analyzed from other locations beyond LTB.

We categorized 10 associations that were not previously present in our 2010 classification of fens in the Sierra Nevada (Sikes et al. 2010). Three of the ten associations have not been previously described: *Carex simulata–Carex scopulorum* (Provisional), *Oreostemma alpigenum,* and *Sphagnum*–graminoid (Provisional) (Figure 5). The other seven associations have been described by other authors, including four listed by Sawyer et al. (2009). One of the ten associations, *Carex aquatilis–Carex utriculata,* has not been previously ascribed to California, but is known from Colorado and Montana (NatureServe 2013b). Appendix III provides the State (S) ranks for alliances and a designation for association rarity (T. Keeler-Wolf, California Department of Fish and Wildlife, personal communication).

Upon visiting 15 sites and conducting 57 stand surveys, CNPS staff updated a geodatabase of point data and polygon boundaries for meadows and fens in the LTB. Based on the new data, other data from the USFS, and aerial imagery, we created detailed maps showing 39 fen vegetation types in 109 polygons representing stands within 14 sites. Fen site maps are provided by Sikes et al. (2011; Figure 4).

Site ranking.—Conservation significance ratings for the known fens of the Lake Tahoe Basin are presented in Appendix IV. A sum of scores for the eight individual criteria led to total scores ranging from 18 to 30 (out of a possible score of 40) and resulted in 13 levels or unique values for the 49 sites (Figure 6).

Figure 5.—An example of the newly described *Oreostemma alpigenum* Association, Washoe Meadows Fen, El Dorado County, California. Photograph by Kendra Sikes.

The fens rating highest for conservation significance are Dave Immeker Fen and Grass Lake East (Figure 7). Several others of the South Basin region rated higher than those in any other fen region of the LTB. The three subwatersheds (HU-12) of the Truckee River watershed had the three highest average conservation ranks, in addition to being the subwatersheds with the most fens recorded. More specifically, the average conservation significance rating for fens of the Angora Creek subwatershed was the highest at 25.0 (n=10). The lowest average rating was 21.0 for both Incline Lake subwatershed in the Incline Village fen region (n=8) and Fallen Leaf Lake subwatershed in the south basin fen region (n=2).

Discussion

We recorded new occurences for three rare mosses (*Bruchia bolanderi, Meesia triquetra,* and *Tomentypnum nitens*) and two rare vascular plants (*Carex limosa* and *Eriophorum gracile*; Figure 8), adding to the resource assessment of the region. We also have documented a richness of vegetation from woody to herbaceous types in LTB fens. The LTB contains approximately half the number of alliances currently identified across all fen habitats in the Sierra Nevada and southern Cascade Ranges (Sikes et al. 2010). This vegetation alliance richness can be attributed to the geologic, hydrologic, and topographic complexity in the LTB.

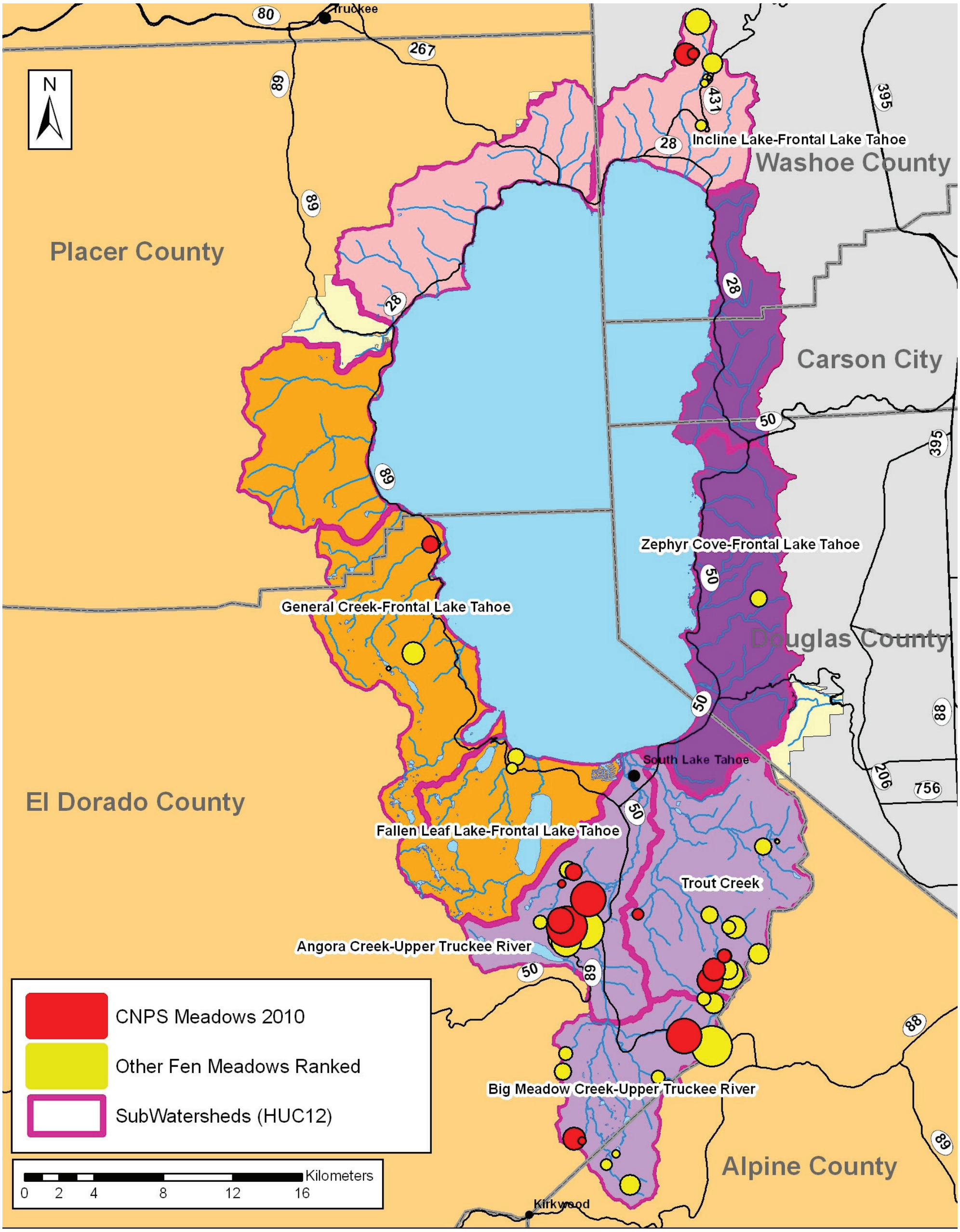

FIGURE 6.—Conservation Rankings of fen sites symbolized with graduated circles, and names of subwatersheds displayed; the largest circles are the highest ratings. Lake Tahoe Basin, California and Nevada.

FIGURE 7.—Grass Lake Fen, El Dorado County, California is a vast fen meadow complex containing a diversity of vegetation types. Photograph by Julie Evens.

By analyzing existing data, we have ranked 49 confirmed fen sites in the LTB based upon eight conservation significance criteria, including inherent diversity considerations and management-related criteria. One value of the ranking process lies in the recognition of vegetation diversity along with other important botanical, site history, and environmental characteristics in some of the smaller and less well-known fens. The application of and expansion of the Chadde et al. (1998) rankings (from seven to eight criteria by splitting within-meadow diversity into the biological diversity and physical-topographic diversity measures) enables managers to consider biological factors separate from environmental factors in evaluating sites. For example, managers can evaluate fen sites for biodiversity and/

FIGURE 8.—*Carex limosa* and *Eriophorum gracile* are rare plants that also form rare vegetation assemblages at Grass Lake Fen, El Dorado County, California. Photograph by Julie Evens.

or rarity (of plant species/vegetation types) as important values for conservation, which may or may not have strong correlations with other environmental or geographical factors. More than five fens that have high rankings (of 4 or 5) for rarity also have high rankings for site quality, while only two fen sites that have high rankings (of 4 or 5) for rarity (of vegetation and species) have high physical diversity. Many fens that have low rankings (1 or 2) for rarity (of species and vegetation) also have low rankings for uniqueness (taking elevation, geology and pH into consideration). On the other hand, no clear correlation between quality and topographic diversity was observed. Thus, a manager could choose between sites with higher quality or uniqueness to maintain their rarity components.

Additionally, the combined conservation significance ranks can assist land managers in making restoration and other management decisions by providing a means for direct comparison between sites. Depending on their purpose, managers can consider only one or more ranking criteria when comparing fens and setting priorities for management, and they should consider high levels of protection for fens receiving high scores (4 or 5) in any criterion. Regarding the regional variation in the rankings, managers can focus on restoration plans for the Incline Village sites with low average ranks (e.g., to restore hydrologic functions), while drafting long-term protective measures to maintain the uniqueness, quality, diversity, or rarity of South Basin sites.

This project presents quantitative and repeatable procedures based upon a comparison of the entire set of sites, with ranks for each criterion based on the position of other sites in a continuum (i.e., rank order was used to assign scores for the 8 different criteria). The additional data collected at each site using the revised protocol added neglible time to the surveys and provided further information to help distinguish features of fen sites; we recommend including these in future surveys (whether ranking of fens is intended or not). We postulate that at least 75% of the fens in the LTB have now been identified and inventoried. Information for remaining unidentified fen locales could be inventoried and incorporated to evaluate the full extent and significance of fen resources of the LTB. However, new sites or new information would require a full analysis of the entire set of fen sites to be incorporated into the ranking.

Our results demonstrate new techniques for ranking the significance of fen sites in the LTB that could be utilized across other lands in California, and beyond, to assist in long-term conservation and management. Our study also contributes to the knowledge of vegetation within fens, including the identification of 10 new associations. Twenty out of the 30 associations in our classification are considered rare. While the vegetation of fens in the LTB may not be particularly unique in comparison to other sites within the Sierra Nevada, the LTB exhibits a high degree of vegetation richness and rarity. Taken together, the fens of the LTB provide an excellent representation of a habitat that is scarce in California.

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APPENDIX I: CONFIRMED FEN SITES WITH STAND SURVEYS ANALYZED IN THE LAKE TAHOE BASIN, CALIFORNIA AND NEVADA

The stands surveyed by the California Native Plant Society are displayed in bold font, and other existing United States Forest Service surveys are in regular font. For subwatersheds and watersheds, Frontal Lake Tahoe is abbreviated as (FLT), and site names are general descriptors rather than official placenames.

Subwatershed	Watershed	Site Name	Owner	No. of Surveys	County	Fen Region
Angora Creek–Upper Truckee River	Upper Truckee River	**Angora Burn Meesia**	**USFS**	**1,** 3	**El Dorado, CA**	**South Basin**
		Angora Creek	**USFS**	3	**El Dorado, CA**	**South Basin**
		Dave Immeker Fen	**USFS**	**4**	**El Dorado, CA**	**South Basin**
		Near Angora Fen	USFS	2	El Dorado, CA	South Basin
		North Upper Truckee	**USFS**	**2,** 2	**El Dorado, CA**	**South Basin**
		Osgood Swamp South	USFS	3	El Dorado, CA	South Basin
		Osgood Swamp West	USFS	2	El Dorado, CA	South Basin
		SE of Angora Lakes	USFS	1	El Dorado, CA	South Basin
		Upper Truckee River	USFS	4	El Dorado, CA	South Basin
		Washoe Meadows	**State Park**	**5,** 2	**El Dorado, CA**	**South Basin**
Big Meadow Creek–Upper Truckee River	Upper Truckee River	Meiss Lake	USFS	2	Alpine, CA	Meiss Country
		South of Meiss Lake	USFS	2	Alpine, CA	Meiss Country
		SW of Meiss Lake	USFS	2	Alpine, CA	Meiss Country
		Big Meadow Creek	USFS	2	El Dorado, CA	Meiss Country
		NW of Elbert Lake	USFS	1	El Dorado, CA	Meiss Country
		Showers Lake	**USFS**	**3,** 1	**El Dorado, CA**	**Meiss Country**
		Showers Lake West	**USFS**	**2,** 1	**El Dorado, CA**	**Meiss Country**
		W of Elbert Lake	USFS	1	El Dorado, CA	Meiss Country
		Freel Meadows	USFS	1	El Dorado, CA	South Basin
		Grass Lake East	USFS	2	El Dorado, CA	South Basin
		Big Meadow	USFS	1	Alpine, CA	Meiss Country
		Grass Lake West	**USFS**	**9,** 15	**El Dorado, CA**	**South Basin**
Fallen Leaf Lake–FLT	General Creek–FLT	Tallac Creek Lower	USFS	1	El Dorado, CA	South Basin
		Tallac Creek Upper	USFS	1	El Dorado, CA	South Basin

APPENDIX I (CONTINUED)

Subwatershed	Watershed	Site Name	Owner	No. of Surveys	County	Fen Region
General Creek–FLT	General Creek–FLT	Crag Lake	USFS	1	El Dorado, CA	West Basin
		Shay Fen, Lonely Gulch	USFS	1	El Dorado, CA	West Basin
		Sugar Pine Fen	**State Park**	**3,** 1	**El Dorado, CA**	**West Basin**
Incline Lake–FLT	Third Creek–FLT	**Below Ginny Lake**	**USFS**	**5,** 1	**Washoe, NV**	**Incline Village**
		Below Incline Lake, E	USFS	1	Washoe, NV	Incline Village
		Below Incline Lake, W	USFS	1	Washoe, NV	Incline Village
		Ginny Lake	**USFS**	**6,1**	**Washoe, NV**	**Incline Village**
		Incline Lake	USFS	3	Washoe, NV	Incline Village
		Liz Fen	USFS	1	Washoe, NV	Incline Village
		Mount Rose	USFS	3	Washoe, NV	Incline Village
		S. of Incline Lake	USFS	1	Washoe, NV	Incline Village
Trout Creek	Upper Truckee River	**Above Hell Hole**	**USFS**	**3**	**El Dorado, CA**	**South Basin**
		Arikara St.	**USFS**	**1,** 4	**El Dorado, CA**	**South Basin**
		Armstrong Fountain Place E	USFS	1	El Dorado, CA	South Basin
		Armstrong Pass	USFS	3	El Dorado, CA	South Basin
		Bear Glade, High Mdws	USFS	2	El Dorado, CA	South Basin
		Fountain Place	USFS	3	El Dorado, CA	South Basin
		Fountain Place Road	USFS	2	El Dorado, CA	South Basin
		Freel Meadows W, top of Saxon	USFS	1	El Dorado, CA	South Basin
		Hell Hole	**USFS**	**9,** 10	**El Dorado, CA**	**South Basin**
		High Meadow	USFS	2	El Dorado, CA	South Basin
		Lower East of Hell Hole	USFS	2	El Dorado, CA	South Basin
		NE of Hell Hole	**USFS**	**4,** 1	**El Dorado, CA**	**South Basin**
		Upper East of Hell Hole	USFS	1	El Dorado, CA	South Basin
Zephyr Cove–FLT	Marlette Lake–FLT	W. of Genoa Peak	USFS	1	Douglas, NV	East Basin

APPENDIX II: SPECIAL STATUS PLANTS FOUND IN MEADOWS WITH CONFIRMED FENS IN THE LAKE TAHOE BASIN, CALIFORNIA AND NEVADA

The number following the decimal point in the CRPR is the threat rank, where 0.2 indicates a moderate degree of threat, and 0.3 indicates a low degree in California (CNPS 2014).

Scientific name	Common name	Family	Global rank[a]	State rank[b]	USFS status[c]	CRPR[d]	No. of fen sites
Vascular Plants							
Carex limosa	mud sedge	Cyperaceae	G5	S3	SI	2B.2	8
Epilobium palustre	marsh willowherb	Onagraceae	G5	S2	SI	2B.3	1
Eriophorum gracile	slender cottongrass	Cyperaceae	G5	S3.3		4.3	6
Schoenoplectus subterminalis	water bulrush	Cyperaceae	G4 G5	S3	SI	2B.3	1
Scutellaria galericulata	marsh skullcap	Lamiaceae	G5	S2	SI	2B.2	1
Utricularia ochroleuca	cream-flowered bladderwort	Lentibulariaceae	G4?	S1		2B.2	1
Non Vascular Plants							
Bruchia bolanderi	Bolander's bruchia	Bruchiaceae	G3	S3?	R5S	2B.2	3
Helodium blandowii	Blandow's helodium	Helodiaceae	G5	S1	R5S	2B.3	2
Meesia triquetra	three-ranked hump moss	Meesiaceae	G5	S4	R5S	4.2	15
Meesia uliginosa	broad-nerved hump moss	Meesiaceae	G4	S3	R5S	2B.2	1
Sphagnum russowii	Russow's peat moss	Sphagnaceae	G5	NR[e]	SI	–	3
Sphagnum squarrosum	spreadleaf peat moss	Sphagnaceae	G5	NR	SI	–	3
Sphagnum subsecundum	sphagnum	Sphagnaceae	G5	NR	SI	–	3
Sphagnum teres	sphagnum	Sphagnaceae	G5	NR	SI	–	1
Tomentypnum nitens	tomentypnum moss	Brachytheciaceae			SI		2

[a] Global Rank is assigned to each species according to its global range, with G3 defined as vulnerable [at moderate risk of extinction], G4 as apparently secure [uncommon but not rare], and G5 as globally common (CNDDB 2011, CNPS 2014).
[b] State Rank is assigned to represent the taxa's status within the state, where S1 is critically imperiled, S2 is imperiled, S3 is vulnerable, and S4 is apparently secure (CNDDB 2011, CNPS 2014).
[c] Special status designations by USFS are represented as R5S for taxa listed on the USFS Pacific Southwest Regional Forester's Sensitive Species List (USFS 2006) and SI for plants on the LTBMU Special Interest List.
[d] CRPR= California Rare Plant Rank = CRPR (CNPS 2014); see *Species and Vegetation Data* section within the Results for more details.
[e] NR = not ranked.

Appendix III: Vegetation classification of alliances and associations with sample size for fens (and other related wet meadows) in the Lake Tahoe Basin, California and Nevada

The state rarity status of each alliance is provided in bold font after its name, where S2 = Imperiled (6–20 viable occurrences statewide), S3 = Vulnerable (21–100 viable occurrences statewide), and S4 = Secure (>100 viable occurrences statewide). Rare associations are marked with an asterisk (*). The number of confirmed fen stands is given under No. of surveys, and in parentheses is the number of additional surveys not confirmed as fens.

Alliance	Association	No. surveys of fens (No. other)
WOODLAND		
Pinus contorta ssp. *murrayana* **S4**		
	Pinus contorta ssp. *murrayana/Vaccinium uliginosum–Rhododendron columbianum*	3 (2)
	Pinus contorta ssp. *murrayana/Carex* spp.	1 (1)
SHRUBLAND		
Alnus incana **S4**		
	Alnus incana ssp. *tenuifolia* *	4 (3)
Kalmia microphylla **S3**		
	Kalmia microphylla/Sphagnum (*fuscum, subsecundum*) *	9 (2)
Rhododendron columbianum **S3**		
	Rhododendron columbianum/Pinus contorta ssp. *murrayana* *	(1)
Salix eastwoodiae **S3**		
	Salix eastwoodiae *	1
Salix lemmonii **S3**		
	Salix lemmonii/Carex spp. *	1
	Salix lemmonii/mesic forb *	2 (4)
Salix orestera **S4**		
	Salix orestera/Carex (*scopulorum*)	3
	Salix orestera/moss (Provisional)	3
Vaccinium uliginosum **S3**		
	Vaccinium uliginosum/Sphagnum teres (Provisional) *	2
	Vaccinium uliginosum/Aulacomnium palustre–Sphagnum (*subsecundum*) *	5 (4)

Appendix III (continued)

Alliance	Association	No. surveys of fens (No. other)
HERBACEOUS		
Bistorta bistortoides–Mimulus primuloides **S4**		
	Bistorta bistortoides–Mimulus primuloides	(1)
	Mimulus primuloides	1 (1)
Carex (*aquatilis, lenticularis*) **S3-S4**		
	Carex aquatilis (*lenticularis*)	9 (7)
	Carex aquatilis–Carex utriculata *	3 (3)
Carex (*illota, luzulina*)/*Bryum pseudotriquetrum* **S2?**		
	Carex capitata (Provisional) *	(1)
	Carex luzulina/Bryum pseudotriquetrum *	1
Carex (*utriculata, vesicaria*) **S4**		
	Carex vesicaria	5 (5)
	Carex utriculata	13 (5)
Carex canescens (Provisional) **S2?**		
	Carex canescens (Provisional) *	1
Carex limosa S3?		
	Carex limosa–Menyanthes trifoliata *	13 (1)
Carex nebrascensis **S4**		
	Carex nebrascensis	1 (4)
Carex scopulorum **S3-S4**		
	Carex scopulorum	3 (5)
Carex simulata **S3?**		
	Carex simulata *	3 (1)
	Carex simulata–Carex utriculata *	8 (1)
Deschampsia cespitosa **S4?**		
	Deschampsia cespitosa–Perideridia parishi	(1)
	Deschampsia cespitosa–Carex nebrascensis	1 (4)
Eleocharis quinqueflora **S4**		
	Eleocharis quinqueflora/Philonotis fontana–Bryum pseudotriquetrum *	1
	Eleocharis quinqueflora	(4)
	Eleocharis quinqueflora/Drepanocladus (*aduncus, sordidus*) *	5
Juncus arcticus **S4**		
	Juncus arcticus var. balticus	(1)
Muhlenbergia filiformis (Provisional) **S4?**		
	Muhlenbergia filiformis (Provisional)	4
Nuphar lutea (Provisional) **S3**		
	Nuphar lutea ssp. *polysepala* (Provisional) *	1 (2)
Oreostemma alpigenum–(*Gentiana newberryi*) **S4?**		
	Oreostemma alpigenum	2
Phalacroseris bolanderi–Juncus oxymeris **S3**		
	Juncus oxymeris/Philonotis fontana *	1
Sphagnum spp. **S3**		
	Sphagnum–graminoid *	1 (1)
Veratrum californicum **S4**		
	Veratrum californicum	(1)

APPENDIX IV: SUMMARY OF CONSERVATION SIGNIFICANCE RANKINGS FOR CONFIRMED FEN SITES IN THE LAKE TAHOE BASIN, CALIFORNIA AND NEVADA

Sites are arranged by Fen Region and then by significance rankings (highest to lowest, with higher values indicating more noteworthy fens). Sites in bold font were visited by CNPS and were afforded full assessment, whereas other sites received automatic scores of 3 for biodiversity and physical diversity. Refer to Figure 6 for a graphical representation of these scores.

Site Name	Uniqueness	Quality	Rarity	Biodiversity	Physical Diversity	Viability	Defensibility	Value	Total Score
East Basin, Douglas Co., Nevada									
W of Genoa Peak	1	5	5	3	3	1	3	1	22
Incline Village, Washoe Co., NV									
Mount Rose	3	5	3	3	3	2	3	3	25
Ginny Lake	**3**	**4**	**2**	**2**	**4**	**4**	**3**	**2**	**24**
Incline Lake	1	3	2	3	3	5	2	4	23
Below Ginny Lake	**3**	**3**	**2**	**3**	**2**	**3**	**2**	**2**	**20**
Liz Fen	3	2	1	3	3	2	2	4	20
Below Incline Lake, W	1	3	1	3	3	3	2	3	19
S of Incline Lake	1	5	1	3	3	2	2	2	19
Below Incline Lake, E	1	3	1	3	3	2	2	3	18
Meiss Country, Alpine and El Dorado Cos., CA									
Showers Lake West	**5**	**3**	**4**	**3**	**3**	**3**	**3**	**1**	**25**
South of Meiss Lake	3	4	2	3	3	4	3	1	23
W of Elbert Lake	3	4	1	3	3	4	3	1	22
NW of Elbert Lake	1	5	1	3	3	4	3	1	21
Big Meadow Creek	3	4	1	3	3	3	3	1	21
SW of Meiss Lake	3	4	1	3	3	2	3	1	20
Big Meadow	1	4	3	3	3	2	3	1	20
Meiss Lake	1	4	2	3	3	2	3	1	19
Showers Lake	**3**	**3**	**2**	**1**	**2**	**4**	**3**	**1**	**19**
West Basin, El Dorado Co., CA									
Shay Fen, Lonely Gulch	3	5	5	3	3	1	3	1	24
Sugar Pine Fen	**3**	**3**	**4**	**4**	**1**	**1**	**3**	**3**	**22**
Crag Lake	1	5	1	3	3	1	3	1	18
South Basin, El Dorado Co., CA									
Grass Lake East	1	4	5	3	3	4	5	5	30
Dave Immeker Fen	**5**	**4**	**5**	**4**	**3**	**3**	**3**	**3**	**30**
Upper Truckee River	3	5	5	3	3	4	3	3	29
Grass Lake West	1	3	4	3	3	4	5	5	28
Washoe Meadows	**3**	**5**	**4**	**3**	**3**	**3**	**4**	**3**	**28**
Osgood Swamp West	5	4	5	3	3	3	3	3	27
Upper E of Hell Hole	5	3	3	3	3	4	4	1	26

APPENDIX IV (CONTINUED)

Site Name	Uniqueness	Quality	Rarity	Biodiversity	Physical Diversity	Viability	Defensibility	Value	Total Score
South Basin, CA (cont.)									
Osgood Swamp South	3	3	4	3	3	3	3	4	26
Above Hell Hole	**1**	**3**	**5**	**2**	**4**	**5**	**4**	**1**	**25**
Freel Meadows	3	3	3	3	3	5	4	1	25
North Upper Truckee	**3**	**4**	**3**	**4**	**3**	**3**	**3**	**2**	**25**
Armstrong Fountain Pl. E	1	3	3	3	3	5	3	3	24
Hell Hole	**1**	**2**	**4**	**2**	**5**	**5**	**4**	**2**	**24**
Lower East of Hell Hole	1	3	4	3	3	4	4	1	23
Armstrong Pass	3	3	3	3	3	4	3	1	23
Angora Creek	**3**	**1**	**3**	**4**	**1**	**3**	**3**	**5**	**23**
Fountain Place Road	1	3	3	3	3	4	2	3	22
Near Angora Fen	3	1	3	3	3	2	3	4	22
Tallac Creek Lower	3	2	3	3	3	2	2	4	22
Bear Glade, High Mdws	1	4	3	3	3	3	2	3	22
NE of Hell Hole	**1**	**3**	**2**	**3**	**2**	**5**	**4**	**1**	**21**
Freel Meadows West, top of Saxon	3	3	1	3	3	4	3	1	21
SE of Angora Lakes	1	5	1	3	3	2	4	2	21
Fountain Place	1	3	1	3	3	5	2	3	21
Tallac Creek Upper	3	4	1	3	3	1	2	3	20
Arikara St.	**3**	**1**	**2**	**5**	**2**	**2**	**2**	**3**	**20**
Angora Burn Meesia	**3**	**1**	**3**	**4**	**1**	**2**	**3**	**3**	**19**
High Meadow	1	4	1	3	3	2	2	2	18