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A Meadow Site Classification for the Sierra Nevada, California

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Meadows are the most biologically active of the plant community types of the Sierra Nevada, California, and serve many purposes. They contribute a high proportion of the forage produced on many forest grazing allotments, park preserves, and wilderness areas. They supply habitats for wildlife populations. By providing scenic vistas, the meadows' timbered edges are favored campsites of forest, park, and wilderness visitors. The meadows also help to filter sediments from water of surrounding slopes, thereby assuring clean streams and lakes. Because of these multipurposes, land managers face a special challenge to maintain, restore, and manage all meadows.

Meadows comprise less than 10 percent of the Sierra Nevada, and they are generally smaller than those of other mountain ranges (Smiley 1921). Because of these features, meadow (as commonly used in the area) includes open grasslands, marshes, bogs, and meadows as usually defined (California Region 1969, Range Term Glossary Committee 1974).

A meadow site is an area of homogeneous species composition, having a general species composition visually different from that of adjacent areas (Ratliff 1979). Although vegetation is a continuum, when a site is delimited, it occupies space. The space is limited, and no two meadow sites are exactly alike. Meadow sites are discrete entities and each site has characteristics peculiar to it. Meadow sites, therefore, are individual units to be classified.

Classification of meadow sites of the Sierra Nevada and of other mountain ranges have been attempted over the years. But a better classification system than now exists for mountain meadows is needed. To assist land managers, applicable cultural treatments—reseeding, weed control, gully stabilization, and grazing management—need to be developed for the *varying kinds of meadow sites* rather than for meadows in general. Standards for the healthy condition of the vegetation, for trends to potential or stable-state vegetation, and for grazing need to be more flexible to deal with variation between or within meadows. Requirements of most meadow plant species for growth and development, and for reproduction are either poorly known or known only generally. Interspecific relationships of meadow species are little understood. A classification system with classes, class descriptions, key, and classification functions can provide managers with a means for clearer communication of knowledge about meadows, a basis for grouping similar sites, and an opportunity for developing technical classifications, such as meadow fragility and condition. Class descriptions give some ideas of potential vegetations, and new sites can be placed into the classifications.

Meadows of the Sierra Nevada have been classified in various ways. Wet and dry or semiwet meadow range sites are recognized and classified by range type (California Region 1969). The range-type designation indicates the vegetation type and the dominant species. A single classification is usually applied to an entire meadow area with little, if any, recognition given to different sites.

Meadows are classed as midaltitudinal or montane and high altitudinal or subalpine and alpine (Sharsmith 1959). Kings Canyon National Park meadows are classified into wet, woodland, and shorthair (*Calamagrostis breweri*) types (Sumner 1941). The wet meadow type is broken into sphagnum, coarse-leaved sedge, fine-leaved sedge, and grass subtypes, and division of the woodland meadows into broad-leaved and coniferous subtypes is suggested (Bennett 1965). Three classes—level meadows, hanging meadows, and stringer meadows—are used along Rock Creek in Sequoia National Park (Harkin and Schultz 1967). Meadows of Gaylor Lake Basin in Yosemite National Park are classed as wet, moist, and dry (Klikoff 1965). The wet type is the shorthair type of Sumner (1941), and the dry type corresponds to the short-hair sedge (*Carex exserta*) type described by Bennett (1965).

Four kinds of meadow soils on the Sierra National Forest are described by the U.S. Department of Agriculture, Soil Conservation Service (1962). They are normal meadow, drained meadow, alluvial timber, and peat meadow soils. All have effective depths of 3 to 5 feet.

Meadows outside the Sierra Nevada have been classified in various ways. A hydric series of developmental stages leads to climax forest in the Black Hills of South Dakota (Hayward 1928). Streamside meadow communities of the Wasatch Plateau can be separated into types on the basis of dominant species (Ellison 1954). Northeastern California meadows are classed as well-drained, open-basin; poorly drained, closed-basin; or moderately drained, closed-basin (Hormay 1943). Three kinds of meadow or marsh associated with "fen peat" are separated from sphagnum bog and aquatic stands on the presence or absence of *Carex rostrata* (beaked sedge) (Dirschl and Coupland 1972). Eight subalpine meadow community types are described for the Olympic Mountains of Washington (Kuramoto and Bliss 1970). Six Rocky Mountain National Park, Colorado, meadow types are defined and divided into montane and subalpine successional sequences (Wilson 1969). Dry, moist, subalpine or alpine moist-to-wet, tule, and wet meadows are the five subformations of the meadow formation (Hall 1979). Within the subformations are 28 series that can be divided into associations—groups of sites having closely similar vegetation. Sedge (*Carex*) and wiregrass (*Juncus*) series are included in the graminoid subformation of the herbaceous formation in southern California (Paysen and others 1980).

Some of the meadow sites in some other areas are similar to those found in the Sierra Nevada. The pond stage of Hayward (1928) and the rostrata sedge marsh and spikerush (*Heleocharis pauciflora,* fewflowered spikerush) bog of Wilson (1969) are examples. Many of the series of Hall (1979) have their counterparts here.

This report describes an initial effort to classify quantitatively the meadows of the Sierra Nevada, California. From 1973 through 1978, 90 meadow sites in the Stanislaus, Sierra, and Sequoia National Forests and in the Yosemite and Sequoia-Kings Canyon National Parks were sampled (*fig. 1*). The first 72 sites were used to develop the classifications, and the other 18 were used to evaluate them.

METHODS

A classification is a summary and an organization (Major 1958). "The purpose of any classification is to so organize our knowledge that the properties of objects may be remembered and their relationships may be understood most easily for a specific objective" (Cline 1967).

Meadow Site Class

Similar meadow sites can be grouped or clustered into a class—an abstract grouping of meadow sites at any categorical level in a classification system. At the lowest level a class of meadow sites would approximate an association (Braun-Blanquet 1932, Hall 1979).

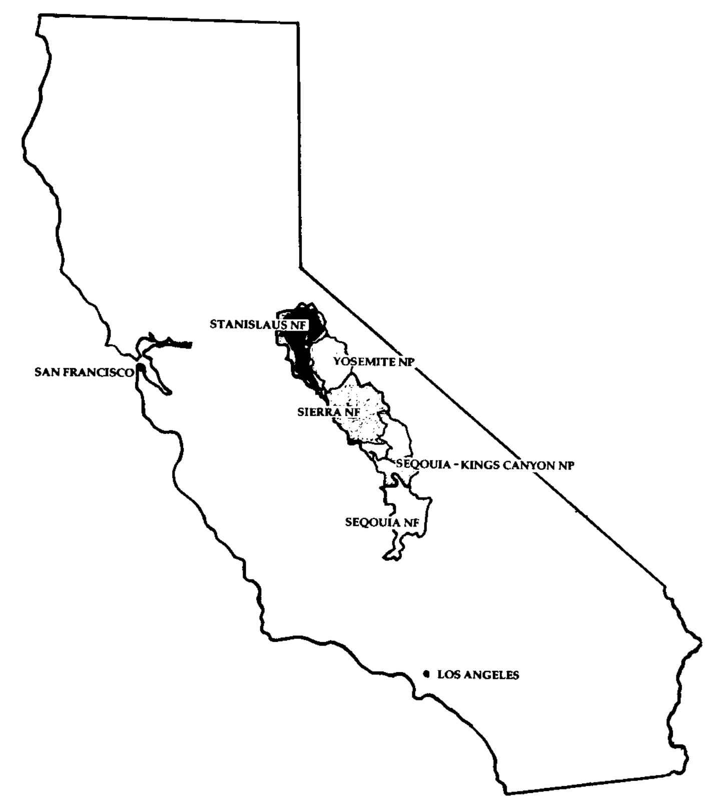

Figure 1—National Forests and National Parks in the Sierra Nevada, California, where meadow sites were sampled.

Classification Criteria

The potential vegetation of a site is preferred for classification purposes to existing vegetation. Because of inadequate knowledge of potentials, however, vegetation as it exists is a criterion of classification.

Dominance is a major criterion for describing vegetation (Noy-Meir and others 1975). Livestock grazing on many of the sites studied, however, prevented use of weight or foliar cover as dominance measures. Because of the grazing factor, frequency was used as an index to dominance.

More than 200 species were found on the sites studied. To include them all in the analyses seemed both unnecessary and unwise. By introducing covariances and interactions, inclusion of nondiagnostic species reduces the effectiveness of clustering techniques (Jancey 1974), and not all species need to be included (Bray and Curtis 1957). SCREEN, a FORTRAN program described by Grigal and Ohmann (1975), provided seven criteria and was the basis for species selection. As a result, 71 species were selected for developing the classification.

Sampling

I assessed frequency on the nearest shoot-to-point basis—the shoot nearest where the point contacts the soil. Fifteen 5-point quadrats were taken in each quadrant of a site for a total of 60 quadrats or 300. points.

Actual basal hits (point contacts with shoot bases or with moss, soil, litter, gravel, rock or wood) were used to express cover and surface conditions, and selected soil properties were determined for each site. Use of these data and shoot frequency as criteria for classification was discussed earlier (Ratliff 1979). Other criteria used in this study to describe the classes derived are elevation, slope, aspect, and drainage.

Cluster Analysis

Techniques of cluster analysis offer the best hope for meaningful grouping of sites. To provide a number of alternatives to select from, I tried three agglomerative and one divisive cluster analyses (Ratliff 1979). Agglomerative analysis starts with the individual sites and progressively combines them. Divisive analysis starts with all sites as one group and progressively divides the group(s). The analysis selected was agglomerative.

Because of interest in sites rather than in species, data were site-standardized. Site standardization equalizes the influence or weight of all sites while stressing dominant species (Noy-Meir and others 1975). The matrix of intersite relationships was formed with standard Euclidean distance as the "resemblance function" (Orloci 1978). The flexible clustering procedure (Clifford and Stephenson 1975, Everitt 1974, and Lance and Williams 1967) was used to recompute distances after each fusion of sites or site groups. A value of -0.25 was assigned the parameter controlling clustering by that procedure; that value is appropriate for most purposes (Williams 1971).

With the structure derived from cluster analysis, the number of final clusters was determined divisively. The method (Ratliff and Pieper 1981) compares the intercluster distances and intracluster distances of each of the two possible clusters in an analysis of variance. Each cluster and the intercluster space are thought of as treatments, with n(n-1)/2 intersite Euclidean distances being response measurements. Each division indicated by the dendrogram is separately tested. A cluster is accepted as final when the F-ratio does not justify its division or when a single site can be split off.

Stepwise discriminant analysis, BMDP program P7M (Dixon 1977), was used to help evaluate the resulting classification. Thirty-eight of the 71 species used in the cluster analysis were selected as having the most indicator value for the final clusters. The 38 species, therefore, were used in the discriminant analysis. Objectives of the analysis were to determine if reallocation of sites among clusters was needed, to assess the viability of the final 14 clusters, to further identify indicator species, and to derive functions for classifying new sites.

The method of Edwards and Cavalli-Sforza (1965) was used to determine whether (over all clusters) significant clustering was indicated. Although the F-ratio as used here and to decide the final clusters (Ratliff and Pieper 1981) will serve to indicate significance, in practice, statements of statistical significance should be avoided.

Classification efficiency was assessed by the method of Orloci (1978). Only at the individual site level, or if all individuals in the clusters are identical, will classification efficiency be 100 percent. Classification efficiency reflects the number of clusters and the within-cluster variations.

RESULTS

Clusters

The 72 sites fell into 14 final clusters. Clusters and corresponding names for classes of Sierra Nevada meadow sites are:

Cluster	Class
A	*Carex rostrata* (beaked sedge)
B	*Poa* (Kentucky bluegrass)
C	*Heleocharis/ Heleocharis* (ephemeral-lake)
D	*Hypericum/Polygonum*/ Viola (hillside bog)
E	*Trifolium/Muhlenbergia* (longstalk clover)
F	*Deschampsia/Aster* (tufted hairgrass)
G	*Carex nebrascensis* (Nebraska sedge)
H	*Heleocharis/ Muhlenbergia* (fewflowered spikerush)
I	*Muhlenbergia/Heleocharis* (pullup muhly)
J	*Agrostis* (bentgrass)
K	*Trifolium/Mimulus* (carpet clover)
L	*Calamagrostis*/*Oryzopsis*(shorthair)
M	*Gentian/Aster* (gentian-aster)
N	*Carex exserta* (short-hair sedge)

These final clusters were derived on the basis of cluster analysis and divisive testing of the dichotomous structure of the resulting dendrogram (*fig. 2*). Significant clustering was indicated (*table 1*), and classification efficiency was 51.4 percent.

Discriminant analysis placed 66 (91.7 percent) of the 72 sites into the clusters derived by cluster analysis. Reallocating the remaining six sites slightly increased classification

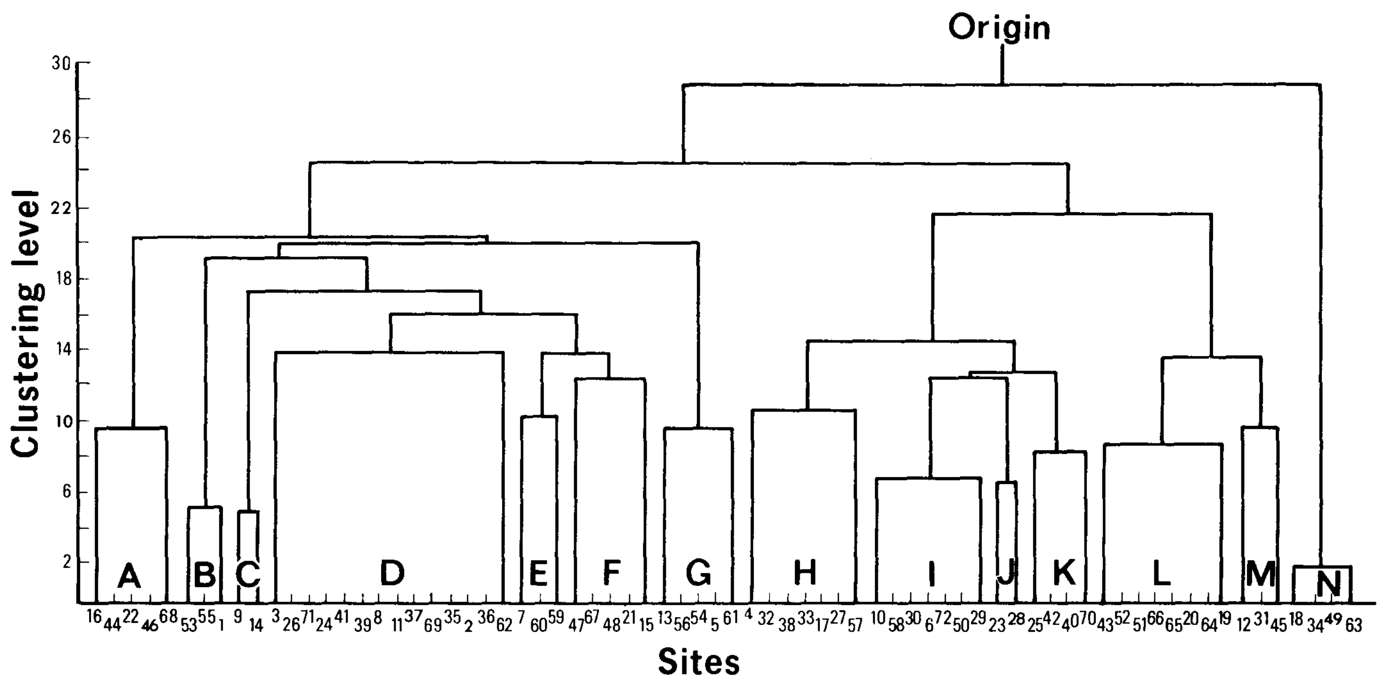

Figure 2—Agglomerative cluster analysis of 72 meadow sites of the Sierra Nevada, California, based upon nearest shoot-to-point species composition. (Standard Euclidean distance, flexible with β = -0.25 procedure, and site-standard deviates standardization)

Table 1—*Analysis of variance of meadow site clustering*

Source	df	Sum of squares	Variance	F[1]
Between clusters	13	2364.37	181.87	4.72
Within clusters	58	2236.16	38.55	
Total	71	4600.53		

[1] $F_{0.99}(13,58) = 2.45$

efficiency (51.8 percent as well as the F-value 4.8) in the analysis of variance.

Two of the clusters (H and I) could not be clearly distinguished by discriminant analysis. Their F-value (1.85) was not significant at the 0.05 level. If these two clusters were combined, 68 sites would be placed the same as by cluster analysis. The dichotomous structure, however, would be altered, and the classification efficiency would be 1 percent lower—because of having one less cluster.

Combining the two clusters with reallocation of sites reduces the classification efficiency by 2 percent. In this situation, site reallocation accentuates the negative effect of combining clusters.

The sites, therefore, were reallocated among the clusters as indicated by discriminant analysis, and 14 clusters were retained. The two questionable clusters were kept separate because of differences in variables other than vegetation (drainage, for example), and to maintain-the dichotomous structure.

Class Indicators

Among the 38 species used in the discriminant analysis, none was restricted to a given cluster (*table 2*). Therefore, no species could be considered "faithful" (Braun-Blanquet

Table 2—*Average nearest shoot-to-point compositions of 38 selected species by cluster*

Species	Cluster													
	A	B	C	D[1]	E	F	G	H[1]	I[1]	J[1]	K[1]	L	M	N
	Percent													
Aster alpigenus[2]	0.01	—	—	2.52	—	5.27	—	8.86	7.17	2.00	—	12.88	13.11	0.01
Aster occidentalis[2]	0.02	—	—	—	4.45	7.47	0.07	1.38	1.67	0.68	0.01	—	—	—
Carex rostrata[2]	78.50	—	0.52	2.19	0.56	—	3.93	2.10	0.06	—	0.01	—	—	—
Carex abrupta	2.00	—	—	7.55	5.57	2.93	1.33	2.15	0.22	11.00	2.13	0.40	—	—
Dodecatheon jeffreyi	0.01	—	—	3.36	—	0.21	0.01	0.01	0.39	1.89	0.08	0.42	0.01	—
Gentiana newberryi[2]	1.67	—	—	—	—	1.60	—	—	0.67	—	—	2.17	10.55	—
Heleocharis pauciflora[2]	0.25	—	—	2.52	3.56	4.40	4.27	33.81	20.17	4.56	12.06	1.71	5.78	—
Juncus nevadensis	1.50	—	—	1.10	—	5.53	—	4.15	2.33	0.01	—	—	—	—
Mimulus primuloides[2]	1.33	0.89	—	6.48	0.22	4.21	0.78	7.05	9.06	5.22	19.73	1.38	4.00	—
Muhlenbergia filiformis[2]	2.58	—	—	6.12	21.89	3.00	15.27	10.86	21.94	7.89	5.67	0.96	9.00	1.08
Polygonum bistortoides[2]	2.76	0.67	—	1.15	0.11	1.35	1.41	0.16	1.46	1.00	0.14	0.05	0.12	—
Viola macloskeyi[2]	0.01	—	—	5.15	—	1.27	0.13	0.05	1.78	10.33	9.87	0.54	—	—
Carex jonesii		0.22	—	1.91	—	0.20	—	—	0.89	0.01	0.80	—	—	—
Danthonia californica		1.78	—	1.20	1.78	1.13	0.01	1.95	2.23	1.45	5.53	—	0.01	—
Hordeum brachyantherum		0.67	—	—	6.11	—	0.01	—	—	—	—	—	—	—
Juncus balticus		1.89	—	0.12	6.73	—	—	0.19	1.45	—	0.07	0.38	—	2.50
Juncus oxymeris		0.78	—	3.67	—	1.53	0.67	—	0.01	0.11	0.73	—	—	—
Poa pratensis[2]		48.33	—	0.36	5.67	0.13	0.27	0.01	—	1.00	0.27	0.04	—	—
Trifolium wormskioldii		2.45	—	0.71	—	—	4.27	0.48	—	—	—	—	—	—
Heleocharis acicularis[2]			58.67	0.83	—	—	2.33	—	0.72	0.34	0.01	—	—	—
Heleocharis palustris[2]			16.00	1.26	—	—	5.87	2.05	—	—	0.13	0.04	—	—
Agrostis scabra[2]				1.48	0.01	0.07	0.21	0.10	1.45	22.34	1.07	—	—	—
Carex ormantha				1.12	—	—	—	2.53	0.78	2.55	0.40	—	—	—
Deschampsia caespitosa[2]				0.98	—	14.20	0.13	0.90	1.78	—	0.01	0.01	0.01	—
Deschampsia danthonoides				0.67	8.68	1.60	—	0.15	—	—	0.54	—	—	—
Hypericum anagalloides[2]				9.41	1.00	1.47	0.61	3.52	1.89	4.23	3.73	0.05	5.00	—
Mimulus tilingii				3.05	—	—	0.21	—	—	0.01	1.20	—	—	—
Oxypolis occidentalis				4.07	—	—	—	—	—	—	0.33	—	—	—
Phalacroseris bolanderi				2.05	—	1.34	0.01	0.10	0.28	1.11	1.40	—	—	—
Scirpus microcarpus				4.48	0.11	—	1.74	0.01	1.00	2.89	7.60	—	—	—
Trifolium longipes[2]				0.81	23.55	2.00	0.87	2.19	1.11	—	—	—	—	—
Trifolium monanthum[2]				0.93	—	1.01	—	0.33	1.07	2.22	11.27	1.21	—	—
Veronica species[2]				0.56	—	—	0.60	—	—	1.44	0.41	—	—	—
Calamagrostis breweri[2,3]						0.93	—	—	0.01	—	—	39.33	9.01	0.25
Carex nebrascensis[2]						0.80	38.20	0.76	1.50	—	—	—	—	—
Scirpus clementis						0.01	—	0.33	—	—	—	2.37	9.11	—
Vaccinium nivictum						0.47	—	—	—	—	—	12.17	13.56	—
Carex exserta[2]						—	—	—	—	—	—	0.17	—	86.00

[1]Contains sites reallocated by the discriminant analysis.
[2]Species used to name the meadow classes.
[3]Includes *Oryzopsis kingii.*

1932). One or more species, however, had sufficient affinity for each cluster to allow naming of the meadow classes.

Thirteen of the species used to name classes (*table 2*) were also selected by discriminant analysis as best for distinguishing between the classes. In order of their entry into the analysis, they were: short-hair sedge, shorthair, slender spikerush (*Heleocharis acicularis*), Kentucky bluegrass (*Poa pratensis*), Nebraska sedge (*Carex nebrascensis*), fewflowered spikerush, beaked sedge, rough bentgrass (*Agrostis scabra),* longstalk clover (*Trifolium longipes*), Newberry gentian (*Gentiana newberryi*), tufted hairgrass (*Deschampsia caespitosa*), western aster *(Aster occidentalis),* and carpet clover (*Trifolium monanthum*). These 13 species are most significant in the class key and are the ones for which classification functions are provided.

Key to Meadow Classes

The pattern for this key is the dichotomous structure of the dendrogram (*fig. 2*). Percentages are nearest shoot frequencies (> = greater than, ≤ = less than or equal to).

1a. *Carex exserta* > 5 pct.......................... Short-hair sedge.
1b. *Carex exserta* ≤ 5 pct.
 2a. (A) *Calamagrostis breweri* > 10 pct.
  (B) *Calamagrostis breweri* > 0, ≤ 10 pct. and *Gentiana newberryi* > 5 pct.
  (C) *Heleocharis pauciflora* > 5 pct. and exceeding species in 2b.
  (D) *Agrostis scabra* > 10 pct.
  3a. Sites as in 2a (A or B).
   4a. *Calamagrostis breweri* > 25 pct......... Shorthair.
   4b. Calamagrostis breweri ≤ 25 pct .... Gentian-aster.
  3b. Sites not as in 2a (A or B).
   4a. *Heleocharis pauciflora* > 25 pct. .... Fewflowered spikerush.
   4b. *Heleocharis pauciflora* ≤ 25 pct.
    5a. *Trifolium monanthum* > 5 pct. ....Carpet clover.
    5b. *Trifolium monanthum* ≤ 5 pct.
     6a. *Agrostis scabra* > 10 pct......................Bentgrass.
     6b. *Agrostis scabra* ≤ 10 pct................Pullup muhly.
 2b. Sites with species in 2a not as indicated and/or the amount of *Heleocharis pauciflora* exceded by *Aster occidentalis, Carex nebrascensis, Carex rostrata, Deschampsia caespitosa, Heleocharis aricularis, Poa pratensis,* or *Trifolium longipes.*
  3a. *Carex rostrata* > 50 pct....................... Beaked sedge.
  3b. *Carex rostrata* ≤ 50 pct.
   4a. *Carex nebrascensis* > 25 pct. .... Nebraska sedge.
   4b. *Carex nebrascensis* ≤ 25 pct.
    5a. *Poa pratensis* > 25 pct. ....Kentucky bluegrass.
    5b. *Poa pratensis* ≤ 25 pct.
     6a. *Heleocharis acicularis* > 25 pct. ....Ephemeral-lake.
     6b. *Helocharis acicularis* ≤ 25 pct.
      7a. *Trifolium longipes, Deschampsia caespitosa,* and/or *Aster occidentalis* > 10 pct.
       8a. *Trifolium longipes* > 10 pct. .... Longstalk clover.
       8b. *Trifolium longipes* ≤ 10 pct. ....Tufted hairgrass.
      7b. *Trifolium longipes, Deschampsia caespitosa,* and *Aster occidentalis ≤ 10* pct. A grasslike or forb not given in 2b will usually be more abundant than *Heleocharis pauciflora* .... Hillside bog.

MEADOW CLASS DESCRIPTIONS

It is not possible to describe adequately all possible variations that may be found within a given class. The following descriptions, therefore, aim to provide modal class concepts on the basis of data used in developing the classification.

In the descriptions, species abundance terms relate to nearest shoot frequencies as follows: few ≤ 5 percent; frequent > 5 percent ≤ 10 percent; plentiful > 10 percent ≤ 25 percent; abundant > 25 percent ≤ 50 percent; and luxuriant > 50 percent. Unless otherwise stated, soil properties referred to are for the 10- to 20-cm depth layer. References to surface variables relate to basal cover derived from the frequency of basal hits. Texture, slope, and reaction classes follow those of the U.S. Department of Agriculture, Soil Survey Staff (1951). Drainage classes are intended to reflect conditions of relative wetness found among meadow sites; however, they are subjective and without quantitative basis. Statements pertaining to management considerations are made on the basis of acquaintance with meadows of the Sierra Nevada.

Beaked Sedge

Site characteristics: The sites are level, poorly and imperfectly drained, but surface water usually is not stagnant (*fig. 3*). Little, if any, moss is present. The soil contains about 20 percent organic matter, with pH about 5.0, and average soil texture is a loam. Beaked sedge may grow as a nearly pure stand and is luxuriant on sites of this class. Few other species are in abundance.

Comments: Sites of this class were identified in Colorado (Wilson 1969). Three distinct types of, beaked sedge meadow were distinguished from meadows without beaked sedge. (Dirschl and Coupland 1972).

Beaked sedge is considered by some to be a secondary or increaser species in wet meadows (California Region 1969), and should be in 40 to 60 cm of water at flowering (Hormay

Figure 3—Beaked Sedge Class, Sky Parlor Meadow, Chagoopa Plateau, Sequoia National Park. (Typical coarse stems in a nearly pure stand, Tule Meadow, Sierra National Forest)

1943). Draining the meadows should result in a decrease of beaked sedge. The wetter portions of a meadow, therefore, are the normal habitat of this species. And, at least in wet meadows, beaked sedge must be considered a primary species.

Beaked sedge may provide good spring forage and, in some countries, it is considered excellent forage for cattle (Hermann 1970). In California, however, it has usually not been well thought of as a forage species. Cattle will use it as the water recedes but not before significant growth has occurred. Beaked sedge sites, therefore, should withstand grazing well. And the manager need not be too concerned about the health of the sedge.

Kentucky Bluegrass

Site Characteristics: Abundant Kentucky bluegrass (*fig. 4*) characterizes this class; however, one or two other species are usually found in some abundance. *Carex* species are present, but do not contribute greatly to the composition.

The sites are nearly level to gently sloping and well-drained. Bare soil comprises about 25 percent and litter about 70 percent of the surface. Moss is absent. Soils are sandy loam to sandy clay loams with pH about 5.5 and are relatively low in organic matter.

Comments: A Kentucky bluegrass association for Northwestern United States has been identified (Hall 1979). Kentucky bluegrass has become the dominant species on what had been bunchgrass meadows in central Oregon (Volland 1978). It increased from less than 1 percent to more than 5 percent of the composition (foliar cover basis) on good to poor condition meadows, respectively (Reid and Pickford 1946). On very poor condition meadows its percentage again was less than 1 percent. Kentucky bluegrass, therefore, must be considered an increaser or secondary species, even though it is excellent forage. And sites of the Kentucky bluegrass class in the Sierra Nevada cannot be considered to be in good condition. Because it is well established, however, management to replace Kentucky bluegrass likely would prove futile.

Ephemeral-Lake

Site Characteristics: The ephemeral-lake sites (*fig. 5*) have very poor drainage and are usually ponded until midsummer. Although slender spikerush is luxuriant here, creeping spikerush (*Heleocharis palustris*) usually dominates the appearance and is plentiful. Microtopographic differences of a few centimeters, altering the depth of water, can markedly alter the composition. Pepperwort (*Marsilea vestita*) is common where water depth is less than 30 cm. Shortawn foxtail (*Alopecurus aequalis*) and ladysthumb knotweed (*Polygonum amphibium*) are common where standing water is a few centimeters deeper.

Ephemeral-lake sites occupy depressed areas with re-

Figure 4—Kentucky Bluegrass Class, Redwood Meadow, Hot Springs Ranger District, Sequoia National Forest. (A dense bluegrass stand, Crane Flat, Yosemite National Park)

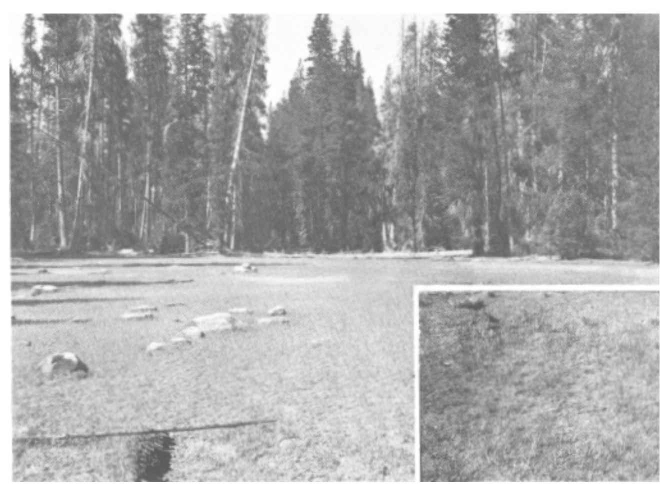

Figure 5—Ephemeral-Lake Class, Minarets Ranger District, Sierra National Forest. (Creeping spikerush [tall], with slender spikerush [short])

stricted surface and subsurface drainage. Moss is generally absent, and bare soil may be in considerable amount. The soils are high in clay, and pH is about 6.0.

Comments: The sites studied and others observed are similar to ephemeral-lake sites in northeastern California and to the pond stage as described by Hayward (1928).

Except where excessive use continues year-after-year, the manager need not be greatly concerned about the condition of ephemeral-lake sites. They are subject to grazing as the water recedes, but the species are able to grow and store reserves before the site is used much.

Hillside Bog

Site Characteristics: Various species may dominate the composition of sites in this class (*fig. 6*). Tinkers penny (*Hypericum anagalloides*), American bistort knotweed (*Polygonum bistortoides*), and species of violet (*Viola*) are all present. The combination is not restricted to this class; however, violets and tinkers penny reach their maximum abundance on these sites.

The sites are mostly sloping to moderately steep, poorly or imperfectly drained, and seep-watered. Moss comprises at least 20 percent of the surface cover. Soils are loams to loamy sands. Amount of organic matter in the surface is usually near or above 20 percent but, at 10 to 20 cm, it is usually much less. Soil reaction is strongly acid, with pH 5.2.

Comments: This class has been recognized and called "hanging meadows" (Harkin and Schultz 1967).

Grazing may contribute to the abundance of violets and tinkers penny. They are low-growing species and their frequencies should be reduced by an increase of taller-growing species. Two such species, which grow on hillside bogs, are tufted hairgrass and bluejoint (*Calamagrostis canadensis*). There are, however, sites ungrazed for some time on which violets and tinkers penny are abundant. Several different associations, therefore, are possible within the hillside bog class. In fact, a reanalysis indicates that there are at least five associations.

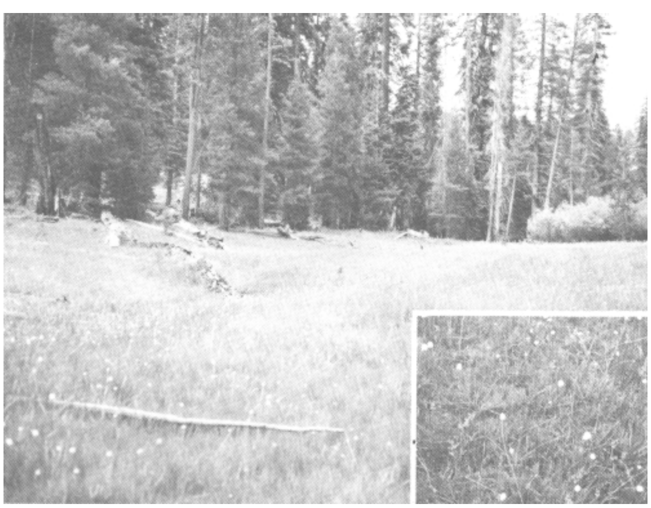

Figure 6—Hillside Bog Class, Willow Meadow, Minarets Ranger District, Sierra National Forest. (Abundant moss, primrose monkey-flower, and American bistort knotweed)

Figure 7—Longstalk Clover Class, near Clover Meadow, Minarets Ranger District, Sierra National Forest. (Abundant clover with western aster)

The steeper, more organic hillside bogs appear to be fragile. Some such sites have been trampled severely, and it is likely best to not graze them, or to permit only light use.

Longstalk Clover

Site Characteristics: Longstalk clover sites (*fig. 7*) vary in appearance in relation to the perennial grasses and grass-likes present. Longstalk clover is plentiful on these sites. It is more abundant than fewflowered spikerush, but pullup muhly (*Muhlenbergia filiformis*) and various other species may individually be more abundant than the clover. The class, therefore, contains a number of associations.

Soils are mostly well-drained sandy loams, loams, or clay loams with pH 5.0 or a little higher. Soil organic matter is less than 10 percent and gravel content is high (16 percent). The sites are level, or nearly level, and moss may be prevalent on some sites.

Comments: These sites are among the best for grazing of livestock, and deer apparently make some use of the clover in spring and early summer. The clover has high forage value. Ecologically, longstalk clover is a secondary species. As taller grass and grasslike plants are reduced under grazing, the clover increases. But under continued heavy use, the clover decreases and annual hairgrass (*Deschampsia danthonoides*) increases.

Tufted Hairgrass

Site Characteristics: Tufted hairgrass (*fig. 8*) is usually plentiful and one or more asters (usually western aster), sedges (*Carex*) or rushes (*Juncus*) generally will be frequent or plentiful. Fewflowered spikerush, pullup muhly, and primrose monkeyflower (*Mimulus primuloides*) may all be present, but are less abundant than tufted hairgrass. Species diversity is usually high. Litter covers between 60 and 70 percent of the surface. Soil, moss, or both, make up most of the remainder. Soil pH is slightly less than 5.0. Soil

Figure 8—Tufted Hairgrass Class, Crane Flat, Yosemite National Park. (Large size plants of tufted hairgrass in excellent health)

textures are sandy loams and organic matter is relatively low. The sites are level to gently sloping and are moderately well- to well-drained. Variations relate mainly to the amounts of tufted hairgrass and other species. On some sites tufted hairgrass shoots may be few and other species may dominate.

Comments: Two tufted hairgrass associations have been identified in moist meadows, and a tufted hairgrass series recognized in dry meadows (Hall 1979). On good condition meadows the composition of tufted hairgrass was reported to be about 70 percent (Reid and Pickford 1946). Poor condition meadows, in contrast, had only 5 percent of that species. Proper grazing management is necessary to maintain tufted hairgrass sites.

The tufted hairgrass class is found extensively in the Sierra Nevada, and some of the other classes derived in this study may represent stages of degeneration from a tufted hairgrass climax. Bluejoint may be found on some tufted hairgrass sites of better condition. Studies have indicated that western aster is an increaser on these sites (Reid and Pickford 1946). It and mat muhly (*Muhlenbergia richardsonis*) may increase on drier sites of the class as grazing reduces tufted hairgrass. On more moist sites fewflowered spikerush and primrose monkeyflower, along with certain rushes and sedges, may be the increasers.

Nebraska Sedge

Site Characteristics: Although other species may be more abundant in this class, Nebraska sedge (*fig. 9*) is the ecological dominant and is abundant. Typically, the sites are level or nearly level and are imperfectly to moderately well-drained. The class is expressed best where water flows over the surface but does not pond. Nebraska sedge is found as a nearly pure stand where overflow water is about 10 cm deep. In deeper water it mixes with beaked sedge, and on drier sites it can be found with tufted hairgrass and a host of other species.

Texture of the soil ranges from clay loam to sandy loam. Soil organic matter is above 20 percent and pH is about 5.3. The surface is generally well-covered with litter. Little moss is present.

Comments: Sites of this class are common in the Western United States, and Hall (1979) recognized Nebraska sedge series in his moist and wet subformations.

Nebraska sedge has been rated as a primary species (California Region 1969). It has also been considered valuable as late-season forage (Hermann 1970). In the Sierra Nevada, Nebraska sedge frequently is grazed season-long and seems to tolerate repeated grazing. Drying of a site as a result of erosion is the most likely cause of reductions in Nebraska sedge.

The next four classes described do not represent potential vegetations. Each class is comprised of sites having similar current vegetations, and the vegetations of the four classes differ. But rather careful study of vegetation is needed to decide to which one of these four classes a site belongs.

Almost all sites of these classes are grazed. The vegetations, therefore, may reflect more the regimes of grazing than any differences in potentials. The main species—those used to name the classes—are not primary or decreaser species. The sites would benefit from improved grazing management. Various caespitose sedges and grasses, such as Star of David sedge (*Carex ormantha*), abruptbeak sedge (*C. abrupta*), Jones sedge (*C. jonesii*), tufted hairgrass, and California oatgrass (*Danthonia californica*) are probably the potential dominants.

Fewflowered Spikerush

Site Characteristics: Fewflowered spikerush (*fig. 10*) may form early pure stands especially in very wet places at high elevations. Sites of the class have more fewflowered spikerush than pullup muhly and primrose monkeyflower combined. And fewflowered spikerush will be abundant and may be luxuriant.

The sites are mostly poorly and imperfectly drained and

Figure 9—Nebraska Sedge Class, Jackass Meadow, Minarets Ranger District, Sierra National Forest. (Healthy, dense stand of Nebraska sedge)

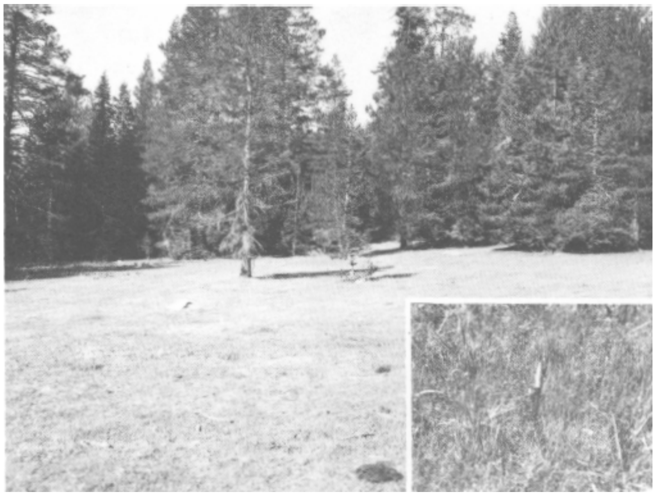

Figure 10—Fewflowered Spikerush Class, upper Bone Yard Meadow, Pine Ridge Ranger District, Sierra National Forest. Site is well grazed. (Typical short growth of fewflowered spikerush on an ungrazed site)

are kept wet by seeps and springs. They are similar, therefore, to the hillside bog sites. But they are mostly level to gently sloping and some sites are well-drained. Abundant moss characterizes the surface. Soils range in texture from silt loams to sandy loams. Reaction is very strongly acid, with pH about 4.9. The surface 10 cm is generally organic, averaging more than 20 percent and the 10- to 20-cm layer has, on the average, about 15 percent organic matter.

Comments: The "spikerush bog" of Wilson (1969) appears to be similar to this class.

Longstalk clover, alpine aster, and California oatgrass may be frequent or more abundant on some sites. And at lower elevations, at least, the abundance of fewflowered spikerush appears to be related to livestock grazing. Taller growing species would be expected to comprise more and fewflowered spikerush less of the composition in the absence of grazing, or on sites in good condition.

Pullup Muhly

Site Characteristics: Pullup muhly sites (*fig. 11*) appear to vary little from those of the fewflowered spikerush class. The main difference is a higher composition of pullup muhly and a correspondingly lower composition of rush.

The sites are level to nearly level and mostly moderately well- or well-drained. Some imperfectly drained sites can be found. Soil textures range from silt loams to sandy loams; reaction is mostly very strongly acid, but ranges to neutral. Although usually above 20 percent in the surface 10 cm, soil organic matter averages about 15 percent between 10 and 20 cm. Moss is a prominent surface characteristic. The similarity and overlap in characteristics of pullup muhly and fewflowered spikerush sites is the apparent reason for the lack of distinction by the discriminant analysis.

Comments: Pullup muhly has been rated as a low value or invader species (California Region 1969). Except for the Kentucky bluegrass and ephemeral-lake sites, it has grown on at least one site of each class. Pullup muhly, therefore, has a broad ecological amplitude, and some of the sites where it was found had not been grazed for many years. My study suggests, therefore, that ecologically, pullup muhly is an increaser rather than an invader species.

In the climax stand, pullup muhly occurs in a somewhat reduced amount. It appears to be able to tolerate considerable shade and may comprise a fairly high percentage of the composition on sites in good or excellent condition. One should not assume that a high amount of this species always indicates poor condition.

Bentgrass

Site Characteristics: Rough bentgrass and Idaho redtop (*Agrostis idahoensis*) typify this class and are plentiful (*fig. 12*). Various speedwells (*Veronica*) and sedges are present. Pullup muhly and primrose monkeyflower may occur in some abundance. Moss is a prominent surface characteristic, and the sites are watered by seeps. Slopes vary from nearly level to gently sloping, and the sites are likely to be poorly and imperfectly drained. Soils are sandy loams, low in organic matter. In the upper 10 cm of soil, however, organic matter may exceed 20 percent. Soil reaction is very strongly acid, with pH about 4.9.

Comments: A series dominated by *Agrostis* species was recognized by Hall (1979).

Taxonomically, rough Bentgrass is similar to Idaho redtop (Hitchcock 1950, Munz and Keck 1959). Generally it is rated low in palatability, but it may be grazed well early in the season (U.S. Department of Agriculture, Forest Ser-vice 1937). Rough bentgrass can grow in wet to fairly dry situations and has been considered to be a low value or invader species of meadows (California Region 1969). A tufted or caespitose species with culms of medium height (somewhat over 30 cm), rough bentgrass occurs naturally in meadows. I think, therefore, that this species is better considered a secondary or increaser species in the Sierra Nevada.

Figure 11—Pullup Muhly Class, an ungrazed meadow, Kings River Ranger District, Sierra National Forest. (Dense stand of pullup muhly with western aster and American Bistort knotweed)

Figure 12—Bentgrass Class, Willow Meadow, Kings River Ranger District, Sierra National Forest. (Tufts of bentgrass with tinkers penny and violet)

Figure 13—Carpet Clover Class, Brush Meadow, Kings River Ranger District, Sierra National Forest. (Small white flowers of carpet clover and basal leaves of western aster)

Carpet Clover

Site Characteristics: Although it does not grow exclusively on sites of this class, carpet clover (*fig. 13*) is frequent or plentiful here. There is much less pullup muhly than on sites of the pullup muhly class; and, relative to the bentgrass class, primrose monkeyflower is more abundant. Violets, panicled bullrush (*Scirpus microcarpus*), and *Carex lemmonii* are all present in some abundance.

The sites are sloping or strongly sloping, watered by seeps, and imperfectly to moderately well-drained. The better-drained sites have little moss and much bare soil. Texture of the soil is a loam or sandy loam. Soil reaction is strongly to medium acid (average pH 5.4) and organic matter is less than 20 percent in the surface as well as between 10 and 20 cm. Variations are mainly related to abundance of the main species and to presence or absence of California oatgrass.

Comments: A low-growing, mat-forming, creeping species, carpet clover prefers moist to wet habitats and has been rated as good to excellent forage (Hermann 1966). Although it is not specifically listed, carpet clover would evidently be considered a primary or decreaser species (California Region 1969). The species will withstand shade from trees bordering a site, but its abundance will be few where taller species are abundant and vigorous. I believe, therefore, that carpet clover, like longstalk clover, should be considered an increaser species.

Most species of monkeyflower are neither sufficiently palatable nor abundant to be valued as forage (U.S. Department of Agriculture, Forest Service 1937). They are all rated as low value or invaders in meadows (California Region 1969). Primrose monkeyflower is plentiful on carpet clover sites, and it is found on sites of every class, except those of the ephemeral-lake and short-hair sedge classes. It is not found away from the meadows. Therefore, I think primrose monkeyflower should be considered a secondary or increaser species, also.

Shorthair

Site Characteristics: Sites of the shorthair class (*fig. 14*) represent an important forage resource in wilderness and backcountry areas. In 1971, sites of the class produced about 121 g per m^2 (1080 lbs/acre).[1]

Shorthair and Sierra ricegrass (*Oryzopsis kingii*) are the dominant species. Slender club-rush (*Scirpus clementis*), Sierra bilberry (*Vaccinium nivictum*), and Newberry gentian are usually present in some abundance. Main variations in the class appear related to amounts of Sierra bilberry and alpine aster (*Aster alpigenus*) present.

Sites of the shorthair class are found in subalpine meadows. The average elevation of the sites studied was 2930 m. Amounts of moss are generally low, and litter makes up more than 50 percent of the surface. Soil textures are mostly sandy loams, with pH 5.0. Organic matter content of the soil is usually less than 10 percent. The sites are nearly level or gently sloping and moderately well- to well-drained.

Comments: The shorthair class was recognized in the Sierra Nevada (Klikoff 1965 and Sumner 1941). As the name indicates, the vegetation is short. Height growth seldom reaches 15 cm, and it is frequently less than 10 cm, even on sites ungrazed for many years. This naturally short growth should not be interpreted to mean that a shorthair site is overused.

Dominants of the climax communities are, I believe, shorthair and Sierra ricegrass. On drier sites, Sierra ricegrass may be more abundant, although shorthair may be so on more moist sites. When together and in vegetative phenological stages, however, these species are most difficult to distinguish. Alpine aster and slender club-rush appear to be increaser species.

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[1] Unpublished data on file at the Pacific Southwest Forest and Range Experiment Station, Fresno, Calif.

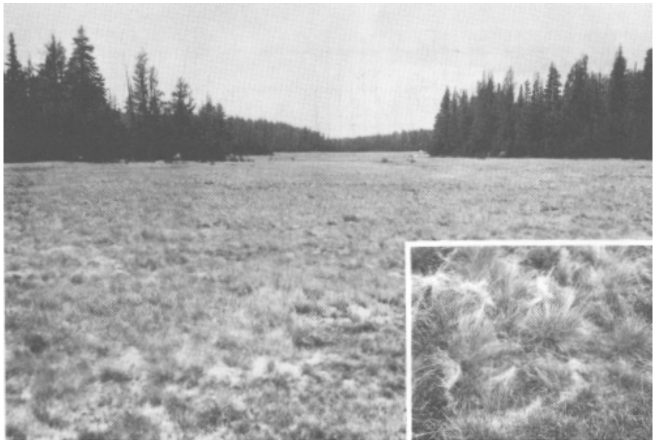

Figure 14—Shorthair Class, Delaney Meadow, Yosemite National Park. (Abundant litter and healthy tufts of grass—here mostly Sierra ricegrass)

Gentian-Aster

Site Characteristics: Except for having smaller amounts of shorthair and larger amounts of bare soil, gentian-aster sites (*fig. 15*) would fall into the shorthair class. Species diversities, amounts of moss, soil organic matter and gravel content, soil texture, pH, slope, and drainage are generally the same as for the shorthair class. Here, however, shorthair is replaced largely by Newberry gentian, fewflowered spikerush, pullup muhly, tinkers penny, and slender club-rush. And there is about 36 percent bare soil as compared with 14 percent bare soil on shorthair sites. Newberry gentian has its greatest abundance on these sites and is about as abundant as alpine aster.

Comments: The three sites representing the gentian-aster class were grazed by livestock. Those of the shorthair class were not. Fewflowered spikerush and slender club-rush appear to be successional species of the sere (Ratliff 1973). It seems likely, therefore, that gentian-aster sites are disturbances of the climax shorthair vegetation.

Short-Hair Sedge

Site Characteristics: Short-hair sedge (*fig. 16*) is clearly the dominant species of this class. On the four sites in this study it comprised an average of 86 percent of the shoot frequency. In an earlier study (Ratliff 1974), the same composition was found for 10 sites by using foliar cover estimated from stereo prints. Species diversity is low. There is little if any moss, and bare soil (48 percent) is the most prominent surface feature. The sites are somewhat excessively or excessively drained and vary from level to strongly sloping. Elevation is usually above 2500 m. Soils are low in organic matter and high in sand. Textures are sandy loams, with gravel making up about 10 percent of the soil mass, and the soils are strongly acid, with pH about 5.1.

Variations in the class appear associated with presence or absence of a tree overstory. Trees may adversely influence the abundance of short-hair sedge and alter the species of forbs present.

Comments: Short-hair sedge sites were recognized (Bennett 1965), and the class is the dry type, as described by Klikoff (1965).

Short-hair sedge is considered to be a secondary species (California Region 1969). It becomes dormant by early August (apparently in response to rapid drying of the soil), but its palatability is equal to that of the similar threadleaf sedge (*Carex filifolia*) (*U.S.* Department of Agriculture, Forest Service 1937). On the study and similar sites, short-hair sedge is the climax dominant of the herb layer and is a primary species.

Short-hair sedge sod responds well to limited grazing. But because of its short growing period, grazing that is too early, too heavy, or both will reduce vigor of the sedge and lead to deterioration of the sod. Deterioration resulting from continued trampling of the sod by people and stock is evident on trails. Once the sod is broken, much time is required for it to rebuild.

CLASSIFICATION OF NEW SITES

The classification functions (*table 3*) were used in a modification of program CONDIT (Jameson and others 1970) to assign the 18 additional sites to classes. CONDIT computes the probabilities of class membership. A simple example will help the reader to understand the procedure (*table 4*).

Each function (F_{ij}) is multiplied by the percentage of composition (X_i) of the corresponding species to derive the score of species i for class j. To the sum of the species scores, the constant (C_j) for the class is added (here subtracted) to obtain the site score (S_j) for the class. Thus, $S_j = C_j + X_1 F_{1j} + X_2 F_{2j} + X_3 F_{3j}$. The maximum score is found and

Figure 15—Gentian-Aster Class, Shorthair Meadow, Kings River Ranger District, Sierra National Forest. (Small tufts of shorthair, alpine aster, Newberry gentian, slender club-rush, and Sierra bilberry)

Table 3—*Species site classification functions for meadows of the Sierra Nevada*

	Cluster													
Species	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Agrostis scabra	0.05	-0.52	-0.57	-0.48	-0.24	0.31	0.21	0.48	0.51	3.81	0.26	0.14	0.06	0.00
Aster occidentalis	.57	.74	.01	.11	1.86	3.77	.50	.15	.69	.02	-.32	-.56	-.04	-.02
Calamagrostis breweri	-.07	.02	-.25	.01	-.14	-.11	.00	.33	.16	.15	.10	5.08	1.04	.15
Carex exserta	.00	.00	.00	.00	.00	.00	.00	.01	.01	.00	.01	.08	.04	-9.83
Carex nebrascensis	.22	-.14	.85	.04	.01	.35	2.81	.01	.20	.10	.04	.00	.07	.00
Carex rostrata	.83	.06	.03	.02	.09	.20	.16	.04	.04	.02	.00	-.01	.06	.00
Deschampsia caespitosa	.89	.51	.32	.26	1.22	4.84	.66	.38	.87	.42	-.03	-.34	.06	-.01
Gentiana newberryi	.99	.37	-.07	-.08	.40	.92	.33	.02	.25	-.17	-.44	.15	4.30	.17
Heleocharis acicularis	.03	-.31	8.38	.09	-.47	.00	.80	-.55	-.21	-.24	.01	-.17	-.14	-.01
Heleocharis pauciflora	.00	.00	-.95	.08	-.29	.14	.13	1.46	.92	.64	.42	.49	.36	.02
Poa pratensis	.10	5.15	-.38	.04	1.40	.34	-.06	.09	.05	-.27	-.08	.02	.08	.00
Trifolium longipes	.18	1.51	-.93	.03	2.50	.69	-.05	-.36	-.18	-.38	-.20	-.20	-.02	.00
Trifolium monanthum	-.07	-.48	1.30	.45	.14	-.19	.11	-.56.	-.22	-.07	2.18	.00	-.56	.03
Constant	-31.56	-127.06	-248.51	-4.12	-39.71	-52.87	-57.89	-25.98	-13.84	-49.88	-17.14	-103.16	-31.06	-425.29

subtracted from each S_j to give the 1n N_j. Corresponding numbers are determined and divided by their sum to give the probabilities.

With low amounts of fewflowered spikerush and moderate amounts of other species, sites with low composition of pullup muhly can be assigned to that class. To be in the pullup muhly class, a site should have about as much or more of that species as it has of fewflowered spikerush. But neither of the two sites assigned to the pullup muhly class (*table 5*) had that condition. Amounts of other discriminating species (*table 6*) offset the influence of fewflowered spikerush.

Fewflowered spikerush and pullup muhly on site 79 are in about the same proportion as on the sites referred to earlier. But absence of other discriminating species gave a higher probability for the fewflowered spikerush class (*table 5*). Changes in amounts of other species, therefore, will determine the class assignment, and the close relation between the fewflowered spikerush and pullup muhly classes will become more apparent.

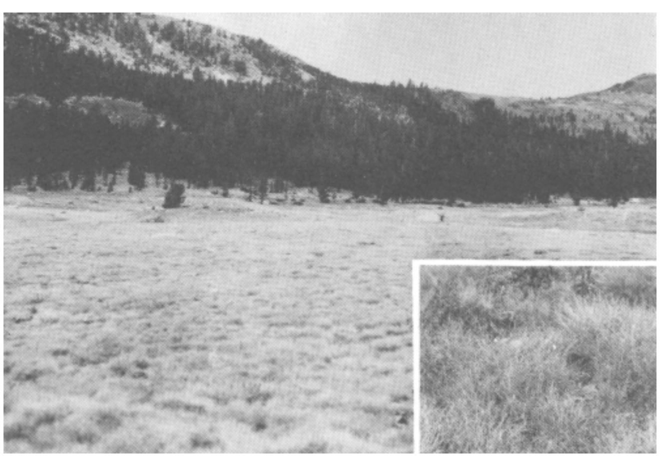

Figure 16—Short-hair Sedge Class, Dana Meadow, Yosemite National Park. (Typical patchiness, but good production, in an excellent condition stand)

The influence of other species is also evident for site 86. More than 40 percent of the composition was fewflowered spikerush, but probability of membership was highest for the tufted hairgrass class. Only a trace amount of tufted hairgrass grew on the site. Western aster, however, was in significant amount and was responsible for the class assignment. Western aster also resulted in site 84 being assigned to the tufted hairgrass class. About 20 percent of western aster appears to indicate a tufted hairgrass potential.

Pullup muhly and fewflowered spikerush sites may have a tufted hairgrass potential. Variables other than current vegetation are about the same at sites 83 and 84 and at sites 85 and 86, and all four are similar. Potential vegetations of these sites should, therefore, be similar. On the basis of data presented, sites 73, 87, and 88 have a tufted hairgrass potential as well. Presence of more shorthair than tufted hairgrass suggests an increaser status for shorthair on these three sites.

The last two sites studied are in the elevational range of shorthair sites. Both have about 27 percent alpine aster. Although they currently fall into the fewflowered spikerush class, their potential vegetation is probably shorthair.

Table 4—*An example of class assignment through calculation of the probabilities of class membership (P_j)*

	Percent	Classes (j)	
		1	2
		Classification functions (F)	
1	5	0.74	0.05
2	10	.89	.25
3	25	.10	.70
Sum of species scores		15.10	20.25
Constants (C_j)		-3.00	-7.00
Score for class (S_j)		12.10	13.25
1n N_j		-1.15	.00
N_j		.32	1.00
$P_j = N_j/1.32$		.24	.76

Table 5—*Class membership for 18 meadow sites of the Sierra Nevada as given by the classification functions (values) and the key (K's)*

Class[2]	Sequential site number[1] 73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Beaked sedge	[3]	1.000 K																
Hillside bog			1.000 K	0.998	0.875		T	0.989 K	0.971 K		T							
Longstalk clover					T K	1.000 K												
Tufted hairgrass										1.000 K		1.000 K		0.762				
Nebraska sedge					0.079													
Fewflowered spikerush	0.023 K						0.561						0.957 K	0.006 K	0.997 K	0.983 K	1.000 K	0.930 K
Pullup muhly	0.975		T	0.002 K	0.045		0.439 K	0.011	0.029		1.000		0.043	0.232	0.003	0017	T	0.070
Carpet clover				T							K							
Gentian-aster	0.002																	

[1]These are the last 18 sites sampled for this study.
[2]Only those classes with positive probabilities are included.
[3]Values are probabilities of class membership. T indicates a probability of less than 0.001 and a blank a probability of 0.0.

These sites may possibly progress through the gentian-aster class.

Tinkers penny, American bistort knotweed, and violet are present on the five sites assigned to the hillside bog class. In that respect they each agree with other sites of the class. Site 77 had too little Nebraska sedge and too little longstalk clover to classify as one of those classes. Sites 80 and 81 are similar to a site reallocated to the hillside bog from the beaked sedge class. Those three sites—68, 80, and 81—may form one of the indicated divisions within the hillside bogs.

Classifications given by the key (*table 5*) agree with those given by the functions for 12 of the 18 sites. Amounts of the 13 species are integrated by the classification functions. Except as the amount of one species leads to the next species to be considered, the key does not integrate the species. Discrepancies are expected. For a particular application, either the functions or the key, but not both, should be used.

Table 6—*Species compositions for computing probabilities of class membership, for 18 meadow sites of the Sierra Nevada*

Species	Sequential site number[1] 73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Agrostis scabra	1.33	—	1.33	0.67	6.33	3.00	—	4.00	7.00	—	1.67	3.33	0.03	0.03	—	—	—	—
Aster occidentalis	6.33	—	—	0.03	—	5.33	—	1.00	—	3.00	11.69	22.00	13.00	22.00	2.06	2.42	0.03	0.03
Calamagrostis breweri	4.00	—	—	—	—	—	—	—	—	—	—	—	—	—	2.36	2.06	—	—
Carex exserta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carex nebrascensis	—	—	0.03	—	19.33	0.33	—	—	—	—	—	—	—	—	—	—	—	—
Carex rostrata	0.33	61.00	—	—	0.33	—	—	17.00	18.67	0.03	—	—	1.67	0.03	0.03	0.03	0.03	0.03
Deschampsia caespitosa	0.33	—	—	—	0.33	0.03	—	1.00	0.03	20.00	0.03	0.03	0.33	0.03	1.03	0.67	—	—
Gentiana newberryi	6.67	—	—	—	—	—	—	—	—	—	3.03	0.33	2.00	6.67	1.69	1.00	0.03	2.67
Heleocharis acicularis	—	—	—	3.67	0.33	0.33	—	—	—	—	0.03	0.03	7.33	2.33	0.03	0.03	—	-
Heleocharis pauciflora	24.33	19.67	—	6.00	7.67	11.00	22.67	5.33	6.67	11.00	20.11	1.67	47.67	42.00	35.75	32.43	41.58	28.10
Muhlenbergia filiformis[2]	8.33	1.00	2.00	3.33	21.33	12.00	7.67	2.33	9.67	6.67	7.68	5.00	16.00	12.67	4.11	8.88	26.55	26.42
Poa pratensis	—	—	0.33	0.33	—	—	—	0.03	—	—	0.03	0.03	—	—	—	—	—	—
Trifolium longipes	—	—	—	0.33	14.33	25.33	—	2.00	—	—	—	—	—	—	—	—	—	—
Trifolium monanthum	1.33	—	0.33	0.33	—	—	—	0.67	—	2.33	5.35	3.33	2.00	0.67	0.33	0.03	—	—

[1]These are the last 18 sites sampled for this study.
[2]Pullup muhly is not required for computing the probabilities; it is included here for comparison with other species and because it names one of the classes.

DISCUSSION

The present meadow site classes appear to be at least two levels above the individual site. That is; at least one additional division is needed to reduce the residual heterogeneity so that the classes of the lowest category correspond to associations (Braun-Blanquet 1932). Presence of this heterogeneity means that some quite-different-looking sites may be assigned to the same class, and a particular site may not fit its class concept particularly well. The opportunity to classify new sites, however, gives new insights into successional relationships and helps in determining site potentials and defining associations.

Best use of the current classification is in conjunction with range types and ecoclasses (Hall 1979). With range types the classes may replace the wet and dry site types and, thereby, expand that categorical level. Within the ecoclass concept the classes may be taken as approximations of series quantitatively derived. Hall's (1979) series, however, are based upon climax or stable-state species, although these meadow site classes are based upon current vegetation. In that respect, the meadow site classes more closely correspond to series as defined in southern California (Paysen and others 1980).

According to the general scheme of Hall (1979), and the altitudinal scheme used by Sharsmith (1959), meadow subformations and series of the Sierra Nevada are as follows:

Subformations	**Series or class**
Montane dry meadow	Kentucky bluegrass
	Tufted hairgrass
Montane moist meadow	Kentucky bluegrass
	Tufted hairgrass
	Longstalk clover
	Nebraska sedge
	Pullup muhly Bentgrass
	Carpet clover
	Fewflowered spikerush
Montane wet meadow	Nebraska sedge
	Fewflowered spikerush
	Beaked sedge
	Ephemeral-lake
	Hillside bog
Montane tule meadow	As given by Hall (1979)
Subalpine alpine dry meadow	Short-hair sedge
Subalpine alpine moist to	Shorthair
wet meadow	Gentian-aster

Presence of a class under more than one subformation indicates that individual sites of the class (as derived in this study) had different moisture conditions. The suggestion is that more than one series having the same major species will eventually be found.

The current meadow site classes and the classification functions provide a basic system from which, as new information is added, a revised classification system will result. A natural system (Cline 1967) of meadow site classification that has associations at the lowest level and a category to represent potential vegetations may evolve. Any classification system, however, is only an approximation of reality. And no classification should be considered final. As a summary a classification "advances," but as an organization it "ossifies" scientific thought (Major 1958). Classification of meadow sites of the Sierra Nevada, therefore, must be a dynamic, continuing process.

APPENDIX

A. Species Index

B. Glossary

Agglomerative cluster analysis—a type of cluster analysis that starts with individual units and progressively combines them until all are in a single group.

Association—a cluster of similar individuals, it is the lowest categorical level.

Basal hit—a point contact with a shoot base or a surface variable at ground level.

Categorical level—all groupings of the same degree of abstraction in a classification (all associations or all series).

Class—an abstract group of individuals or groups within a particular categorical level (an association or a series).

Class indicator—a species or factor that is diagnostic of a particular class or that discriminates between classes.

Classification—the process of combining or partitioning individuals into groups.

Classification efficiency—the extent to which variation between individuals is accounted for by the groups derived.

Classification function—a species coefficient derived by discriminant analysis.

Cluster analysis—any of several techniques used to combine or divide a number of items into groups of similar individuals.

Decreaser—a species of the climax vegetation that will decrease with overgrazing.

Dendrogram—a classification structure that indicates dichotomous hierarchical relationships.

Dichotomous structure—a structure which, throughout, is successively divided into two parts.

Discriminant analysis—a method for finding the most likely class to which an individual belongs.

Divisive cluster analysis—a type of cluster analysis that starts with individuals as a single group and progressively divides them into small-size groups of similar individuals.

Dominance—as used here, those species having high shoot-to-point frequencies. In general, the degree of control exerted by a particular species on the community.

Ecoclass—a uniform coding system in which vegetation of a site is identified by subformation (potential vegetation), series (dominant climax species), and association.

Increaser—a species of the climax vegetation that will (for a time) increase and then decrease with overgrazing.

Invader—a species not of climax vegetation that will invade with overgrazing. (Sometimes species present in small amounts that increase with overgrazing are considered invaders.)

Individual—one of the items (sites) to be classified.

Meadow—wetland or semiwetland that supports a herbaceous cover of emergent hydrophytes, mesophytes, and/or intermediate species, and dry herbland of the subalpine and alpine types. Except for some dry herblands, herbaceous cover is continuous, unless interrupted by trees or rocks.

Meadow site—an area of meadow of homogeneous species composition, having a general species composition visually diffrent from that of adjacent areas; an individual unit to be classified.

Series—a class composed of similar associations.

Shoot-to-point frequency—the proportion of shoot-to-point hits on a species.

Shoot-to-point hit—the live shoot nearest to the basal hit.

Site class—a grouping of individual sites or groups of sites at any categorical level; as used here, a site class is a series or an approximation thereof.

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This report describes 14 meadow site classes derived through techniques of agglomerative cluster analysis. The class names are: *Carex rostrata* (beaked sedge), *Poa* (Kentucky bluegrass), *Heleocharis/Heleocharis* (ephemeral-lake), *Hypericum/Polygonum/ Viola* (hillside bog), *Trifolium/Muhlenbergia* (longstalk clover), *Deschampsia/Aster* (tufted hairgrass), *Carex nebrascensis* (Nebraska sedge), *Heleocharis/ Muhlenbergia* (fewflowered spikerush), *Muhlenbergia/Heleocharis* (pullup muhly), *Agrostis* (bentgrass), *Trifolium/Mimulus* (carpet clover), *Calamagrostis/Oryzopsis* (shorthair), *Gentiana/Aster* (gentian-aster), and *Carex exserta* (short-hair sedge). Stepwise discriminant analysis is used to derive classification functions for quantitatively classifying new sites. A key to the classes is provided.

Retrieval Terms: meadow, meadow site, meadow ecology, meadow management, Sierra Nevada, classification