DeBenedetti and Parsons. 1984. Postfire Succession on a Sierran Subalpine Meadow.
Amer. Midl. Nat. 111(1): 118-125

Postfire Succession in a Sierran Subalpine Meadow

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ABSTRACT: A lightning-ignited fire in 1977 burned a subalpine meadow in Kings Canyon National Park, California. Vegetation establishment and succession were studied for 4 years after the fire. Herbaceous cover increased from 2.3%, immediately after burning, to 123.8% in 1981. Broadleaf species were dominant the 1st year with grass and graminoid species becoming dominant in later years. The fire also resulted in some soil puddling and rill formation although no catastrophic changes were observed.

INTRODUCTION

During the summer of 1977, a lightning-ignited fire entered and spread through most of Ellis Meadow, a subalpine meadow in Kings Canyon National Park, California. The fire burned within the meadow for nearly 2 months before being extinguished by autumn precipitation. National Park Service fire management policy allows naturally ignited fires to burn in many high elevation areas (Parsons, 1977). Fire is known to have a profound effect on many Sierran plant communities; however, information on postfire succession of subalpine meadows is virtually nonexistent. Behavior of the fire in Ellis Meadow and the circumstances which allowed ignition have been previously discussed by DeBenedetti and Parsons (1979). This paper describes the establishment and succession of meadow vegetation during the 1st 4 years after the fire. The effects of the fire on meadow drainage patterns and soil stability are also considered.

STUDY AREA

Ellis Meadow is one of several subalpine meadows found within the Roaring River drainage of Kings Canyon National Park. It is ca. 12 ha in size and is located on a small plateau at an elevation of 2790 m. Physiographically, Ellis Meadow is a generally flat, basin-type meadow with vegetated margins (Benedict and Major, 1982). The surrounding forest is predominantly lodgepole pine (*Pinus contorta ssp. murrayana*)[1]. The dominant prefire wide-leaf sedge, tallgrass vegetation of the study area is characteristic of the region (Benedict, 1981). This community is dominated by *Carex rostrata, Deschampsia caespitosa, Agrostis idahoensis and Juncus mexicanus*. Common herbaceous species include *Mimulus primuloides, Perideridia parishii, Viola macloskeyi* and several species of Epilobium. Most of the meadow surface is highly irregular, consisting of low-lying troughs between the root crowns of the tufted grasses and sedges.

The wide-leaf sedge-tallgrass plant community is characteristic of meadows where the water table remains within a few centimeters of the surface throughout the summer. Overlapping plant canopies commonly result in foliar cover in excess of 100% while

[1]Nomenclature follows Munz and Keck, 1959, and Munz, 1968

aboveground biomass ranges from 300-600g/m~ dry weight. Low temperatures and a generally anaerobic surface soil environment slow the rate of decomposition. As a result, an organic layer of up to 30 cm in depth overlays a loamy sand soil.

Most of the wide-leaf sedge-tallgrass community within Ellis Meadow burned during the 1977 lightning fire. The fire smoldered where it was intense, spreading at a rate of less than 0.5 cm/min. The fire burned nearly all of the organic layer including sub-surface and aboveground organic matter (DeBenedetti and Parsons, 1979).

The weather during the 4-year study period following the fire was quite variable. The water content of the 1 April snow pack near Ellis Meadow was 180%, 97%, 147'po and 75% of the 15-year average in 1978, 1979, 1980 and 1981, respectively. Although summer thundershowers contribute only a small proportion of the water to subalpine meadows in the Sierra Nevada, their timing may be critical to the presence and abundance of certain species.

Fig. 1.-Lowered surface level, puddling and vegetation establishment are all evident 1 year after fire in Ellis Meadow. The background shows an unburned portion of the meadow.

METHODS

Two permanent line transects were established on 30 September 1977, immediately following the fire in Ellis Meadow (Fig. 1). A total of 10.95 m of the two transects spanning the intensely burned portion of the meadow were used for this study. Intensely burned sites could be visually differentiated from those burned less intensely by the extent to which the organic layer was consumed. Surfaces were lower in the more intensely burned areas where ash depths exceeded 2 cm.

Total cover of ash, rocks, logs and burned and unburned vegetation was measured along each transect immediately after the fire. Mean ash depths associated with each surface cover type were also measured. During the final week of September or the 1st week of October for each year between 1978 and 1981 the two transects were resampled by measuring the foliar cover of individual plant species as they intercepted a tape placed along the transect line.

Two types of community similarity indices were used to evaluate postfire vegetation change. Sorensen's Index [IS = 2C/(A + B) x 100, where C is the number of species in common to two samples with A and B being the number of species in each] is a measure of floristic similarity. Motyka modified this index to include quantitative values (Muller-Dombois and Ellenberg, 1974). We used Motyka's Quantitative Index [ISM, = 2Mw/(MA+ MB) x 100] to compare change in vegetative cover. Mw is the sum of the smaller cover values of the species in common to samples A and B which respectively have cover values MA and MB.

Ten to 20 0.1 m^2 plots randomly located in intensely burned and unburned portions of the meadow were monitored for the presence of conifer seedlings at the end of the 1st and 3rd years following the fire. Evidence of erosion was qualitatively described and photographed each year.

RESULTS AND DISCUSSION

Immediate postfire. – The fire reduced vegetation on 42.7% of the total transect to ash (Table 1). Ash segments included prefire spaces between root crowns as well as individual plants consumed entirely by a combination of surface and subsurface fire. Another 41.1% of the total transect length had partially burned herbage, but with the root mass and upper soil layer completely burned. Here, subsurface fire with sporadic or less intense surface flare-ups resulted in near complete consumption of the root mass and surface soil layer, while leaving portions of the aboveground vegetation substantially intact. These sections largely correspond to the areas occupied by the prefire root crowns of relatively robust tufted grasses, sedges and rushes. The root mass was destroyed, whereas the herbage was unburned on 3.5% of the area sampled. Only ca. 0.25 m (2.3%) of unburned vegetation survived on the two transects (Table 1).

Where present, ash depth ranged from 1-20 cm ($\bar{x}$ = 9.0 cm, n = 66, Table 1). Mean ash depths were significantly greater ($p>.05$) when charred vegetation remained at the surface in association with ash ($\bar{x}$ = 11.1 cm, n = 29), than when only ash was present ($\bar{x}$ = 7.2 cm, n = 32).

One year postfire. – Extensive colonization and stabilization of the surface soil and ash areas occurred during the 1st year following fire. Cover of live herbaceous vegetation increased to 36.3% 1 year after burning (Table 2). Moss and liverworts were not found immediately after the fire. However, they covered 30. 7% of the transects after 1 year. Additionally, 24.5% of the surface was covered by water with moss growing below the surface. Hence, by the end of the first growing season (and quite probably by midseason), much of the surface of the most intensely burned portions of the meadow was effectively protected from serious sheet erosion by a nearly continuous ground cover of mostly prostrate matted plant.

Seven broadleaf and six grass and graminoid species (including sedges and rushes) occurred on the transects in 1978 (Table 2). Cover of broadleaf species was 28.1%, or 77% of the total vascular cover present at the end of the 1st year. Cover of grasses and grammoids was 8.2/o, or 23% of the total vascular cover.

The three annual species encountered (*Gnaphalium palustre, Muhlenbergia filiformis and Mimulus guttatus*) accounted for 24% of the cover of vascular plants present at the end of the 1st year following the fire. All other species were perennials.

Mimulus primuloides var. pilosellus was most frequently encountered and also had the greatest cover. These small plants formed dense matted clumps up to 40 cm in diam. *Gnaphalium palustre* was the second most important species observed as measured by foliar cover. *Agrostis idahoensis* and *Carex rostrata* were the most important grass or graminoids present. *Deschampsia caespitosa* was widely distributed throughout intensely burned portions of the meadow and was generally more abundant than in our study area. While nearly all plants present were established from seeds or spores, it appeared that *D. caespitosa* also re-established vegetatively. All of the vascular plant species encountered along the transects during the 1st year of the study were observed in later years. Casual observations of intensely burned sites adjacent to the transects indicated

TABLE 1. – Surface types, cover and mean ash depths immediately following fire (combined data for two transects)

Surface type	Total cover cm	Total cover %	Mean ash depth cm ± SE
Charred vegetation with ash[a]	445.8	41.1	11.1 ± 0.79
Uncharred vegetation with ash[b]	38.2	3.5	11.4 ± 1.70
Uncharred vegetation without ash[c]	25.4	2.3	---
Ash[d]	462.8	42.7	7.2 ± 0.62
Rock	35.6	3.3	---
Rock with ash	66.0	6.1	3.8
Log	10.2	0.9	---
Total	1,084.0	99.9	---

[a] Surface vegetation partially consumed, disconnected from root mass by subsurface fire
[b] Surface vegetation unconsumed, root mass destroyed by subsurface fire
[c] Surface vegetation unconsumed, root mass largely unaffected
[d] Surface vegetation entirely consumed, root mass largely consumed

that additional herbaceous colonizers included *Gayophptum sp.* and *Hypericum anagalloides*.

The appearance and character of the intensely burned areas differed substantially from that of those burned less severely. Few of the grass or graminoid species on the latter areas were seriously injured by the fire. Although their tops may have been charred or removed by the fire, aboveground biomass and cover of grass and graminoids appeared comparable to unburned sites 1 year later. The common postfire annual, Gnaphalium palustre, was absent from these areas. Subsurface fire was light or absent and ash depth rarely exceeded 2 cm in the lightly burned areas.

Where the fire was most intense, the surface of the meadow was lowered between 10 and 25 cm relative to adjacent vegetation. Soil puddling occurred in most of these areas. The initial stages of channelization in the form of shallow rills (less than 7. 5 cm in depth) were sometimes present. These were probably the result of a heavy rain that occurred in early September 1978 (it is estimated that in excess of 10 cm fell in 24 hr).

TABLE 2.—Percent cover by species following the 1977 fire

	1978	1979	1980	1981
Agrostis idahoensis	3.2	4.1	9.3	10.4
Carex rostrata	2.7	3.1	11.7	12.4
Muhlenbergia filiformis	0.5	0.9	--	0.3
Deschampsia caespitosa	0.2	11.1	18.5	17.8
Heleocharis pauciflora	--	19.3	17.2	24.8
H. acicularis var. *bella*	--	--	6.1	--
Juncus nevadensis	--	--	1.7	5.2
Other grasses and graminoids (# species)	1.6(2)	3.3(2)	5.4(2)	4.2(3)
Subtotal grasses & graminoids	8.2	41.8	69.9	75.1
Mimulus primuloides var. *pilosellus*	16.2	29.8	20.8	34.0
Gnaphalium palustre	5.5	0.8	--	--
Mimulus guttatus	2.6	0.2	1.0	--
Sagina saginoides ver. *hesperia*	1.4	0.2	--	--
Callitriche verna	1.2	2.1	1.2	--
Epilobium brevistylum/Epilobium sp.	0.8	3.7	6.9	5.4
Viola macloskeyi/V. adunca	0.4	--	0.2	0.4
Hypericum anagalloides	--	0.5	--	0.7
Stellaria longipes	--	0.2	0.1	0.2
Trifolium monanthum	--	0.5	2.2	6.8
Salix sp.	--	0.1	--	--
Dodecatheon sp.	--	--	0.2	0.8
Unknown herb	--	--	--	0.4
Subtotal broadleaf species	28.1	38.1	32.6	48.7
Total vascular vegetation	36.3	79.9	102.5	123.8
Water over moss (plus algae)	24.5	3.5	--	--
Moss and liverworts	30.7	30.4	46.4	21.3
Total bryophytes	55.2	33.9	46.4	21.3
Total vegetation	91.5	113.8	148.9	145.1
Total nonplant	9.7	7.9	5.5	2.2

Colonizing vegetation generally surrounded the rills.

Postfire succession. – Total cover of vascular plants increased from 36.3% in 1978 (1 year postfire) to 79.9%, 102.5% and 123.8% in 1979, 1980 and 1981, respectively (Table 2). Grass and graminoid species, which accounted for only 8.2'7o ground cover in 1978, increased to 75.1'7o cover by 1981. Correspondingly, broadleaf species in- creased from 28. 1% cover in 1978 to 48. 7% in 1981. This represented a decline in per- cent of total vascular vegetation cover contributed by broadleaf species from 77% in 1978 to 39% in 1981 (Table 2).

The proportion of total vascular plant cover composed of annual species declined from a high of 24% in 1978 to a low of 1% in 1981. Absolute cover by annuals declined steadily during the 2nd through 4th year postfire with the exception of 1980 (Table 3). In 1980, *Heleocharis acicularis* var. *bella*, an annual *Cyperaceae*, made its only appearance, covering 6.1% of the transect surface. Even with the boost from *H. acicularis* var. *bella*, absolute cover of annuals remained lower than the 1st year postfire level of 8.6%. Thus while annuals were relatively important in the initial postfire colonization and stabilization of Ellis Meadow, they were replaced by perennials in succeeding years.

The total number of vascular plant species encountered increased from a low of 13 in 1978 to a high of 17 in 1979 (Table 3). This number remained essentially constant through the fourth season following the fire. Whereas the number of species remained static, there was considerable flux in composition from year to year (Table 2). Species that appeared in the 1st year following fire (1978) and that were still present in 1981 (1st-year cohort) comprised the most important group of plants for every postfire year, both in terms of their contribution to the number of species present and to total cover (Table 2). Total cover by vascular vegetation increased by at least 25% in each of the 4 postfire years, but the relative contribution by species of the 1st-year cohort remained essentially constant (ranging from 71% in 1978 to 68% in 1981). No species were en- countered only during the 1st year following fire.

The four species appearing in the 2nd year following fire (1979) that were still present in 1981 (2nd-year cohort) were also important. The relative contribution of this 2nd-year cohort to total vascular cover was also quite stable (26% in 1979, 19% in 1980 and 26% in 1981). One member of the 2nd-year cohort, *Heleocharis pauciflora*, had the highest cover value among all grass or graminoid plants encountered in 1979 (the 1st year of its appearance) and 1981. Another 2nd-year cohort species, *Trifolium monanthum*, increased steadily in cover through 1981. The other 2nd-year cohort species (*Hypericum anagalloides* and *Stellaria longipes*) declined in relative cover following their first appearance.

Two species appeared first in the 3rd year following the fire (1980) and persisted through 1981. Both species, *Juncus nevadensis and Dodecatheon sp.*, increased substantially in cover in 1981. *Gnaphalium palustre* (an annual) and *Sagina saginoides* var. *hesperia* (perennial) were present only during the 1st 2 years following fire. *Gnaphalium palustre* had accounted for 15% of the total 1st-year vascular plant cover. Two rather unimportant species, in terms of cover, were present during the 1st 3 years following fire before disappearing in 1981 (*Mimulus guttatus* and *Callitriche verna*).

Conditions may have been too dry for support of the water-loving C. verna in much of the study area in 1981.

Bryophytes (mosses and liverworts) covered 55.2% of the transects the 1st year after burning (this includes areas covered by moss with standing water over it). These levels (especially the contribution of liverworts) were much greater than those observed in unburned portions of the meadow. Cover by bryophytes was highest (Table 2) in 1978 and 1980, both of which were wet years (April snow survey water content levels in the southern Sierra Nevada typically exceeded 150% of the long-term average) and was lowest in the driest year (1981). Average intercept length along the transects was also much greater in wet years (19.9 cm and 16.3 cm in 1979 and 1981, respectively). Whereas the effect of such factors as the release of nutrients by the fire and increasing competition from vascular plants during succession on the growth of bryophytes is unknown, it is suggested that the cover and size of bryophyte colonies increase in wet years and decrease in dry years in the early post burn environment.

While 9.7% of the transects' surface was not covered by some form of vegetation 1 year postfire (1978), this was reduced to 2.2% by 1981 (Table 2). Vegetation became increasingly layered during the postfire period as total vegetative cover increased to nearly 150% by 1981. The susceptibility to surface erosion has been correspondingly reduced. Rills forming within the lowered, intensively burned portion of the meadow do not appear to have increased in number or size since 1978.

Many of the lodgepole pine seedlings and saplings located around the periphery of Ellis Meadow were killed by fire. The trees were generally burned through at the base but were often lest standing with green needles on the branches. Most of these trees were still standing in1981. No seedling lodgepole pines were observed during any of the 4 years following the fire burned portions of the meadow.

Similarity indices. – Community similarity based upon floristics (Sorenson's Index)

TABLE 3. – Abundance and cover of annuals, perennials, monocots and dicots in intensely burned site for 1st 4 years following 1977 fire

		Annual vs. perennial		
Years since fire	Total no. of species	% Species annual	% Cover annual	% Cover perennial
1	13	23	8.6	27.7
2	17	24	2.4	77.5
3	16	13	7.1	95.4
4	17	12	1.0	122.8

		Dicot vs. monocot		
Years since fire	Total no. of species	% Species monocot	% Cover monocot	% Cover dicot
1	13	46	8.2	28.1
2	17	41	41.8	38.1
3	16	50	69.9	32.6
4	17	53	75.1	48.7

indicated that the similarity between successive pairs of years did not change appreciably during the study (Fig. 2A). Thus, this rate of change in composition was nearly constant over the study period. However, the reduced similarities between 1978-1980 and 1978-1981 indicated a change in composition.

The Motyka Index, based on cover values, indicated that the similarity of vegetation between successive pairs of years increased steadily through the postfire period (Fig. 2B). This is probably due to the stabilization in cover by such dominant species as *Agrostis idahoensis, Carex rostrata*, *Deschampsia caespitosa* and *Heleocharis pauciflora*. The similarity between 1978 and succeeding years decreases markedly as succession progresses. The magnitude of the change in the character of the vegetation between 1978 and 1981 is better shown by this index than by the floristic index. The comparison reflects the large increases in cover by dominant species occurring in the 3rd and 4th years following fire (Table 2).

SUMMARY AND CONCLUSIONS

While the lack of preburn vegetation data prevents precise comparison, it is clear that the vegetation in the most intensely burned portions of Ellis Meadow is succeeding toward that characteristic of the preburn state. Dominance of vegetative cover of grasses and graminoids is becoming re-established while bare areas are rapidly disappearing. However, an equilibrium or steady state has not yet been reached. Individual species continue to appear and disappear and several species that first appeared in the 2nd and 3rd years following fire continued to increase in importance during 1981 (e.g., *Trifolium*

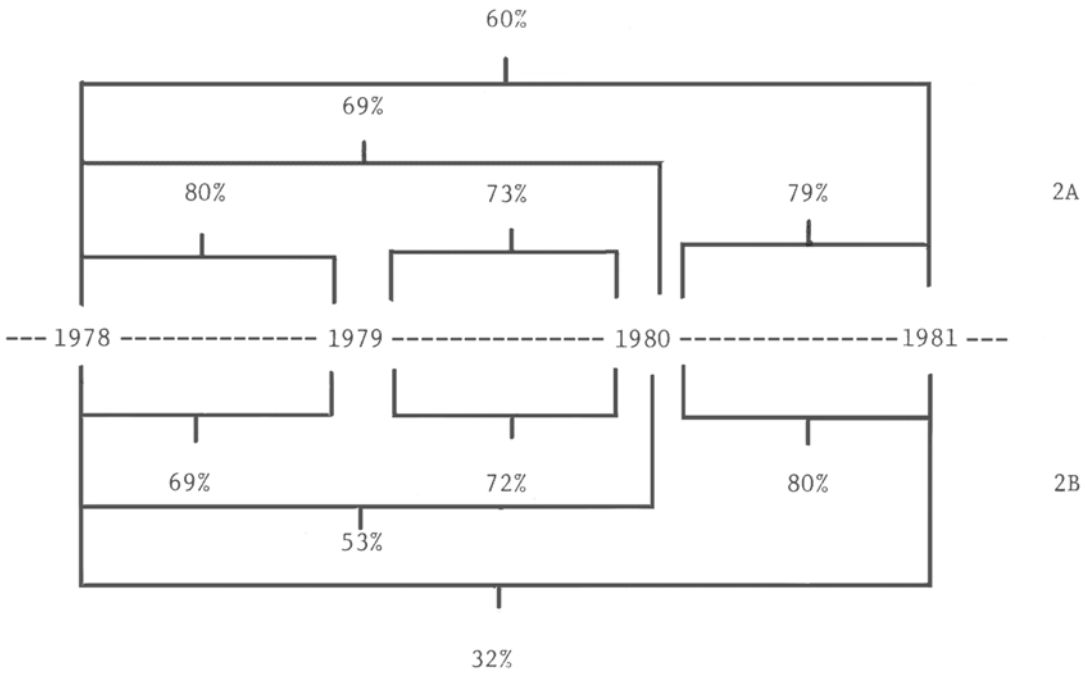

Fig. 2.—A. Sorenson's Index of floristic similarity for selected pairs of years, 1978-1981. B. Motyka's Quantitative Index of similarity applied to cover values for selected pairs of years, 1978-1981

monanthum, Juncus nevadensis, Dodecatheon sp.). Observations over the next decade will be required to fully differentiate between short- and long-term responses of the vegetation to fire.

An observation made immediately after the fire was that the surface of the meadow was lowered relative to adjacent vegetation in those areas where fire was intense. Soil puddling and initial stages of channelization soon occurred in these areas. We hypothesized that this would alter overall meadow drainage patterns and change the distribution of major plant communities. Subsequent observation has not supported this hypothesis. Whereas more hydric vegetation colonized some of the lowered areas, replacing more mesic species, this has occurred only locally and does not constitute a major alteration of plant communities. The drainage pattern and moisture regime appear to have been only marginally affected.

Encroachment of trees into Ellis Meadow has been at least temporarily slowed as no trees have become established within burned areas since the fire. The mortality of young lodgepole pine around the meadow periphery indicated that fire can and does influence the forest-meadow boundary (DeBenedetti and Parsons, 1979, Franklin et al., 1971).

Catastrophic change in the character of Ellis Meadow has not occurred in the 1st 4 years following the fire. Soils have been stabilized by dense vegetative cover. Shallow rills now have vegetated margins and have not expanded since their initial appearance. It should be recalled that Ellis Meadow is a generally flat basin meadow, of the type that has been suggested to be relatively stable (Benedict and Major, 1982). If it had been on a slope, erosion might have been severe and vegetation might have become established more slowly.

Acknowledgments. – This study was supported by National Park Service Natural Science funds. Field assistance was provided by Tom Warner, Beth Sheekey and Tom Stohlgren. Ray Ratliff, Nathan Benedict, Jim Griffin, Jim Hickman and W. B. Critchfield all provided valuable review comments on an earlier draft of the manuscript.

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Submitted 7 September 1982 Accepted 28 January 1983