Vegetation Recovery in Sedge Meadow Communities Within the Red Bench Fire, Glacier National Park

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ABSTRACT

The Red Bench Fire of 1988 was the most significant fire to occur within the North Fork of the Flathead River drainage since 1926. Several wet sedge meadows were burned within Glacier National Park. To determine the effects of fire on vegetation recovery in these sedge meadows, measurements were taken for 3 years postfire on permanent plots that included ground and vegetation cover, cover and constancy for individual plant species, vegetation similarity values, and plant community diversity. Percentages of bare ground decreased, while basal vegetative cover, total organic cover and litter cover increased. Graminoid cover remained relatively stable after the first year, while forb cover decreased. *Carex rostrata* rapidly increased in coverage and dominates the vegetative community. Two grasses and 7 forbs continued to increase in coverage during the period. Five graminoids and 8 forbs increased in constancy. Vegetation similarity values between years show that the plant community changed most the first year. Plant species vary considerably among plots. The average number of species per plot and species richness increased during the period. Overall diversity appears to have increased throughout the period.

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INTRODUCTION

The Red Bench fire occurred late in the fire season of 1988 under extremely dry conditions. This fire is significant in that it occurred in a relatively short time under a combination of high wind and low fuel moistures during an extreme drought (Bushey 1990). The fire followed a major mountain pine beetle epidemic that peaked in 1978, which provided large quantities of dead and downed woody fuel. The fire began west of Polebridge, jumped the North Fork, and burned approximately 17,000 ha along the northwestern boundary of Glacier National Park.

The Red Bench Fire was the most significant fire to occur within the North Fork of the Flathead River drainage since 1926. Fire history indicates that the 62-year interval between 1926 and 1988 was the longest fire-free period in the drainage since 1600.

National park managers and the public are considerably interested in maintaining park vegetation in a natural state and maintaining vegetation types that are limited in area and unique in composition. Such is the case with the wet sedge meadows in Glacier National Park. Sedge meadows throughout the park are relatively few in number and of limited area, often being the major natural openings within extensive coniferous forests.

Several sedge meadows were burned. Such meadows normally sustain surface fires that burn only litter fuels. However, some of the meadows in the Red Bench Fire sustained ground fires that burned deep into organic layers, often to mineral soil. Limited information exists relative to the influence of such low-frequency, high-intensity fires of this severity on sedge meadow cover types.

The main objective of this study is to determine the effects of fire on vegetation recovery in these sedge meadows in Glacier National Park. Specific objectives are to determine fire impacts on plant community diversity characteristics, constancy and average cover for individual plant species, average ground and vegetation cover values for each community, and vegetation similarity values between years and within years for 1, 2, and 3 years postfire.

LITERATURE REVIEW

Fire History

Indian-set fires were apparently important in shaping the vegetation encountered by early European travelers throughout the northwestern United States and western Canada. Lewis (1980) presented considerable evidence that the hunter-gatherer native societies often fired the sedge meadows to reduce trees and brush while encouraging a diverse mosaic of herbaceous vegetation.

Indians in the region acquired horses after 1700, which may have led to increased use of fire (Roe 1955). Fires improved forage for the animals (Barrett 1980; Lewis 1982).

Lewis (1982) discussed the role of presettlement Indians in maintaining open meadows within the boreal forests of Alberta. In numerous interviews with older individuals, he ascertained that Indians traditionally burned wet meadows having peat soils to prevent invasion by brush or trees. By burning in spring, the soils were sufficiently wet to protect subterranean parts of grasses, sedges, and forbs against fire damage. Occasionally, the meadows were burned in fall after the first snows had melted to reduce the fire intensity. One informant reported that until quite recently, Indians burned the meadows on the margins of Wood Buffalo Park to make better "buffalo grass" (identified as sedges, especially *Carex atherodes*). Numerous informants said that the meadows were burned annually to keep out woody plants.

Fire Effects

DeBenedetti and Parsons (1979) described a subalpine meadow burned by a lightning-caused fire in Kings Canyon National Park, California, during a severe drought in the summer of 1977. Ellis Meadow, about 12 ha in size, was dominated by two sedges (*Carex scopulorum* and *C. rostrata)* and a bunchgrass (*Deschampsia caespitosa*). This vegetation type indicates that the water table usually remains at or near the soil surface throughout the summer. Dead plant material decomposes slowly, so that an organic layer of up to 30 cm in depth overlies the soil. The researchers surmised that during a prolonged drought, such meadows may be especially fire-susceptible. The fire was mostly of light to moderate intensity. It consumed most of the above-ground organic matter, and some of the green vegetation. Some but not all of the roots and rhizomes were consumed, and the depth of organic matter consumption was irregular. They concluded that such fires are infrequent in these wet meadows but are a natural part of such communities.

DeBenedetti and Parsons (1984) reported on 4 years of postfire vegetation and soil responses on Ellis Meadow. Two permanent line transects were used to measure percent foliar cover (total and individual species). They found extensive plant colonization and soil stabilization the first growing season postfire. Much of the soil surface was well protected by vegetation the first year following the fire. Total vascular vegetative cover was 36.3, 79.9, 102.5, and 123.8% the first through fourth years postfire. Susceptibility to surface erosion was correspondingly reduced. They conclude that encroachment of trees, mostly *Pinus contorta,* had been at least temporarily slowed because no seedlings were observed. They also concluded that, while lack of prefire vegetative data prevent direct comparisons, the vegetation on Ellis Meadow is obviously succeeding to that characteristic of the preburn vegetation.

STUDY AREA

Seven permanent 0.04 ha Ecodata plots were established in 1989 on 4 sedge meadows burned by the fire. Four additional plots were established in 2 other sedge meadows in 1990. National Park Service personnel assisted in site selection using aerial photos and personal knowledge of the North Fork area. These plots were located to sample the 6 burned sedge meadows within the Red Bench Fire.

METHODS

Forest Service and Park Service scientists decided to use established Ecodata sampling procedures developed by Northern Region of the Forest Service. This provides for establishment of permanent 0.04 ha macroplots for long-term sampling. Procedures for establishing and sampling Ecodata plots, along with data entry and analysis, are described in the Ecosystem Classification Handbook (USDA Forest Service 1987).

Plot Establishment and Data Collection

A 0.04 ha macroplot (20.1 m × 20.1 m) was permanently established on each site. One corner was marked by a permanent stake (metal fence post), while the other 3 corners were marked with metal spikes.

Within each macroplot, 25 microplots were established in a manner repeated in all plots. Five transects were randomly established in each macroplot, and 5 microplots were established along each transect. Each microplot is a 3.9 cm × 7.9 cm rectangle. These microplots were used to measure ground cover (bare soil, gravel, rock, moss, litter/duff, basal vegetation, and wood), number of plant species, plant species names, nested rooted frequency, and foliar canopy cover data. Microplots were remeasured each year to assess changes in vegetation and ground cover over time.

Data were collected on 7 plots (3 in 1 meadow, 2 in 1 meadow, and 1 in each of 2 meadows) in 1989. These plots were resampled in 1990 and 1991, along with the 4 new plots (2 per meadow) that were established in 1990. Sampling was conducted during midsummer at peak of plant growth.

Fire Severity

Fire severity descriptions vary. Vierick and Schandelmeier (1980) stated that fire severity is the effect of fire on some part of the ecosystem, including forest floor, tree canopy, or some other component. Lyon and Stickney (1976) indicated that fire severity relates to the degree that on-site plants survive or reproduce following the fire, whether from on-site meristematic tissues, onsite seeds, or seeds that invade from off-site plants. Wells et al. (1979) added that fire severity also relates to degree of loss of organic matter, protective cover, volatile nitrogen, and other elements.

Ryan and Noste (1985) described a method under development to classify the ecological severity of a fire. They suggested 4 ground char classes (unburned, light, moderate, deep) and described criteria for visual determination. These classes were used in this study to describe fire severity on each macroplot.

Data Analysis and Presentation

Data have been analyzed and summarized using the Strata analysis within Ecopac on a mainframe computer of the Northern Region I, U. S. Forest Service. Ecopac does not provide statistical comparisons and probability levels for comparisons used in this study; thus, statistical analyses are not included in this preliminary report. Individual analyses are summarized below.

Ground and Vegetative Cover

Ground cover characteristics are summarized in percentages from microplot data for bare ground/gravel cover, rock cover, organic cover, basal vegetation cover, woody cover, and litter cover. Vegetative cover is also summarized in percentages from microplot data as tree cover, shrub cover, graminoid cover, and forb cover.

Cover Values for Individual Plant Species

Average cover values for individual plant species were calculated from microplot cover data. All plant species encountered were included for sedge meadow plot analysis.

Constancy for Individual Species

Constancy is a synthetic characteristic of a community, rather than a single stand. It is based on species encountered in releves, in this case microplots. Thus, constancy (as defined by Barbour et al. 1980) is the number of microplots within a plot which contain the species, expressed as a percentage (USDA Forest Service 1987). Average constancy values express how evenly the species is distributed throughout the plots and community.

Vegetation Similarity Values

Vegetation similarity values (100 equals total similarity) are compared within years and between years. These measures of similarity allow one to determine how similar the vegetation is among sites within each community and between years. Between-year values compare a community (one year) to another community (the next year).

Within-year similarity values are of 2 types: (1) *internal similarity*—calculated as the average similarity among all plots within a given year and (2) *relative similarity*—calculated as the average similarity of plots within a year when compared to a plot representative of that year. The representative plot is taken from the constancy-average table.

Community Diversity

Community diversity in our study is expressed as (1) *average Shannon-Wiener diversity index,* (2) *average number of species,* (3) *species richness,* and (4) *average dominance index.*

The Shannon-Wiener (S-W) index is based on the composition and cover of plant species in a plot. High S-W indices (greater than 1.0) are computed when the plot has high coverages and many species. S-W indices are used as a comparison of diversity among plots.

The average number of species is a direct method of determining diversity across a plot and is calculated as the average number of species within subplots. The higher the average number of species, the higher the diversity.

Fig. 1. Unburned sedge meadow shows almost complete dominance by *Carex rostrata* and encroachment of woody plants around the edges.

Fig. 2. Presence of woody fuel ignited peat in isolated patches, providing shallow depressions for ponds and potential for increased biodiversity.

Species richness is simply the number of species present. For two completely even communities, the one with the larger number of species will have the higher diversity index. When the data set is a sample of the community, species richness may be underestimated because rare species may be missed (Hunter 1990).

The average dominance index (a number from 0 to 1) was developed by the Ecosystem Management Group of the Northern Region and indicates the degree of dominance by one or more species on a plot (USDA Forest Service 1987). Plots with high coverages of one species and low coverages of remaining species tend to generate high dominance indices (near 1.0).

RESULTS AND DISCUSSION

No preburn descriptions of the sedge meadows in our study were available for comparison to postburn conditions. However, several other nearby unburned sedge meadows were viewed. These all have dense stands of *Carex rostrata* with almost complete exclusion of other species (Fig. 1). Vegetation covers the entire surface of each meadow with the exception of occasional open water.

The sedge meadows within the Red Bench fire were not uniformly burned by the fire. The region was experiencing drought conditions during 1988; thus, it is assumed that the surface area covered with water in each meadow was less than under normal precipitation. The wet meadows within the area all have a layer of peat as thick as 30-46 cm overlaying the mineral soil. The peat surface generally was charred but not consumed by the fire. In those microsites where shrubs, standing trees, or surface wood were present, wood combustion ignited the peat, which burned to mineral soil. This accounted for approximately 10.1% of the surface area of the meadows.

By the end of the second summer postfire, *Carex rostrata,* which dominates the wet meadows, had regrown from buried rhizomes. It was dense and lush. On the microsites of exposed mineral soil, partial revegetation by annual forbs, perennial forbs, grasses, and isolated plants of *Carex rostrata* had occurred. During 1991, *Carex rostrata* continued to increase and the exposed mineral soil was even more vegetated. In spring and fall of the second and third years, the depressions of exposed mineral soil were mostly under standing water, providing for greater variety of microsites and flora (Fig. 2).

Site Characteristics

Seven of the 11 sedge meadow plots had low ground cover disturbance in which a significant amount of the fine fuel burned, leaving unburned patches of litter. Four other plots had moderate disturbance in which nearly all of the fine fuels were consumed and there was patch distribution of litter consumption. None of the plots were judged as high disturbance with many areas of exposed mineral soil and fairly even distribution of litter consumption. Thus, it appears that a fire of this severity can be expected to consume the peat to mineral soil only in small patches across the sedge meadows. Total peat consumption appears to be associated with the presence of woody fuel.

Ground Cover

Ground and vegetative cover characteristics were measured within each plot and the data are summarized in Table 1. Bare ground/gravel values encountered in point sampling were 10.0% the first year and 4.0% the third year following the fire. This is to be expected as more vegetative cover was recorded, especially that of *Carex rostrata,* which annually covered more of the initial bare microsites.

Table 1. Average ground and vegetative cover values for sedge meadow sites.

Cover	1989 (n = 7)	1990 (n = 11)	1991 (n = 11)
Ground cover			
Bare ground/gravel cover (%)	10.0	10.1	4.0
Rock cover (%)	0.4	0.3	0.0
Organic cover (%)	89.1	90.3	97.8
Basal vegetation cover (%)	12.7	16.3	11.5
Woody cover (%)	1.6	1.8	1.6
Litter cover (%)	74.3	71.8	80.0
Vegetative cover			
Tree cover (%)	0.1	0.1	0.0
Shrub cover (%)	0.3	0.5	0.1
Graminoid cover (%)	64.0	68.0	77.1
Forb cover (%)	2.4	2.5	5.1

Basal vegetative cover values were 12.7, 16.3 and 11.5% for the 3 years following the fire. Total organic cover changed from 89.1 to 97.8%, while litter cover went from 74.3 to 80.0% over the 3-year period. It appears that actual vegetative cover across the meadows did not decrease, but rather comprised less of the total percentage of ground cover as litter from the first 2 years of plant growth accumulated in greater amounts.

Woody cover was only present in small amounts, and remained relatively stable, as the few shrubs present were those that sprouted from live root crowns that survived the fire. New shrub seedlings were not observed in any of the meadows.

The percentage of tree cover remained near 0.1% throughout the 3-year study. Shrub cover measured within microplots changed from 0.3 and 0.5% the first 2 years to a low level of 0.1% the third year. Graminoid cover values ranged from 64% the first year to 77.1% the third year, and forb cover values changed from 2.4 to 5.1% during the 3 years. Nearby unburned sedge meadows have very few woody plants present, probably because of the high water tables. Past fires may have reduced tree encroachment. It is to be expected that natural succession will return the meadows to a graminoid-dominated cover, as these data indicate.

Average Cover Values

Estimates of average cover values of individual plant species for the 3 years are presented in Table 2. Twenty-eight taxonomic units were identified.

Shrubs. Salix sp. is present in some of the meadows, but at such a low level that its coverage is insignificant. Shrubs are not expected to reach any significant level of importance within this community in the near future.

Table 2. Average cover values for individual plant species within the sedge meadow community.

Plant species	1989 (n = 7)	1990 (n = 11)	1991 (n = 11)
Shrubs			
Salix sp.	—		
Graminoids			
Agrostis sp.	—	0.0	0.5
Calamagrostis inexpansa	0.0	2.4	2.4
Calamagrostis purpurascens	0.0	6.5	6.5
Carex sp.	0.5	0.0	—
Carex rostrata	55.7	68.7	68.7
Grass (unidentified)	3.0	0.5	0.5
Juncus sp.	3.7	3.6	3.3
Phalaris arundinacea	0.5	0.0	—
Phleum pratense	0.5	0.0	—
Puccinellia pauciflora	—	0.0	0.5
Forbs			
Annual forb (unidentified)	0.5	0.0	—
Angelica dawsonii	—	0.0	3.0
Aster conspicuus	—	0.0	0.5
Aster foliaceus	3.0	0.0	—
Bidens cernua	1.8	0.0	—
Circium arvense	—	0.0	0.5
Epilobium angustifolium	5.3	3.0	0.5
Epilobium glandulosum	0.0	2.4	8.5
Galium sp.	0.0	0.5	0.5
Mentha arvensis	13.4	10.1	5.3
Polygonum amphibium	2.4	3.7	3.2
Potentilla palustris	0.0	1.3	1.3
Scutellaria galericulata	0.5	3.0	1.8
Senecio crassulus	0.0	3.0	3.0
Taraxacum officinale	0.5	0.0	—
Typha latifolia	0.0	0.5	0.0
Ferns			
Equisetum sylvaticum	5.3	4.5	5.3

Graminoids. Ten grass and sedge taxa are listed in Table 2. Of these, *Carex rostrata* is the dominant species. Its average coverage values ranged from 55.7% in 1989 to 68.7% in 1990 and 1991 and it dominates the vegetative community. During the 3 years postfire, *Calamagrostis inexpansa* and *C. purpurascens* coverage values increased from 2.4 to 6.5%, respectively. Other taxa cover values have either remained stable or have declined. They are all at low percent coverage values.

Forbs. Seventeen taxa were encountered in microplots throughout the 6 sedge meadow communities. Of these taxa, 7 appear to have higher average coverage values over the 3 years postfire, 6 appear to have lower values, and 4 appear to have remained relatively constant (Table 2), although actual values were not statistically compared. Seven of these taxa contribute the majority of the forb/fern coverage. Of these, *Epilobium angustifolium* and *Mentha arvensis* almost disappeared in the macroplots over the 3 years, while *Epilobium glandulosum* and *Senecio crassulus* appear to have increased. *Polygonum amphibium, Scutellaria galericulata,* and *Equisetum sylvaticum* remained relatively stable.

Constancy for Individual Species

Constancy is the percentage of microplots within a plot that contain the species. Average constancy values express how evenly the species is distributed throughout the plots and community. The utility of constancy values (Table 3) is in their expression of how widely distributed or clumped that species is over the area.

Comparisons of constancy values among years helps one to assess whether or not a species is spreading, remaining stable, or withdrawing. Increases in constancy values for sprouting species provide some evidence that these species may be increasing through recruitment of new plants from seed germination. If sprouting species remain rather stable in constancy values, the original plants and their distribution may have derived from surviving live root crowns, with little or no seedling recruitment.

Nonsprouting species with increasing constancy values over the 3 years indicate recruitment from seed germination. Conversely, declines in constancy values indicate either that seed production is limited or that the seedlings are unable to compete with existing vegetation.

Trends in constancy values are assessed by comparing those of the first year postfire to those of the third year. During the second year, regrowth from live root crowns may still be occurring. By the third year, it is assumed that increases in constancy reflect recruitment from seed germination.

Shrubs. Salix sp. was slow in sprouting during the first year postfire but had sprouted from underground buds and spread by the third year. This relationship is expressed in the constancy values (Table 3). No *Salix* sp. was recorded for 1989 but 9.1% of the macroplots contained the species in 1991 (Table 3).

Graminoids. Carex rostrata had 100% constancy the first year postfire, and maintained this constancy through the third year (Table 3). This species was thus present in all macrosites and dominates the community. *Agrostis* sp., *Calamagrostis inexpansa, C. purpurascens, Juncus* sp., and *Puccinellia pauciflora* all appear to have increased in their distribution throughout the plots (Table 3), although constancy values were not statistically compared. Recruitment of new graminoid plants probably derives from both resident seeds and new seed production. *Carex* sp., an unidentified grass, *Phalaris arundinacea,* and *Phleum pratense* all remained at low constancy values or disappeared from the microplots, apparently being unable to compete with other, more aggressive species.

Table 3. Constancy values for individual plant species within the sedge meadow community.

Plant species	1989 (n = 7)	1990 (n = 11)	1991 (n = 11)
Shrub			
Salix sp.	—	0.0	9.1
Graminoids			
Agrostis sp.	—	0.0	9.1
Calamagrostis inexpansa	0.0	36.4	36.4
Calamagrostis purpurascens	0.0	18.2	18.2
Carex sp.	28.6	0.0	—
Carex rostrata	100.0	100.0	100.0
Grass (unidentified)	14.3	9.1	9.1
Juncus sp.	42.9	63.6	72.7
Phalaris arundinacea	14.3	0.0	—
Phleum pratense	14.3	0.0	—
Puccinellia pauciflora	—	0.0	9.1
Forbs			
Annual forb (unidentified)	14.3	0.0	—
Angelica dawsonii	—	0.0	9.1
Aster conspicuus	—	0.0	9.1
Aster foliaceus	14.3	0.0	
Bidens cernua	28.6	0.0	
Circium arvense	—	0.0	9.1
Epilobium angustifolium	28.6	9.1	9.1
Epilobium glandulosum	0.0	36.4	36.4
Galium sp.	—	18.2	18.2
Mentha arvensis	57.1	36.4	27.3
Polygonum amphibium	57.1	81.8	81.8
Potentilla palustris	0.0	27.3	27.3
Scutellaria galericulata	28.6	18.2	18.2
Senecio crassulus	0.0	9.1	9.1
Taraxacum officinale	14.3	0.0	—
Typha latifolia	0.0	9.1	0.0
Ferns			
Equisetum sylvaticum	28.6	27.3	27.3

Forbs. Constancy values among the 17 forb/fern species present in the macroplots varied considerably for 3 years following the fire (Table 3). Of those species occurring in at least 10% of the macroplots the first year, *Aster foliaceus, Bidens cernua, Taraxacum officinale* and an unidentified annual forb were totally absent by the third year. *Angelica dawsonii, Aster conspicuus, Circium arvense,* and *Galium* sp. were not encountered the first year and were present in at least 9% of the plots by the third year. *Equisetum sylvaticum* remained relatively unchanged and was present in approximately one-third of the plots for each of the 3 years.

Vegetation Similarity Values

Between Years. Table 4 presents vegetation similarity values (0–100) between years. In comparing the similarity value of a year to that of another year, it is possible to estimate total community change (plant succession) over 1 year. Comparisons of 1989 vs. 1990 and 1990 vs. 1991 shows similarity values of 75.9/100 and 90.3/100, respectively. In each comparison, the vegetation of the second year is set at 100. The comparative

Table 4. Vegetation similarity values between years and within years (mean and SD) for sedge meadow sites.

Similarity values	1989 vs. 1990 (n = 7)		1990 vs. 1991 (n = 11)
Between years similarity values	75.9		90.3
	1989 (n = 7)	1990 (n = 11)	1991 (n = 11)
Within years similarity values			
Internal	54.1 (19.7)	69.2 (14.6)	66.9 (21.1)
Relative	63.0 (13.4)	71.7 (7.6)	67.7 (9.0)

value then shows how similar the vegetation of the previous year is to the vegetation of the second year. Thus, the plant community appears to have changed more from 1989 to 1990 than from 1990 to 1991.

Within Year. Internal and relative similarity values among plots within a year show variability in vegetation among the plots. Internal similarity values (average similarity among all plots within a given year) were 54.1 in 1989, 69.2 in 1990, and 66.9 in 1991 (Table 4). Relative similarity values (calculated as the average similarity of plots within a year when compared to a plot representative of that year) followed the same general pattern as the internal similarity. Vegetation variability among plots is expected to persist for several years until the dominant species, *Carex rostrata,* increases in density and revegetates bare spots where the peat was burned to mineral soil.

Community Diversity

Diversity indices are used by ecologists to provide quantitative expressions with which the diversity of 1 community (or data set) can be compared to that of another (Hunter 1990). Usually a data set is a community and the elements of a set are plant species. In our study, diversity is calculated as an average across the 11 macroplots for each year. Thus, changes in community diversity can be compared between or among years.

Ecologists calculate diversity by use of formulas that combine species richness (number of species present) and evenness (distribution of abundance among different species) to determine whether a community with more richness or one with more evenness has greater diversity. These formulas are weighted more heavily to species richness (Hunter 1990). Single species communities are defined as having a diversity of zero.

Average Shannon-Wiener diversity index values for the sedge meadows burned in 1988 were 0.30 in 1989, 0.28 in 1990 and 0.27 in 1991 (Table 5). High S-W indices (greater than 1.0) are computed when the plot has high coverages and many species. The low S-W index values across the sedge meadows reflects relatively low species diversity. Any decrease in S-W values is based on a decrease in species evenness.

Table 5. Sedge meadow community diversity characteristics.

Characteristic	1989 (n = 7)	1990 (n = 11)	1991 (n = 11)
Avg. S-W diversity index	0.30	0.28	0.27
Avg. number of species	4.9	5.0	5.5
Species richness	15.0	15.0	20.0
Average dominance index	0.63	0.71	0.76

The average number of species encountered in 39 cm × 79 cm microplots across a macroplot was 4.9 in 1989, 5.0 in 1990 and 5.5 in 1991 (Table 5). Any real increase would indicate an increased recruitment of new species within the macroplot during the 3 years.

Species richness (total species encountered in all microplots) also indicates a recruitment of new species into the macroplot. Average number of species encountered within a macroplot was 15 in 1989, 15 in 1990, and 20 in 1991. Not all species recorded in 1989 were still present in 1991; thus, more than 5 new species were recruited by 1991.

The average dominance index for a plot is calculated as a number from 0 to 1 and indicates the degree of dominance by 1 or more species on a plot. Plots with high coverages of 1 species and low coverages of remaining species tend to generate high dominance indices (near 1.0). Thus, an increase in the average dominance index indicates an increase in dominance over time. The average dominance index for all plots was 0.63 in 1989, 0.71 in 1990, and 0.76 in 1991 (Table 5). Average cover values in Table 2 show that *Carex rostrata* has much the highest cover value and that this species dominates the meadows.

In comparing the plant community diversity indices among the 3 years postfire, it may appear that these indices are not consistent in describing changes in species diversity. However, these apparent contradictions are readily explained. Species richness can increase due to recruitment of a few plants of additional species, but they can become less important in the community. An increase in *Carex rostrata* coverage can lead to an increase in the average dominance index and a corresponding decline in community evenness. The decline in evenness can lead to a decline in S-W diversity index values.

Fig. 3. *Carex rostrata* dominates the sedge meadow 3 years after the burn.

Ecological Considerations

Most of the surface area of burned sedge meadows was revegetated the year following the fire (Fig. 3). Plant colonization has occurred from existing rhizomes and roots and to a lesser extent from seeds. Soils were stabilized and no erosion was apparent.

Unvegetated or partially vegetated microsites were present where peat had been completely consumed by the fire, leaving exposed mineral soil. These soils are slower in returning to natural vegetation because rhizomes and roots were destroyed. This provides sites for other herbaceous species to occupy, contributing to increased diversity.

Tree encroachment into the sedge meadows was much reduced, as no seedlings were found. Shrubs were regrowing from sprouting root crowns, but a significant number of charred root crowns appeared dead by the end of the third year postfire.

We lack prefire vegetative data to characterize the unburned meadows for direct comparison. However, in viewing unburned sedge meadows outside of the burn, it is obvious that the vegetation is rapidly returning to that present on unburned meadows. The number of plant species within the meadows continued to increase through the third year. However, average diversity decreased as *Carex rostrata* increased in dominance.

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LITERATURE CITED

Barbour, Michael G., Jack H. Burk, and Wanna D. Pitts. 1980. Terrestrial plant ecology. Benjamin/Cummings Publ. Co., Inc., Menlo Park, CA.

Barrett, Stephen W. 1980. Indians and fire. Western Wildlands 6(3):17–21.

Bushey, Charles L. 1990. The 1988 Red Bench Fire: documentation of fire behavior, fire weather, and preburn fuel conditions in the North Fork of the Flathead River Valley. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. Coop. Agreement No. INT-89439-RJVA.

DeBenedetti, Steven H., and David J. Parsons. 1979. Natural fire in subalpine meadows: a case description from the Sierra Nevada. Journal of Forestry 77(8): 477–479.

DeBenedetti, Steven H., and David J. Parsons. 1984. Postfire succession in a Sierran subalpine meadow. American Midland Naturalist 111(1):118–125.

Hunter, Malcolm L, Jr. 1990. Wildlife, forests, and forestry—Principles of managing forests for biological diversity. Prentice-Hall, Inc., Englewood Cliffs, NJ.

Lewis, Henry T. 1980. Indian fires of spring. Natural History 89(1):76–78, 82–83.

Lewis, Henry T. 1982. A time for burning. Occasional Publ. No. 17. Boreal Institute for Northern Studies, University of Alberta.

Lyon, L. Jack, and Peter F. Stickney. 1976. Early vegetal succession following large Northern Rocky Mountain wildfires. Pages 355–373 *in* Proceedings, Tall Timbers fire ecology conference and Intermountain Fire Research Council fire and land management symposium No. 14: 1974 October 8–10; Missoula, Montana. Tallahassee, Florida: Tall Timbers Research Station.

Roe, F. G. 1955. The Indian and the horse. University of Oklahoma Press, Norman.

Ryan, Kevin C., and Nonan V. Noste. 1985. Evaluating prescribed fires. Pages 230–238 *in* J. E. Lotan, B. M. Kilgore, W. C. Fischer, R. W. Mutch, tech. coord. Proceedings-Symposium and workshop on wilderness fire: 1983 November 15–18; Missoula, Montana. Gen. Tech. Rep. INT-182. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

United States Department of Agriculture, Forest Service. 1987. Ecosystem classification handbook FSH 12/87 R-1 Supp. 1. Region 1, Missoula, Montana.

Vierick, Leslie A., and Linda A. Schandelmeier. 1980. Effects of fire in Alaska and adjacent Canada—a literature review. BLM-Alaska Tech. Rep. 6. Anchorage, Alaska: U.S. Department of the Interior, Bureau of Land Management.

Wells, Carol G., Ralph E. Campbell, and others. 1979. Effects of fire on soil: Forest Service national fire effects workshop; Denver, Colorado. Gen. Tech. Rep. WO-7. Washington, DC; U. S. Department of Agriculture, Forest Service.