Post-fire Ecological Studies in the Organ Mountains.

Monitoring Sensitive Species and Vegetation.

Volume 3 – Post-fire Vegetation Map, Vegetation and Stream Channel Sediment Monitoring

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Overview

During the period of June 12 through June 22, 1994 an extensive wildfire spread through the northern portion of the Organs Mountains of southern New Mexico (Figure 1). These mountains harbor numerous sensitive species of flora and fauna including five candidates for Federal listing under the Endangered Species Act. To facilitate planning in the context of Fort Bliss operations in the mountain range, biological monitoring programs were established to evaluate the effect of the fire on targeted sensitive species, vegetation patterns and response, and overall watershed conditions.

While volumes 1 and 2 of this report are devoted to detailed sensitive plant and animal studies, respectively, this volume focuses on general post-fire vegetation studies. The emphasis here is on montane conifer forests and woodlands because they provide habitat for rare and endemic species, including Organ Mountain Figwort (*Scrophularia laevis*) and possibly Standley's draba (*Draba standleyi*), along with chipmunks and land snails. We first present a detailed map of post-fire vegetation in the study area with an analysis of the extent of the 1994 fire and the degree of burning by major vegetation type that took place within the fire perimeter (Section I). We then report the results from the first four years of monitoring at 20 permanently established sites in these communities (Section II).

Besides the direct effect of fire in these upland communities, there can be a downstream effect on sensitive species that grow directly in the channel, such as the Organ Mountain primrose (*Oenothera organensis*). The addition and removal of sediment may have a significant impact on this species. Hence, eight channel sediment monitoring sites were established in conjunction with other *Oenothera organesis* studies detailed in Volume 1. The results from two years of monitoring sediment load changes are reported here (Section III).

The results presented here also support the associated on-going spatial-temporal fire modeling studies for the Organ Mountains (Muldavin 1996). The final results of modeling efforts will be presented in a later companion report that will include an evaluation of landscape-level effects of fire on sensitive species and to support the development of a fire management plan for the Organ Mountains.

Study Area

Location

The Organ Mountains are located in south-central New Mexico at 32°20'N latitude and 106°31'W longitude (Figure 1). They lie between the San Andres range to the north and the Franklin range to the south in a relatively continuous chain of north-south trending ranges. The San Andres-Organ-Franklin cordillera is surrounded by shrub desert, flanked on the west by the Rio Grande River and on the east by the Tularosa Valley.

The vegetation studies are limited to areas that were burned during the 1994 fire. All sites lie north of Soledad Canyon with most sites in the upper watersheds of Fillmore, Rucker and Indian Hollow canyons. North Canyon, the majority of which was not burned, was used as a "control" for the channel sediment load studies (Figure 2).

Climate

No meteorological records exist for locations directly within the Organ Mountains. However, in nearby Las Cruces (elevation 1,183 m), records indicate a unimodal pattern of seasonal precipitation distribution with a dominant summer component. Average rainfall is approximately 21.5 cm/year with over half (53%) generated by summer monsoonal storms that occur between of July and September. These months also show the lowest year-to-year variability in rainfall. Average monthly precipitation during the fall, winter and spring is comparatively sparse, averaging less than 2.5 cm/month, but is highly variable from year to year. June precipitation is the most variable from year to year, perhaps reflecting variability in timing of the onset of the summer rainy season. The July to September period is also typically the warmest with maximum temperatures averaging 24.6 C°. The coldest months are December and January with temperatures averaging 5.4 C° and 5.3 C°, respectively. In contrast to precipitation, monthly temperature shows little inter-annual variability.

Mountain relief undoubtedly modifies the precipitation and temperature observed in Las Cruces. At elevations above 2,400 m, rainfall is probably double that recorded in Las Cruces, suggesting that precipitation in the uppermost elevations of Fillmore Canyon could be as much as 43 cm. Because temperature decreases at a rate of 7.5 C°/1000 m (Dick-Peddie and Moir 1970), estimated temperatures in the upper elevations of Fillmore Canyon would be approximately 11 C°. Differences are also evident in the number of frost-free days between Las Cruces (210) and the uppermost elevations of Fillmore Canyon (150)(Muldavin *et al.* 1994).

Another characteristic feature of the Las Cruces climate is the "arid foresummer," which is typical of the Southwest in general. Precipitation decreases during the spring, while temperatures increase. By June, temperatures may equal or sometimes exceed those recorded during the summer months. These dry, hot conditions (arid foresummer) continue until the arrival of the summer rains, generally in late June or early July.

Figure 1. General Study Area

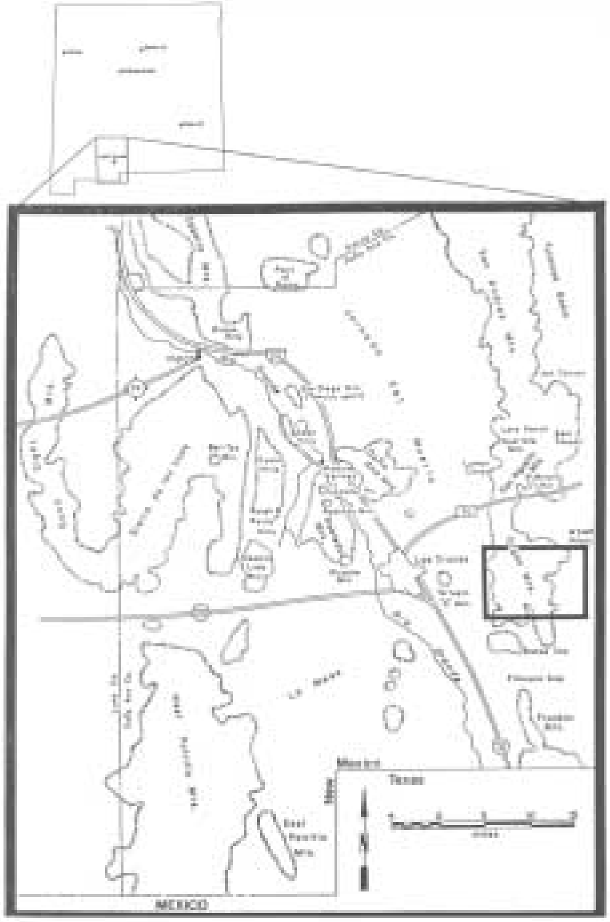
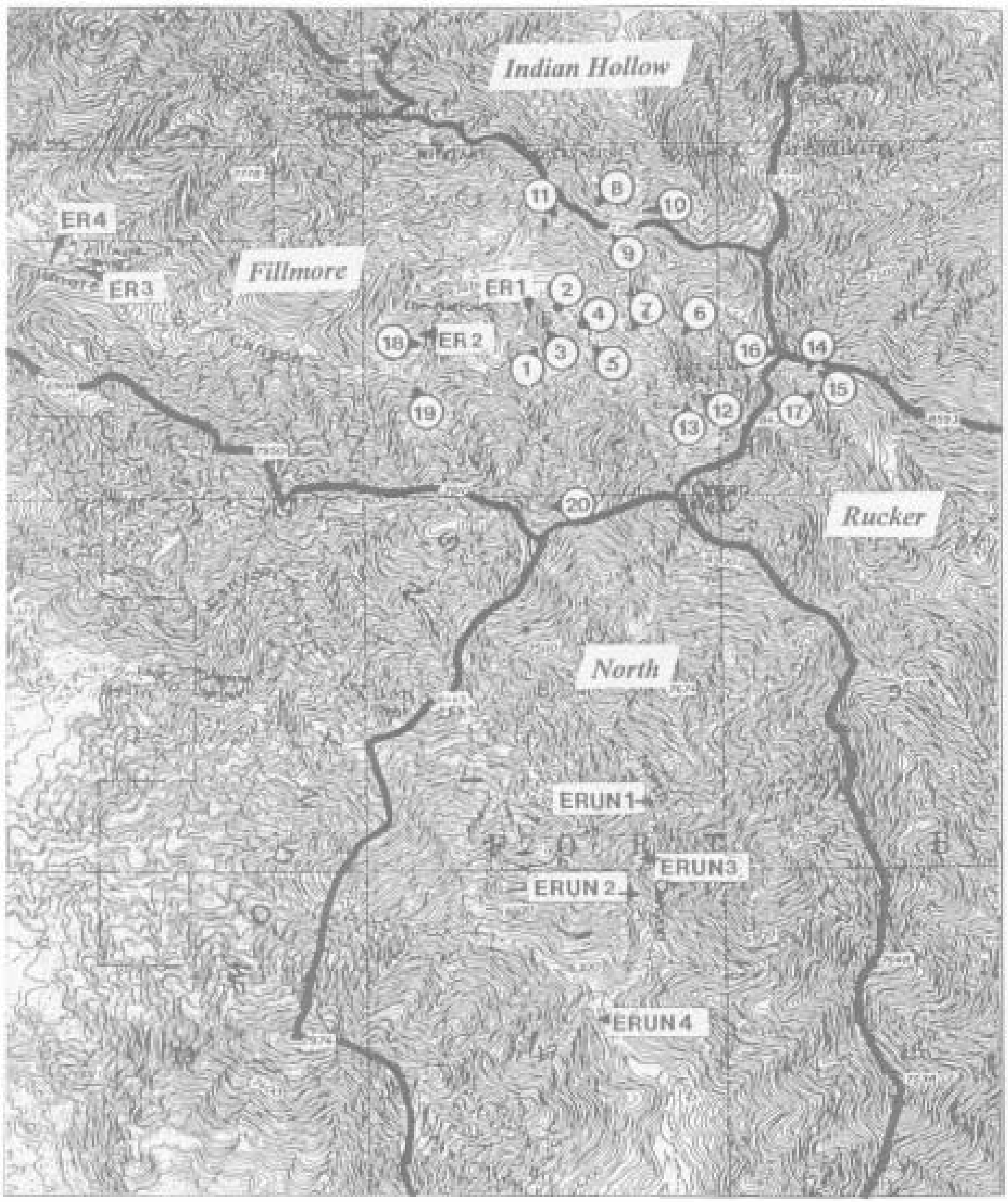


Figure 2. Study sites



Base: Organ Peak 7.5' Quadrangle

During the period of study precipitation was quite variable as suggested by weather records from the nearest station in Las Cruces, NM in the river valley to the west (Figure 3). June of 1994, when the fire started, was exceptionally dry, but this was followed by an exceptionally wet July, and then a drop-off again in August and through the rest of the growing season. August precipitation, normally the peak month of the year, was also very poor in 1995, 1996 and 1998. Only 1997 was near normal for late summer precipitation, and 1998 was particularly poor.

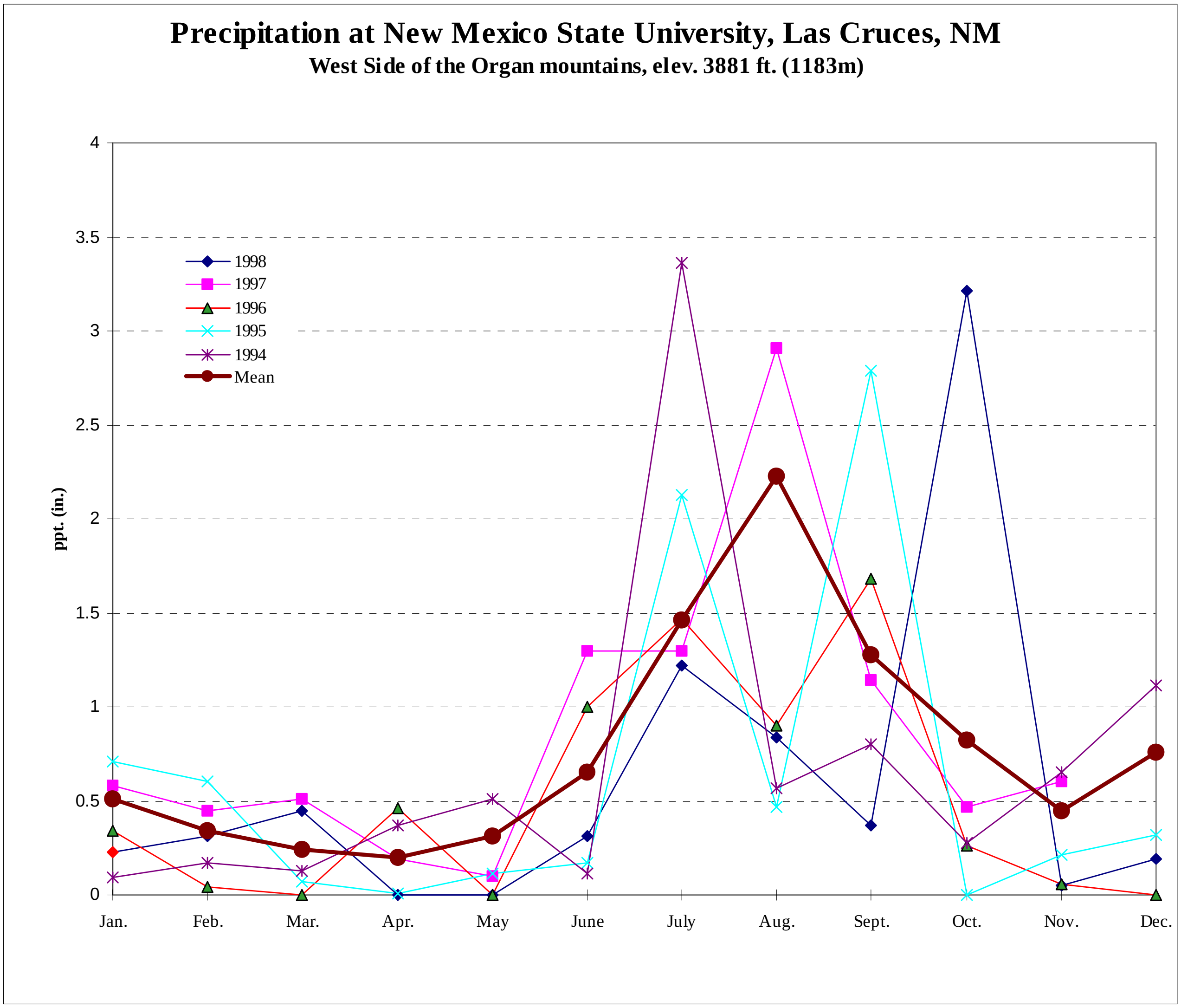


Figure 3. Monthly average precipitation at New Mexico State University, Las Cruces, located approximately five miles west in the Rio Grande Valley at about 2,000 feet lower than the lowest point in the study area.

Vegetation

Muldavin *et al.* (1994) provided a detailed description of vegetation communities in the Organ Mountains. For our purposes here we have delineated nine general vegetation classes:

> Montane Conifer Forest dominated by ponderosa pine and Douglas-fir;
>
> Montane Mesic Scrub dominated by Gambel oak (*Quercus gambelii*);
>
> Mixed Woodland dominated by pinyon pine (*P. edulis*), alligator juniper (*Juniperus deppeana* and gray oak (*Q. grisea*) or Arizona white oak (*Q. arizonica*);
>
> Montane Xeric Scrub, dominated by mountain mahogany (*Cercocarpus montanus*);
>
> Canyon Oak Woodlands, dominated by gray oak and Arizona white oak;
>
> Woodland Savanna dominated by alligator juniper and oaks with an occasional pinyon;.
>
> Foothill Grasslands dominated by mesic bunch grasses such as sideoats grama (*Bouteloua curtipendula*), hairy grama (*B. hirsuta*) and bull muhly (*Muhlenbergia emersleyi*);
>
> Desert Grasslands dominated by more arid species such as black grama (*B. eriopoda*) and usually with a significant shrub component, most commonly catclaw mimosa (*Mimosa aculeaticarpa*);
>
> Desert Shrubland dominated by tall shrubs such as honey mesquite (*Prosopis glandulosa*), creosostebush (*Larrea tridentata*) and whitethorn acacia (*Acacia neovernicosa; A. constricta*).

Montane Conifer Forest communities occur between 2,280-2,590m (7,500-8,500 ft) on north-facing slopes and tend to be discontinuous, interrupted by other vegetation types and/or topographic features. Generally, Douglas-fir is found at higher elevations and/or in sites with deep soils that maintain higher moisture levels throughout the year (*e.g.*, in head slopes and drainages). Ponderosa pine is found on more exposed sites with shallower soils, perhaps reflecting the higher tolerance of ponderosa pine to more xeric conditions. Douglas-fir communities tend to be closed-canopy forests with shrubby understories, while ponderosa pine communities are more open and commonly have grassy understories. The forests are often found associated with Gambel oak dominated mesic shrublands and montane grasslands. These may have formed where previous fires have occurred and overstory conifer reproduction has failed.

Drier south- and west-facing slopes support xeric woodlands dominated by low stature pinyon pine, alligator-bark junipers and evergreen oaks. These slopes may also support extensive xeric montane shrublands dominated by mountain mahogany which may have formed after fire swept through xeric woodland sites, or they may support foothill grasslands. At lower elevations they give way to desert grasslands and shrublands with canyon oak woodlands in the darinages.

Section I -- Organ Mountains 1994 Post-fire Vegetation Map

Introduction

A detailed vegetation map was developed to describe the extent and the general nature of the impacts on vegetation of the 1994 fire the central portion of the Organ Mountains (north of Soledad Canyon). The map not only serves to illustrate the direct characteristics of the fire, but also is being used in the fire modeling efforts of the project. Hence, the map uses the same basic vegetation classes as those described above, but is modified into specialized map units reflecting differing fuel characteristics that are important in the modeling. Below we describe the construction of the map and provide an analysis of the size and other characteristics of the fire within each of the major vegetation types.

Methods

The map was based on the photo interpretation of pre- and post-fire photography from 1980, 1985, and 1994. The 1994 photography was false-color infrared and flown by NASA in November of 1994 following the fire, and was part of a pilot project testing air-borne digital sensors. Hence, it was not intended to be used photogrametrically and did to have the normal controls associated with commercial aerial photography, but was the only available photography that had been flown soon after the fire. We reproduced the photography in 9 by 9-inch contact prints and then delineated polygons on acetate overlays. The initial interpretation was done on the 1994 photography and then transferred to the more controlled 1985 true-color photography for later collation. Line work was digitally transferred to an Arc-Info coverage through a series of photogrametric stereo models. Pacific Western Technologies (formerly Koogle and Poule Engineering) of Albuquerque, NM performed the stereo modeling and transfer work. The polygon coverage was then brought into ArcView 3.0a (Environmental Systems Research Institute, 1998) and further edited and enhanced in the context of a digital elevation model and a Thematic Mapper satellite imagery. A drainage pattern (stream channel) layer was also constructed to provide additional context. An annotated final map was developed in ArcView and plotted at 1:25,000 scale. The ArcView project files will also be available on a compact disk along with other data from the studies.

A 1994 fire perimeter line was provided to us by the Bureau of Land Management (BLM), Las Cruces Area Office. It is based on aerial reconnaissance by the BLM during the duration of the fire. The line work was imported from their GIS to ours directly without modification, and approximates the maximum extent of the fire by June 24, 1994. This fire perimeter was used to compute statistics on each of the vegetation types within a consistent burn area.

The map was ground-truthed during three expeditions into the mountains during, 1996, 1997 and 1998. In addition, data from the plant and animal surveys was incorporated into the analysis to create a validation set of over 100 GPS located points.

Results

The vegetation map at 1:25,000 scale is provided in an accompanying map tube. For illustrative purposes we have reproduced the map at a much smaller scale (1:75,000) in Figure 4. For additional clarity the legend to the map and the areas of each of the map units are provided in Table 1. The lower elevation flanks and surrounding basin bottoms are dominated by extensive areas of Desert Grassland and Desert Shrubland, respectively. At higher elevations the Desert Grasslands grade into Foothill Grasslands or Mixed Woodland Savanna. The canyon bottom drainages at lower elevations support stringers of Canyon Oak Woodland dominated by evergreen oaks such as gray oak (*Quercus grisea*) or Arizona white oak (*Q. arizonica*), or in some cases Arroyo Riparian vegetation dominated by Apache plume (*Fallugia paradoxa*) or desert willow (*Chilopsis linearis*). The are is a small amount of Riparian Forest in Fillmore Canyon at the Narrows dominated by box elder (*Acer negundo*).

Upper, steeper slopes of warm aspects are dominated by Mixed Woodlands of pinyon pine (*Pinus edulis*), alligator juniper (*Juniperus deppeana*) and with occasional evergreen oaks. Large brush fields of Montane Xeric Scrub or chaparral also occur on similar sites, but ones presumably with a history of relatively recent fire. They are dominated by mountain mahogany (*Cercocarpus montanus*) or scrub live oak (*Q. turbinella*), both of which resprout vigorously after fire. On cooler, north-facing slopes a combination of Montane Conifer Forest and Montane Mesic Scrub occur. The forests are mostly open canopied and dominated by either ponderosa pine (*Pinus ponderosa*) or Douglas-fir (*Pseudotsuga menziesii*). In some ravines and near-ridgeline hollows the small, closed canopy forest of Douglas-fir does occur (and on the northern flank of the range white fir or *Abies concolor* occurs in isolated pockets). On similar aspects there are large stands of the Montane Mesic Scrub dominated by Gambel oak (*Q. gambelii*), that presumably at one time had an overstory of conifers that were eliminated by repeated fires or possibly logging in some cases. The topographic and aspect relationships among these types is illustrated in Figure 5.

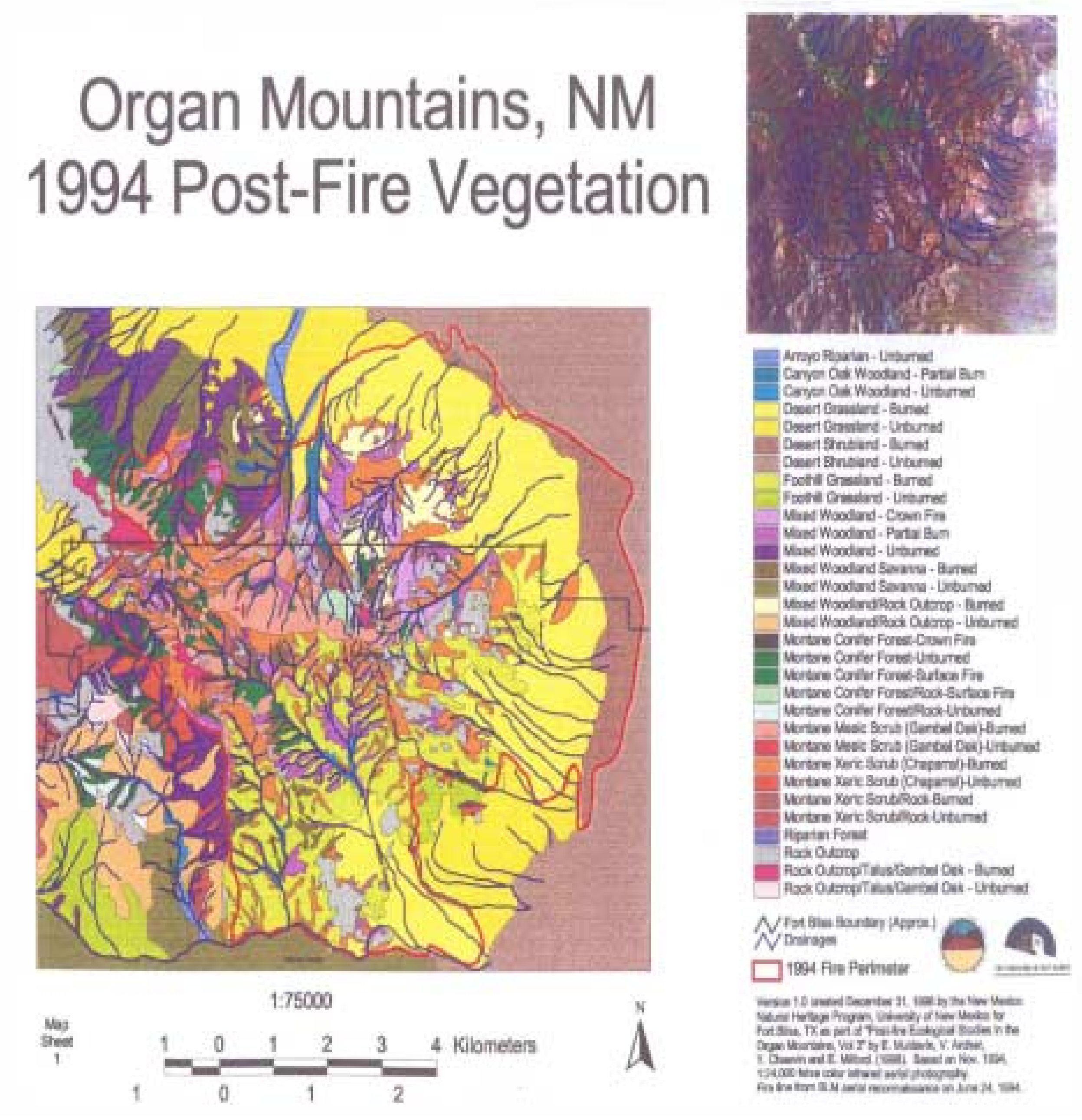
Because the Organ Mountains are so rugged and have extensive areas of exposed rock, cliffs and rock talus, we have identified additional map units based on rockiness corresponding to Mixed Woodland, Montane Conifer Forest, Xeric and Montane Mesic Scrub. Because of their rockiness fire is expected to behave differently in these types. We have also identified a simple Rock Outcrop unit with little or no vegetation (although fire did occur in this unit).

On the map, the 1994 BLM fire perimeter is delineated which shows that the fire extended over approximately 5,580 ha (13,780 acres), but not in a uniform way. The fire began from lightning strikes near the top of the mountains at Organ Peak and burned in all directions. It burned throughout Fillmore Canyon to the west and northwest (including Organ Needle, which it nearly reached the top of!). It burned to the east and southeast through Rucker and Dorsey Canyons and extended out over the eastern flank through Glendale and Pete Johnson Canyons down to the desert floor. To the south it more or less stopped at Soledad Creek and did not burn the southern Organ Mountains. It also did not extend very far into North Canyon, nor into Ice Canyon on the southwest side. To the north it did extend down into Indian Hollow and around Sugarloaf to the canyons along the northern flank towards Granite Peak (Maple, Texas

Table 1. Legend map units for the Organ Mountains 1994 Post-fire Vegetation Map with total areas mapped for each unit and associated percentage mapped area.

Code	Map Unit Name	Ha	Acres	%
32	Arroyo Riparian - Unburned	72.4	178.8	0.67
37	Canyon Oak Woodland - Partial Burn	89.8	221.8	0.84
33	Canyon Oak Woodland - Unburned	77.7	191.9	0.72
18	Desert Grassland - Burned	1624.3	4012.0	15.1
17	Desert Grassland - Unburned	946.5	2337.9	8.82
14	Desert Shrubland - Burned	398.3	983.1	3.71
13	Desert Shrubland - Unburned	1471.6	1469.1	13.7
10	Foothill Grassland - Burned	806.0	1990.8	7.51
9	Foothill Grassland - Unburned	288.1	711.6	2.68
6	Mixed Woodland - Crown Fire	160.6	396.7	1.50
5	Mixed Woodland - Partial Burn	404.4	998.9	3.77
4	Mixed Woodland - Unburned	498.4	1231.1	4.64
25	Mixed Woodland Savanna - Burned	101.1	249.7	0.94
24	Mixed Woodland Savanna - Unburned	685.1	1692.2	6.38
29	Mixed Woodland/Rock Outcrop - Burned	162.0	400.1	1.51
31	Mixed Woodland/Rock Outcrop - Unburned	357.1	882.0	3.33
3	Montane Conifer Forest-Crown Fire	13.1	32.4	0.12
2	Montane Conifer Forest-Surface Fire	304.6	752.4	2.84
1	Montane Conifer Forest-Unburned	150.8	372.5	1.40
28	Montane Conifer Forest/Rock-Burned	61.3	151.4	0.57
35	Montane Conifer Forest/Rock-Unburned	21.2	52.4	0.20
8	Montane Mesic Scrub (Gambel Oak)-Burned	412.2	1018.1	3.84
7	Montane Mesic Scrub (Gambel	19.0	46.9	0.18
12	Montane Xeric Scrub (Chaparral)-Burned	742.8	1834.7	6.92
11	Montane Xeric Scrub (Chaparral)-Unburned	98.6	243.5	0.92
26	Montane Xeric Scrub/Rock-Burned	54.2	133.9	0.50
27	Montane Xeric Scrub/Rock-Unburned	183.3	452.8	1.71
22	Riparian Forest	1.7	4.2	0.02
16	Rock Outcrop	408.8	1009.7	3.81
21	Rock Outcrop/Talus/Gambel Oak - Burned	76.6	189.2	0.71
36	Rock Outcrop/Talus/Gambel Oak - Unburned	44.7	110.5	0.42

Figure 4. A reduced version of the Organ Mountains, NM 1994 Post Fire Vegetation Map.



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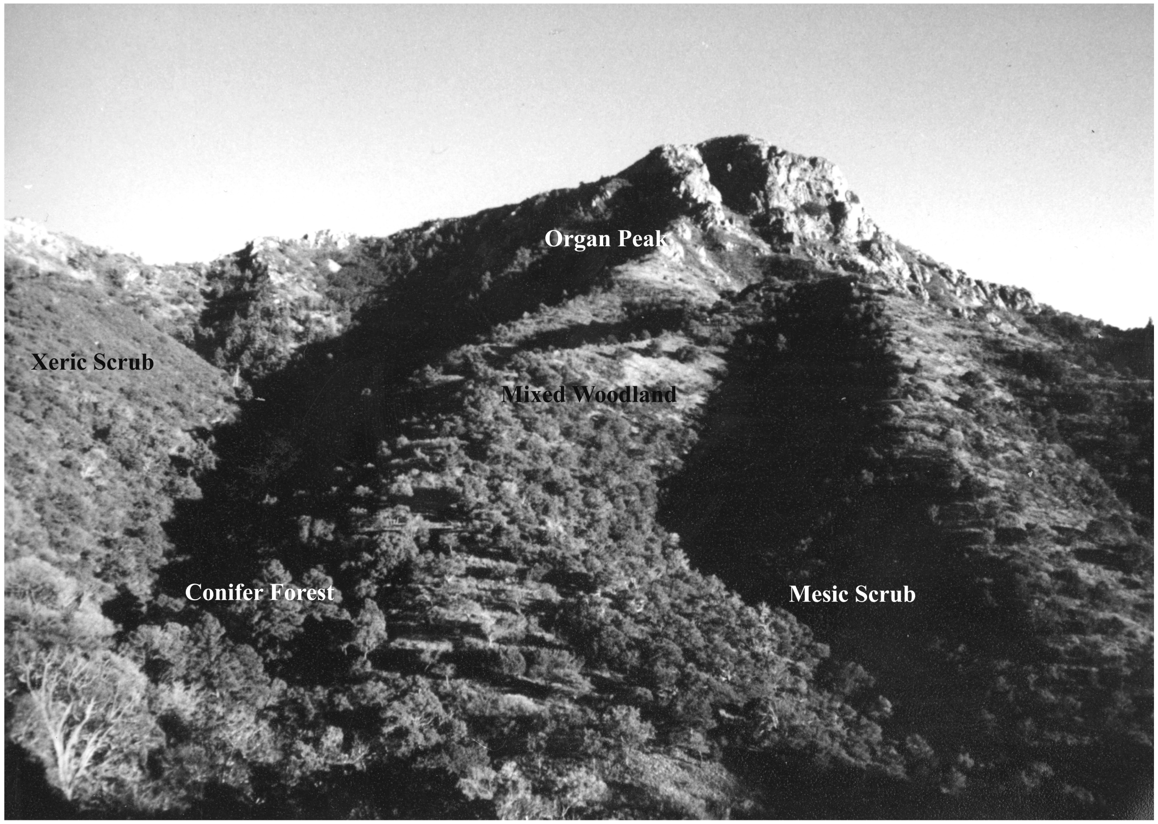


Figure 5. View of Organ Peak looking south illustrating the topographic and aspectual relationships among vegetation types. Mixed Woodland and Xeric Scrub are found on corresponding southwesterly slopes, while Montane Conifer Forest and Mesic Scrub are found on northerly slopes.

and Ash). Fire suppression efforts prevented the fire from reaching Aguirre Springs Campground and the White Sands Missile Range Post.

The fire behaved in different ways depending on vegetation type (Table 2). Almost all of the Montane Conifer Forest and Montane Mesic Scrub (Gambel oak) within the fire perimeter sustained at least a surface fire. With respect to the forest, it was mostly surface fire that burned through either a grassy or shrubby understory where it did not attain the intensity to either burn or immediately kill the overstory trees (there is little lower branching ladder fuel on the pines). At the higher topographic positions along ridgelines some crown fire did occur, destroying about 4.7% of the remaining forest, particularly Douglas-fir (Figure 6). Gambel Oak Scrub burned in a patchy way, some times burning off the entire canopy (Figure 7), or remaining at the surface and removing only a few overstory shrubs (Figure 8). Many stands of Mixed Woodland did not burn or received very light and patchy surface fires (Figure 8). But a significant amount (154 ha; 380 acres) of mature Mixed Woodland did sustain stand destroying crown fires (Figure 9). In addition, almost all of the Xeric Scrub or chaparral burned, usually removing the crowns of the mountain mahogany and oaks (figure 10). Based on what could be detected from aerial photography almost all of the adjacent foothill grasslands also all burned. At lower elevations light surface fires slept through the Woodland Savanna and Desert Grasslands and extended a short distance into the Desert Shrublands where the combination of fire suppression and low fuels limited the fire.

Most of the rocky classes also burned as the fire followed lanes of vegetation in the cracks and crevices, and jumped from patch to patch across the surface of the rocks. Canyon Oak woodlands did burn, but it mostly very light and patchy surface fire. The fire appeared to have been inhibited by the relatively mesic conditions of the sites. Finally, Arroyo Riparian and Riparian Forest were relatively resistant to fire. Some Apache plume stands did burn, but they were to small to map. In others, the fire burned right up to the edge and stopped. In the case of the Riparian Forest, the protection afforded by the rock outcrops of the Narrows may have prevented the fire from destroying the stand.

Discussion

Much of the area designated as Montane Conifer Forest is a sparse, very open canopied woodland. The open canopy of these forests may be a reflection of soil conditions that restrict growth, or past fires that have steadily removed trees without replacement, or possibly past climate extremes such as the 1950's drought which may have killed off a number of trees. Regardless of cause, closed canopied forest are now rare in the Organs, and they are also where most of the crown fires occurred. Hence, the impact of crown fires is more significant than the 4.7% would suggest. We would estimate that upwards of 25% of the closed canopied forest were actually destroyed in the 1994 fire.

The significance of fire in upland Mixed Woodlands like these dominated by pinyon pine and juniper has been often been dismissed because of relatively low fuel loads and frequencies (Gottfried et al., 1997). But it is clear that fire does occur in this type, and the estimated 154 ha (380 acres) of crown-burned woodlands attest to a greater impact than previously thought. In fact the large amounts of Xeric Scrub that cover much of the mountains may reflect extensive, stand destroying fires through woodlands in the past.

Overall, recurring fires like that of 1994 may have a very significant impact on the extent of the woodlands and forest of the Organ Mountains, perhaps decimating them below sustainable levels. The approaches taken to both fire and forest management will be critical in determining the face of this landscape in the future and the biota associated with it.

Table 2. Map unit areas for the entire mapped area and for various burn classes within the burn perimeter or maximum extent of the fire.

Map Unit Name (MU)	**Total Mapped Area (ha)**	**Area Within Burn Perimeter**	**% of Total in Burn**	**Unburned Area within Burn**	**%**	**Surface/ Partial Crown Burn**	**%**	**Complete Crown Burn**	**%**
Arroyo Riparian - Unburned	72.4	0.9	1.2	0.9	100.0	0	0	--	--
Canyon Oak Woodland	167.5	97.1	58.0	19.9	20.5	77.2	79.5	--	--
Desert Grassland	2570.8	1614.8	62.8	12.5	0.7	1602.6	99.3	B	--
Desert Shrubland	1869.9	381.9	20.4	1.6	0.4	380.3	99.6	--	--
Foothill Grassland	1094.1	794.3	72.5	6.2	0.5	788.1	99.2	B	B
Mixed Woodland	1063.4	568.1	53.4	53.1	9.3	361.0	63.5	154.0	27.2
Mixed Woodland Savanna	786.2	79.4	10.1	10.0	12.3	69.3	87.4	B	--
Mixed Woodland/Rock Outcrop	519.1	152.5	29.3	0.5	0.1	152.5	99.9	--	--
Montane Conifer Forest	468.5	269.4	57.5	1.7	4.6	255.1	94.7	12.6	4.7
Montane Conifer Forest/Rock	82.6	39.6	47.9	0	0	39.6	100.0	--	--
Montane Mesic Scrub (Gambel Oak) Oak) Burned	431.2	406.7	94.3	0	0	406.7	100.0	--	--
Montane Xeric Scrub (Chaparral)-Burned	841.4	762.3	90.5	14.3	1.9	748.0	98.1	--	--
Montane Xeric Scrub/Rock	237	67	28.2	0	0	67	100.0	--	--
Riparian Forest	1.7	1.7	100	1.7	100.0	0	0	--	--
Rock Outcrop	408.8	271.3	66.4	--	--	--	--	--	--
Rock Outcrop/Talus/Gambel Oak Burned	121.3	34.4	28.4	0	0	34	100	--	--
TOTAL/SUMMARY	**10736.2**	**5586.6**	**52.0**	**122.4**	**2.1**	**4726.0**	**84.6**	**166**	**3.0**

Figure 6. View of Montane Conifer Forest in the south fork of Fillmore Canyon. The 1994 fire mostly swept through at the surface, but near the ridgeline to North Canyon a crown fire did occur, killing several trees.

Figure 7. The 1994 often destroyed the canopies of Gambel oak (foreground) in the Montane Mesic Scrub communities, but on several sites the oaks quickly resprouted from the rootcrowns.

Figure 8. In some Gambel oak stands such as this one in upper Fillmore Canyon, the fire swept through at the surface and did not kill the larger, older oaks (foreground). In the background the fire went around a mature Mixed Woodland stand leaving it intact.

Figure 9. Some Mixed Woodland stands such as this one in upper Fillmore Canyon were destroyed in a crown fire that left little behind in terms of cover or rooted material to stabilize the slopes.

Figure 10. In this Montane Xeric Scrub community near the ridgeline separating Fillmore Canyon from Indian Hollow, the canopies of mountain mahogany were destroyed by the fire, but resprouted vigorously.

Figure 11. Mosaic of Montane communities in and along the south flank of Fillmore Canyon. Montane Mesic Scrub is seen in the foreground with a mixture of Montane Xeric Scrub, Mixed Woodlands and Conifer Forest on the background slopes.

Section II -- Post-Fire Vegetation Monitoring

Introduction

Proper natural resources management requires assessing the response of ecosystems to disturbances such as fire. Of particular importance in the Organ Mountains is the complex matrix of forest, woodland and scrub communities in which the sensitive species are imbedded (figure 11). In the Southwest, little is actually known about direct responses of these communities to fire and types of successional dynamics that occur. Early on, Leopold (1924) suggested that there was a successional relationship after fire that ran from grasslands, to scrub or chaparral, and finally to mature forest and woodlands, but he provided no quantitative analysis. These relationships as they might occur in the Organ Mountains are schematically outlined in Figure 12, and are based on the topographic and aspectual relationships observed currently among the communities, e.g., where communities of a given successional trajectory occupy similar soils, slope positions and aspects at a given elevation (see Figure 4). This schematic provides a working, albeit simplified hypothesis or model for understanding the dynamics of these ecosystems.

To test the model directly, eighteen high-precision monitoring plots were established in upper Fillmore, Indian Hollow and Rucker Canyons during the Fall of 1995. One additional transect was established in Fall 1996 for a total of twenty study sites. Sites were chosen to sample a wide variety of forest and woodland types that had differing degrees of burn impacts and initial conditions. Sites that had been surveyed before the fire by Mehlhop et al. (1994) were also given priority. The location of each site is shown in Figure 2. The cover of all species was estimated and canopies of perennial species actually charted at the end of the growing seasons for the three years 1995, 1996 and 1997. Changes in cover were calculated and simple and multivariate statistics used to evaluate vegetation type responses through time.

Methods

Each site consisted of a pair of transect lines 20 meter long and 10 meter apart, running perpendicular to the slope (Figure 12). The beginning and end of each transect was marked with two-foot, 3/8 inch rebar pounded into the ground to within six inches of the surface (where possible). The beginning rebars were tagged with aluminum tags (site number and A or B line). Site locations were mapped on 7.5’ USGS quadrangles in the field and the rebar locations were determined using GPS (Trimble Geoexplorer units were used and positions corrected with the Pathfinder program). Directions to each site, distance and bearing of each transect from a local landmark and a sketch of the plot layout were recorded on the specially designed datasheets.

A fiberglass meter tape was stretched tautly and as close to the ground as possible between the start and end rebars. Cover of all species was estimated in 1/20-square-meter quadrat frames (Daubenmire frames) placed at meter intervals beginning at the 0.5 meter mark through 19.5 meters for a total of 20 quadrats per transect (quadrats were 0.2 meters wide and 0.5 meters long with their shorter width running along the transect from the 4/10 to 6/10 meter marks, and the length running perpendicular to the transect line and up slope). Typically the B transect was upslope from the A transect, although this varied at some sites and individual site diagrams should be consulted for atypical sites and for the orientation of the start and end quadrats.

Percent canopy cover for all species excluding trees was visually estimated in each quad (all vegetation within one meter of the ground). Percent cover of basal vegetation, litter, soil and rock was also recorded. To increase precision, canopy cover was also charted for each quadrat. In 1995 all species were mapped, but in 1996 and 1997 only shrub and perennial grass canopies were mapped.

In addition to canopy cover, shrub abundance was measured along each transect using line intercept methods. Any shrub cover that overhung the transect tape, within one meter of the ground, was recorded with the start and end point of the overhanging cover and the shrub species.

Voucher specimens were collected and species identifications confirmed against the University of New Mexico and New Mexico State University herbarium specimens. Photos were taken down the transect lines from each end rebar every year.

For analysis, all quadrat cover data was entered into a Microsoft (MS) Accesses database and then analyzed using SAS, MS Excel and Systat for Windows. Average absolute cover per species over the forty quads per site was computed and used in subsequent analysis. Each site was classified according the general vegetation types described above. Simple means of the major species by site were calculated. To parsimoniously describe the response of vegetation at each site, a Canonical Discriminant Analysis (CDA) was performed using a correlation matrix of the most abundant species or lifeform types as variables, and years as the groups. Wilk's Lamda was used in a general significance test for the difference among years. The canonical scores of each stand through time were plotted in a three-dimensional space of the first three canonical discriminant functions. A between-groups correlation structure was also computed to illustrate the correlations between the original species variables and the derived canonical variates.

A copy of the database on disk is included as a Data Addendum to this report. The addendum also includes a hard copy of the data files, photocopies of all 1997 field data sheets organized by site with site summary descriptions, and documentary photographs.

Successional Models

Woodlands

Open ground,
scattered forbs -----> *Cercocarpus* Shrublands ----->Pinyon-Juniper Woodlands
and grasses.

Forests

Dense, rich
forb cover --->*Quercus gambelii* Shrublands ----> *Pseudotsuga menziesii* Forest

Moderately grassy ground cover-------------------------> *Pinus ponderosa* Forest

Figure 12. Simplified successional models for forest and woodlands of the Organ Mountains based on topographic chrono-sequences observed in the study area.

Diagram of typical Site layout.

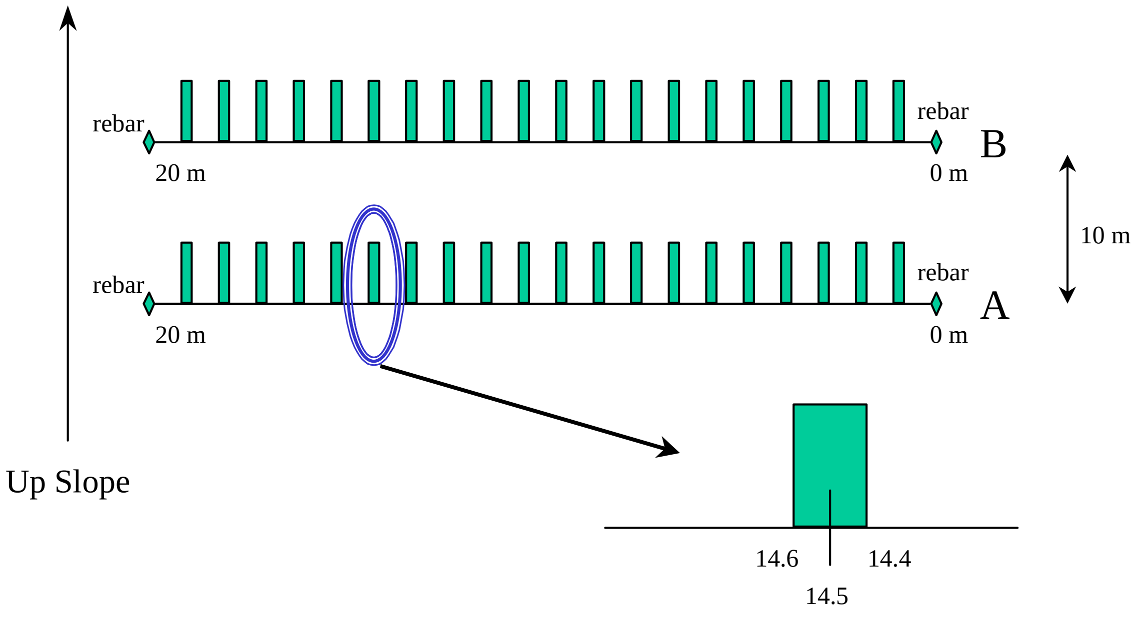


Figure 13. Vegetation monitoring plot design. 1/20-meter quadrat frames are placed at meter intervals beginning at the 0.5 meter mark through 19.5 meters for a total of 20 quadrats per line (quadrats were 0.2 meters wide and 0.5 meters long). .

Results

The 20 post-fire monitoring vegetation plots established in the Organ Mountains following the 1994 fire cover a broad spectrum of montane woodland and forest types. The basic characteristics of each site are listed in Table 3. Eight are from Mixed Woodland communities dominated by pinyon (PINEDU), alligator juniper (JUNDEP) and gray oak (QUEGRI), or from the Xeric Scrub successional correlates dominated by mountain mahogany (CERMON) or the scrub form of gray oak. Of these, Plot FBMON18, is dominated solely by a very open canopy of alligator juniper with a very grassy understory and is best described as Woodland Savanna. Because of its uniqueness in the data set it was removed from subsequent analysis. The other twelve plots represent Montane Conifer Forest communities or successional correlates dominated by either ponderosa pine (PINPON) or Douglas-fir (*Pseudotsuga menziesii;* PSMEN) with grassy understories dominated by junegrass (*Koelaria macrantha*; KOEMAC) and other grasses, or shrubs such as Gambel Oak (*Q. gambelii;* QUEGAM) or snowberry (*Symphoricarpos palmeri*; SYMPAL).

Species and Functional Group Responses

The response of vegetation over the period of record from the Fall of 1995 through the Fall of 1998 was variable, but with marked changes in species composition and detectable trends. Over 149 species operating taxonomic units (otu's) of plants were encountered on the monitoring plots (see Appendix A for complete species list). Some occurred only once, while others occurred as many as 60 times over all four years. Complete summary tables of species averages by year and site are provided in Appendix B.

Many of the more common species showed definite trends in abundance, even over this short period of record. Some of this variation was possibly due to differential precipitation over the four years (1997 was the wettest, 1998 the driest), other responses were a function of species life-history traits and possibly the intensity of the burn. We don't know what the response was immediately after the fire in July and August of 1994, but in the following first year of monitoring (1995) responses were still low to moderate compared to succeeding years. In general annual forbs peaked in 1996 and declined afterward (Figure 14). This is exemplified by *Chenopodium graveolens* (fetid goosefoot), which developed very high covers in 1996 and virtually disappeared the following year (Figure 15). Other annuals and biennials such as *Cerastium ntutans* (nodding chickweed), *Hackelia besseyi* (Bessey's stickseed) and *Thlaspi montanum* (alpine pennycress) showed similar trends. The lower response in 1995 may have been due to below normal precipitation in June as compared to above normal for 1996, which may have had consequences for germination of some species. Or, alternatively, well below normal August 1995 rainfall may have suppressed production. Regardless, it took essentially three rainy seasons following the fire for annuals to peak, and then they suddenly declined in 1997, despite average or better moisture throughout the growing season. This mostly reflects a life history response typical of annuals and biennials with respect to recently disturbed substrates.

Table 3. Organ Mountains Post-fire vegetation monitoring site characteristics. Site number corresponds to the mapped locations in Figure 2. Acronyms are given the pre-burn vegetation community type in acronyms (see Appendix A for species names, if necessary), degree of burn, its successional status before the burn, and the location of the site in UTM coordinates.

Site Number	Site Name	Woodland / Forest	Community Type	Burn status	Pre-Fire Succession	NW UTM Northing	NW UTM Easting
FBMON01	Little Rock House	Forest	QUEGAM/SYMPAL	MEDIUM	Mid	3578545	353648
FBMON02	Middle Rock House-North Face	Forest	QUEGAM/SYMPAL	MEDIUM	Mid	3578725	353758
FBMON03	Little Rock House	Woodland	PINEDU/BOUGRA	HIGH	Late	3578621	353754
FBMON04	Middle Rock House Canyon	Woodland	PINEDU/MUHMON	UNBURNED	Late	3578625	353891
FBMON05	Middle Rock House Canyon	Woodland	BOUGRA/KOEMAC	MEDIUM	Late	3578524	353951
FBMON06	Upper Fillmore (Maple Canyon)	Forest	PSEMEN/QUEGAM	LOW	Late	3578639	354285
FBMON07	Lower Rock House Canyon	Forest	PINPON/BOUGRA	LOW	Late	3578661	354039
FBMON08	Upper Indian Hollow	Forest	PINPON/KOEMAC	MEDIUM	Late	3579203	353956
FBMON09	Upper Fillmore Needles Ridge	Woodland	PENEDU/YUCBAC	HIGH	Late	3579051	353991
FBMON10	Upper Indian Hollow	Forest	QUEGAM/SYMPAL	MEDIUM	Mid	3579127	354155
FBMON11	Upper North Fork Fillmore Canyon	Woodland	PINEDU/YUCBAC	HIGH	Mid	3579155	353736
FBMON12	Upper Rock House Canyon	Forest	PINPON/QUEGAM	MEDIUM	Late	3578353	354366
FBMON13	Upper Rock House Canyon	Forest	QUEGAM/SYMPAL	MEDIUM	Mid	3578270	354303
FBMON14	Dome Saddle	Woodland	CERMON/YUCBAC	UNBURNED	Mid	3578476	354810
FBMON15	Dome Saddle	Woodland	CERMON/YUCBAC	HIGH	Mid	3578454	354878
FBMON16	Dome Saddle	Forest	PSEMEN/QUEGAM	LOW	Late	3578544	354668
FBMON17	Dome Saddle	Forest	PINPON/QUEGAM	MEDIUM	Late	3578368	354830
FBMON18	The Narrows	Woodland	JUNDEP/BOUCUR	LOW	Late	3578567	353091
FBMON19	Lower Fillmore South Fork	Forest	PINPON/KOEMAC	MEDIUM	Late	3578393	353099
FBMON20	Upper Fillmore South Fork	Forest	PSEMEN/QUEGAM	MEDIUM	Late	3577821	353638

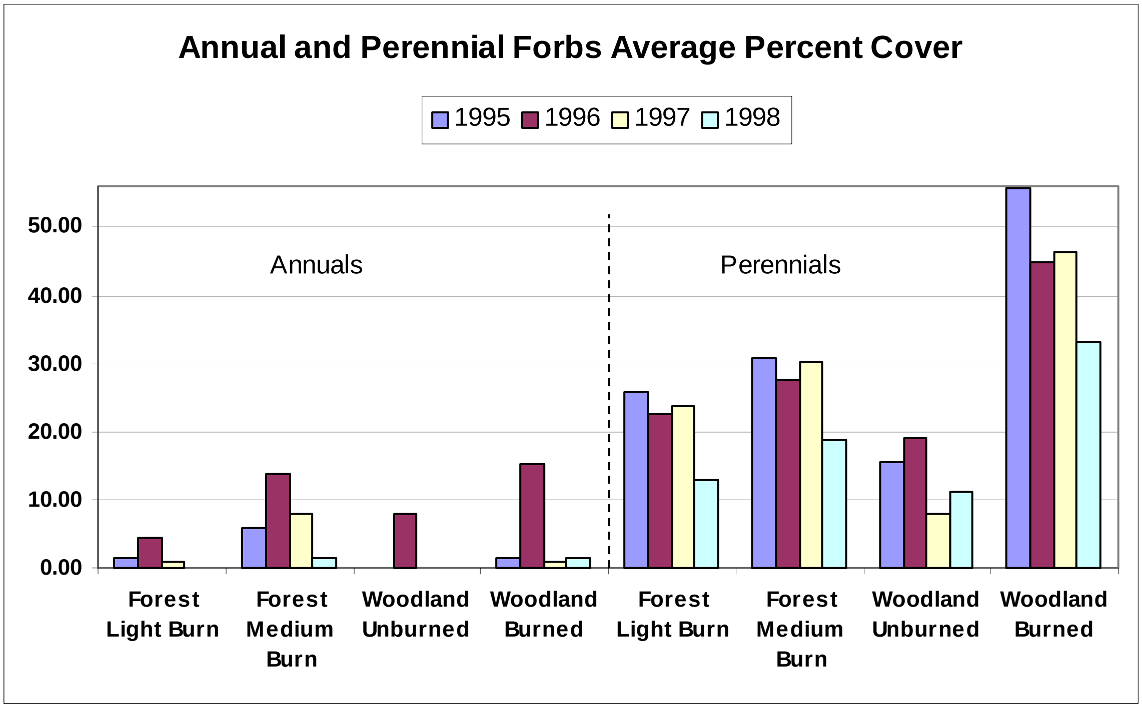


Figure 14. Average cover of annual and perennial forbs by year among major vegetation groups.

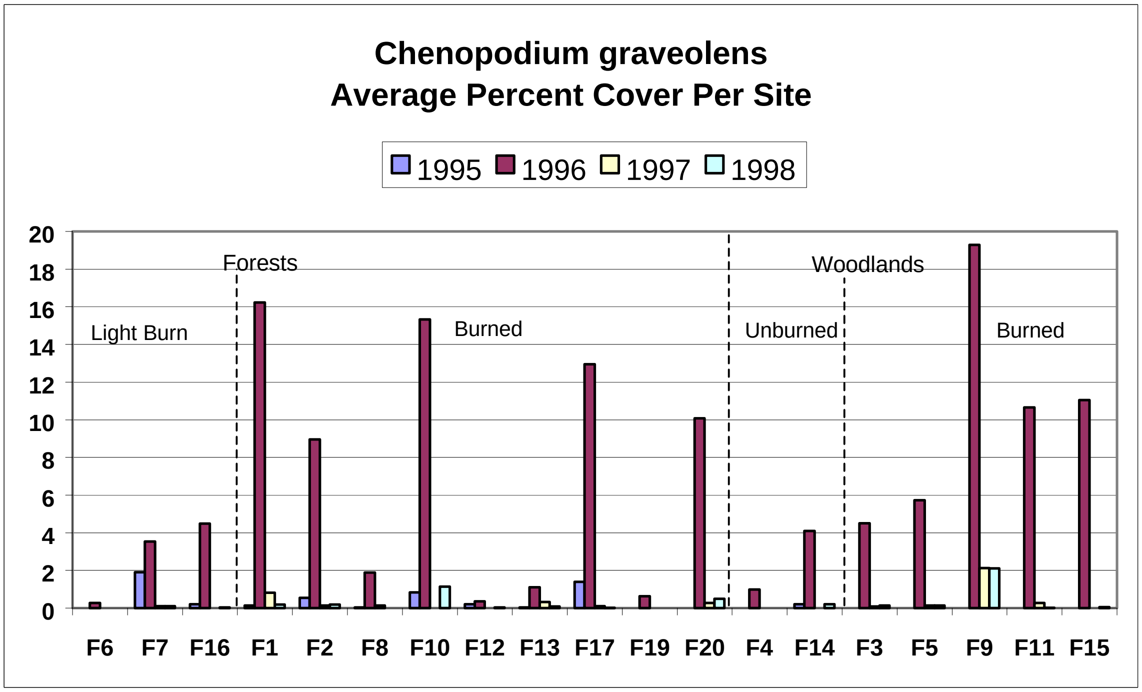


Figure 15. Average cover of *Chenopodium graveolens* per site and year.

Perennials forbs in contrast almost immediately approached peak production by 1995 and maintained relatively high cover until 1998 (Figure 14). A typical pattern was exhibited by *Heliomeris multiflora* (showy goldeneye), a short-lived perennial sunflower that was particularly abundant on woodland sites. It generally increased cover over the first two or three years and then began to decline. By 1998 its numbers were significantly reduced (Figure 16). This confirms the common perception of *H. multiflora* as an early successional species following fire in woodlands. Other perennial forbs such as *Achillea millifolium* (yarrow), *Glandularia bipinnatida* (Dakota mock verbain) and *Oxalis alpina* (woodsorel) showed a similar down trending pattern following the initial high abundance in the first years following the fire. *Ageratina herbacea* (fragrent snakeroot), *Erigeron flagellaris* (trailing fleabane) in the forests, and *Mirabilis multiflora* (desert four o'clock) in woodlands showed a mix of responses across sites, decreasing on some but continuing to increase on others (Figure 17). Lastly, *Artemisia carruthii* (Carruth's sagewort) and *A. ludovicianna* (Louisiana sagewort) are still showing an upward trend or maintenance as of 1998 (Figure 18). Perennial forbs that were common in more mature stands before the burns were still present, but at low levels i.e., *Thalictrum fendleri* (meadow rue), *Linum lewisii* (Lewis flax), *Vicia americana* (American vetch) and *Hedeoma plicata* (false pennyroyal). Overall the combination of annual and perennial forb cover reached its peak in 1996, and cloaked the hillside with displays of vivid colors.

Perennial grass response was somewhat variable, but generally speaking grass cover on sites that were grassy before the fire tended recover as grassy sites within three years, and then dip again in the dry year of 1998 (Figure 19). For example, *Poa fendleria* (mutton bluegrass), based on pre-fire releve data, was well represented (10-15% cover) on sites F1, F19 and F20 before the fire, and showed a recovery to near those levels, even on moderate to high intensity burns on these sites (Figures 20). *Bouteloua gracilis* (blue grama), *Bromus ciliatus* (fringed brome), *Elymus arizonicus* (Arizona wheatgrass), *Muhlenbergia paucflora* (New Mexico muhly) and *Koeleria micrantha* (June grass) had similar responses. But, the comparison of unburned woodland with burned suggests that recovery has not been fully attained.

Overall, woody shrubs show a trend of continued increased cover over time, mostly as a reflection of resprounting (Figure 21). But on a site by site basis there was considerable variability. *Symphoricarpos palmeri* (snowberry), a dominant shrub in the mesic forests and shrublands, recovered quickly on some sites (F1, F2, F and F17), but not on others (F12 and F13) where is had been previously an understory dominant (Figure 22). Similarly, *Quercus gambelii* (Gambel oak), the ubiquitous dominant understory tree and shrub before the fire, is recovering, but more slowly than expected, and was particularly impacted on F1 and F13 where it had been well represented before the fire (Figure 23). Turing to the xeric shrublands, *Cercocarpus montanus* (mountain mahogany) has been even slower to respond. Sites F14 and F15 are two paired *Cercocarpus* dominated plots less than 50 meters apart on unburned and burned sites, respectively (Figure 24). After a little over four years the burned site cover of *Cercocarpus* is still less than 20% of the unburned control. The woodland sites F3 and F11 lacked significant amounts of *Cercocarpus* in the understory before the fire and are not show very much in the response. There was some response in F9, but it was a more open *Pinus edulis* (pinyon) stand that was surrounded by *Cercocarpus* shrublands and probably had some in it before the fire removed the canopy. This suggests that the successional model proposed for woodlands in Figure 12 is perhaps either slow to be realized or not applicable. Longer-term monitoring of conditions on these sites is required before a conclusion can be reached.

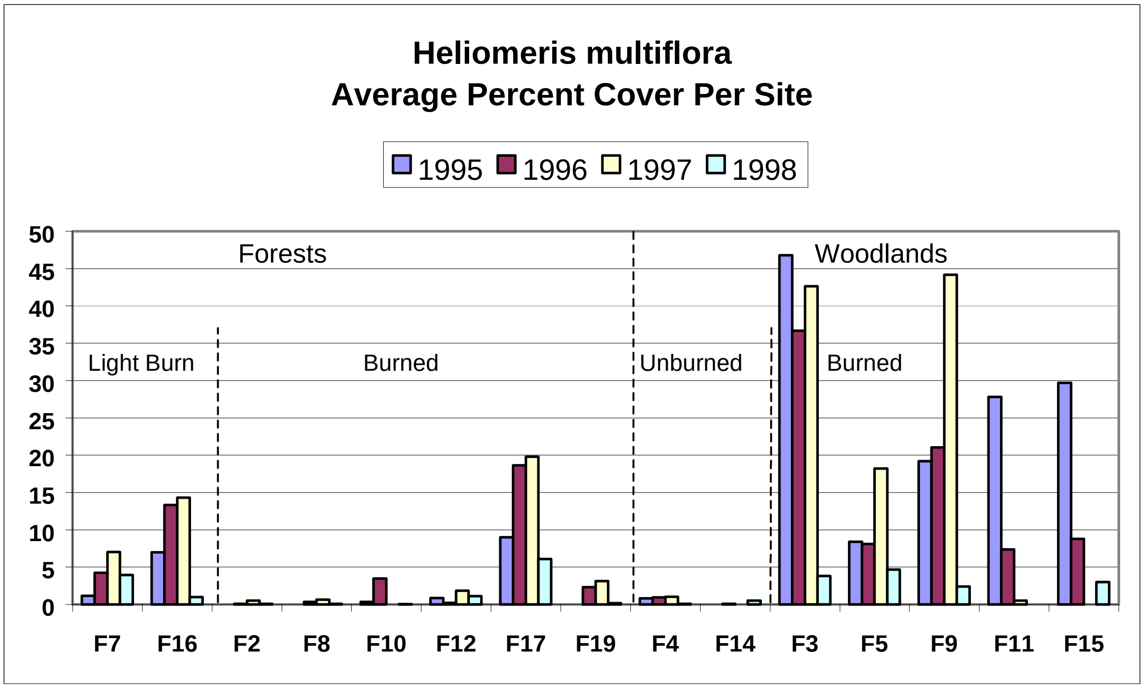


Figure 16. Average cover of *Heliomeris multiflora* per site and year.

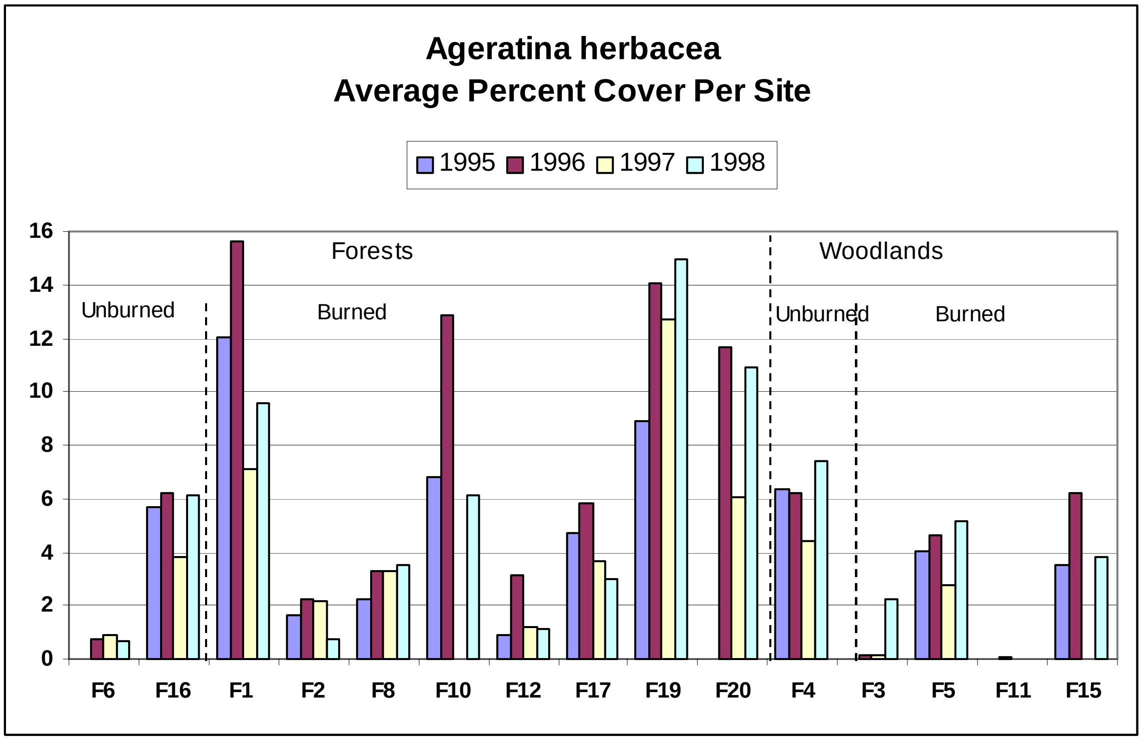


Figure 17. Average cover of *Agertina herbacea* per site and year.

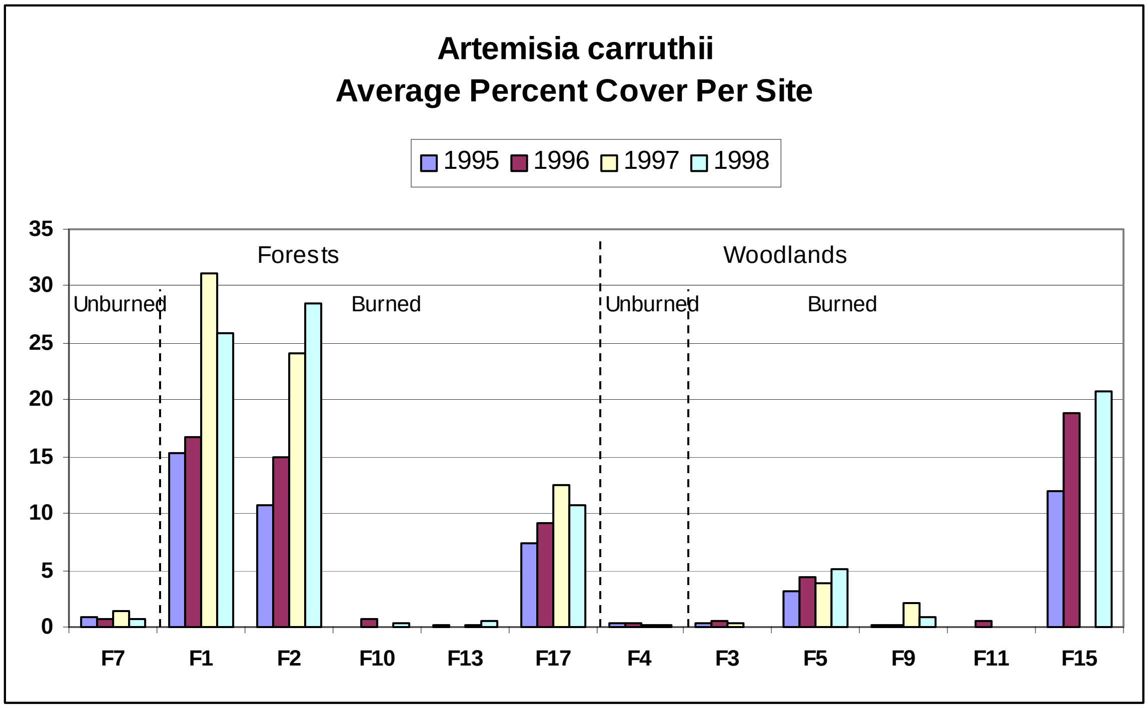


Figure 18. Average cover of *Artemisia caruthii* per site and year.

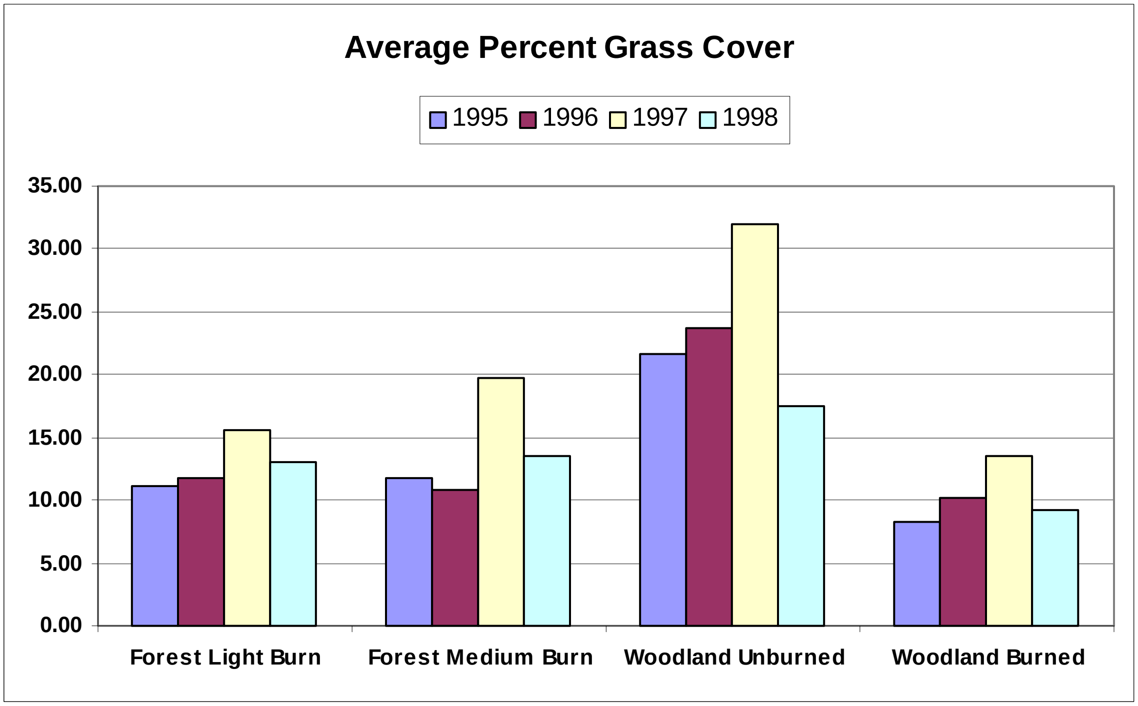


Figure 19. Average cover of grasses and grass-like (graminoid) plants by year among major vegetation groups.

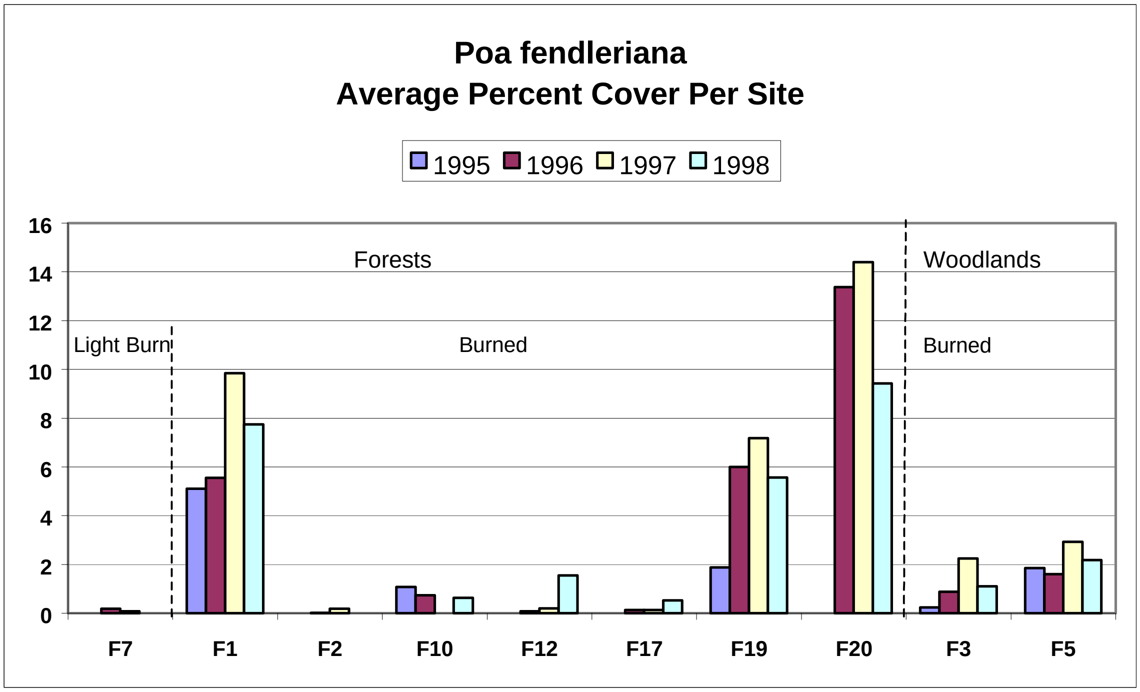


Figure 20. Average combined cover of *Poa fendleriana* per site and year.

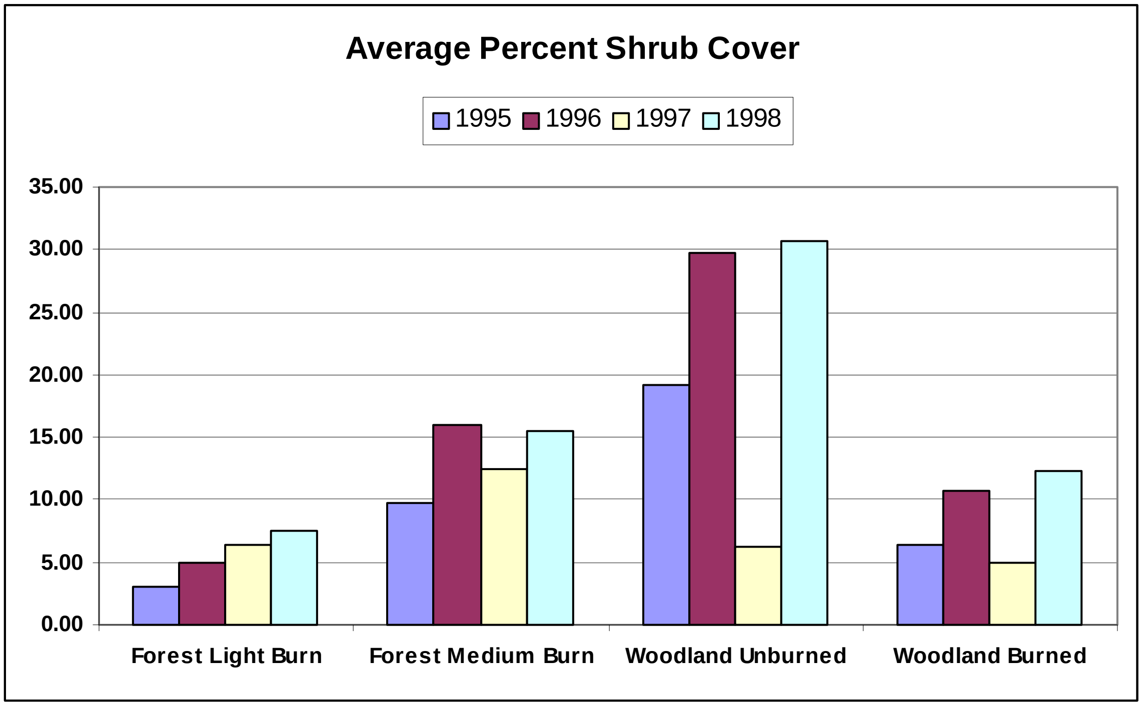


Figure 21. Average cover of woody shrubs by year among major vegetation groups.

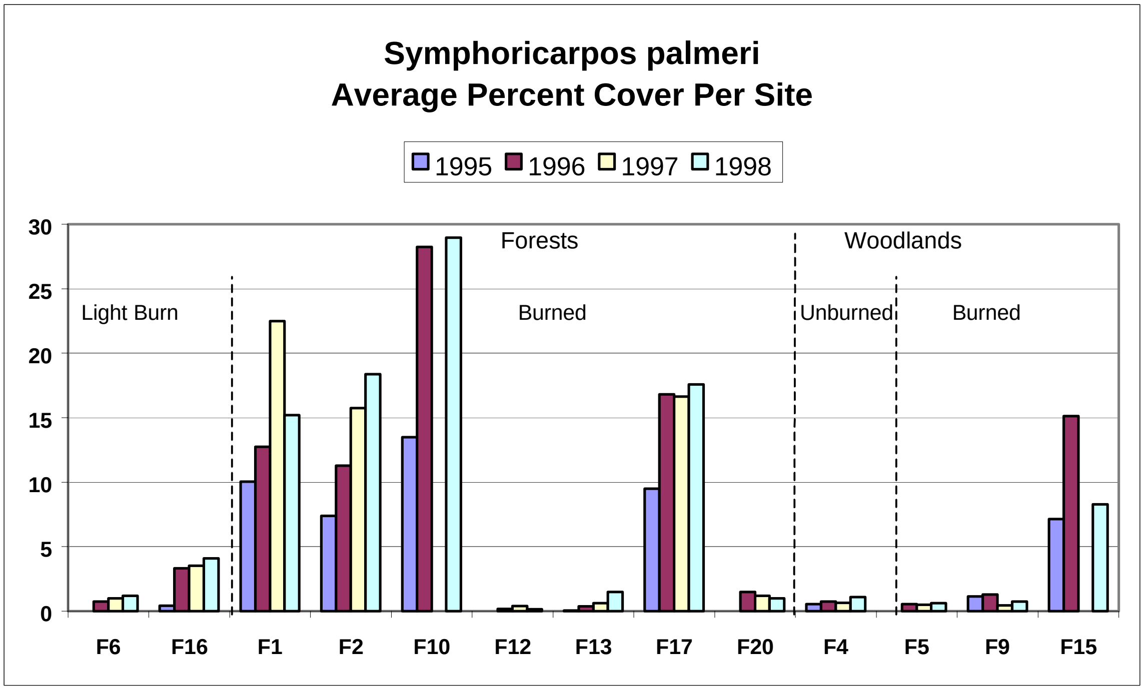


Figure 22. Average cover of *Symphoricarpos palmeri* per site and year.

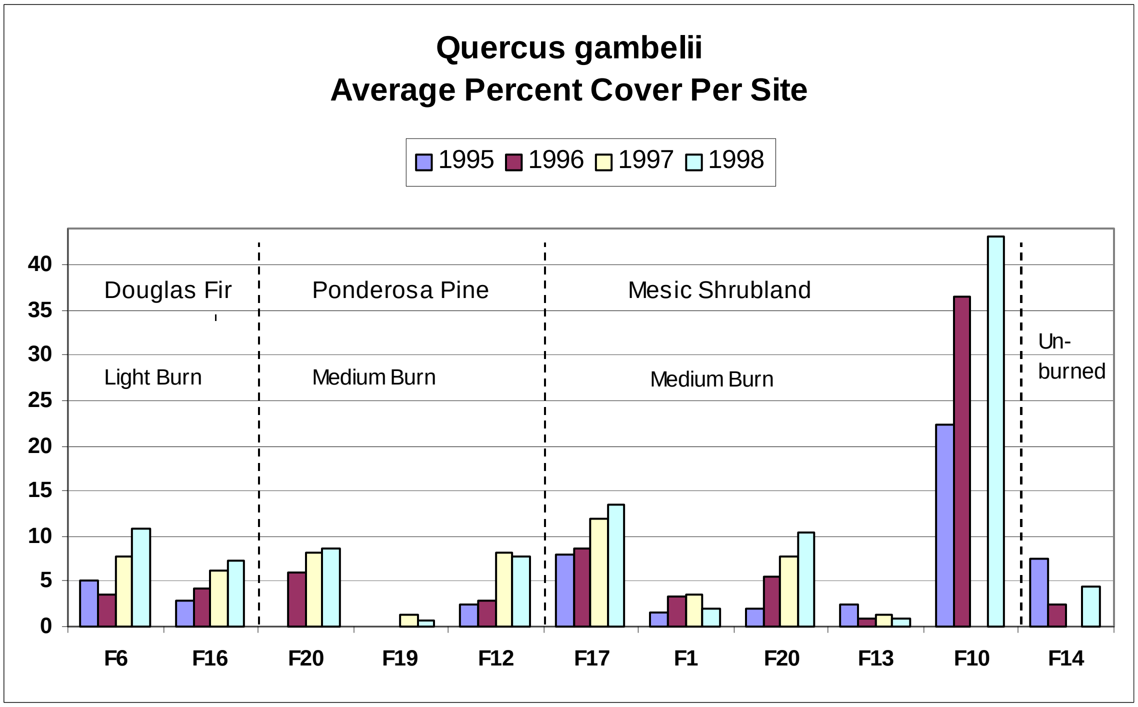


Figure 23. Average cover of *Quercus gambelii* per site and year.

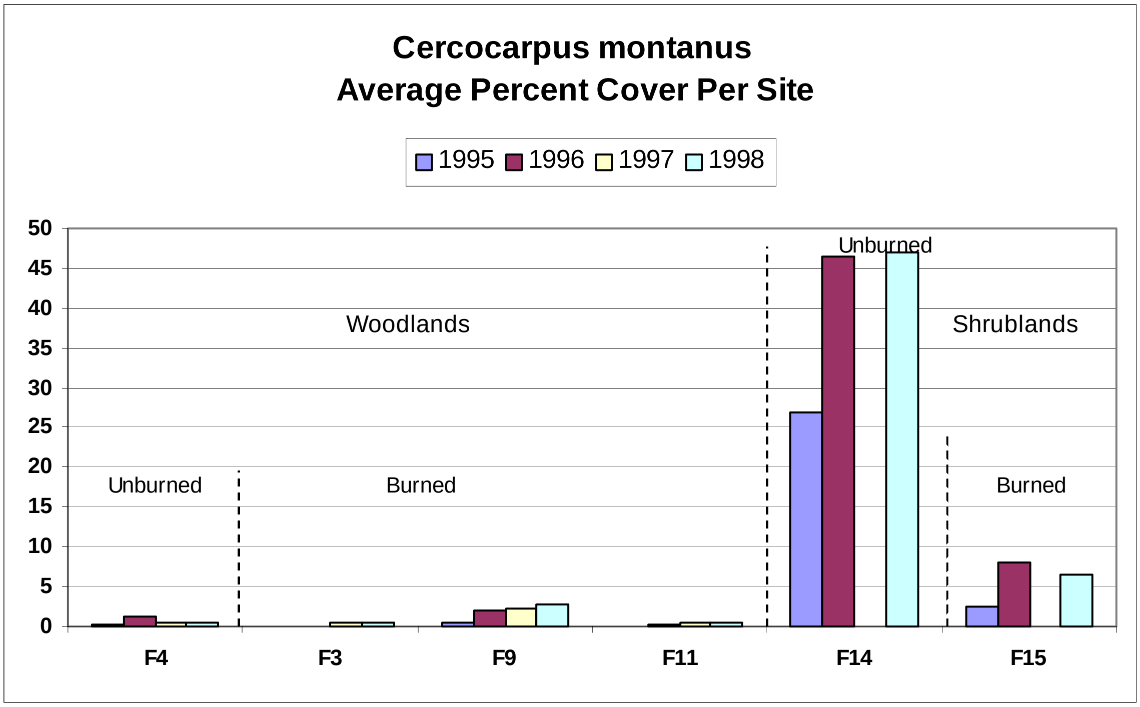


Figure 24. Average cover of *Cercocarpus montanus* per site and year.

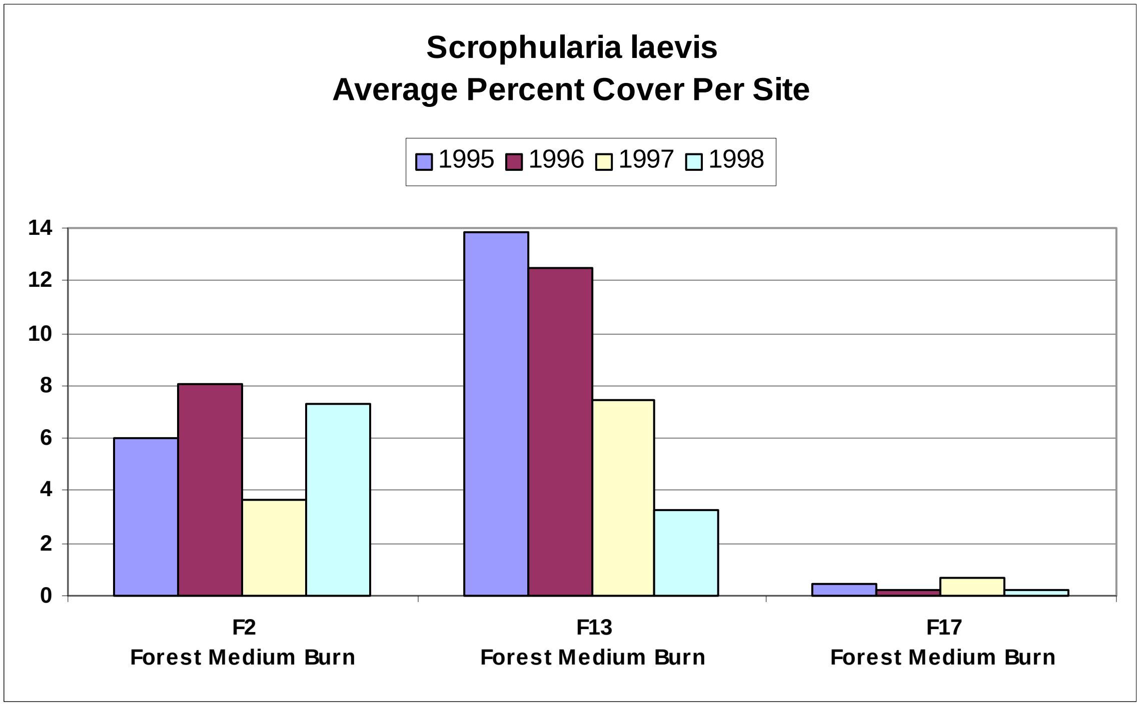


Figure 25. Average cover of *Scrophularia laevis* per site and year.

Sensitive Species Response

Only one sensitive species was directly present in the monitoring plots, and that was *Scrophularia laevis* (Organ Mountains figwort). On F17, where we know it was high in cover prior to the fire, its cover has remained low (Figure 25). On F13 and F2 it appears to have had a strong initial response to the fire, but we don't know what it's pre-fire status was at these sites, hence conclusions about it response to fire based on this data may be limited and premature without further monitoring.

Multivariate Models of Community Response

Using Canonical Discriminant Analysis (CDA), we developed to two multivariate statistical models that help describe the overall community response and successional trajectories through time: one for woodland related sites and one for forests. CDA acts to maximize differences among groups, which in this case are years, by constructing a series of derived variables (canonical discriminant variates or functions) based a set of species that hopefully show the most change in abundance over time. Each function explains a unique amount of variation in the system, and the set of functions (there are as many as there are years in this case) represents an optimal solution for differentiating among years with respect to species composition. The first canonical discriminant function (CAN1) explains the most variation and discriminates the most among years; CAN2 is next, etc., each accounting for less and less of the variation. Usually, only the first two or three functions are significant—the rest representing statistical "noise" (as measured by probability tests).

To interpret the analysis, the original variables (species) are correlated to the derived functions to determine the contribution of each species to differentiating among years. This results in "correlation structures" which are presented in Tables 4 and 5 for woodlands and forest models, respectively. The species used in the model are listed along with and their correlation to each of the first three functions (remaining two functions were not significant). In a similar fashion to regression analysis, individual plots can be scored on the functions and graphed in relative position to one another in a three dimensional space of the first three functions (Figure 26). This further helps interpret relationships among years and sites, and serves to outline the successional trajectories through time.

With respect to woodland-related plots, the mean values (centroids) for each year are fairly well separated from one another in the discriminant space (Figure 26a). There is definite trajectory from 1995 to 1996 and back down again in 1997 and away, and then a smaller movement from 1997 to 1998—all reflecting the peak of biomass development in 1996 and 1997 followed by decline and the emergence of longer-lived perennial species. The year 1996 is strongly differentiate from the other years on CAM1 where it is represented by the strong positively correlated species, particularly *Heliomeris multiflora* (Table 4). Conversely, the negative values are associated with the other years, particularly with 1997, and to a lesser extent 1995 and 1998 (although the overall correlations are weaker). CAN2 effectively isolates 1998, and the strong positive correlations of *Artemisia carruthii*, *A. ludoviciana* and *Salvia lyciodes* reflect the persistance of longer lived perennial forbs even during a dry year. *Cercocarpus* was also becoming important in 1998 relative to other species. The year 1995 is weakly isolated on

CAN3, and with the exception of *Muhlenbergia montana* (mountain muhly), is not strongly correlated with any species, reflecting the lower overall abundance of vegetation in the first full season following the fire.

Among forests there is also a distinctive trajectory from 1995 to 1996, rising up and away along CAN1 and CAN2, respectively. Then from 1996 to 1997 along CAN2, followed by a decent along CAN3 to 1998 (Figure 26b). CAN1 is particularly effective in isolating 1998 from 1995 and 1996, where increased shrub growth along with long-lived perennial forbs are associated with the former (*Quercus gambelii*, *Symphoricapus*, and *Artemisia ludovicianna*), and annual and short-lived forbs with the latter (*Chenopodium garveolens*, *Erysimum capiatatum* and *Oxalis alpinia*) (Table 5). The year 1996 is a mixture, but it mostly serves to isolate 1996 further from 1995, primarily as a function of different annuals becoming abundant in the different years, but shrubs also play a role. CAN3 serves to mostly isolate 1997 and is primarily asociated with the peak of grass cover (*Bromus ciliatus, Poa fendleriana* and *Koelaria macrantha*).

Table 4. Canonical Discriminant Analsysis correlation structure for woodland monitoring plots through time. Correlations between original variables and the derived canonical discriminant variates (functions) along with eigenvalues and proportion of the variance accounted for by each function.

Species	**CAN1**	**CAN2**	**CAN3**
Artemisa carruthii and *ludoviciana*	0.077	0.995	0.069
Bouteloua gracilis	0.982	-0.168	0.088
Cercocarpus montanus	-0.378	0.923	0.071
Chenopodium graveolens and *neomexicanum*	0.150	-0.383	-0.911
Glandularia bipinnatifida	0.550	0.753	0.362
Heliomeris multiflora	0.984	0.081	-0.159
Koeleria macrantha and *Poa fendleriana*	0.964	0.093	-0.249
Muhlenbergia montana	-0.292	-0.550	0.783
Muhlenbergia pauciflora	-0.639	-0.757	0.137
Salvia lycioides	-0.088	-0.988	-0.124
Sphaeralcea fendleri	-0.281	-0.689	-0.668
Viguiera dentata	-0.390	0.122	-0.913
Mirabilis multiflora	0.800	0.026	0.600
Eigenvalue	5.280	1.451	0.829
Proportion	0.698	0.192	0.110

Table 5. Canonical Discriminant Analsysis correlation structure for forest monitoring plots through time. Correlations between original variables and the derived canonical discriminant variates (functions) along with eigenvalues and proportion of the variance accounted for by each function.

Species	**CAN1**	**CAN2**	**CAN3**
Achillea millefolium	0.872	-0.168	0.459
Ageratina herbacea	0.357	0.914	-0.192
Artemisia carruthii and *ludoviciana*	-0.768	-0.084	0.635
Bromus ciliatus and *lanatipes*	-0.452	-0.195	0.870
Chenopodium alubum	-0.888	0.295	-0.354
Chenopodium graveolens and *neomexicanum*	0.675	0.738	-0.025
Elymus arizonicus	-0.406	-0.822	-0.399
Erigeron flagellaris	-0.741	-0.175	0.649
Erysimum capitatum	0.926	-0.369	-0.074
Geranium caespitosum	0.869	0.040	0.492
Hackelia besseyi	0.466	-0.830	-0.305
Heliomeris multiflora	0.493	0.121	0.862
Koeleria macrantha and *Poa fendleriana*	-0.347	-0.017	0.938
Oxalis alpina	0.998	-0.060	0.012
Quercus gambelii	-0.767	0.606	-0.209
Robinia neomexicana	-0.217	0.972	0.088
Scrophularia laevis	0.911	-0.111	-0.398
Stellaria cuspidata	0.467	-0.561	0.683
Symphoricarpos palmeri	-0.591	0.794	0.143
Thlaspi montanum	0.462	-0.857	-0.227
Vicia americana	-0.046	0.853	0.519
Hymenoxys vaseyi	0.145	0.087	0.986
Cerastium nutans	0.401	-0.802	0.443
Eigenvalue	3.765	1.720	0.875
Proportion	0.592	0.271	0.138

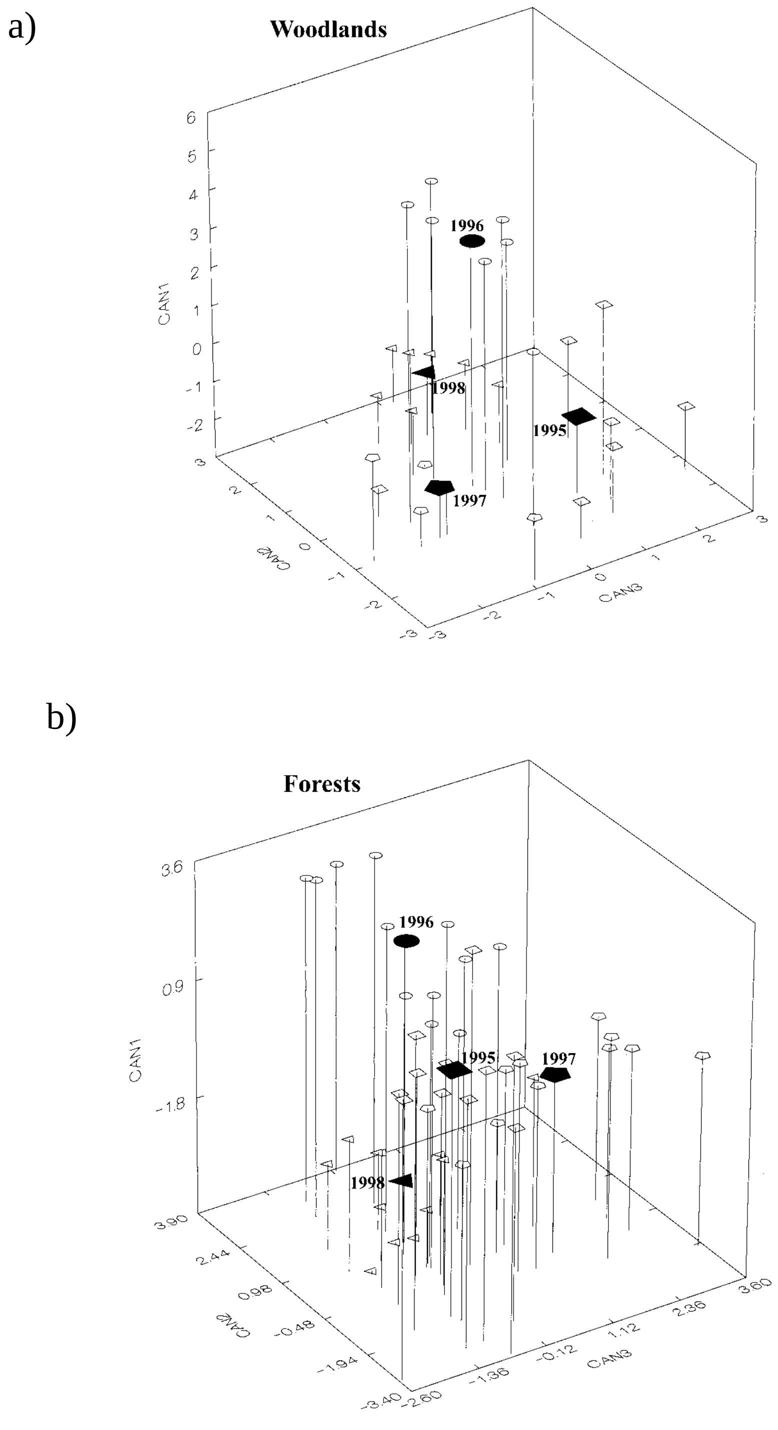


Figure 26. Distribution of monitoring plot scores through time on the first three Canonical Discriminant functions (CAN1, 2, & 3). Centroids are marked by the year and indicate the corresponding symbols for each year. The maximum difference among years is reached in 1996 when forb cover peaked in both woodlands (a) and forests (b).

Discussion

The results from the first four years of post-fire monitoring indicate definite successional trends in both woodlands and forest that are related to a combination of climatic conditions, life history traits of the species, and pre-fire vegetation type. Annual, biennial and short-lived perrenial forbs increased in abundance from 1995 to 1996 and dominated the sites. In 1997 they began to decline, despite more than adequate moisture. Different annuals were prevalent in each year reflecting a combination of differential germination in response to specific precipitation patterns for each year, and species-specific strategies in reponse to disturbance. In contrast, perennial grasses and long-lived forbs, mostly recovering from pre-fire rootstocks, continued to increase in cover until the severe drought year of 1998 when there was a marked decline. But these groups do not appear to have yet reached the same level of abundance they had before for the fire, except in a few sites where burning was light. Shrubs response was mostly through resprouting, and was slower than expected for the major long-lived dominants such as *Quercus gambelii* (Gambel oak) and *Cercocapus montanus* (mountain mahogany). Responses varied among sites with some that had been dominated by these shrubs before the fire showing a weak regrowth, while in others the shrubs responded vigorously.

Although our Canonical Discriminant Analysis suggest the initiation of successional pathways that conform to the proposed general models (herbaceous stages followed by shrublands and then development of mature woodlands and forest), the period of record is too short to reach definite conclusions on the efficacy of the models. In particular will there be the consistent development of a shrubland stage followed by conifer and oak overstories? Effective sexual reproduction of the major shrub species was not yet very evident. Hence site that were severely burned may remain in a herbaceous stage for a significant period of time. Overstory tree regeneration, particularly by conifers, during the course of the study was rare event both on and off the monitoring sites. It may take several years before the right combination of moisture, temperature and site availability occur to bring about successful natural initiation of shrub and tree stages. This can have significant consequences for the structure and pattern of these landscapes and ultimately for the sensitive biota the inhabit them.

The consequences of this seedling "bottleneck" are being addressed to some degree through a spatial-temporal modeling effort on fire and growth in these forests and woodlands. But to answer some of these questions the modeling effort can go only so far, and these issues must be addressed with further studies and monitoring. Of particular importance is developing a more thorough understanding of the germination requirements and other life history traits of the keystone species in these ecosystems. In addition, patience is needed to directly track and evaluate changes through time beyond this initial four-year project. Such monitoring can not only help answer persistent questions, but also becomes a measure of long-term success.

Section III - Post-fire Stream Channel Sediment Monitoring

Introduction

High precision channel monitoring sites were established to monitor post-fire sediment load and its effect on the Organ Mountains evening primrose (*Oenothera organensis*), a sensitive species that grows directly in the stream channels of the major watersheds of the Organ Mountains. Eight sites were established; four in the heavily burned Fillmore Canyon watershed representing the fire "treatment" effect, and four in the lightly burned (<10%) North Canyon which served as the "control" (Figure 2). Sites were distributed from the upper to the lower ends of the watersheds and usually within populations of *Oenothera* (one site, Fillmore Canyon 1 in upper Fillmore does not currently support Oenothera, but is a site of active sediment deposition). At each site, three surveying transects were established perpendicular to the channel at the upper end, middle and lower end of the *Oenothera* population. Elevations along the transects were repeatedly measured relative to a permanent benchmark, providing data for construction of detailed channel profiles of the channel bottom and sideslope surfaces. Channel profiles were then compared through time to detect significant changes in channel geometry and sediment load.

The sites were established in the Spring of 1996 before the onset of the summer rainy season, and monitored though two rainy seasons after the fire. At this time, significant sediment deposition has been qualitatively detected only at the upper Fillmore site. After establishment the sites were re-read after the summer rains of 1996 and 1997 to assess the overall channel changes on a seasonal basis, since the summer rainy season is considered to the be the most effective time period for sediment transport. However, during this short period of record there have also been high variations in summer precipitation. The highest summer rainfall occurred in 1996 as measured on the basin floor at the White Sands Missile Range Post (Figure 27) and there was observed stream flow in Fillmore Canyon that year. The next highest was 1997, but the peak occurred earlier in the summer and stream flow was nominal, and hence sediment transport may have been minimal in Fillmore Canyon. In 1995, precipitation was also lower than 1996, but peaked at the same time as 1996. Also, during these two years, there was surface flow observed in Fillmore. The effectiveness of this flow for sediment transport is unknown. Hence, because of the short period of record on these transects, any conclusions drawn from them must be considered preliminary

Watershed Descriptions

Fillmore and North canyons are rugged and steeped slopes watersheds that share Organ Peak in their headwaters and hence similar geological substrates, but their drainage axes are located at almost 90 degrees from each other (see Figure 2 in Study Area). Fillmore has extensive north-facing slopes that support mesic forests and shrublands, as well as xeric woodlands and shrublands on the warmer slopes. Whereas North Canyon has extensive south-facing slopes that are dominated by xeric woodlands and shrublands. There are some forested areas, but they occur high in the watershed on easterly slopes.

There are also differences in channel gradient and morphology. Channel gradients in both canyons are moderate to steep (Figures 28 and 29), but Fillmore Canyon tends to have more moderate gradients, and a wider valley bottom with less overhanging vegetation. North Canyon, in contrast, has a somewhat steeper and narrower channel often lined with vegetation and less exposed.

Despite these moderate contrasts in vegetation and channel morphology, both canyons support populations of *Oenothera organesis* in the main channels, and the unburned North canyon serves as the best available control watershed to the extensively burned Fillmore Canyon. North was burned in only in a small portion of the watershed near the Organ Peak. All other adjacent watersheds were burned extensively.

For directions and additional site descriptions, please refer to *Oenothera* site charactizations in Volume I of this report.

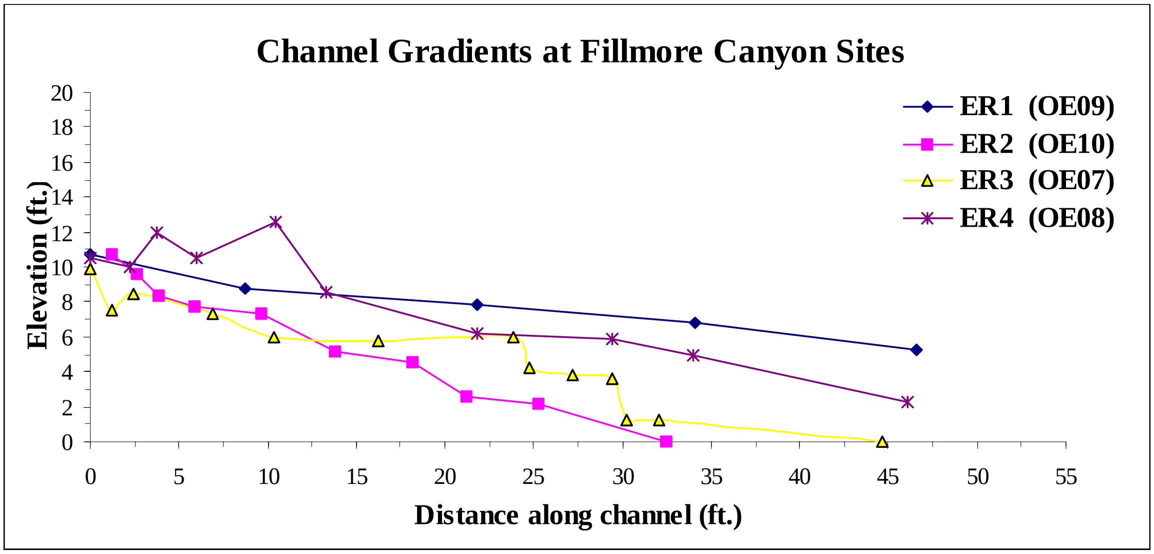


Figure 28 Channel gradient for each site in Fillmore canyon. Legend is arranged descending from furthest upstream.

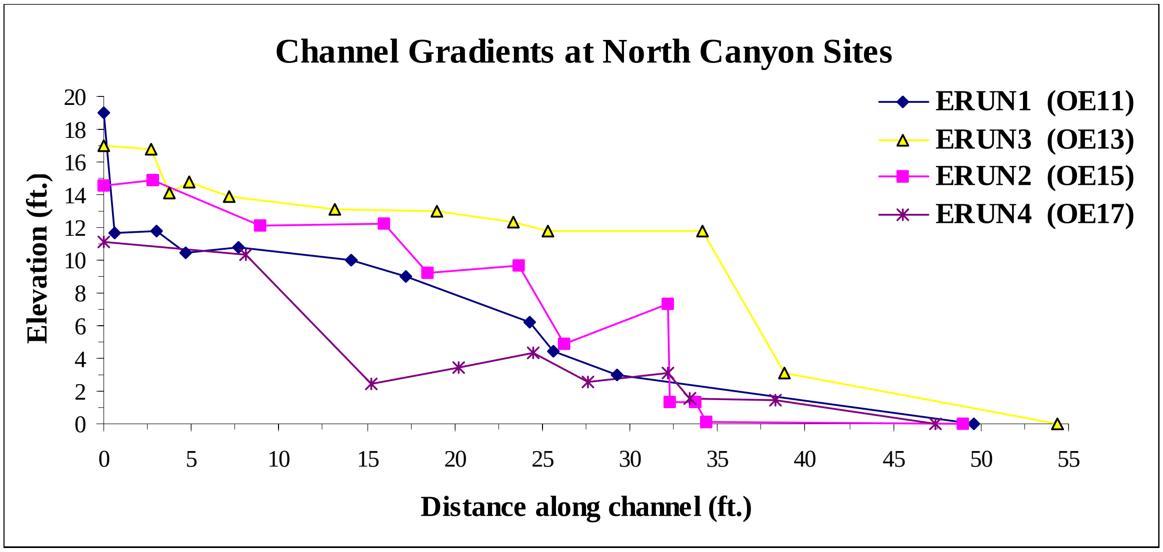


Figure 29. Channel gradient for each site in North Canyon. Sites are arranged descending from furthest upstream

Methods

Cross-section Measurement Protocols

Equipment Required :

1. Self-leveling level transit with tripod and 1lb plumb-bob (Wild NA24 Transit).
2. Stadia rod that graded into tenths of feet (Mound City SVR-25-TENTHS MODEL 903040).
3. 30 meter plastic or metal tape (Keson Model OTR-30m).
4. A string level.
5. 50m by 5 mm cord for tying between rebar to keep the tape taught in the wind.
6. 3 lb. sledge hammer to re-establish rebar as necessary .

Measurements.

Measurements include channel cross-sectional elevations, channel gradients, and photo-points at each transect. Each transect is monumented by a rebar at both ends and is tagged with aluminum identification tags which indcate transect number (for example ER1 Upper Transect). In addition to the transects end rebars, a permanent benchmark was established in a secure location outside the immediate channel was used to calibrate the height of instrument and current rebar positions. The transit was established at or near the beginning rebar, and the height of instrument established relative to the benchmark. A meter tape was stretched as tauntly as possible bewteen the two rebars. Using the middle cross-section hair of the scope, the cross-sectional distance between the instrument and opposite re-bar was first recorded, and then the distance and elevation benchmark was back-sighted (BM). Initially, the azimuth angle of the instrument was zero'd on the opposite re-bar across the channel and elevation and stadia-based distance were read. Then the back-sight on the BM performed, recording the turned angle, elevation and stadia.

The scope was then returned to the opposite re-bar and elevations were read to the nearest tenth of inch at half meter intervals along a tape, starting at one meter from the instrument side and proceeding to the opposite re-bar. The tape was always placed at the bottom of the re-bar, next to the ground surface. For the Spring 1996 measurements, the tape was attached at 0 meters by tying the hook end such that it abutted the inner face of the re-bar. In Fall 1996, the tape was simply hooked over the re-bar, subtracting an eighth inch of from the Spring length and positions. Notes were taken on substrate directly below the rod (boulder, rock, cobble, gravel, sand, loam and litter-see Table 6 for specific size classes), placement of the point with regard to the channel (hillslope, bank, channel edge, active channel), and general vegetation. For each transect at least one repetition of readings was required. If the elevation values differed by 0.05 ft., then a third reading was taken and the values averaged. Back-sights were turned twice for each transect, initially after zeroing on the opposite channel re-bar and after all the elevation measurements had been taken.

To insure repeatability and get a feel for the variation of rod placement, we would switch the rod-person and the instrument person between runs. Other methods employed that strengthened repeatability were plumbing each point and using a cord to reduce the flex from wind blowing the meter tape. The cord was tied between the end point re-bar and clipped to the tape.

Channel gradient measurements were taken with the instrument at the clearest line of site over a significant length of channel. The instrument station at the second transect typically gave the clearest overall view. Elevations along the channel measured,distances using stadia and angle to points were taken throughout the channel length. Placement of the pole highlighted holes but was generally confined to the average gradient of the channel. The zero azimuth was set on either the opposite rebar or the BM.

Repeat photo points were established at one end of each transect and 35mm photographs taken upstream, along the transect, and downstream. A small chalk board was used to identify the site, transect and date within each photo. Notes were taken on azimuth, photo number, transect, end rebar and outstanding features within the photo. General shots of the cross-sections were taken on some sites, but most had only one general site photo.

Table 6: Substrate size classes derived from Rosgen (1996)

Bedrock	Underlying parent material
Boulder	> 20 inches
Rock	10 - 20 inches
Cobble	2.5 - 10 inches
Gravel	2mm - 2.5 inches
Fines	< 2 mm

Analysis

Elevation profile diagrams of the cross-sections were constructed for each year of measurement and then overlaid by referencing the elevations along a transect to a common fixed point between years. The far end re-bar of each transect was used for all the transects except for the middle transect at OE07, the upper transect at OE08, and the upper transect at OE 13 which used the beginning rebar. These diagrams provide a readily accessible visual mode for evaluating cross-section differences in spatial context.

Differences in elevation at survey points were also computed between years and an analysis of variance with unequal sample sizes was performed to detect significant differences between canyons, sites, transects and years.

Results

At the transect level within sites there were significant differences among years for the periods of Spring to Fall 1996 and Fall 1996 to Fall 1997. These differences will be examined in detail below for each transect. Transect level differences did not necessarily translate into significant differences at the site or canyon level. In 1996, the year with the greatest summer precipitation, significant differences were detected within both canyons among sites (North, P=0.02; Fillmore, P=.07), but no overall significance between the two canyons was found. This is part due to the high within variance among transects at a given site relating to the limits of precision. There can be small variations of reading even on solid rock. But more importantly, changes that are observed can be small but very different in nature e.g. the canyons may have similar magnitudes of change but the type of change with respect to substrate type is different, particularly with respect to litter versus fine sediment loads. There were also no significant site or canyon differences detected after the 1997 rainy season, but there was little or no surface flow in the canyons during the summer. Finally, there were unexpected cattle impacts to some channel cross-sections in Fillmore Canyon that disrupted the profile readings and added to the variance in the data.

Site Level Changes – Fillmore Canyon

Fillmore Canyon 1 [ER1 (OE09)]. This site is located in the upper watershed along the middle fork of Fillmore, approximately 500 m above the Narrows at the lower end of "Juniper Flat" (at the confluence of a small drainage entering from the north). This site provides the highest elevation marker for sediment movement in the watershed. At the time of establishment sediment had already been deposited in the channel (Figure 30 photo) that had not been there prior to the fire (personnel observation, E. Muldavin). In 1996 there was an aggregation of sediments, particularly in the upper transect (Figure 31a) with minor amounts in the middle transect (Figure 31b). This is also reflected in the overall higher percentage of fine sediments at the site than others in the canyon (see Figure 43 - 46). There were no significant changes in 1997, and in fact there was some indication the sediment levels may have peaked or were declining (Figure 32 photo).

Fillmore Canyon 2 [ER2 (OE10)]. Located at just below the Narrows as the channel exits the canyon constriction. It supports a sparse population of *Oenothera*. The stream gradient is steepest here of all the sites in Fillmore, and more similar to the gradients of the North canyon sites (*see* Figures 28 and 29). There was some evidence of sediment moving into the site in 1996 but little in 1997 (Figure 33). In the middle transect there is a primary channel and secondary overflow channel. Though not sediment was detected in the primary channel, there were some signs of aggregation in the secondary channel between meters 1.5 and 3 (Figure 33b). The area also had swept vegetation and fine textured material. The lower transect lies just below a sharp drop zone (*see* Figure 28), and the channel at this point has steep banks with a mixture of rocks and cobbles in the active channel; changes here may reflect large rock movement rather than fine sediment transport.

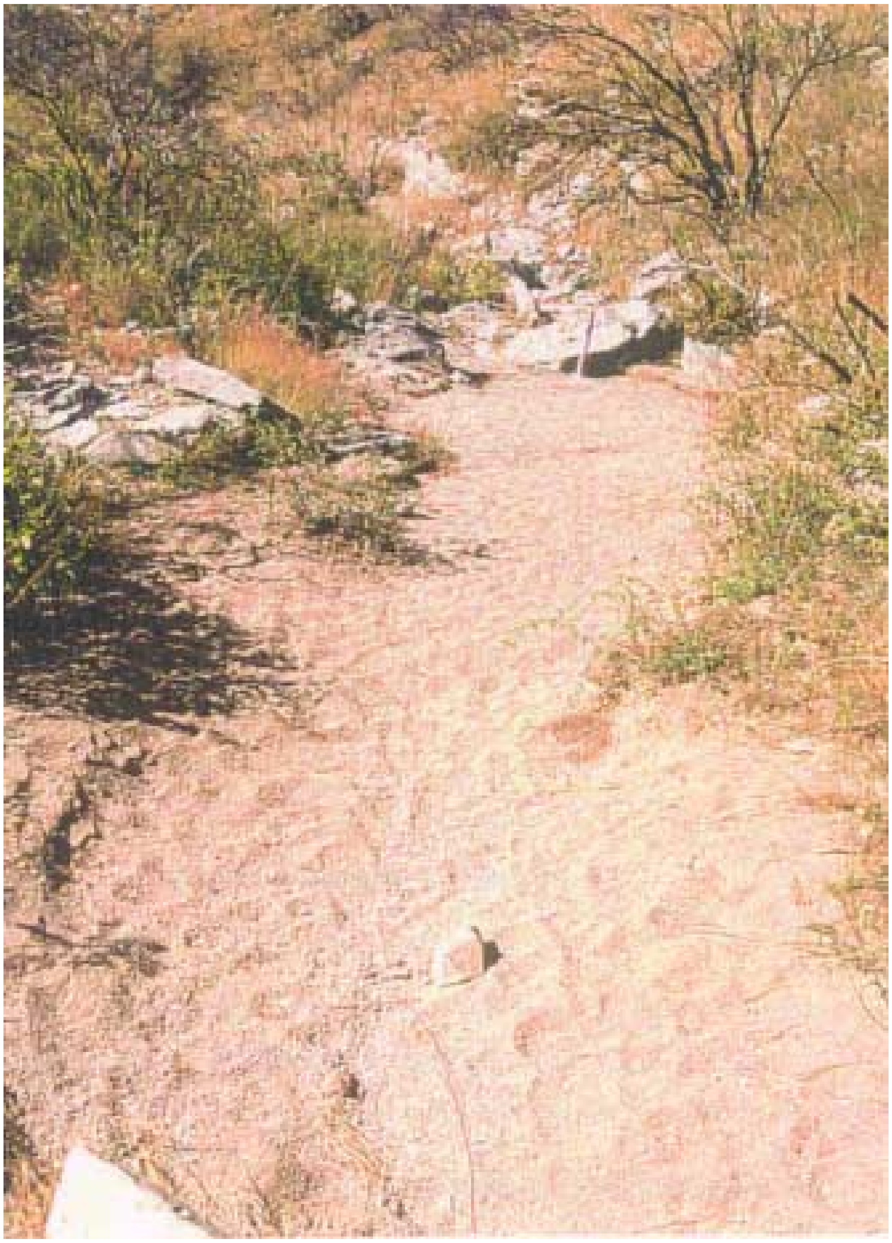


Figure 30: Photo shows the fire-related sediment load following the fire in 1994. Photo is taken 100 meters above the Narrows in the middle fork channel of Fillmore Canyon. Photo by Esteban Muldalvin, Fall 1996.

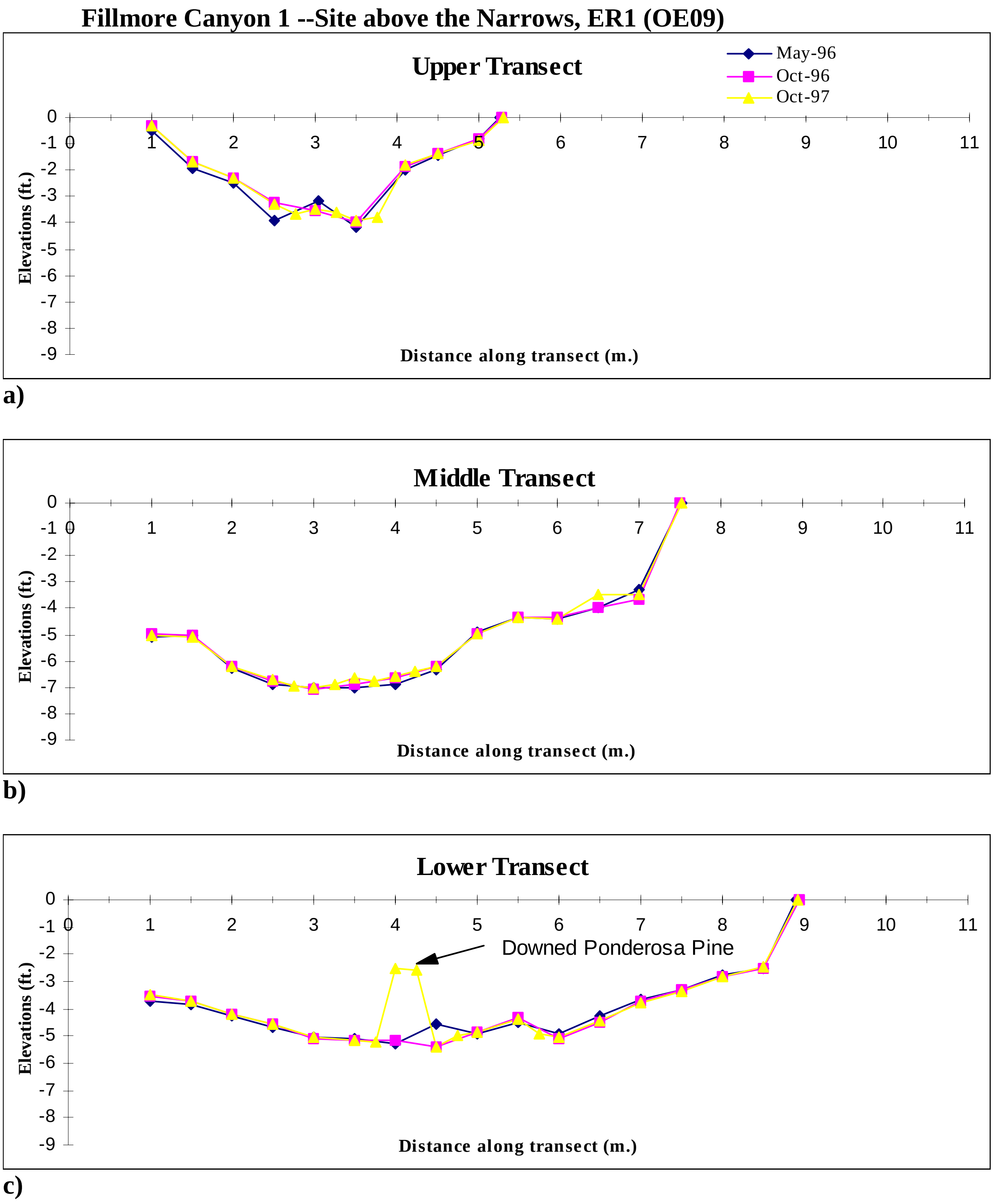


Figure 31. Fillmore Canyon 1 stream cross-sections for 1996-97 [ER1 (OE09)]. The site is located above the Narrows in the upper Fillmore watershed which was extensively burner in 1994.

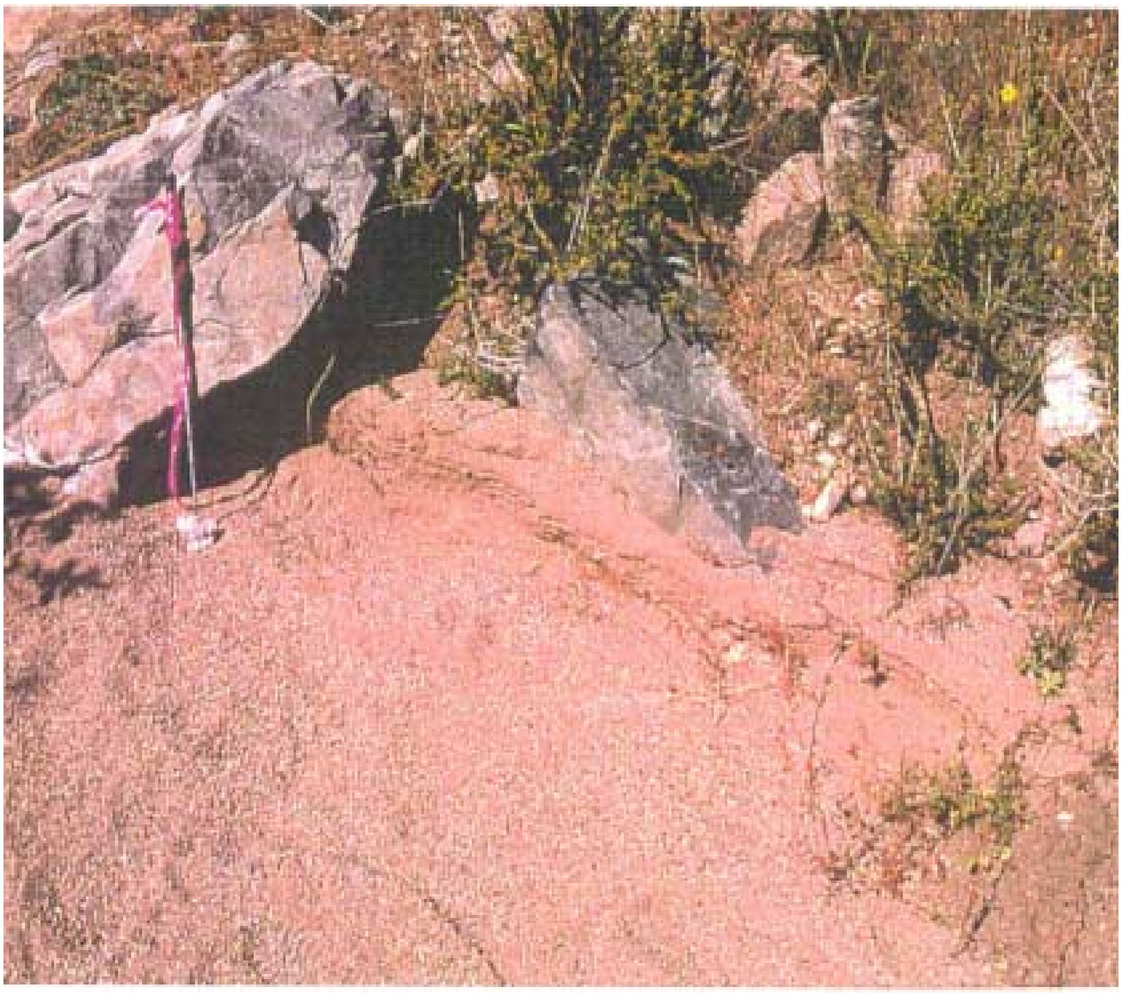


Figure 32: Photo is a zoom of Figure 30 illustrating the peak sediment load following the fire in 1994. Notice the coarse sand/ fine gravel texture of the sediment. Photo by Esteban Muldalvin, Fall 1996.

Fillmore Canyon 2 -- Site at Narrows, ER2 (OE10)

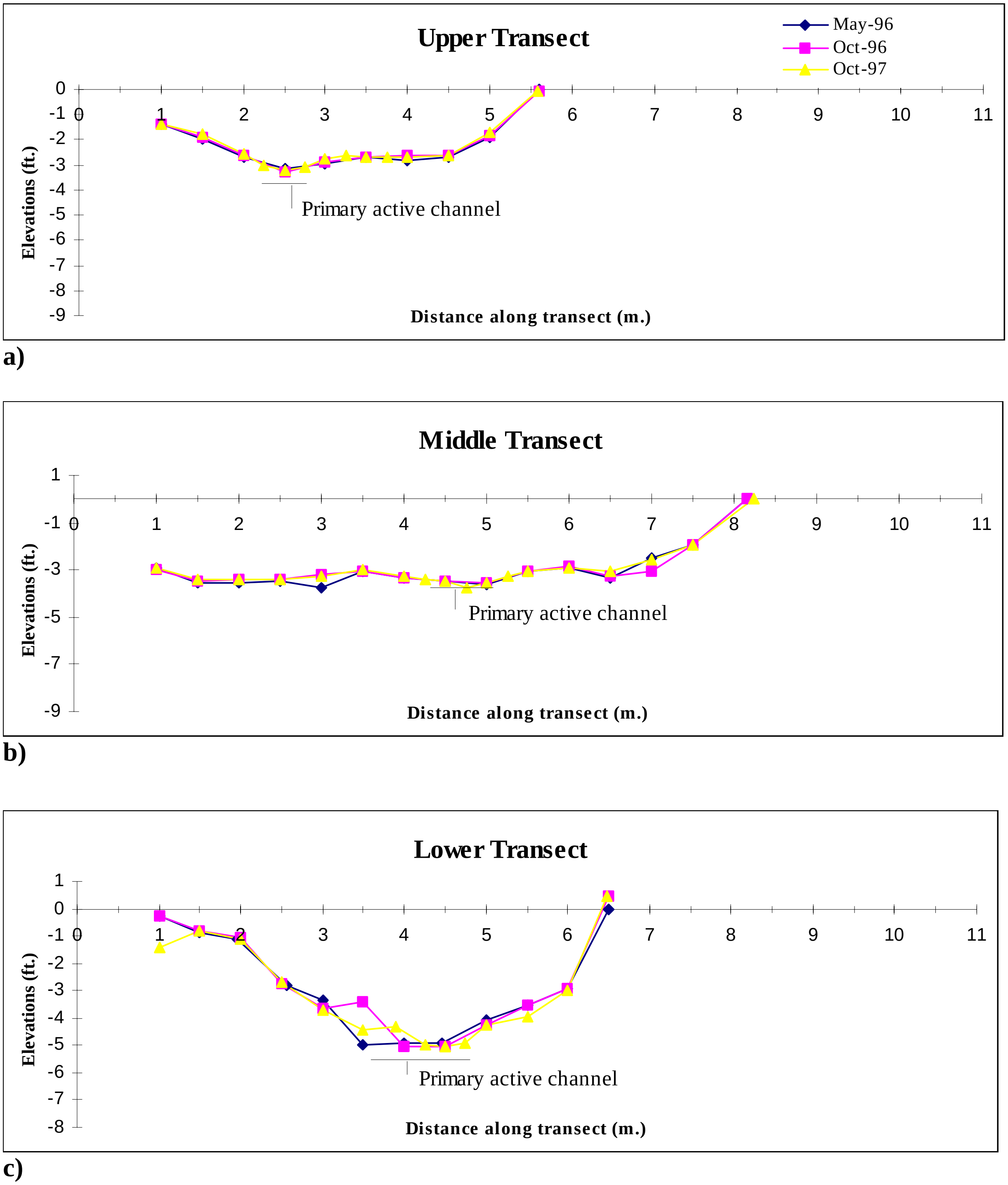


Figure 33. Fillmore Canyon 2 stream cross-sections for 1996-97 [ER2 (OE10)]. This burned site is located just below the Narrows at mid-watershed in Fillmore Canyon.

Fillmore Canyon 3 [ER3 (OE07)]. This site is located approximately two hundred meters above Fillmore Spring. It was re-measured in 1996 only. It supports a robust population of *Oenothera* in a moderately wide channel. This site has very steep banks and a moderately steep gradient (Figure 28). A bedrock chute is found just above the site (this also occurs at Fillmore Canyon 4 and North Canyon 1 and 4). Overall, fine sediments appear to be less here than in the upper sites (*see* Figure 45). There is some evidence for gravel accumulation during 1996 in the upper transect at the base of the chute (Figure 34a). In contrast, in the middle transect there was some indication of degradation in 1996 in the center of a very large concentration of *Oenothera organensis* (Figure 34b). Yet in the lower transect (Figure 34c) there was some aggregation, though small, with overall changes minimal (Figure 35 photo).

Fillmore Canyon 4 [ER4 (OE08)]. This site is located at Fillmore Spring proper and supports a sparse population of *Oenothera*. Channel is characterized by low banks, moderate channel width and a moderate to low gradient (*see* Figure 28). Velvet ash and white oak form a dense closed canopy. Evaluating change on these transects is confounded by significant cattle disturbance that has intensified since the establishment of the transects. The upper transect in Figure 36a is very uneven with respect to deposition and erosion within and among years, perhaps reflecting cattle trampling. Disturbance may have loosened banks and the creek bottom causing local sediment loss and gains within this site that do not reflect watershed level transport. This particularly may be the case in the middle transect where a “water trough” is now located 10 feet from the far re-bar (Figure 36b). The lower transect is the most protected transect and is positioned at the sharpest drop in gradient. Some gravel may have been removed during the summer of 1996.

Site Level Changes – North Canyon

North Canyon 1 [ERUN1 (OE11)]. This is the highest watershed site in North Canyon and supports a moderate population of *Oenothera*. Site has a very steep gradient with bedrock chutes directly above and below it. Coarse materials such as boulders and rock dominate the channel substrate along with organic litter (*see* Figure 47). The tree canopy is dense (Douglas-fir and white oak). There was effectively little or no change at this site over the period of record. The upper transect in Figure 37a showed no change. The differences on the middle and lower transects reflect difficult measurement points on rock and cobble edges rather than actual changes on substrate composition.

North Canyon 2 [ERUN3 (OE13)]. This site is located 250 meters below North Canyon 1 in a springy area supporting a robust population of *Oenothera* (just before a 10 meter waterfall). The overstory canopy is moderate and dominated by small velvet ashs and white oaks. The channel gradient is moderate with presence of finer materials than in other sites in the canyon (*see* Figure 48), but still most deposition is in the form of organic litter (Figure 38 photo) Once again there are little or no changes from year to year (Figure 39).

Fillmore Canyon 3 -- Above Fillmore Spring, ER3 (OE07)

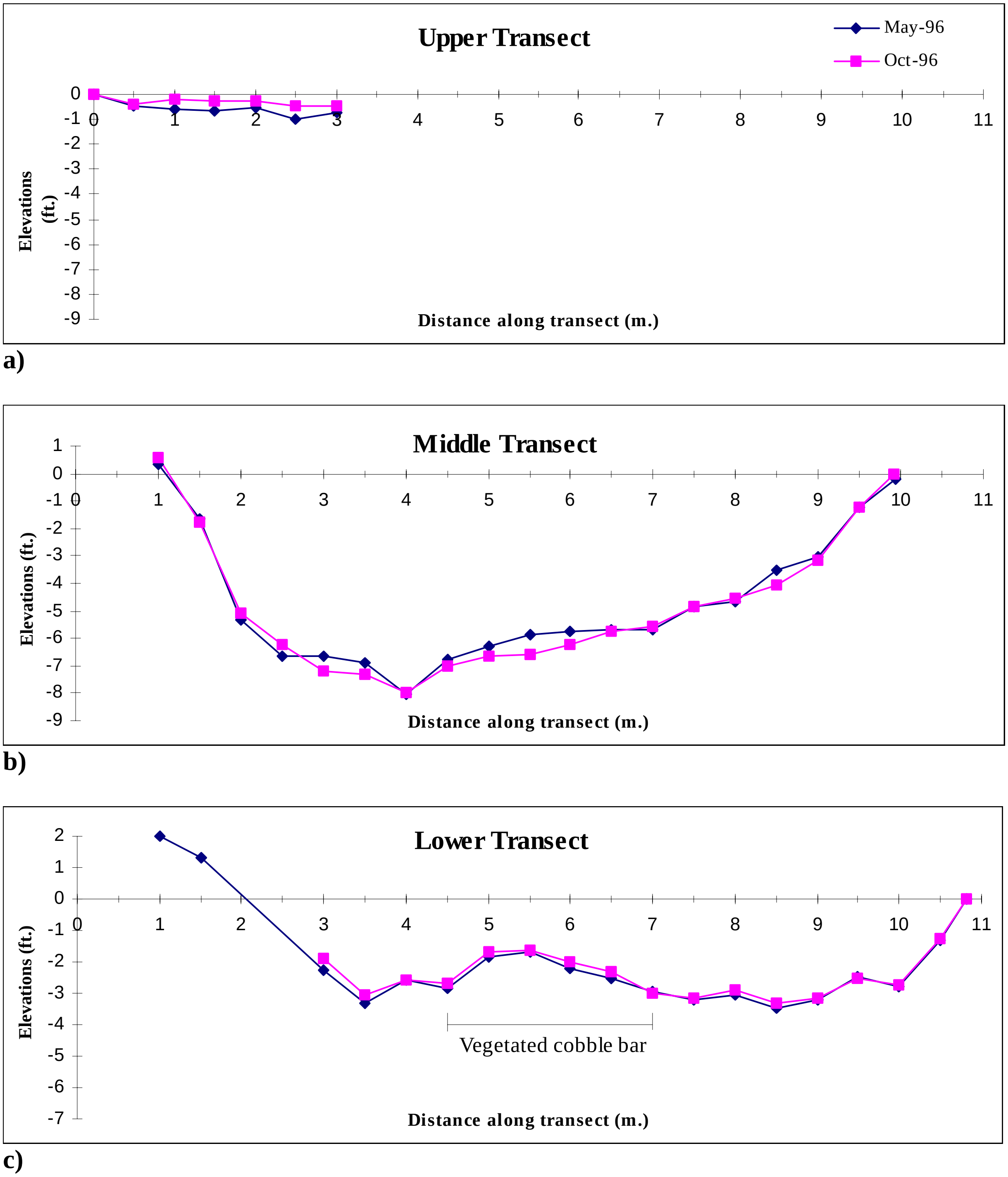


Figure 34. Fillmore Canyon 3 channel crossestions for 1996-97 [ER3 (OE07)]. The burned site is just above Fillmore Spring in the lower watershed

Figure. 35: Photo illustrates small aggregation in channel at the lower transect of Fillmore 3. *Oenothera organensis* is very abundant here, seen in the left and upper portions of the photo. Also notice the full range of texture sizes, indicative of Fillmore canyon. Photo by Vince Archer, Fall 1996.

Fillmore Canyon 4 -- Site at Fillmore Spring, ER4 (OE08)

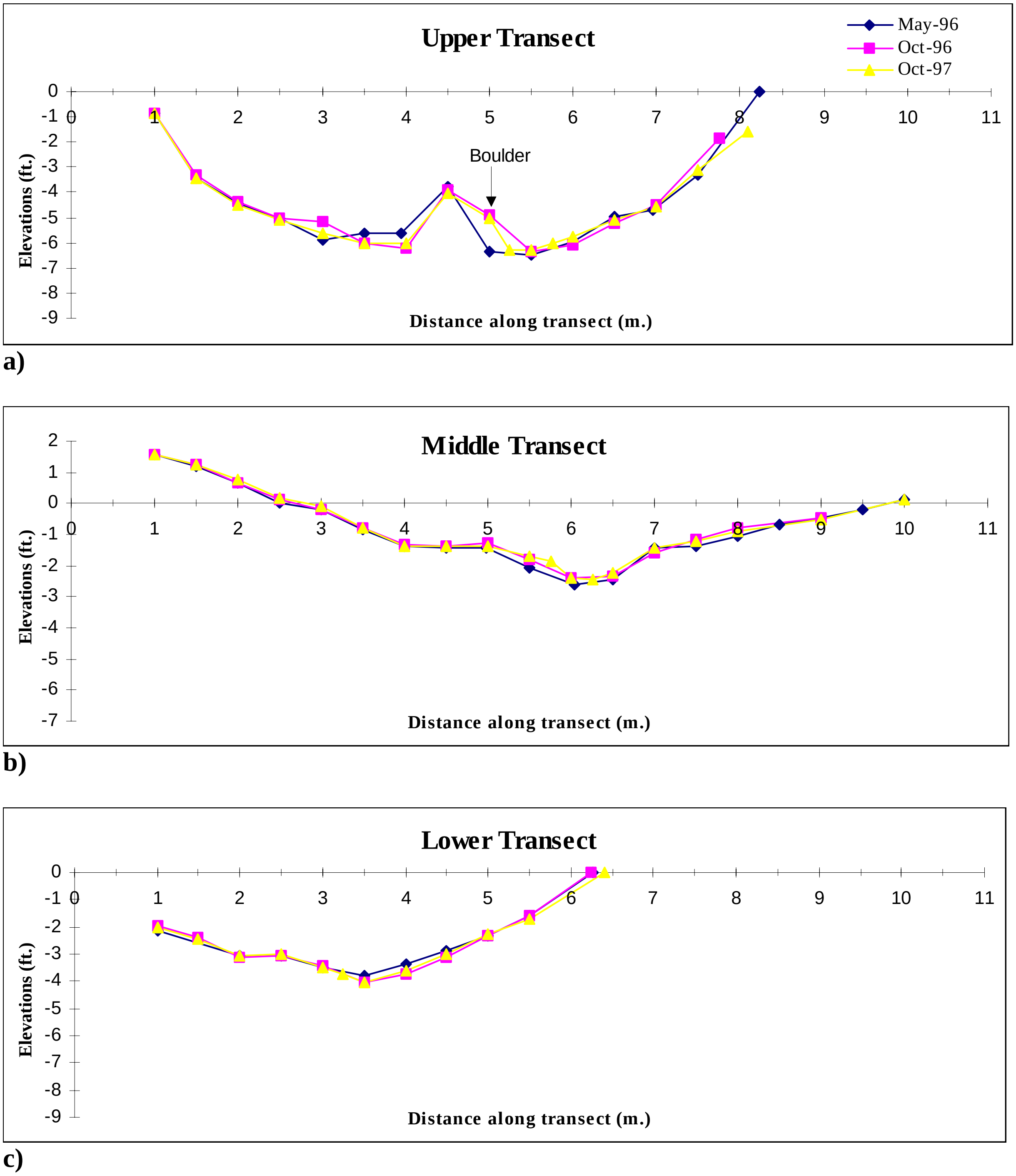


Figure 36. Fillmore Canyon 4 channel cross-sections for 1996-77 [ER4 (OE08)]. This burned site is located that Fillmore Spring and is lowest monitoring site in the watershed.

North Canyon 1 - Uppermost Site, ERUN1 (OE11)

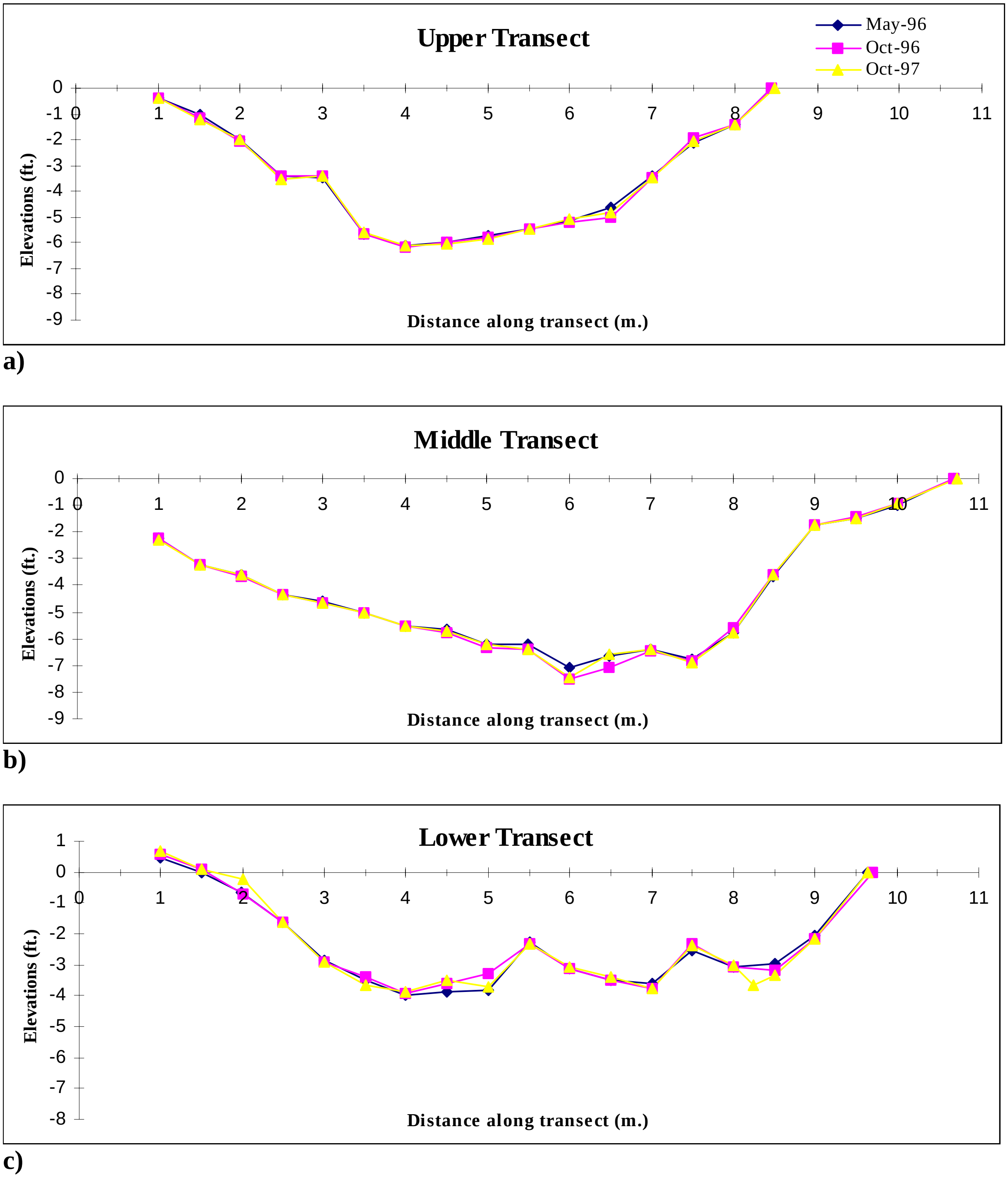


Figure 37. North Canyon 1 channel cross-sections for 1996-97 [ERUN1 (OE11)]. This is the uppermost site in North Canyon which was not been sinifcantly burned in 1994

Figure 38: High litter accumulation at North 2. Photo by Vince Archer, Fall 1996.

North Canyon 2 -- Second Highest Site, ERUN3 (OE13)

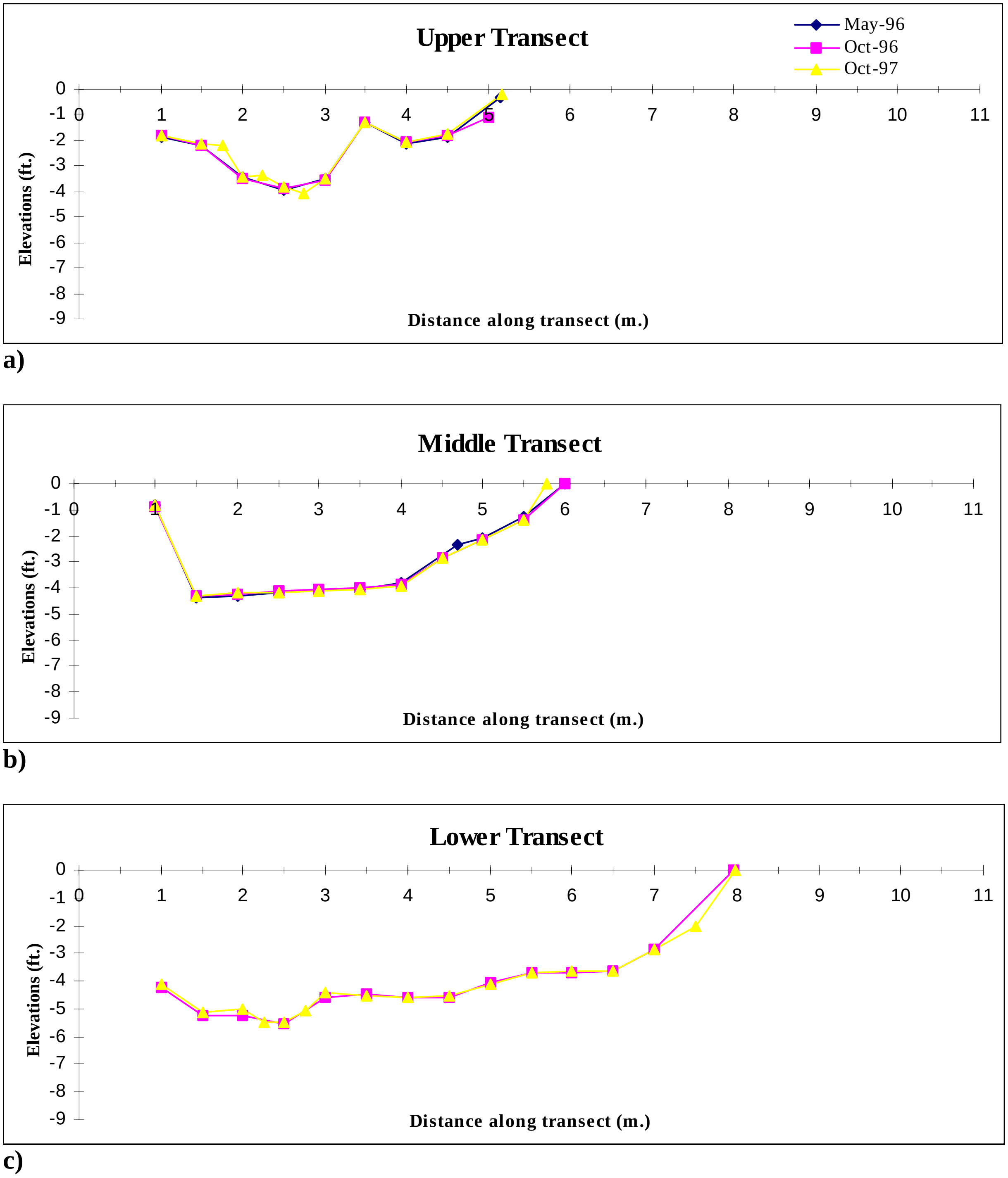


Figure 39. North Canyon 2 channel cross-sectiions for 1996-97 [ERUN03 (OE13)]. This unburned site is the second highest monitoring site in the North Canyon watershed.

North Canyon 3 [ERUN2 (OE15)]. This site is located 150 meters below North Canyon 2 in a relatively narrow portion of the channel with an exposed face of rhyolite bedrock on the west side of the drainage. This is the longest site at around 50 meters from the top transect to the bottom transect. Small exposed pools with minor drops make for small areas of gravel and soil amongst bedrock and boulder (Figure 29). This site has little tree canopy, but does support a small *Oernothera* population. There were few changes in substrate from 1996 through 1997. A small amount of gravel was deposited in the upper transect in 1996 (Figure 40a). In the other transects, fluctuations were due mostly to changing amounts of leaf litter rather than gravel (Figure 41 photo).

North Canyon 4 [ERUN4 (OE17)]. This site is located approximately one hundred meters below the major confluence of the west-fork of North Canyon and the main channel. It is also situated below a bedrock waterfall and supports a sparse population of *Oenothera*. Canopy cover is moderate and dominated by net-leaf hackberry, velvet ash and white oak. This site had more gravels than other sites in the canyon (*see* Figure 50), particularly in the upper transect (Figure 42a). Yet there was little or no change in the channel cross-sections from point to point, except for small accumulations and losses of litter here and there.

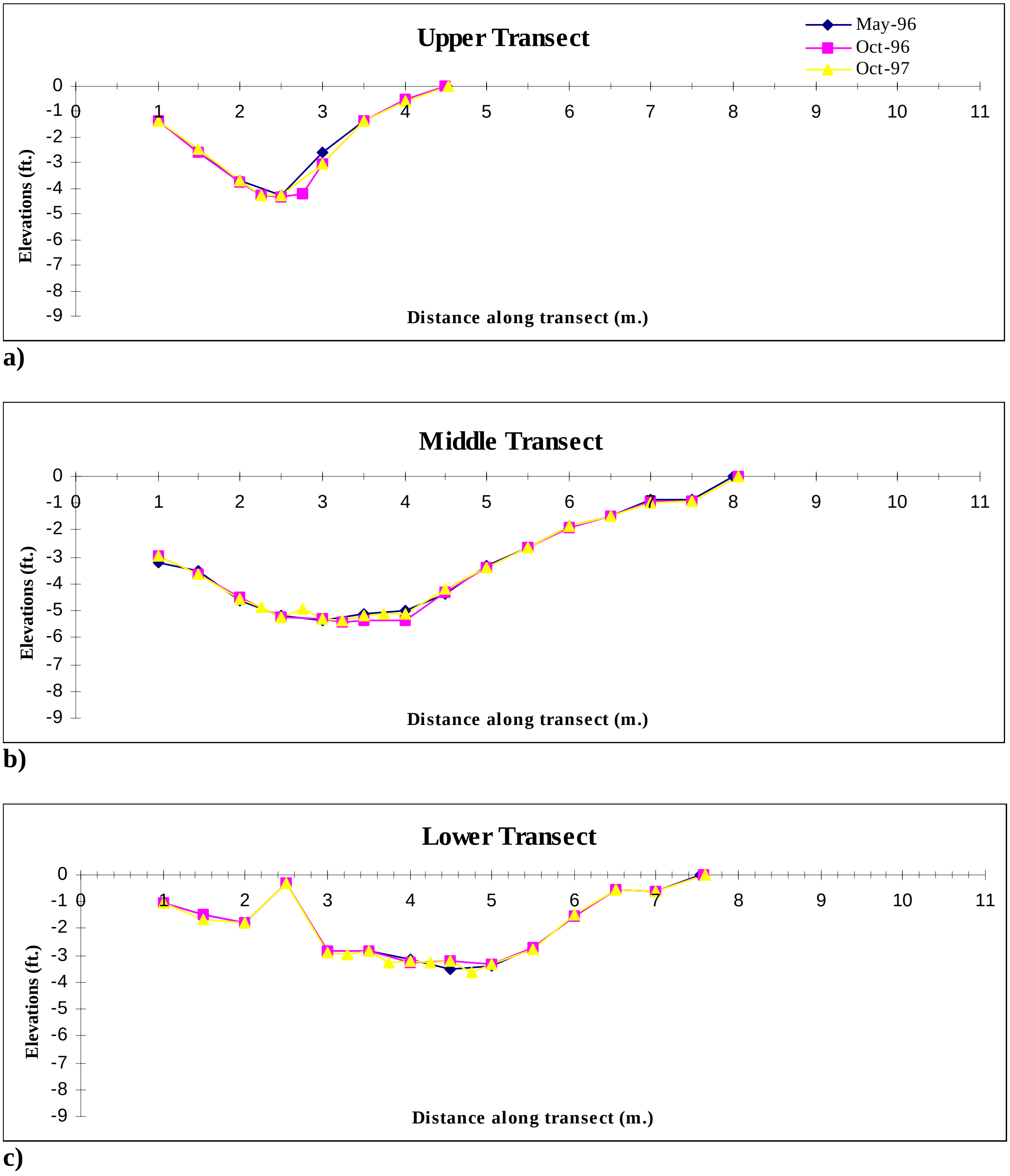
Channel Substrate Composition

On a landscape scale there are broad differences in surface substrate composition between the drainages that may reflect differences in burn treatment. Figures (43 -50) illustrate substrate composition at each site over a two year period averaged over all transects at the site. Substrate is broken down into texture classes and expressed as a percentage of total readings within the active channel. Litter was measured separately from sediment and is also expressed as a percentage of all readings within the active channel.

Fillmore Canyon has all sizes of sediment, from fines to boulder and bedrock (Figure 43-46), and there is always a significant fine sediments fraction (sands, silts and clays) at all sites. In contrast, North Canyon has little or no fine sediments in three out of the four sites, and on the whole there are larger amounts of rocks and boulders (Figure 47-50).

North Canyon sites tend to have larger litter accumulations than Fillmore suggesting that litter is more mobile in Fillmore due to increased flows. In both canyons there was commonly a reduction in litter in 1996, perhaps reflecting the greater rainfall and runoff. An increase in litter was seen in 1997 where there were few runoff events. Increased flows in Fillmore may be due to the size of the watershed, or possibly to upslope conditions as well.

North Canyon 3 -- Third Highest Site, ERUN2 (OE15)


Upper Transect

Middle Transect

Lower Transect

Figure 40. North Canyon 3 channel cross-sections for 1996-97 [ERUN2 (OE15)]. This unburned site occurs at mid-watershed.

Figure 41: Photo shows litter accumulation indicative of North Canyon at the upper transect of North 3. Photo by Vince Archer, Spring 1995.

North Canyon 4 – Lowest Site, ERUN4 (OE17)

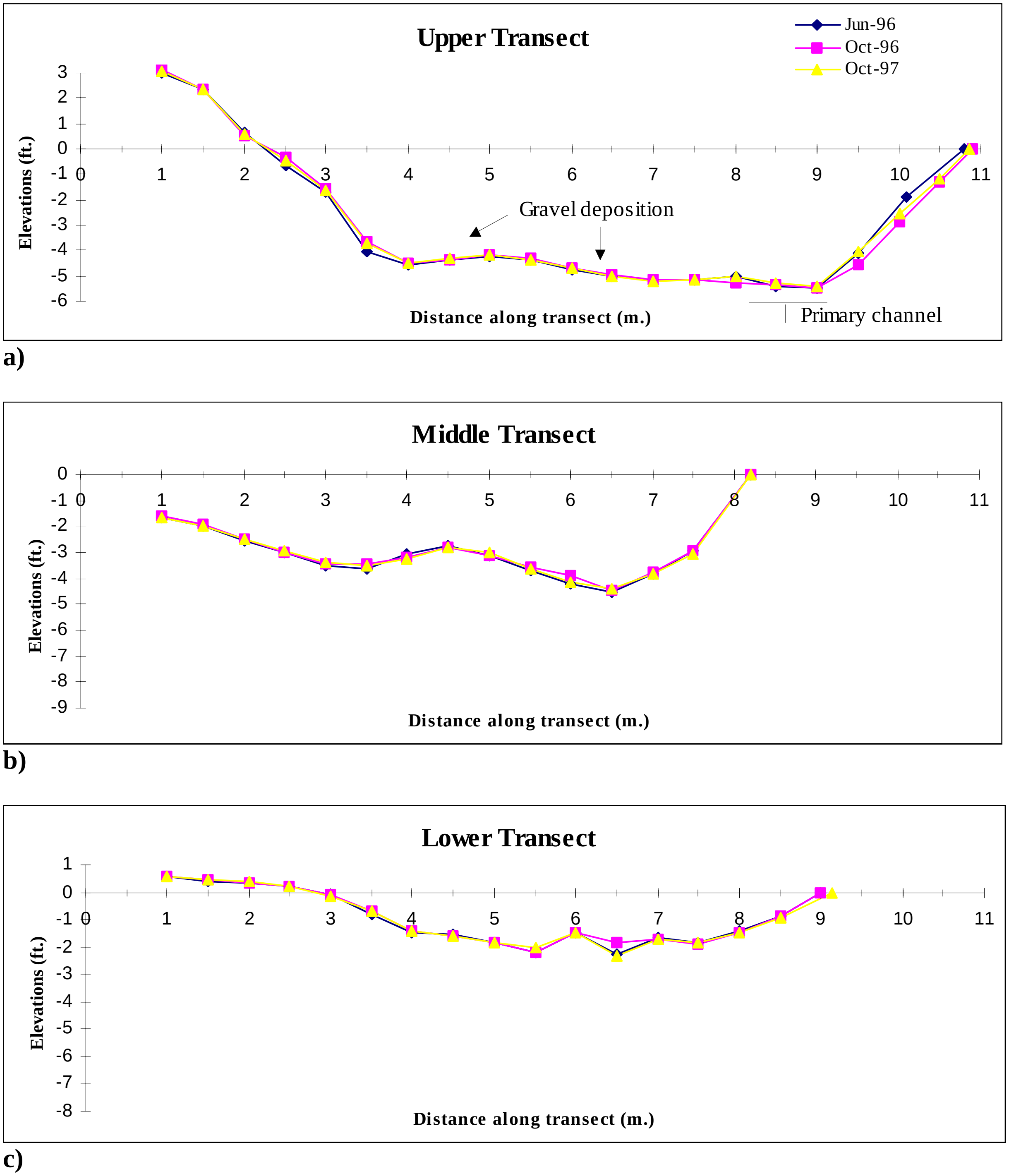


Figure 42. North Canyon 4 channel sediment cross-sections for 1996-97 [ERUN4 (OE17)]. This lowest unburned site in North Canyon.

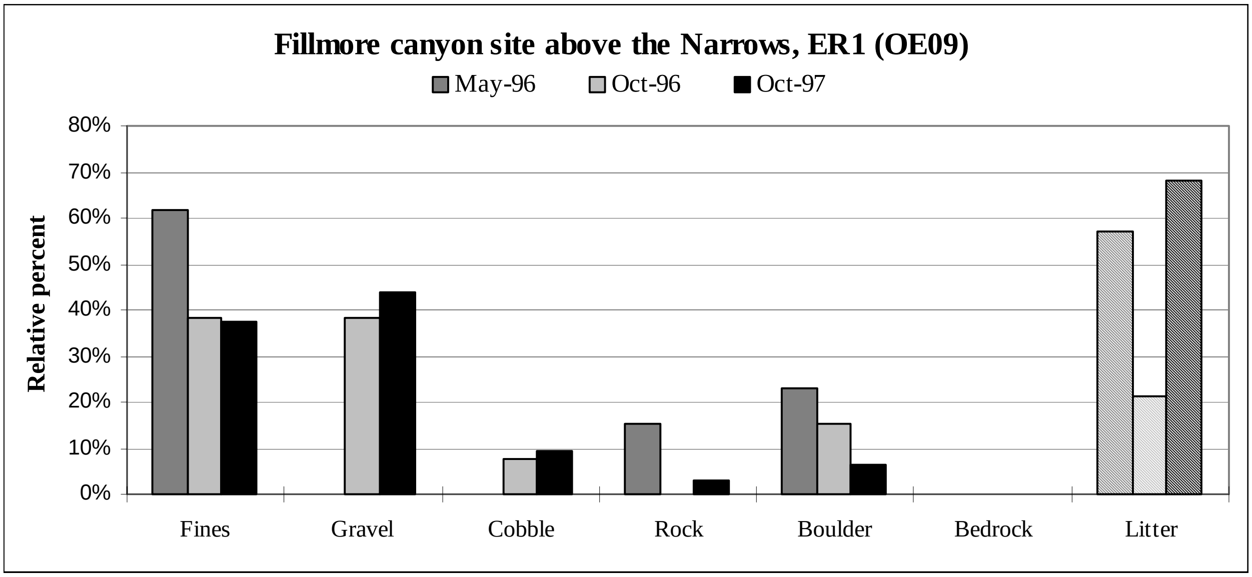


Figure 43. Surface substrate by size class and type per year for Filmore Canyon 1 site.

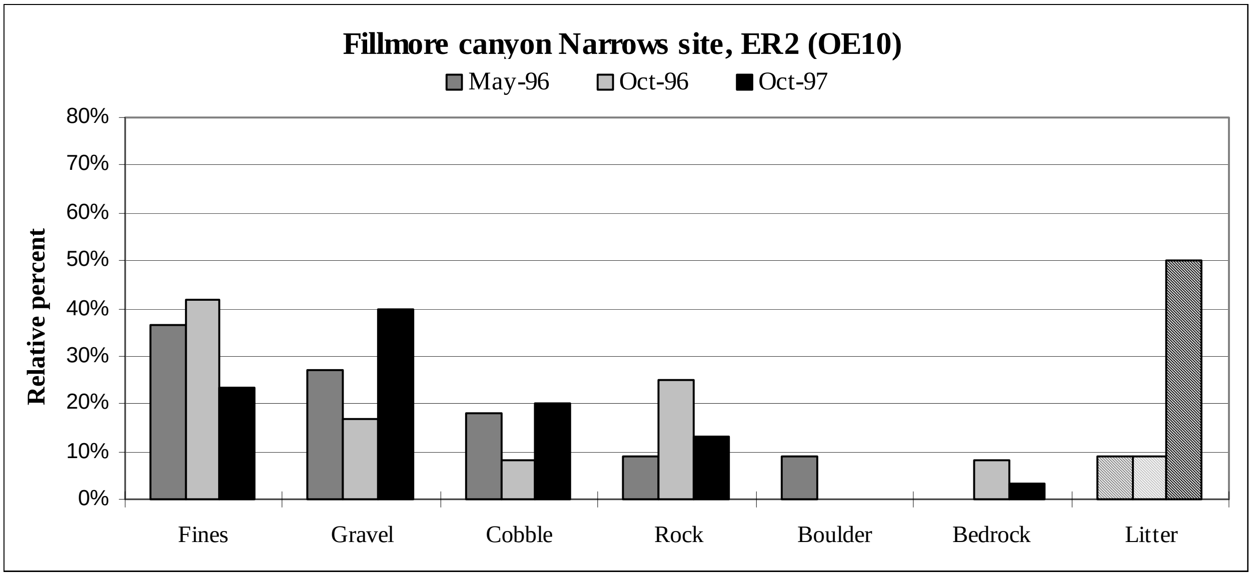


Figure 44. Surface substrate by size class and type per year for Filmore Canyon 2 site.

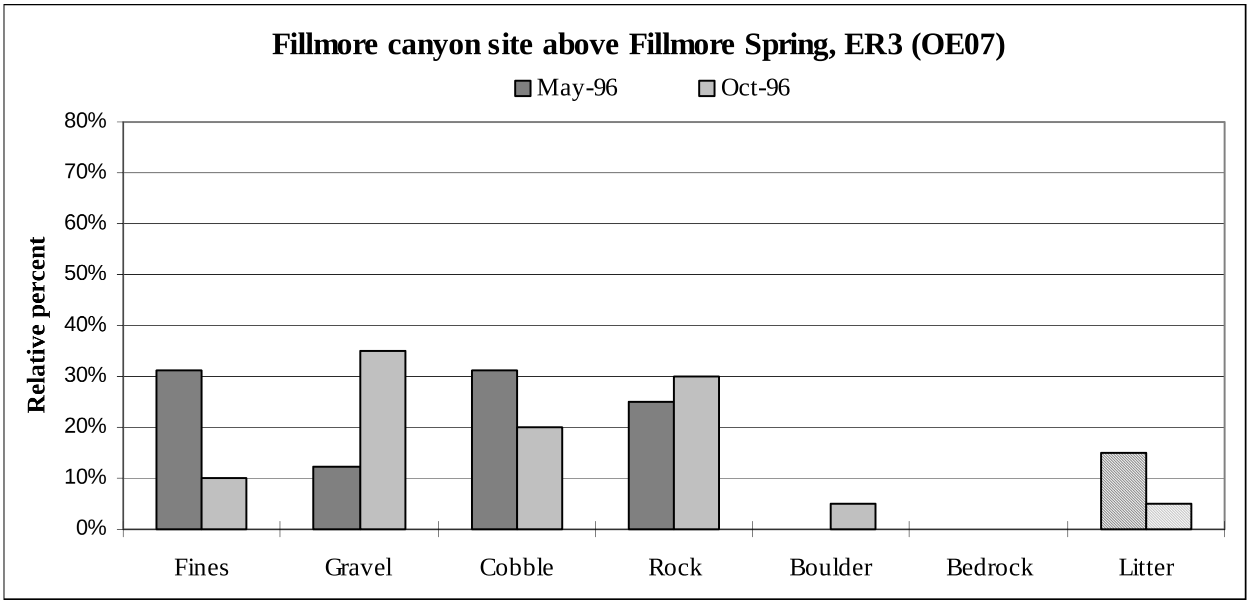


Figure 45. Surface substrate by size class and type per year for Filmore Canyon 3 site.

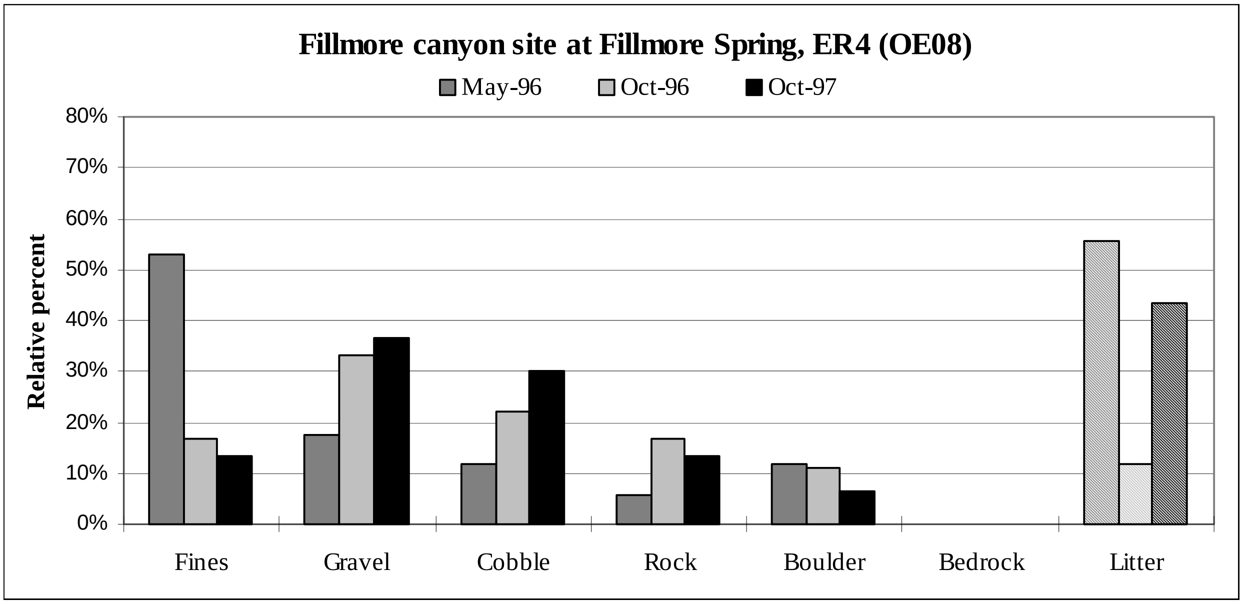


Figure 46. Surface substrate by size class and type per year for Filmore Canyon 4 site.

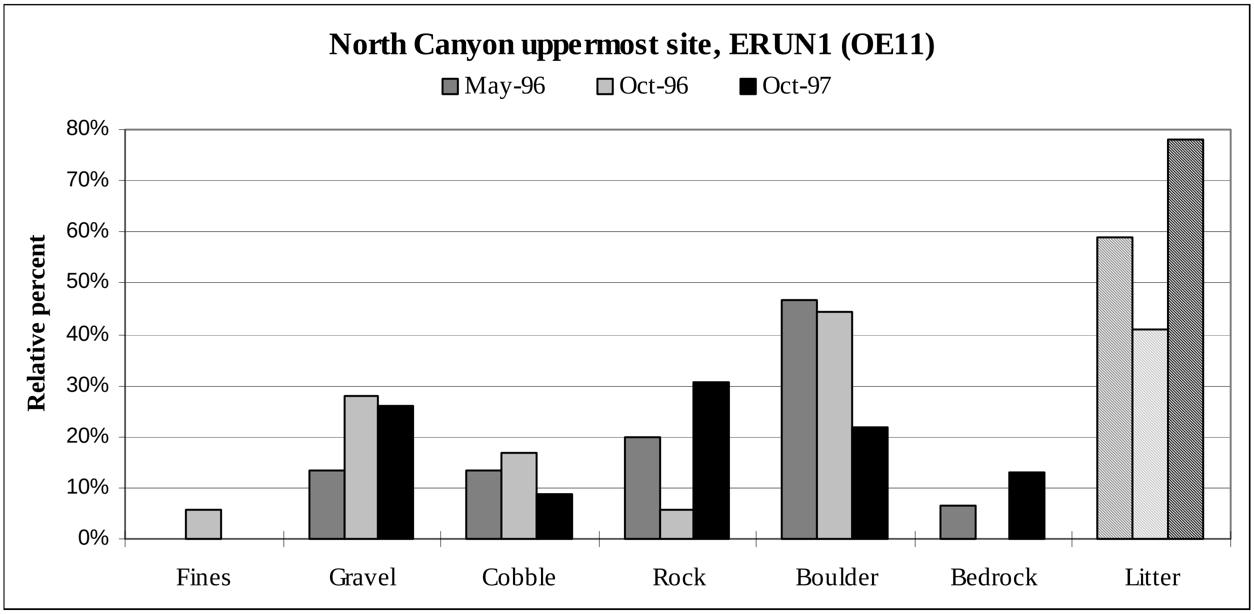


Figure 47. Surface substrate by size class and type per year for North Canyon 1 site.

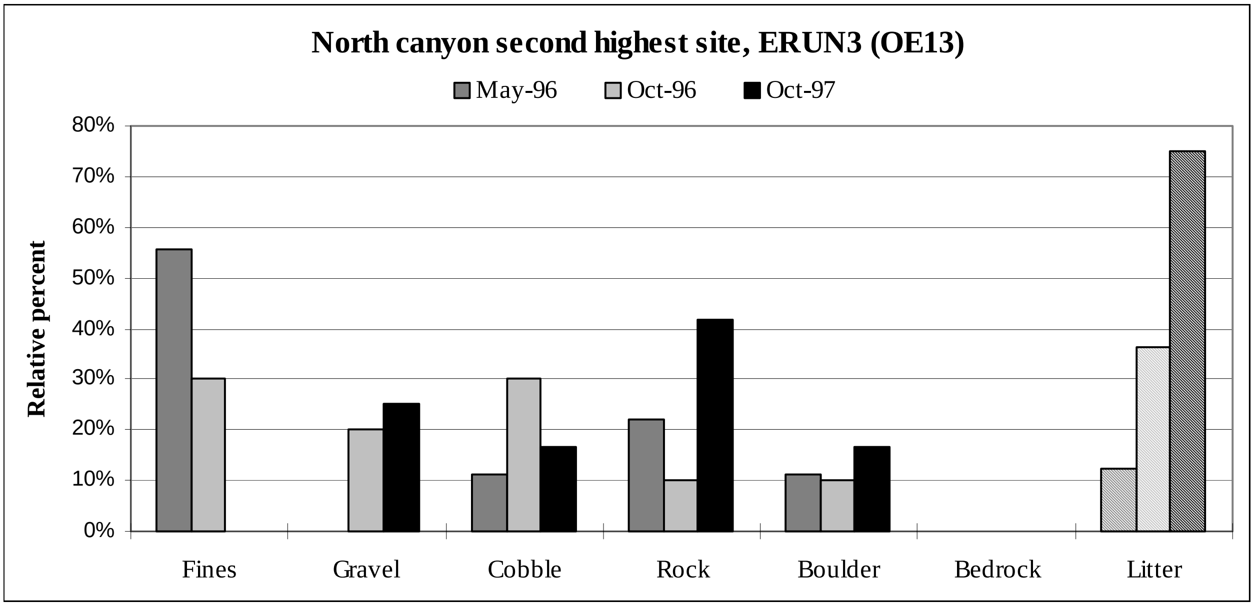


Figure 48. Surface substrate by size class and type per year for North Canyon 2 site.

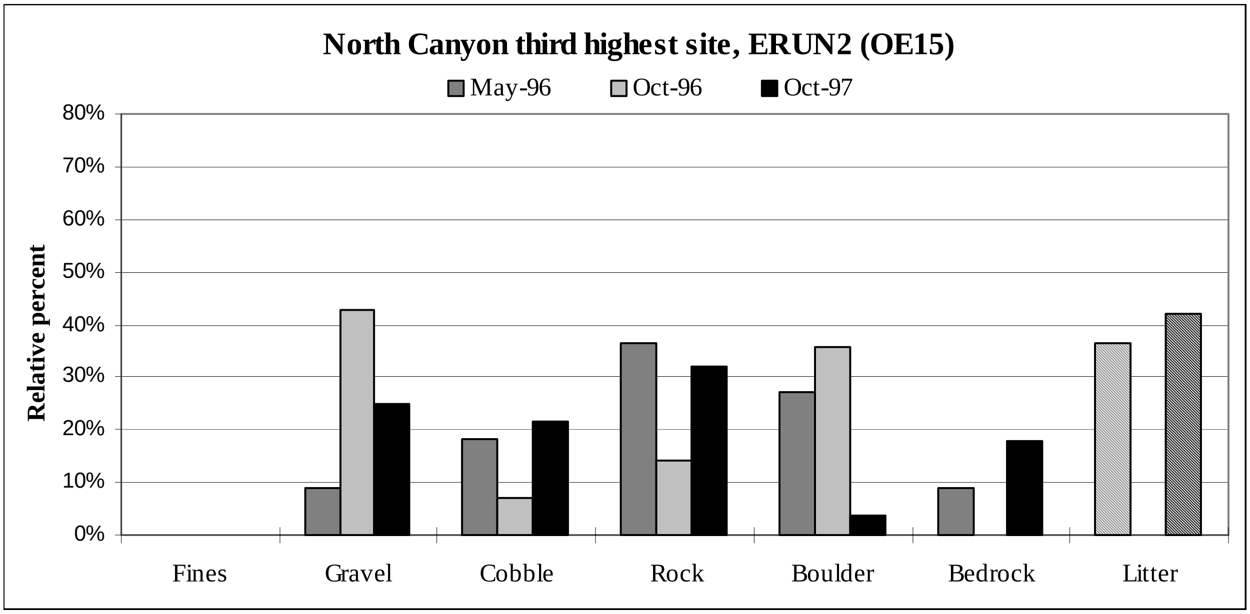


Figure 49. Surface substrate by size class and type per year for North Canyon 3 site.

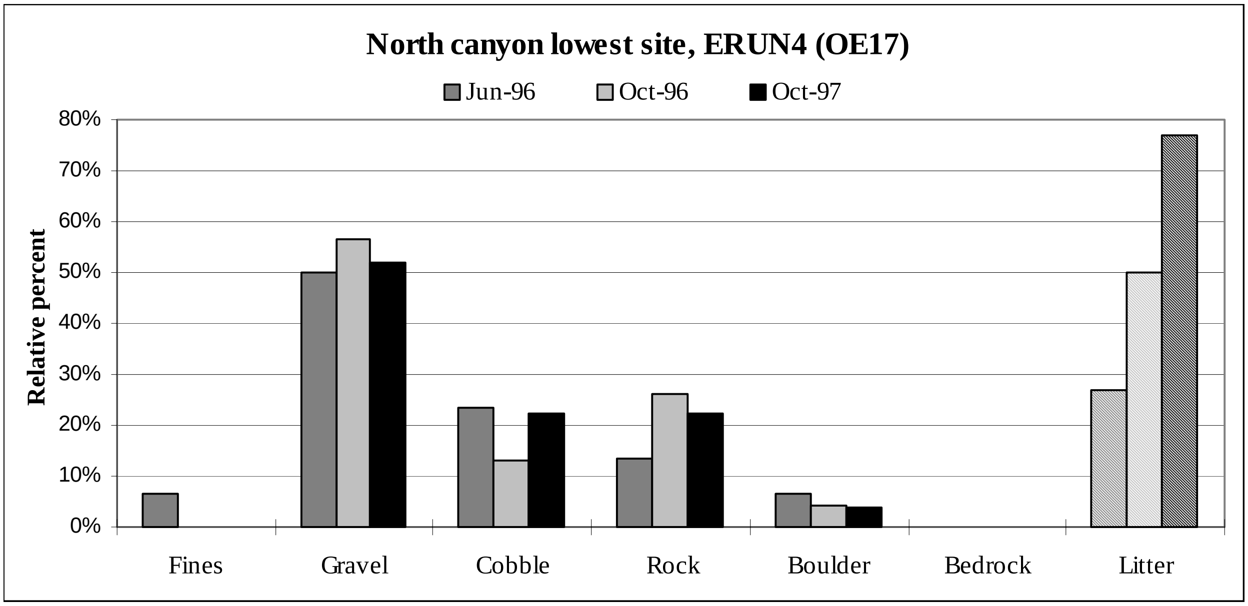


Figure 50. Surface substrate by size class and type per year for North Canyon 4 site.

Discussion

Based on the measurements presented here and from past observations we suggest that changes in channel sediment loads are just now beginning to become apparent in Fillmore Canyon, possibly the result of the fire de-stabilizing the slopes in 1994. It was visually apparent that sediment had moved into and just below the Fillmore Canyon 2 site at the Narrows by 1997. Sediment transport was also indicated by subtle changes in profile morphology in the upper sites of the canyon, although these were difficult to detect statistically given the short period of record and limited sampling points. In contrast, North canyon seemed unchanged over the sample period. The changes detected were predominately due to fluctuations in litter loads or and measuring errors on hard to read points.

With respect to litter, North Canyon has larger litter accumulations than Fillmore suggesting that litter is more mobile in Fillmore from increased flows. In both canyons there was commonly a reduction in litter in 1996, perhaps reflecting the greater rainfall and runoff. An increase in litter was seen in 1997 where there were few runoff events. Increased flows in Fillmore may be due to the size of the watershed, or possibly to upslope conditions as well.

The differences between the canyons are not easily attributed to geological or topographic characteristics. Geologic parent materials vary little; though there may be slightly more granitic rock in Fillmore. Fillmore is a more open and somewhat larger drainage with lower gradients to the streams, and this may contribute to the increased deposition of fines rather than having them wash out of the watershed. But North is not that much smaller nor do the gradients differ that much between canyons. Alternatively, the increase in fines in Fillmore may be related to upslope conditions of increased erosion on exposed burned slopes. The soils on the burned slopes in the first and second year after the 1994 fire were very unstable with little or no perennial vegetation holding the surface in place during those first years (personal observation, E. Muldavin). The fact that mostly litter accumulates in North rather than fine sediments suggest that the sediment source on the un-burned slopes is considerably more stable.

In Fillmore, vegetation is becoming re-established on the slopes which may buffer further soil loss. What we may be viewing is a pulse of sediment from the fire that is gradually moving through the channels of Fillmore. A longer period of record and increased sampling density will be required to reach more definitive conclusions and to relate those conditions to the status of *Oenothera organensis.*

References

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