Pioneer plant communities five years after the 1988 Yellowstone fires

by Robert J Ament

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Biological Sciences
Montana State University

Abstract:
The Yellowstone fires of 1988 burned many different types of vegetation. This initiated secondary succession in environments from valley bottoms to alpine tundra. Five years after fire, plant communities were measured. Species presence was recorded in 100 m^2 macroplots and cover was sampled in twenty 1000 cm^2 quadrats. Pioneer community composition after severe fire in late-seral vegetation was compared across the elevational gradient in nine environmental types with three replications in each. In two of the subalpine fir environments, communities arising from four different pre-fire serai stages were sampled to test the hypothesis that pioneer community compostion differs when early-seral versus late-seral forests burn in one environmental type.

Plant cover tends to decrease with increasing elevation. Along the elevational gradient, the wet grasslands had the strongest recovery from fire (plant cover averaged 97%), while the lowest cover was in the subalpine zone near treeline (39% average cover). Species richness was between 32 and 42 species per 0.01 hectare in the seven lowest environmental types. Diversity in the two highest elevational environmental types was distinctly low (19 and 20 species/0.01 hectare, respectively). Forty-two of the 262 species identified occurred in nearly all environments. Many of the others were concentrated in various portions of the gradient (i.e. grasslands, montane forests, subalpine fir forests). Each species and its distribution was tabulated.

To test the hypothesis that pioneer communties were influenced by previous vegetation, ordinations (principal component analysis and principal coordinate analysis) were conducted on postfire communities representing four pre-fire serai stages. Neither method indicated communities arising from any pre-fire serai stages were distinct from any others. Chi-square goodness-of-fit to random distribution and Monte Carlo randomizations of individual species in these environmental types identified only three species that were significantly non-randomly distributed among postfire communities from pre-fire serai stages. All three were more strongly represented in pioneer communities from early prefire serai stages. Eighteen species in each environmental type possibly had non-random distributions (P=0.06 to 0.15) indicating they may deserve further study.

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APPROVAL

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Robert John Ament

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Date May 25, 1995

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TABLE OF CONTENTS

TABLE OF CONTENTS--Continued

TABLE OF CONTENTS--Continued

LIST OF TABLES

LIST OF TABLES--Continued

LIST OF TABLES--Continued

LIST OF TABLES--Continued

LIST OF FIGURES

ABSTRACT

The Yellowstone fires of 1988 burned many different types of vegetation. This initiated secondary succession in environments from valley bottoms to alpine tundra. Five years after fire, plant communities were measured. Species presence was recorded in 100 m^2 macroplots and cover was sampled in twenty 1000 cm^2 quadrats. Pioneer community composition after severe fire in late-seral vegetation was compared across the elevational gradient in nine environmental types with three replications in each. In two of the subalpine fir environments, communities arising from four different pre-fire seral stages were sampled to test the hypothesis that pioneer community compostion differs when early-seral versus late-seral forests burn in one environmental type.

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To test the hypothesis that pioneer communties were influenced by previous vegetation, ordinations (principal component analysis and principal coordinate analysis) were conducted on postfire communities representing four pre-fire seral stages. Neither method indicated communities arising from any pre-fire seral stages were distinct from any others. Chi-square goodness-of-fit to random distribution and Monte Carlo randomizations of individual species in these environmental types identified only three species that were significantly non-randomly distributed among postfire communities from pre-fire seral stages. All three were more strongly represented in pioneer communities from early pre-fire seral stages. Eighteen species in each environmental type possibly had non-random distributions (P=0.06 to 0.15) indicating they may deserve further study.

GENERAL INTRODUCTION

The Yellowstone fires of 1988 burned all types of vegetation. Thus, secondary succession was initiated in numerous environments.

Five years after the fires, in the summer of 1993, this study was conducted to describe early pioneer communities appearing after severe fire in climax vegetation of nine environmental types. Seed banks of most of the study sites had been examined by Clark (1991). These sites and nine more were visited to acquire three replicate pioneer communities in each of nine major environmental types of the northern Rocky Mountains.

The pioneer communities of the nine environmental types have never been described and compared. These environments represent relative positions along the elevational gradient so that direct gradient analyses of pioneer communities can be performed. This approach also allows examination of species distribution patterns on the elevational gradient.

In comparing pioneer communities following severe fire in late-seral vegetation of different environments, it was also possible to test whether pioneer communities would differ if early-seral vegetation in these environments had burned. Thus, in Part II, in two environmental types, the effects of the pre-fire vegetation (different seral stages) on postfire community composition appearing five years after severe fire was examined. This hypothesis was tested on both integrated communities (via ordination) and on individual species. The distribution of individual species in pioneer communities on a gradient of pre-fire seral stage was assessed with three different statistical tests.

PART I

PIONEER COMMUNITIES FIVE YEARS AFTER FIRE IN NINE ENVIRONMENTAL TYPES ALONG THE ELEVATIONAL GRADIENT

INTRODUCTION

Yellowstone Fires.

In the summer and fall of 1988 Yellowstone National Park and adjoining lands, both public and private, experienced the most extensive wildfires of the century. In three months, a series of fires burned 276,533 hectares (683,305 acres) of forests and grasslands (Rothermal and others 1994). The fires were started by both lightning and human ignitions. The northern Rocky Mountains (NRM) had not experienced a combination of fires of this size and extent since 1910 when over 1,200,000 hectares (3,000,000 acres) of the forests in Montana and Idaho burned (Pyne 1982).

The burning in Yellowstone was the most significant ecological event that a National Park has experienced (Scullery 1989). The fires also burned large parts of the surrounding National Forests [Bridger-Teton, Gallatin, Shoshone and Targhee], as well as lands under other ownership.

The fires left a landscape comprising grasslands, shrublands, forests and alpine tundra effected to varying degrees by fire. The result was a mosaic of burn intensities and patch sizes reaching from valley bottoms to the alpine ridges. The heterogeneity of the burn was superimposed over a pre-fire landscape that contained vegetation of different environmental zones each occupied by vegetation of different ages (Knight and Wallace 1989).

The scope of the fires should not have been an unexpected occurrence in the temporal scale of centuries (Whitlock and others 1994). In the late 1600s and early 1700s several equally large fire events had burned extensive areas in Yellowstone National Park's high volcanic plateaus (Romme 1982). Intervals between stand-replacing fires are often three hundred years in these subalpine fir forests. At lower elevations, where the shrub-steppe is interspersed with coniferous forest, eight to ten large fires burned previous to the twentieth century (Houston 1973). The average fire interval for the lower elevation northern range is twenty to twenty-five years. Thus, studies of the two different environments in YNP, subalpine forests and shrub-steppe, indicates that although they have different fire regimes, the Greater Yellowstone Ecosystem (GYE) has a history of extensive fires that predates settlement, fire management strategies and suppression.

Fire size events are described logarithmically with time (Pyne 1982). That is, large events are infrequent, medium-sized ones more common, and smaller fires are much more numerous. Thus, while the 1988 fires' size was a rare ecological occurrence in recent time, burns of a smaller dimension are a common component of the disturbance regime in plant communities of the Greater Yellowstone Ecosystem and the NRM. The many fires of 1988, were of varying intensities, in all types of plant communities on the environmental gradient, and established a landscape-level disturbance pattern typical of the northern Rocky Mountains.

Objectives

The Yellowstone fires of 1988 created an unusual opportunity to describe and compare postfire pioneer communities that established themselves concurrently in many different environments. Vegetation dominated by sagebrush, Douglas fir forests, aspen groves, mountain meadows, subalpine fir forests, and alpine tundra were burned.

The objective was to locate stands (with three replications) burned at maturity (near-climax) in major environments (nine habitat types) representing the altitudinal gradient. Resultant information will be useful in predicting early postfire succession after future fires on sites in these environments.

To make the study finite, sites were selected from those where the pre-fire vegetation was near-climax and all were severely burned.

Since this study is to describe pioneer communities of major elevational zones an environmental classification system was used to characterize the study sites. The only ecological classification widely employed in the NRM (Daubenmire 1952, Steele and others 1983, Mueggler and Stewart 1980) was used for this study. The units of this classification are environmental types (habitat types) and they are descriptors of the environment--not of the vegetation. This report will use the term -- "environmental type" -- synonymously with habitat type (HT).

Environmental Classification

The environmental type (habitat type) is the basic unit for classifying and identifying land potential (Daubenmire 1966). Thus, it can be used both to distinguish sites with different environmental conditions and to extrapolate observations from such sites to a larger geographic setting. It would be expected that the composition of a pioneer community appearing after stand-replacing fire, in any specified NRM habitat type, will approximate corresponding units of the environmental type observed in Yellowstone after the 1988 fires. This expectation is based on the assumption that similar environmental and historical constraints are operative on all units of a habitat type.

In the United States, the habitat type system of environmental classification was developed in eastern Washington and northern Idaho (Daubenmire 1952). It was extended to the forests of Montana (Pfister and others 1977), the forests of eastern Idaho and western Wyoming

(Steele and others 1983) and the grasslands/shrublands of Montana (Mueggler and Stewart 1980). Most of the riparian areas of Montana have been added to this system (Hansen and others 1995). The vegetation of Yellowstone National Park has been described with this environmental classification (Despain 1990).

While acknowledging some variability between sites this system of classification nonetheless regards all units of an environmental type to be comparable across the landscape. Thus, units with a similar environment, regardless of the present successional status, are all categorized as the same habitat type.

The environmental type of a land unit is identified by recording the climax vegetation that occupies the site. If the vegetation is not at climax, then the vegetation that would occur at climax is deduced and recorded. On the burned sites of this study, potential was identified by examination of adjacent unburned vegetation, unburned material left within the sample stand, and vegetation maps of Yellowstone National Park (Despain and others, unpubl.)

This classification of vegetation appears to conflict with the continuum theory (Curtis and MacIntosh 1951, Gleason 1962, Whittaker 1960, Goodall 1963) of plant community change across the landscape. Observation that vegetation sometimes varies continuously over the landscape has prompted many to doubt that plant communities comprise distinct, coevolved plant populations. Classification is useful for studies like this and for explanations of the results whether or not there is a belief in discontinuites in vegetation composition.

This study uses the environmental type of classification with the knowledge that the scheme may divide a continuum into arbitrary, somewhat variable units. This choice was to maximize the extrapolation of our observations. In defense of the habitat type classification method, it was stated, "while this debate may be of interest academically, it need not preoccupy the natural resource managers and field biologists who need a logical, ecologically-based classification with which to work" (Pfister and others 1977). It is due to the efficacy of the habitat type that this study utilizes this classification system as the basis of describing early postfire pioneer communties in various environments in the Greater Yellowstone Ecosystem.

In defense of discontinuities that would sometimes support discrete typal communities, Daubenmire demonstrated the use of his data could also support a continuum theory. He showed that the methodology and interpretation of continuum theory adherents are biased against observation of coevolved units (Daubenmire 1966). Further contrasts of continuum and classification theory are summarized by continuum adherents (MacIntosh 1967, Whittaker 1967), a proponent (Dansereau 1968), and an integrator (Allen and Hoekstra 1992). The latter note that viewpoints affect the conclusions drawn; while continuum advocates use the individual species as their point of departure, advocates of distinct units consider the ecosystem from the spatial scale of the landscape.

Pioneer Communities of NRM Habitat Types

Most vegetation classifications are based on undisturbed, mature plant communities. Early seral communities appearing in major environmental types (habitat types) have rarely been described. The few environments that have been investigated in the northern Rocky Mountains are pioneer communities of forested types in western Montana and northern Idaho. Most of these studies have been on lands disturbed by management activities either directly or on adjacent sites. A compilation by habitat type of postfire pioneer communities in coniferous forests that have been described in the NRM is listed in Table 1.

In another forest type, after a prescribed fire south of Yellowstone NP, on the Bridger-Teton National Forest, a three year study of aspen community response to moderate and high intensity burning was conducted (Bartos and Mueggler 1981). This was described before aspen communities had been classified (Mueggler 1988) for the intermountain western United States.

Table 1. Northern Rocky Mountain coniferous forest postfire pioneer community studies by habitat type.

Habitat type	Primary[1] Investigator	
Abies lasiocarpa/Xerophyllum tenax	Lyon	1976
" " " "	Lyon	1984
" " " "	Arno*	1985
Abies lasiocarpa/Menziesia ferruginea	Arno*	1985
Abies lasiocarpa/Linnaea borealis	Crane*	1983
Pseudotsuga menziesii/Vaccinium globulare	Arno*	1985
Pseudotsuga menziesii/Physocarpus malvaceus	Arno*	1985
" " " "	Crane*	1983
Pseudotsuga menziesii/Vaccinium globulare	Crane*	1983
Tsuga heterophylla/Pachistima myrsinites	Stickney	1986

[1] Other authors contributed to studies marked with an asterisk(*) (Arno and others 1985, Crane and others 1983).

There have been several reports of grassland and shrubland pioneer communities after fire; but, these studies did not use habitat types to characterize study site environments. An ungrazed grassland dominated by Rough fescue, *Festuca scabrella* was found to quickly return to pre-burn composition within three years in western Montana (Antos and others 1980). Three sagebrush studies west and south of the GYE were in sagebrush, *Artemisia tridentata*, dominated stands (Harniss and Murray 1973, Humphrey 1984, and Akinsoji 1988). The long-term study in the Snake River plain (Harniss and Murray 1973) recorded vegetative transformation for thirty years.

This study describes pioneer communities in nine different habitat types of grassland, shrubland, and forest after severe fire. The habitat types considered do not overlap the environments of previous studies. All of the sites were located in a landscape unaffected by multiple-use management both before and after the fires.

METHODS

Study Area

This study was conducted in Yellowstone National Park and should reasonably represent major environmental types of the Greater Yellowstone Ecosystem (GYE) and the northern Rocky Mountains. The GYE is a mountainous area surrounding Yellowstone National Park (Figure 1). It straddles the continental divide and is mid-way between the equator and the north pole; the 45th degree northern latitude runs through it from east to west. It includes Yellowstone National Park, six adjacent National Forests, two National Wildlife Refuges as well as other public and private land holdings. Grand Teton National Park is included in the southern portion of the ecosystem. There is a complexity of land ownership and its changing environmental character make definition of exact boundries for the GYE difficult (Glick and others 1991). The land base is approximately 17 million acres (7 million hectares) and includes portions of the states of Idaho, Montana, and Wyoming.

The climate of the area is characterized by long, cold winters and short, cool summers. The temperatures are typical of a cool, dry continental climate and vary with elevation (Weaver 1980, Despain 1990). Most of the area receives between thirty and fifty inches of annual precipitation depending on the elevation (Despain 1990). Lower elevations in the northwest corner of Yellowstone National Park receive only 10 to 12 inches (25 to 31 cm.). Higher elevations receive well over 70 inches (178 cm.) of precipitation annually (Glick and others 1991). The climates along the elevation gradient have been described for the northern Rocky Mountains for each vegetation type (Weaver 1980). Elevations in the region vary from 1300 meters in the river valleys to over 4,000 meters near the summits in several of the ranges.

Despain (1990) describes the geology of the Yellowstone area. Five separate blocks of sedimentary and granitic formations were uplifted during the Laramide orogeny: the Beartooth, Targhee, Gallatin, Washakie, and Teton uplifts. During the Eocene, volcanic activity extruded andesite and basalt. Later, in the Pliocene, more faulting and uplift occurred. In the more recent Quartenary, a violent explosion generated a large caldera which contains the present Yellowstone Lake, destroyed portions of Mount Washburn and adjacent mountain ranges. It spread rhyolitic tuff and flows over most of the area. Glacial activity in the Pleistocene left kettle and kame topography, moraines, glacial till, and erratics in the valley bottoms.

Soils vary and depend on parent materials, climate, and associated vegetation. Forest soils are commonly alfisols or inceptisols with shallow, rocky profiles (Trettin 1986).

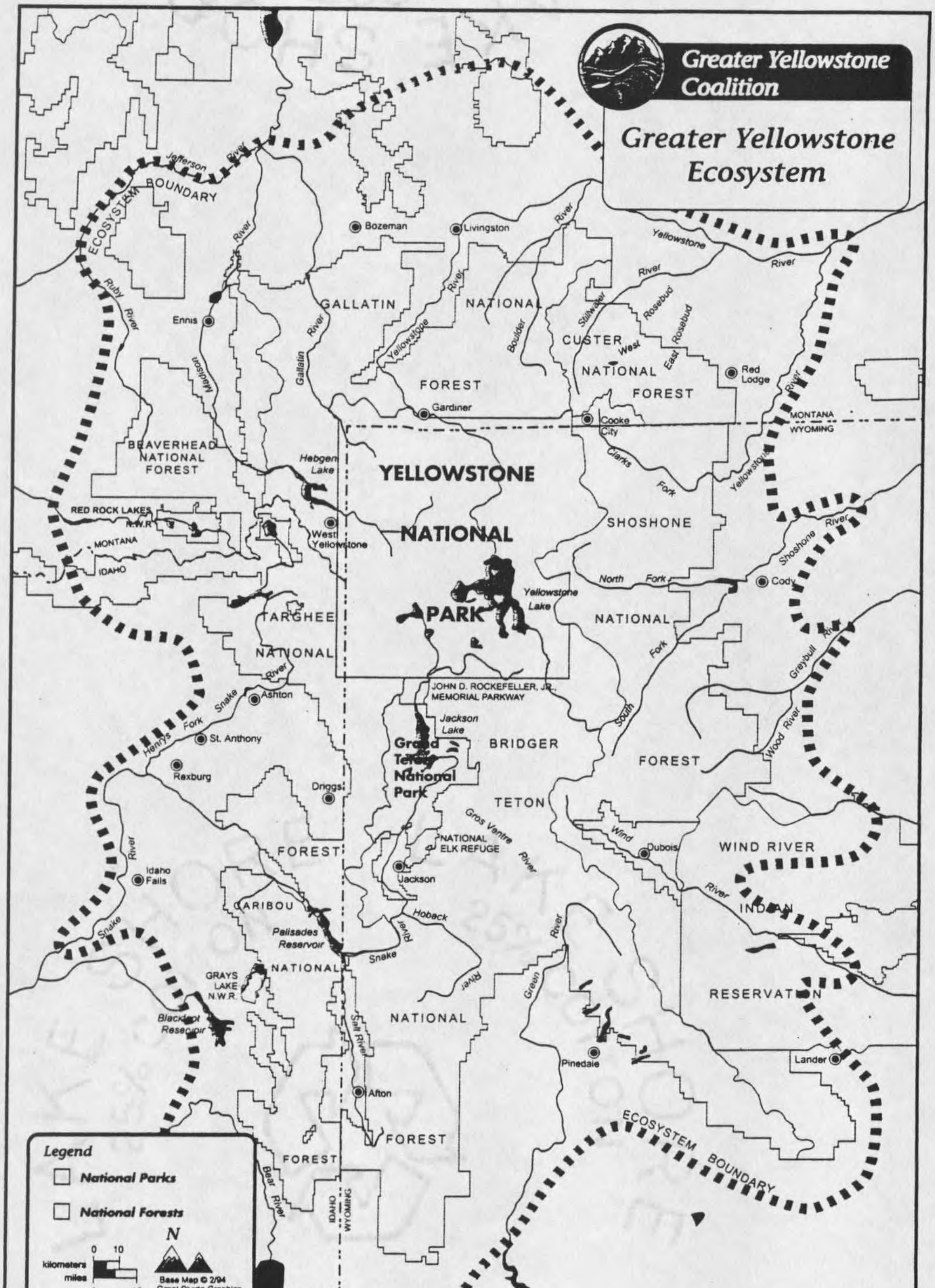

Figure 1. The Greater Yellowstone Ecosystem (courtesy of the Greater Yellowstone Coalition).

Grasslands and shrublands occur primarily on mollisols (Munn and others 1978) in the NRM. These are derived mostly from alluvium and are typically well drained. In the higher valleys and mountain meadows mollisols commonly form on fine-grained alluvium and heavy soils derived from shales and andesitic volcanics (Despain 1990). Predominant parent materials of the soils in the Yellowstone area are andesite and rhyolite (Despain 1990). These two underlying bedrocks arose from separate volcanic events in the tertiary and quartenary, respectively.

Key characteristics of soils; such as carbon/nitrogen ratios, nitrogen concentrations, pH, cation exchange capacity and phosphorous availability change in a predictable manner as one moves from dry, low elevation grasslands up through the forested zone to the alpine in the northern Rockies Mountains (Weaver 1979). Like the vegetational gradient, the soil gradient reflects changes in abiotic and biotic processes with differences in climate.

Study Site Selection

To characterize pioneer communities of each of the vegetational zones three sample stands were located in each of nine habitat types which were severely burned in 1988. The location of the sites sampled are listed in Table 2 and displayed in Figure 2. Each site's environmental type is listed in Table 3.

Table 2. Sample stand codes, names, legal descriptions (Universal Transverse Mercator - Zone 12), elevations and relative fertility.

Stand Code	Site Name	UTM Coordinates	Elevation (meters)	Soils[1]
A1	Crystal Bench	49730 N, 5532 E	1920	A
A2	Lamar	49672 N, 5619 E	2067	A
A3	Canyon West	49521 N, 5619 E	2621	A
B1	Bunsen	49765 N, 5243 E	2164	A
B2	Waterplant	49774 N, 5231 E	2042	A
B3	Blacktail	49743 N, 5416 E	2195	A
C1	Terrace	49787 N, 5213 E	2269	A
C2	Floating Island	49762 N, 5433 E	2044	A
C3	Wraith	49761 N, 5299 E	2072	R
D1	Bunsen	49746 N, 5244 E	2134	A
D2	Lamar	49673 N, 5657 E	2127	A
D3	Waterplant West	49776 N, 5230 E	2059	A
E1	Lamar	49689 N, 5618 E	2012	A
E2	Frog Rock	49780 N, 5342 E	2114	A
E3	Washburn	49660 N, 5450 E	2438	A
F1	Indian Creek	49683 N, 5174 E	2316	A
F2	Heart Junction	48966 N, 5385 E	2245	A
F3	North Indian Creek	49688 N, 5172 E	2316	A
G1	Willow Park North	49681 N, 5208 E	2246	R
G2	North Roaring Mtn.	49598 N, 5208 E	2316	R
G3	Tuff Creek	49441 N, 5132 E	2121	R
H1	Golden Gate	49756 N, 5215 E	2251	R
H2	Madison	49440 N, 5015 E	2238	R
H3	Grotto Geyser	49246 N, 5126 E	2246	R
I1	South Canyon	49495 N, 5401 E	2380	A
I2	Southeast Swan	49716 N, 5221 E	2199	A
I3	Obsidian Creek	49653 N, 5206 E	2253	A
J1	Washburn	49637 N, 5438 E	2626	A
J2	Blacktail	49764 N, 5395 E	2275	A
J3	Specimen	49720 N, 5574 E	2074	A
K1	Fan Creek	49781 N, 4967 E	2230	A
K2	Cygnet Lakes	49469 N, 5315 E	2569	R
K3	Canyon - Norris	49521 N, 5372 E	2469	R
L1	Lulu Pass	49865 N, 5866 E	2487	A
L2	Willow Park	49628 N, 5215 E	2254	R
L3	Grizzly Trailhead	49609 N, 5207 E	2322	R
M1	West Thumb	49192 N, 5335 E	2377	A
M2	Lewis Lake	49039 N, 5306 E	2412	R
M3	Lewis Canyon	48974 N, 5275 E	2359	R
N1	Little Thumb	49185 N, 5312 E	2503	R
N2	Canyon - Norris	49522 N, 5374 E	2469	R
N3	Virginia Falls	49507 N, 5282 E	2417	R
O1	Washburn High	49618 N, 5443 E	2804	A
O2	Observation	49570 N, 5363 E	2692	A
O3	Washburn Low	49641 N, 5443 E	2534	A

Table 2--Continued.

P1	Observation East	49569 N, 5370 E	2681	A
P2	Dunraven	49576 N, 5435 E	2560	A
P3	West Dunraven	49600 N, 5427 E	2659	A

[1] Soils: Substrate of soils derived from: A - Andesite, basalt, sedimentary (fertile soils); R - Rhyolite, gneiss, granite (infertile, well-drained soils)

The majority of the sites were originally located by Clark (1991) immediately after the 1988 fires for a seed bank investigation and were relocated with his help. The present study found stands used in that project by locating the metal stakes left in 1988 with the aid of a metal detector. Sites were located near an unburned portion of the plant community so that verification of vegetative composition and therefore the habitat type and seral stage could be made.

Of Clark's 45 transects, 39 were suitable for this study. Six of the original transects were unusable due to logging disturbance, mis-classification, or could not be relocated. Habitat type maps of Yellowstone National Park (Despain and others, unpubl.) were used to find new sites for replacement stands. These replacement stands are noted in Table 2.

Three new sites were established to provide additional replications for cover types originally under-sampled. The new sites were located with Despain and others' (unpubl.) habitat type map and verified by noting adjacent unburned vegetation.

Figure 2. Location of stands sampled in or near Yellowstone National Park. Letters indicate habitat type, numerals indicate replications. A-*Deschampsia caespitosa/Carex spp.*, B- *Pseudotsuga menziesia/Symphoricarpos albus*, C-*Pseudotsuga menziesia/Calamagrostis rubescens*, D-*Populus tremuloides/ Calamagrostis rubescens*, E-*Artemisia tridentata/ Festuca idahoensis*, F,G,H,I-*Abies lasiocarpa/Calamagrostis rubescens*, J-*Festuca idahoensis/ Agropyroncaninum*, K,L,M,N-*Abies lasiocarpa/Vaccinium scoparium*, O,P-*Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium*.

All stands sampled for this study were within Yellowstone National Park's boundries except one, this was located on Gallatin National Forest lands north of Yellowstone National Park.

Environmental Types

The nine environments studied are defined by the habitat type classification. Grasslands and shrublands were described by Mueggler and Stewart (1980), forested sites were classified by Steele and others (1983). Aspen stands (Mueggler 1988) were from a classification but may not be climax communities.

The nine environmental types' location in the landscape is shown in Figure 3. There are other habitat types present in the GYE, thus, the listed HTs are not necessarily continuous within a given landscape; they appear instead as a mosaic. Each is described.

Artemisia tridentata/Festuca idahoensis (ARTR/FEID)

This moderately mesic shrubland HT predominates on slopes of less than 40 percent. Annual precipitation varies between 16 and 30 inches (Mueggler and Stewart 1980). The moister end of the type supports deeper soils and higher productivity. Bigleaf sagebrush/Idaho fescue HT has high plant and litter cover. Soils are fertile with a dark upper

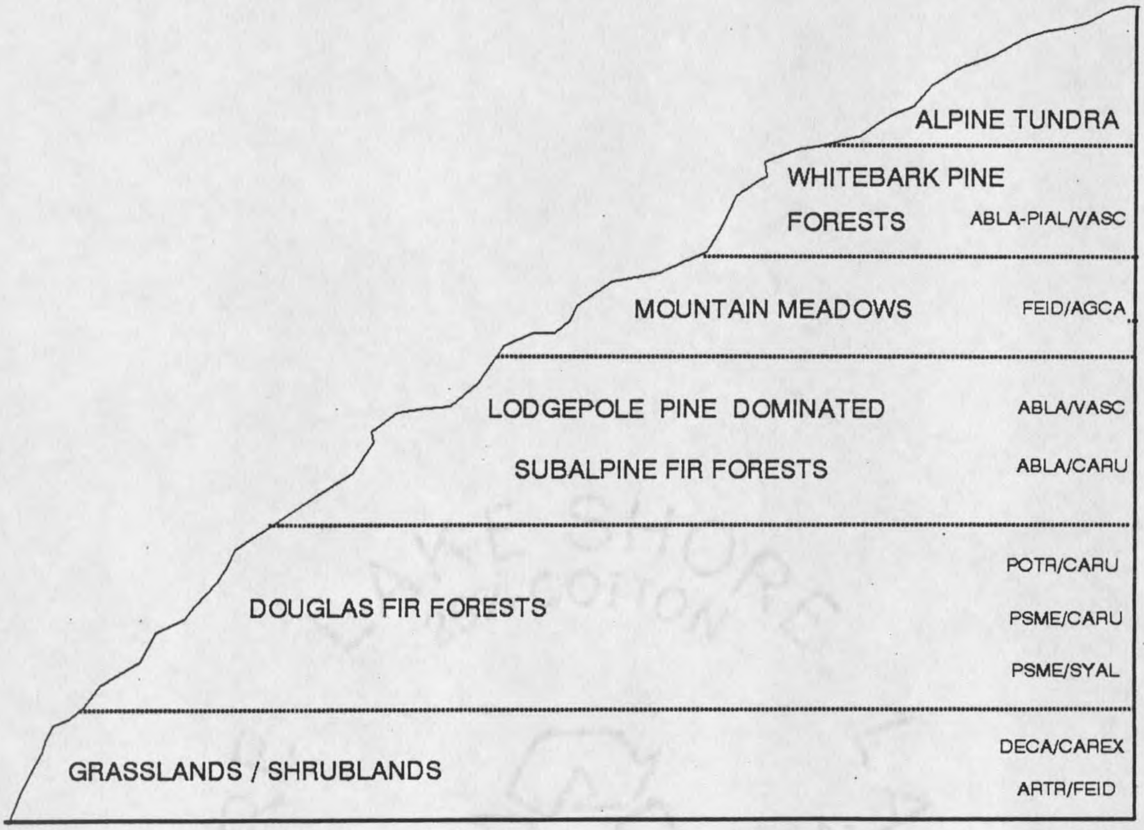

Figure 3. Schematic representation of nine major environmental types along an elevational gradient in the Greater Yellowstone Ecosystem.

horizon. Soils are slightly acidic to neutral. Fires are common in this environment.

Festuca idahoensis/Agropyron caninum (FEID/AGCA)

The Idaho fescue/Bearded wheatgrass HT is characterized by a high forb cover. It is found on moderate to high elevation slopes. Thus, the growing season is shorter than many grasslands and evapotranspiration is lower (Mueggler and Stewart 1980). Soils sampled in this HT in Yellowstone National Park were cryoborolls and had high fertility and a dark surface horizon (Trettin 1986).

Deschampsia cespitosa/Carex spp. (DECA/CAREX)

The tufted hairgrass/sedge habitat type occurs in grassy depressions or over perched water tables. No clear association with one particular sedge species was evident in the stands sampled. Moisture is abundant and during portions of the growing season water stands on the soil surface. Gleying of soils indicates saturated soils with some oxidation. On adjacent sites, Idaho fescue grasslands were present. Therefore, due to extremely wet soils this environmental type represents a topoedaphic climax community under the polyclimax concept (Tansley 1935). In this type histosolic soils occur on very poorly drained alluvium (Trettin 1986). Fires only occur here late in the season when the graminoids are cured and standing water has evaporated.

Pseudotsuga menziesii/Symphoricarpos albus (PSME/SYAL)

This habitat type occupies the lower elevations on slopes and benches under *Pseudotsuga* forests. Douglas-fir/snowberry inhabits moderately warm climates with moist soils. Cryumbrepts and cryoborolls are common to this HT (Trettin 1986). Soils have significant accumulations of organic matter and relatively high moisture retention. Arno (1980) found a 15-30 year fire free interval in this Douglas-fir series. Similarly, Houston (1973) calculated a fire frequency of 20 to 25 years in this vegetation.

Pseudotsuga menziesii/Calamagrostis rubescens (PSME/CARU)

This is often the highest elevation of the Douglas-fir series and occurs on moderately dry mountain slopes. The dominant tree species is Douglas-fir both in seral and climax vegetation. Pinegrass, *Calamagrostis rubescens* decreases after overstory removal by fire or logging because the sites become too dry and warm for this species (Pfister and others 1977). Shrubs are usually sparse in this type. Soils on stands studied were derived from andesite (Table 2). This type has a similar fire regime as the PSME/SYAL habitat type.

Populus tremuloides/Calamagrostis rubescens (POTR/CARU)

The aspen/pinegrass community type occupies relatively moist benches and slopes irrespective of steepness and aspect. It occurs over a wide range of elevations. The vegetation is simple both in structure and composition. Annuals are never abundant (Mueggler 1988). The extensive root system of aspen usually creates clones and these below ground parts survive fire and resprout soon after. Because of rare occurrences of conifers this is often a climax community type.

Abies lasiocarpa/Calamagrostis rubescens (ABLA/CARU)

This habitat type is usually located east of the continental divide in Montana but in the GYE it occurs on both sides. It is notably absent from the Wind River and Absaroka ranges (Steele and others 1983). It occupies a relatively warm environment with fertile soils. At climax, dense carpets of *Calamagrotis* leave little exposed soil. During extended dry periods the grassy understory can carry surface fires under lodgepole pine seral forests in this habitat type (Despain 1990). Soils sampled in the subalpine fir/pinegrass HT were cryoborolls with a very thick dark surface horizon, high water retention and high fertility (Trettin 1986).

Abies lasiocarpa/Vaccinium scoparium (ABLA/VASC)

This is the most widespread forest habitat type in the GYE and the northern Rocky Mountains. Subalpine fir is the climax tree species but often this HT is dominated by lodgepole pine because fire commonly occurs before *Abies lasiocarpa* becomes dominant. Grouse whortleberry is a small shrub that dominates the understory and often forms a continuous cover. This HT occupies cool, relatively dry sites on mid- to upper mountain slopes and benches.

Abies lasiocarpa - Pinus albicaulis/ Vaccinium scoparium (ABLA-PIAL/VASC)

This environmental type lies above the ABLA/VASC HT and often reaches to treeline. Whitebark pine and lodgepole pine are the seral tree species while subalpine fir becomes dominant with some Engelmann spruce at climax. Due to the relatively extreme climatic conditions this HT has low productivity and slow stand development. Soil water stress during the growing season is rarely present in this type (Weaver 1990). Whortleberry is the common shrub and other forb and graminoid species are sparser than in forests below. Soils are typically thin and poorly developed in these cold forested climates. Stand-replacing fires are on long cycles of 200-300 years (Romme 1982).

Cover Types

Within any of the nine environmental types different seral stages or cover types occur. After disturbance the original vegetation is replaced. Developing vegetation is often partitioned into a series of seral stages or cover types. Cover types for forested stands in Yellowstone National Park have been defined (Despain 1990).

Despain's (1990) cover types partition the four stages of forest development common to many forest ecosystems, including those recovering from fire (Peet 1992) into five types. The first is the establishment phase (LP0) and the second is the tree thinning stage (LP1). The third phase delineates the change in the overstory as subsequent understory trees enter the canopy containing the original postfire cohorts (LP2 and LP3), the mid- and late-successional stages. The last stage (LP4), climax, is the steady-state, as the forest stand reaches a relatively stable composition (Oliver and Larsen 1990, Peet and Christiansen 1987). This pattern of development is found in many Rocky Mountain coniferous forests, aspen stands, boreal forests, as well as others (Peet 1992).

The four seral stages sampled in the subalpine fir forests are abbreviated as LP0, LP1, LP2, and LP3 by reference to the seral dominant lodgepole pine. They are described in greater detail in Part II of this study. In subalpine fir forests, where whitebark pine codominates with lodgepole pine in the seral stages, only one cover type was sufficiently widespread to provide three replications - whitebark pine two (WB2). WB2 is similar to LP2 except it occurs in subalpine fir stands near treeline.

Part I of this study concentrates on pioneer communities arising after severe fire in mature communities of the nine habitat types. However, stands from pre-fire seral stages (immature stages) in the subalpine fir environment were sampled. Data from these stands have been included in several releve tables to compare species establishing in pioneer communities following seral stages with those establishing after mature types.

A summary of each sample stand's code, geographic name, habitat type, and cover type when appropriate, is located in Table 2. This table also indicates which of the stands are sampled from Clark's (1991) original study and which have been replaced or added.

Sampling Methods

All sample sites were visited between June to September of 1993. The metal stakes delineating each site were 25 meters apart. Stakes were installed similarly in comparable locations for new study sites. These stakes define the center line of a 25 m. by 4 m. macroplot. The macroplot extends two meters on either side of this line. The plot size examined in this study was within parameters suggested

Table 3. Study site stand codes, geographic names, habitat types and cover types.

Stand Code	Stand Name	Habitat Type[1]	Pre-fire Cover Type2
A1	Crystal Bench	DECA/CAREX	
A2	Lamar	DECA/CAREX	
A3	Canyon West	DECA/CAREX	
B1	Bunsen	PSME/CARU	
B2	Waterplant	PSME/CARU	
B3	Blacktail	PSME/CARU	
C1	Terrace	PSME/SYAL	
C2	Floating Island	PSME/SYAL	
C3	Wraith	PSME/SYAL	
D1	Bunsen	POTR/CARU	
D2	Lamar	POTR/CARU	
D3	Waterplant West	POTR/CARU	
E1	Lamar	ARTR/FEID	
E2	Frog Rock	ARTR/FEID	
E3	Washburn	ARTR/FEID	
F1	Indian Creek	ABLA/CARU	LP0
F2	Heart Junction*	ABLA/CARU	LP0
F3	North Indian Creek*	ABLA/CARU	LP0
G1	Willow Park North**	ABLA/CARU	LP1
G2	North Roaring Mtn.	ABLA/CARU	LP1
G3	Tuff Creek	ABLA/CARU	LP1
H1	Golden Gate	ABLA/CARU	LP2
H2	Madison	ABLA/CARU	LP2
H3	Grotto Geyser	ABLA/CARU	LP2
I1	South Canyon	ABLA/CARU	LP3
I2	Southeast Swan	ABLA/CARU	LP3
I3	Obsidian Creek**	ABLA/CARU	LP3
J1	Washburn	AGCA/FEID	
J2	Blacktail	AGCA/FEID	
J3	Specimen	AGCA/FEID	
K1	Fan Creek	ABLA/VASC	LP0
K2	Cygnet Lakes*	ABLA/VASC	LP0
K3	Canyon - Norris	ABLA/VASC	LP0
L1	Lulu Pass	ABLA/VASC	LP1
L2	Willow Park	ABLA/VASC	LP1
L3	Grizzly Trailhead**	ABLA/VASC	LP1
M1	West Thumb	ABLA/VASC	LP2
M2	Lewis Lake	ABLA/VASC	LP2
M3	Lewis Canyon	ABLA/VASC	LP2
N1	Little Thumb**	ABLA/VASC	LP3
N2	Canyon - Norris	ABLA/VASC	LP3
N3	Virginia Falls	ABLA/VASC	LP3
O1	Washburn High	ABLA-PIAL/VASC	WB2
O2	Observation	ABLA-PIAL/VASC	WB2
O3	Washburn Low**	ABLA-PIAL/VASC	WB2

Table 3--Continued.

Stand Code	Stand Name	Habitat Type[1]	Pre-fire Cover Type[2]
P1	Observation East**	ABLA-PIAL/VASC	WB3
P2	Dunraven High	ABLA-PIAL/VASC	WB3
P3	West Dunraven	ABLA-PIAL/VASC	WB3

* New Transects

** Transects replaced due to logging,etc.

[1] Forested habitat types (Steele and others 1983), grassland/shrubland habitat types (Mueggler and Stewart 1980), and the aspen community type (Mueggler 1988) are: *Artemisia tridentata/Festucaidahoensis* (ARTR/FEID), *Festuca idahoensis/ Agropyroncaninum* (ARTR/AGCA), *Deschampsia caespitosa/ Carex spp.*(DECA/CAREX), *Pseudotsuga menziesia/ Symphoricarpos albus* (PSME/SYAL), *Pseudotsuga menziesia/ Calamagrostis rubescens* (PSME/CARU), *Populus tremuloides/ Calamagrostis rubescens* (PSME/CARU), *Abies lasiocarpa/ Calamagrostis rubescens* (ABLA/CARU), *Abies lasiocarpa/ Vaccinium scoparium* (ABLA/VASC), *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* (ABLA-PIAL/VASC).

[2] Cover types are described by Despain (1990).

(Mueller-Dumbois and Ellenberg 1974) for examination of temperate forest undergrowth (50-200 meters squared) and dry grasslands (50-100 meters squared).

Each stand was visited once during the growing season. The species list, therefore, is a minimal estimate of species present in postfire pioneer communities. Spring ephemerals were potentially overlooked at sites visited later in the season. Late season flowering plants' cover abundance was most likely underestimated at sites visited early in the growing season. These effects were minimized because low elevations were sampled first and higher elevation communities were visited later in the season.

The data was collected in one growing season, thus, controlling many variables. Completion of sampling in one season had two advantages. First, it removed any analyses of variability between growing seasons due to different seasonal factors affecting plant cover (annual precipitation, length of growing season, etc.). Second, there is no compositional change as a function of time to consider. Thus, time as a factor does not vary.

Two measures of the plant community were made in each 0.01 hectare macroplot. First, floristic composition was measured by species presence in the macroplot. Species presence, although a crude measure for comparison of stands (Greig-Smith 1983), habitat types, or seral stages, is useful in determining in which environments each species is at least minimally successful. Therefore, this measure will aid in determining species success across the environmental gradient. Species presence is simply the identification to the species level of all vascular plants within the macroplot.

Second, plant cover was recorded as a measure of species performance. Cover was measured as the vertical projection of the crown area of a species to the ground as a percent of the reference area. In this study, the reference area was a 20 cm by 50 cm quadrat or 0.1 meter squared. Cover is a better measure of plant biomass than density and thus more ecologically significant (Daubenmire 1968).

Cover was estimated by sub-sampling the macroplot with twenty quadrats. The quadrats or microplots were placed alternately along either side of the 25 m tape measure stretched between the two terminal metal stakes. The quadrats were located one meter apart on alternate sides of the tape starting at meter three and ending at meter twenty-two.

Within each of the twenty quadrats in each sample stand, species cover was recorded using a cover scale. Each species present in a quadrat was assigned a cover class (Table 4) as defined by a range of percent cover (Daubenmire 1959) and refined by Bailey and Poulton (1968). This methodology is easily duplicated and the cover classes are used to minimize sampling error (Daubenmire 1959).

Table 4. Cover classes, cover class ranges and midpoints (Bailey and Poulton 1968).

COVER CLASS	RANGE OF COVER (%)	CLASS MIDPOINTS (%)
7	95-100	97.5
6	75-95	85
5	50-75	62.5
4	25-50	37.5
3	5-25	15
2	1-5	3
1	0-1	0.5

Besides vascular plant cover, several other cover categories were recorded. These included bare soil, litter, dead woody residue greater than three inches in diameter

(7.5 cm), mosses and hornworts. Woody residue greater than three inches in diameter is referred to as coarse woody debris by fire ecologists and has many important physical, chemical and biological functions (Graham and others 1994).

The mean cover for each vascular plant species and ground cover type was calculated by summing the appropriate class mid-points across all quadrats, dividing by twenty, and multiplying by one hundred. Total percent cover for each site was calculated by summing all mean percent cover for individual species and ground cover types.

The few taxonomic difficulties were resolved as follows. Several sample sites had species that were in a phenological stage such that only the genus could be determined. Non-vascular plants were classified to phylum for bryophyta (mosses) or to genus for the lone identifiable hornwort - Marchantia spp. Two lupines were difficult to separate when not in flower so they have been combined. They were *Lupinus argenteus* and *L. sericeus*. For convenience, on forested sites *L. argenteus* was used and for shrublands/ grasslands *L. sericeus* was used. Unknown specimens were taken to the Yellowstone National Park Herbarium each evening during the field season to positively identify them with herbarium specimens. Thus, a cumulative knowledge of rare or difficult taxa was acquired during the field studies.

Voucher specimens were pressed and dried. A list of plant species found and the sampling site location from which it was collected is given in Appendix A. These specimens reside at the Montana State University Herbarium (MONT). Final determinations of difficult taxa were completed at the Montana State University Herbarium and were verified by Dr. Jack Rumely, associate curator. Nomenclature of plant species usually follows Hitchcock and Cronquist (1973). Species identified in this study but not included in their treatment of the Pacific Northwest flora follow Dorn (1992). Also, species that Hitchcock and Cronquist present as varieties but now are considered species follow Dorn (1992). Each species identified in the study is listed in Appendix B with its authority.

RESULTS

One objective is to list and quantify the species present in pioneer communities of nine common environmental types of the northern Rocky Mountains; Table 5 and Table 6 present this information.

The headers of Table 5 and Table 6 list environmental types from grasslands/shrublands (E,J,A) through montane forests (C,B,D) to subalpine fir forests (I, N, P). These columns present pioneer species establishing after fire in mature pre-fire communities. The last three columns (F,K,O) present pioneer communities of pre-climax (seral stage) stands burned in three subalpine fir environments (F-ABLA/CARU, K-ABLA/VASC, O-ABLA-PIAL/VASC).

The left column in Table 5 lists species present in more than one sample site. The left column in Table 6 lists species present only once in the entire study. Information appended to the species list in Table 5 includes origin (an asterisk indicates exotic species), life-form (graminoids-G, forbs-F, shrubs-S, or trees-T) and duration (annual-A, biennial-B, or perennial-P).

Table 5 is broken into sections containing species with particular distributions on the elevational gradient. That is, species that occur in a single environmental type (Table

5, Sections C, E, and G) those that occur in a few similar types (Table 5, Sections D and F) or those that occur everywhere in pioneer communities (Table 5, Sections A and B). There were several with bimodal distributions (Table 5, Section H).

Values that occur in the body of the table indicate the constancy of each species in each habitat type. A zero indicates uniform absence, one is one occurrence, two is two occurrences, and three shows that the species was always present in pioneer communities studied in the environmental type.

Data from the pre-fire seral stages is discussed in more detail in Part II of this report. However, since seral stands from the subalpine forest zone share species with sites from the grassland/shrubland and montane environments these data are summarized in the last three columns of Table 5 and Table 6.

Table 5. Pioneer communities appearing five years after severe fire in climax vegetation of nine environmental types along the elevational gradient of the Greater Yellowstone Ecosystem and in several seral stages of subalpine fir environments.

		Pre-fire Communities											
		Mature									Seral[1]		
		Habitat Types[2]											
Species[3]	Life-form[4]	E	J	A	C	B	D	I	N	P	F	K	O
Section A: Species commonly present in all environments													
Potentilla gracilis	PF	2	1	1	2	.	2	1	.	.	d	.	.
Phleum pratense*	PG	2	2	3	2	3	2	1	.	.	a	a	.
Campanula rotundifolia	PF	2	1	1	.	1	2	2	.	.	f	a	.
Penstemon procerus	PF	2	1	1	2	.	.	2	.	.	b	1	.
Calamagrostis rubescens	PG	.	1	1	1	3	3	3	.	.	f	.	1
Cirsium scariosum	PF	1	1	3	1	.	1	1	.	.	c	a	.
Bromus carinatus	PG	1	1	1	2	1	3	1	.	.	f	1	.
Collomia linearis	AF	1	2	2	2	3	2	3	1	.	f	1	.
Fragaria virginiana	PF	1	.	2	3	2	3	3	2	.	f	c	.
Carex praticola	PG	2	1	1	1	.	2	1	2	.	.	.	.
Agropyron caninum	PG	3	3	2	3	2	2	2	.	2	f	.	2
Agoseris glauca	PF	2	3	2	2	3	2	2	.	1	f	b	3
Polygonum douglasii	AF	1	1	2	.	1	2	1	.	2	f	.	1
Epilobium paniculatum	PF	.	1	1	2	1	2	1	.	1	f	c	.
Arabis glabra*	BF	1	1	1	3	3	.	.	.	1	f	f	1
Antennaria microphylla	PF	2	3	1	1	1	.	3	1	1	f	c	2
Taraxacum officinale*	PF	2	2	3	3	3	3	3	2	1	f	f	2
Achillea millefolium	PF	3	3	3	3	3	3	3	2	2	f	f	3
Poa nervosa	PG	2	1	.	3	3	2	3	1	1	f	c	3
Stipa nelsonii	PG	3	2	.	2	3	1	2	1	.	f	e	1
Astragalus miser	PF	1	2	.	1	2	3	2	.	.	f	.	1
Tragopogon dubius*	BF	1	1	.	1	1	2	.	1	1	c	d	.
Lupinus argenteus/sericeus	PF	3	2	.	.	2	3	2	2	.	f	f	2
Senecio serra	PF	1	1	.	3	3	3	1	.	2	a	c	.
Epilobium angustifolium	PF	.	.	1	3	3	2	3	3	3	f	f	3
Collinsia parviflora	AF	.	.	1	2	1	1	2	1	2	f	c	2
Section B: Species of weak distribution in all environments													
Festuca idahoensis	PG	3	3	.	1	.	.	2	.	.	2	e	1
Arabis drummondii	PF	1	1	.	1	.	1	1	.	1	b	a	1
Androsace septentrionalis	A/BF	1	2	.	.	1	.	1	.	.	2	.	1
Viola adunca	PF	.	1	3	.	.	1	1	.	.	a	.	.
Potentilla glandulosa	PF	1	.	.	1	1	.	1	.	.	e	.	.
Geranium viscosissimum	PF	1	.	.	2	2	3	1	.	.	a	a	.
Aster foliaceus	PF	1	.	.	1	.	.	1	.	1	3	.	1

Table 5--Continued.

Species[3]	Life-form[4]	E	J	A	C	B	D	I	N	P	F	K	O
		Habitat Types[2]											
Agoseris aurantiaca	PF	1	.	.	.	1	.	.	.	.	e	c	.
Aster ascendens	PF	1	.	.	.	1	1	1	.	.	.	.	.
Perideridia gairdneri	PF	1	.	.	.	1	3	.	.	.	1	a	.
Epilobium glaberrimum	PF	1	.	.	.	1	.	2	2	3	a	f	.
Descurainia richardsonii	AF	.	1	.	2	.	.	.	.	1	b	1	3
Arabis holboellii	PF	.	2	.	.	2	.	.	.	.	f	c	1
Cerastium arvense	PF	.	3	.	1	1	.	1	.	.	b	a	1
Gayophytum diffusum	AF	.	1	.	.	.	1	.	1	.	f	2	.
Carex hoodii	PG	.	.	1	.	2	1	.	.	.	c	.	1
Section C: Species primarily of grasslands/shrublands													
Koelaria cristata	PG	3	2	.	.	.	.	.	.	.	.	.	.
Oxytropis deflexa	PF	1	1	.	.	.	.	.	.	.	.	.	.
Artemesia cana	S	1	1	.	.	.	.	.	.	.	.	.	.
Artemesia frigida	S	1	1	.	.	.	.	.	.	.	.	.	.
Chrysothamnus viscidiflorus	S	1	1	.	.	.	.	.	.	.	.	.	.
Erigeron gracilis	PF	1	2	.	.	.	.	.	.	.	.	.	.
Eriogonum umbellatum	PF	2	3	.	.	.	.	.	.	.	.	.	.
Linum lewisii	PF	1	2	.	.	.	.	.	.	.	.	.	.
Anemone spp.	PF	.	2	.	.	.	.	.	.	.	.	.	.
Saxifraga rhomboidea	PF	.	1	1	.	.	.	.	.	.	.	.	.
Senecio streptanthifolius	PF	2	.	1	.	.	.	.	.	.	.	.	.
Stellaria longipes	PF	1	.	1	.	.	.	.	.	.	.	.	.
Aster occidentalis	PF	1	1	2	.	.	.	.	.	.	.	.	.
Poa palustris	PG	.	.	3	.	.	.	.	.	.	.	.	.
Carex lanuginosa	PG	.	.	2	.	.	.	.	.	.	.	.	.
Juncus balticus	PG	.	.	2	.	.	.	.	.	.	.	.	.
Salix geyeriana	S	.	.	2	.	.	.	.	.	.	.	.	.
Eriophyllum lanatum	PF	1	.	.	.	.	.	.	.	.	e	.	.
Rumex acetosella*	PF	1	.	.	.	.	.	.	.	.	e	a	.
Potentilla diversifolia	PF	.	1	1	.	.	.	.	.	.	.	.	1
Danthonia spicata	PG	1	1	1	.	.	.	.	.	.	2	.	.
Section D: Species primarily of grasslands/shrublands and montane forests													
Stipa richardsonii	PG	1	1	.	1	.	.	.	.	.	.	.	.
Phlox hoodii	PG	2	1	.	1	.	.	.	.	.	.	.	.
Agropyron spicatum	PG	2	2	.	1	.	.	.	.	.	.	.	.
Geum triflorum	PF	.	1	.	1	.	.	.	.	.	.	.	.
Allium cernuum	PF	.	1	.	1	.	.	.	.	.	.	.	.
Erythronium grandiflorum	PF	.	1	.	1	.	.	.	.	.	.	.	1
Erigeron speciosus	PF	1	1	.	1	2	.	.	.	.	.	.	.
Potentilla arguta	PF	.	.	3	1	.	.	.	.	.	.	.	.
Epilobium ciliatum	PF	.	.	3	2	2	.	.	.	.	.	.	.

Table 5--Continued.

Species[3]	Life-form[4]	E	J	A	C	B	D	I	N	P	F	K	O
		Habitat Types[2]											
Artemisia tridentata	S	3	.	1	2	1	1	.	.	.	d	.	.
Thlaspi arvense*	AF	1	3	1	1	.	1	.	.	.	b	.	.
Thalictrum occidentale	PF	.	.	1	.	1	1	.	.	.	1	.	.
Bromus ciliatus	PG	1	.	.	.	2	.	.	.	.	2	.	.
Chenopodium fremontii	AF	.	1	.	2	.	1	.	.	.	b	.	1
Trifolium hybridum*	PF	2	1	2	.	1	.	.	.	.	.	.	.
Erysimum inconspicuum	B/PF	1	.	.	1	1	1	.	.	.	.	.	.
Symphoricarpos albus	S	.	1	.	1	1	2	.	.	.	.	.	.
Galium boreale	PF	2	.	1	3	2	2	.	.	.	.	.	.
Myosotis sylvatica	PF	1	1	.	.	1	1	.	.	.	.	.	.
Solidago missouriensis	PF	1	1	.	.	2	1	.	.	.	.	.	.
Poa juncifolia	PG	3	3	1	.	1	1	.	.	.	.	.	.
Aster hesperius	PF	.	.	2	.	.	1	.	.	.	.	.	.
Lithospermum ruderale	PF	1	.	.	.	.	1	.	.	.	.	.	.
Aster campestris	PF	1	.	.	.	.	2	.	.	.	.	.	.
Astragalus agrestis	PF	1	2	.	.	.	1	.	.	.	.	.	.
Trifolium longipes	PF	1	.	1	.	.	1	.	.	.	.	.	.
Bromus marginatus	PG	.	.	1	.	.	1	.	.	.	.	.	.
Section E: Species primarily of montane and seral subalpine fir forests													
Oryzopsis exigua	PG	.	.	.	1	.	.	.	.	.	b	b	.
Lepidium virginicum	A/PF	.	.	.	1	.	.	.	.	.	.	.	1
Geranium bicknellii	AF	.	.	.	1	1	.	.	.	.	.	.	.
Viola canadensis	PF	.	.	.	1	1	.	.	.	.	.	.	.
Zigadenus venonosus	PF	.	.	.	.	2	.	.	.	.	.	.	.
Symphoricarpos oreophilus	S	.	.	.	.	2	.	.	.	.	.	.	.
Corydalis aurea	A/BF	.	.	.	.	1	.	.	.	.	a	.	.
Balsamorhiza sagittata	PF	.	.	.	.	1	1	.	.	.	.	.	.
Lactuca seriola	AF	.	.	.	.	2	1	.	.	.	.	.	.
Hackelia floribunda	B/PF	.	.	.	.	1	1	.	.	.	.	.	.
Elymus cinereus	PG	.	.	.	.	2	1	.	.	.	.	.	.
Melilotus officinalis*	AF	.	.	.	.	2	1	.	.	.	a	.	.
Berberis repens	S	.	.	.	.	1	2	.	.	.	a	.	.
Populus tremuloides	T	.	.	.	.	1	1	.	.	.	.	f	.
Pseudotsuga menziesia	S	.	.	.	1	.	1	.	.	.	.	.	.
Geranium richardsonii	PF	.	.	.	1	.	1	.	.	.	.	.	.
Linanthus septentrionalis	AF	.	.	.	1	.	1	.	.	.	a	.	.
Cynoglossum officinale*	BF	.	.	.	1	1	1	.	.	.	.	.	.
Iliamna rivularis	S	.	.	.	1	2	1	.	.	.	.	.	.
Rosa acicularis	S	.	.	.	2	2	2	.	.	.	.	.	.
Aster conspicuus	PF	.	.	.	2	2	1	.	.	.	b	.	.
Spiraea betulifolia	S	.	.	.	1	2	1	.	.	.	a	a	.
Cirsium vulgare*	BF	.	.	.	1	1	1	.	.	.	b	c	.
Lomatium dissectum	PF	.	.	.	1	.	.	.	.	.	1	.	.

Table 5--Continued.

Species[3]	Life-form[4]	E	J	A	C	B	D	I	N	P	F	K	O
		Habitat Types[2]											
Solidago spp.	PF	.	.	.	.	1	.	.	.	.	b	.	.
Section F: Species common in all forest environments													
Phacelia franklinii	A/BF	.	.	.	1	.	.	1	.	.	1	.	.
Osmorhiza depauperata	PF	.	.	.	.	1	1	.	1	.	a	.	.
Aster integrifolius	PF	.	.	.	.	.	1	1	.	.	1	d	.
Frasera speciosa	PF	.	.	.	.	.	1	1	.	.	.	.	1
Gentiana amarella	PF	.	.	.	.	.	1	1	.	.	.	.	1
Solidago multiradiata	PF	.	.	.	.	.	2	1	1	.	f	a	1
Elymus glaucus	PG	.	.	.	2	1	1	1	2	.	f	a	2
Carex geyeri	PG	.	.	.	1	1	.	.	2	.	f	b	.
Fragaria vesca	PF	.	.	.	1	1	.	.	1	.	.	b	.
Poa interior	PG	.	.	.	1	1	1	.	.	1	.	.	.
Hieracium albiflorum	PF	.	.	.	1	.	.	.	2	2	d	c	.
Trisetum spicatum	PG	.	.	.	1	.	.	3	3	3	f	f	3
Nemophila breviflora	AF	.	.	.	2	.	.	.	.	1	.	.	.
Gayophytum racemosum	AF	.	.	.	.	1	.	1	1	.	.	e	1
Arnica cordifolia	PF	.	.	.	.	2	.	2	3	3	f	c	3
Cirsium arvense*	PF	.	.	.	.	1	.	1	1	.	f	b	.
Carex rossii	PG	.	.	.	.	1	.	3	3	3	f	f	3
Capsella bursa-pastoris*	AF	.	.	.	.	1	.	1	.	.	b	.	.
Draba stenoloba	AF	.	.	.	.	.	1	1	1	1	.	.	.
Section G: Species common in subalpine fir forests													
Phleum alpinum	PG	.	.	.	.	.	.	1	.	.	.	a	.
Cerastium fontanum	B/PF	.	.	.	.	.	.	1	.	.	e	.	.
Gnaphalium vicosum	A/BF	.	.	.	.	.	.	.	2	.	.	.	.
Aquilegia flavescens	PF	.	.	.	.	.	.	.	1	.	1	.	.
Gnaphalium spp.	A/BF	.	.	.	.	.	.	1	.	.	.	a	.
Antennaria racemosa	PF	.	.	.	.	.	.	1	1	.	.	a	.
Pinus contorta	T	.	.	.	.	.	.	1	2	.	f	f	.
Sitanion hystrix	PG	.	.	.	.	.	.	1	.	1	f	c	1
Hieracium gracile	PF	.	.	.	.	.	.	1	.	1	.	a	1
Vaccinium scoparium	S	.	.	.	.	.	.	1	3	3	d	f	2
Sedum lanceolatum	PF	.	.	.	.	.	.	.	.	1	.	a	.
Vaccinium globulare	S	.	.	.	.	.	.	.	.	1	.	e	.
Poa scabrella	PG	.	.	.	.	.	.	1	.	2	.	.	3
Section H: Species of bimodal distribution													
Carex raynoldsii	PG	1	.	.	.	.	.	1	.	.	.	.	.
Senecio canus	PF	1	.	.	.	.	.	1	.	.	.	.	.
Viola nuttallii	PF	3	.	.	.	.	.	2	.	.	f	.	1
Silene oregana	PF	.	1	.	.	.	.	.	.	.	b	.	.

Table 5--Continued.

Species[3]	Life-form[4]	Habitat Types[2]											
		E	J	A	C	B	D	I	N	P	F	K	O
Arenaria congesta	PF	.	1	.	.	.	.	2	.	.	b	.	.
Danthonia intermedia	PG	.	1	.	.	.	.	2	.	.	f	.	.
Draba nemorosa*	AF	.	2	.	.	.	.	1	.	.	.	2	.
Barbarea orthoceras	PF	.	.	1	.	.	.	.	.	.	a	.	.
Senecio sphaerocephalus	PF	.	.	1	.	.	.	.	.	.	.	.	1
Deschampsia cespitosa	PG	.	.	3	.	.	.	1	.	.	.	.	.
Calamagrostis canadensis	PG	.	.	2	.	.	.	1	1	1	.	.	.
Phlox longifolia	PF	1	1	.	.	.	.	1	.	.	.	.	.
Agrostis scabra	PG	1	.	1	.	.	.	1	1	1	f	f	2
Section I: Species primarily of seral stages													
Phacelia hastata	PF	.	.	.	.	.	.	.	.	.	c	.	.
Melica bulbosa	PG	.	.	.	.	.	.	.	.	.	d	.	.
Aster meritus	PF	.	.	.	.	.	.	.	.	.	a	a	.
Arnica parryi	PF	.	.	.	.	.	.	.	.	.	.	a	1
Hieracium cynoglossoides	PF	.	.	.	.	.	.	.	.	.	.	e	1
Polemonium pulcherrimum	PF	.	.	.	.	.	.	.	.	.	.	.	2

[1] Pre-fire seral subalpine fir forests: F-ABLA/CARU, LP0 cover type K-ABLA/VASC, LP0 cover type (a denotes species presence in LP1, b-LP2, c-LP0 and LP1, d-LP0 and LP2, e-LP1 and LP2, f-all three seral stages), O-ABLA-PIAL/VASC, WB2 cover type.

[2] Habitat types listed in order of increasing elevation. Grasslands: E-FEID/ARTR, J-FEID/AGCA, A-DECA/CAREX. Douglas fir forests: C-PSME/SYAL, B-PSME/CARU, D-POTR/CARU. Subalpine fir forests: I-ABLA/CARU, N-ABLA/VASC, P-ABLA-PIAL/VASC.

[3] Values denote number of occurrences in three sample stands of 0.01 hectare. Asterisk (*) represents exotic species.

[4] Life-form and duration: A-annual, B-biennial, P-perennial, G-graminoids, F-Forbs, S-Shrubs, and T-trees.

Table 6. Pioneer species with only a single occurrence appearing five years after severe fire in climax vegetation of nine environmental types along the elevational gradient of the Greater Yellowstone Ecosystem and in several seral stages of subalpine fir environments.

	Pre-fire Communities											
	Mature									Seral[1]		
	Habitat Types[2]											
Species	E	J	A	C	B	D	I	N	P	F	K	O
Astragalus kentrophyta	1	.	.	.	.	.	.	.	.	.	.	.
Atriplex nuttallii	1	.	.	.	.	.	.	.	.	.	.	.
Carex vallicola	1	.	.	.	.	.	.	.	.	.	.	.
Chaenactis douglasii	1	.	.	.	.	.	.	.	.	.	.	.
Lewisia rediviva	1	.	.	.	.	.	.	.	.	.	.	.
Lappula redowskii	1	.	.	.	.	.	.	.	.	.	.	.
Orthocarpus luteus	1	.	.	.	.	.	.	.	.	.	.	.
Astragalus adsurgens	.	1	.	.	.	.	.	.	.	.	.	.
Astragalus purshii	.	1	.	.	.	.	.	.	.	.	.	.
Astragalus vexilliflexis	.	1	.	.	.	.	.	.	.	.	.	.
Besseya wyomingensis	.	1	.	.	.	.	.	.	.	.	.	.
Camelina microcarpa	.	1	.	.	.	.	.	.	.	.	.	.
Castilleja pallescens	.	1	.	.	.	.	.	.	.	.	.	.
Delphinium nuttallianum	.	1	.	.	.	.	.	.	.	.	.	.
Erysimum cheiranthoides	.	1	.	.	.	.	.	.	.	.	.	.
Polygonum bistortoides	.	1	.	.	.	.	.	.	.	.	.	.
Lomatium cous	.	1	.	.	.	.	.	.	.	.	.	.
Senecio integerrimus	.	1	.	.	.	.	.	.	.	.	.	.
Taraxacum laevigatum	.	1	.	.	.	.	.	.	.	.	.	.
Carex spp.	.	1	.	.	.	.	.	.	.	.	.	.
Poa cusickii	.	1	.	.	.	.	.	.	.	.	.	.
Stipa lemmonii	.	1	.	.	.	.	.	.	.	.	.	.
Potentilla fruticosa	.	.	1	.	.	.	.	.	.	.	.	.
Salix wolfii	.	.	1	.	.	.	.	.	.	.	.	.
Arnica longifolia	.	.	1	.	.	.	.	.	.	.	.	.
Arnica mollis	.	.	1	.	.	.	.	.	.	.	.	.
Equisetum arvense	.	.	1	.	.	.	.	.	.	.	.	.
Erigeron acris	.	.	1	.	.	.	.	.	.	.	.	.
Galium trifidum	.	.	1	.	.	.	.	.	.	.	.	.
Gentiana detonsa	.	.	1	.	.	.	.	.	.	.	.	.
Mentha arvensis var. canadensis	.	.	1	.	.	.	.	.	.	.	.	.
Senecio cymbalarioides	.	.	1	.	.	.	.	.	.	.	.	.
Solidago canadensis	.	.	1	.	.	.	.	.	.	.	.	.
Veronica serpyllifolia	.	.	1	.	.	.	.	.	.	.	.	.
Carex microptera	.	.	1	.	.	.	.	.	.	.	.	.
Carex rostrata	.	.	1	.	.	.	.	.	.	.	.	.
Carex sartwellii	.	.	1	.	.	.	.	.	.	.	.	.
Luzula campestris	.	.	1	.	.	.	.	.	.	.	.	.
Muhlenbergia richardsonis	.	.	1	.	.	.	.	.	.	.	.	.

Table 6--Continued.

Species	Habitat Types[2]											
	E	J	A	C	B	D	I	N	P	F	K	O
Poa trivialis	.	.	1	.	.	.	.	.	.	.	.	.
Linnaea borealis	.	.	.	1	.	.	.	.	.	.	.	.
Rubus idaeus	.	.	.	1	.	.	.	.	.	.	.	.
Conimitella williamsii	.	.	.	1	.	.	.	.	.	.	.	.
Erigeron compositus	.	.	.	1	.	.	.	.	.	.	.	.
Galium bifolium	.	.	.	1	.	.	.	.	.	.	.	.
Hackelia deflexa	.	.	.	1	.	.	.	.	.	.	.	.
Osmorhiza chilensis	.	.	.	1	.	.	.	.	.	.	.	.
Phlox multiflora	.	.	.	1	.	.	.	.	.	.	.	.
Valeriana dioica	.	.	.	1	.	.	.	.	.	.	.	.
Ceanothus velutinus	.	.	.	.	1	.	.	.	.	.	.	.
Chrysothamnus nauseosus	.	.	.	.	1	.	.	.	.	.	.	.
Sheperdia canadensis	.	.	.	.	1	.	.	.	.	.	.	.
Aster pereglans	.	.	.	.	1	.	.	.	.	.	.	.
Castilleja miniata	.	.	.	.	1	.	.	.	.	.	.	.
Hackelia micrantha	.	.	.	.	1	.	.	.	.	.	.	.
Linaria dalmatica	.	.	.	.	1	.	.	.	.	.	.	.
Silene latifolia	.	.	.	.	1	.	.	.	.	.	.	.
Dactylis glomerata	.	.	.	.	1	.	.	.	.	.	.	.
Astragalus eucosmus	.	.	.	.	.	1	.	.	.	.	.	.
Allium brevistylum	.	.	.	.	.	1	.	.	.	.	.	.
Anemone parviflora	.	.	.	.	.	1	.	.	.	.	.	.
Arenaria laterifolia	.	.	.	.	.	1	.	.	.	.	.	.
Corallorhiza trifida	.	.	.	.	.	1	.	.	.	.	.	.
Senecio pseudaureus	.	.	.	.	.	1	.	.	.	.	.	.
Trifolium pratense	.	.	.	.	.	1	.	.	.	.	.	.
Trifolium repens	.	.	.	.	.	1	.	.	.	.	.	.
Verbascum thapsus	.	.	.	.	.	1	.	.	.	.	.	.
Rorippa islandica	.	.	.	.	.	.	1	.	.	.	.	.
Poa fendleriana	.	.	.	.	.	.	1	.	.	.	.	.
Poa pratensis	.	.	.	.	.	.	1	.	.	.	.	.
Abies lasiocarpa	.	.	.	.	.	.	.	1	.	.	.	.
Picea engelmannii	.	.	.	.	.	.	.	1	.	.	.	.
Ribes lacustre	.	.	.	.	.	.	.	1	.	.	.	.
Vaccinium membranaceum	.	.	.	.	.	.	.	1	.	.	.	.
Muhlenbergia racemosa	.	.	.	.	.	.	.	1	.	.	.	.
Arabis lemonii	.	.	.	.	.	.	.	.	1	.	.	.
Arabis lyallii	.	.	.	.	.	.	.	.	1	.	.	.
Astragalus alpinus	.	.	.	.	.	.	.	.	1	.	.	.
Salix bebbiana	.	.	.	.	.	.	.	.	.	1	.	.
Anaphalis margaritacea	.	.	.	.	.	.	.	.	.	1	.	.
Deschampsia elongata	.	.	.	.	.	.	.	.	.	a	.	.
Poa compressa	.	.	.	.	.	.	.	.	.	a	.	.
Stipa occidentalis	.	.	.	.	.	.	.	.	.	a	.	.
Arctostyphalos uva-ursi	.	.	.	.	.	.	.	.	.	a	.	.
Ribes cereum	.	.	.	.	.	.	.	.	.	a	.	.
Microsteris gracilis	.	.	.	.	.	.	.	.	.	a	.	.

Table 6--Continued.

Species	Habitat Types[2]											
	E	J	A	C	B	D	I	N	P	F	K	O
Hordeum brachyantherum	.	.	.	.	.	.	.	.	.	b	.	.
Cirsium spp.	.	.	.	.	.	.	.	.	.	b	.	.
Crepis atrabarba	.	.	.	.	.	.	.	.	.	b	.	.
Senecio crassulus	.	.	.	.	.	.	.	.	.	.	1	.
Spergularia rubra	.	.	.	.	.	.	.	.	.	.	1	.
Arnica latifolia	.	.	.	.	.	.	.	.	.	.	a	.
Epilobium anagallidifolium	.	.	.	.	.	.	.	.	.	.	a	.
Penstemon fruticosus	.	.	.	.	.	.	.	.	.	.	a	.
Marchantia spp.	.	.	.	.	.	.	.	.	.	.	b	.
Lupinus lepidus	.	.	.	.	.	.	.	.	.	.	.	1
Phacelia sericea	.	.	.	.	.	.	.	.	.	.	.	1
Rumex paucifolius	.	.	.	.	.	.	.	.	.	.	.	1
Sibbaldia procumbens	.	.	.	.	.	.	.	.	.	.	.	1
Veronica wormskjoldii	.	.	.	.	.	.	.	.	.	.	.	1
Bromus inermis	.	.	.	.	.	.	.	.	.	.	.	1

[1] Seral pre-fire subalpine fir forests: F-ABLA/CARU, LPO cover type; K-ABLA/VASC, LPO cover type; O-ABLA-PIAL/VASC, WB2 cover type. Letters denote seral cover types other than LPO: a-LP1, b-LP2 (Despain 1990).

[2] Habitat types are from grasslands/shrublands: E-FEID/ARTR, J-FEID/AGCA, A-DECA/CAREX, Douglas fir forests: C-PSME/SYAL, B-PSME/CARU, D-POTR/CARU, subalpine fir forests: I-ABLA/CARU, N-ABLA/VASC, P-ABLA-PIAL/VASC. Presence is in 0.01 hectare plots (n=3).

The mean species richness and its standard deviation of pioneer communities for each of the nine environments was calculated (Table 7). These communities are derived from climax pre-fire vegetation. Because only three sites were sampled for each environmental type, the standard deviation is often greater than the mean. A graphic display of mean species richness of the three postfire sample stands in each habitat type of mature pre-fire communities is found in Figure 4. The data presented is from Table 7.

The cover comparison of pioneer communities after severe fire in mature communities was condensed by summing cover of species in vegetational classes (i.e. trees, shrubs, herbs, graminoids) and ground cover types (i.e. coarse woody debris, litter, etc.). Each value is the mean for the three stands of each habitat type. The cover has been partitioned among life-forms and types of ground cover. The data is listed in Table 8.

Natural regeneration of tree species, seedling density, in the six forested environmental types after severe fire in mature communities was compared (Table 9). All habitat types were sampled three times. Included is data for subalpine fir habitat types that were burned in immature seral stages. Each seral stage (cover type) was sampled three times. Thus, the total sample size for the ABLA/VASC and ABLA/CARU HTs was twelve. The total sample size for ABLA-PIAL/VASC was six.

Table 7. Vascular plant species richness of pioneer communities five years after severe fire in mature communities of nine environmental types in the Greater Yellowstone Ecosystem. Habitat types are arranged in order of increasing altitude.

Habitat type[2]	Life Form[1] Trees	Shrubs	Forbs	Graminoids	Total
ARTR/FEID	0.0(0.0)	2.0(1.0)	26.7(12.9)	9.7(1.2)	38.0(11.8)
FEID/AGCA	0.0(0.0)	1.3(2.3)	25.3(1.5)	8.0(2.0)	34.7(0.6)
DECA/CARE	0.0(0.0)	2.0(1.0)	20.0(3.8)	10.7(2.1)	32.7(4.9)
PSME/SYAL	0.3(0.6)	3.0(1.7)	26.3(8.5)	7.7(2.5)	37.3(11.8)
PSME/CARU	0.3(0.6)	4.7(3.5)	28.3(6.1)	9.0(1.7)	42.3(7.5)
POTR/CARU	0.6(1.2)	2.7(2.3)	26.3(8.5)	6.0(3.0)	37.0(9.5)
ABLA/CARU	0.3(0.6)	0.3(0.6)	23.0(2.0)	10.7(4.0)	34.3(5.0)
ABLA/VASC	1.3(1.5)	1.7(1.2)	11.7(2.1)	5.7(0.6)	20.3(3.2)
ABLA-PIAL	0.0(0.0)	1.3(0.6)	12.7(2.1)	5.0(1.0)	19.0(1.0)

[1] Mean number of species per 0.01 hectare by habitat type (N=3). The standard deviation of the three sample stands is in parentheses.

[2] Habitat types are abbreviations for *Artemisia tridentata/ Festuca idahoensis* (ARTR/FEID), *Festuca idahoensis/ Agropyron caninum* (ARTR/AGCA), *Deschampsia caespitosa/ Carex* species (DECA/CAREX), *Pseudotsuga menziesia/ Symphoricarpos albus* (PSME/SYAL), *Pseudotsuga menziesia/ Calamagrostis rubescens* (PSME/CARU), *Populus tremuloides/ Calamagrostis rubescens* (PSME/CARU), *Abies lasiocarpa/ Calamagrostis rubescens* (ABLA/CARU), *Abies lasiocarpa/ Vaccinium scoparium* (ABLA/VASC), *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* (ABLA-PIAL).

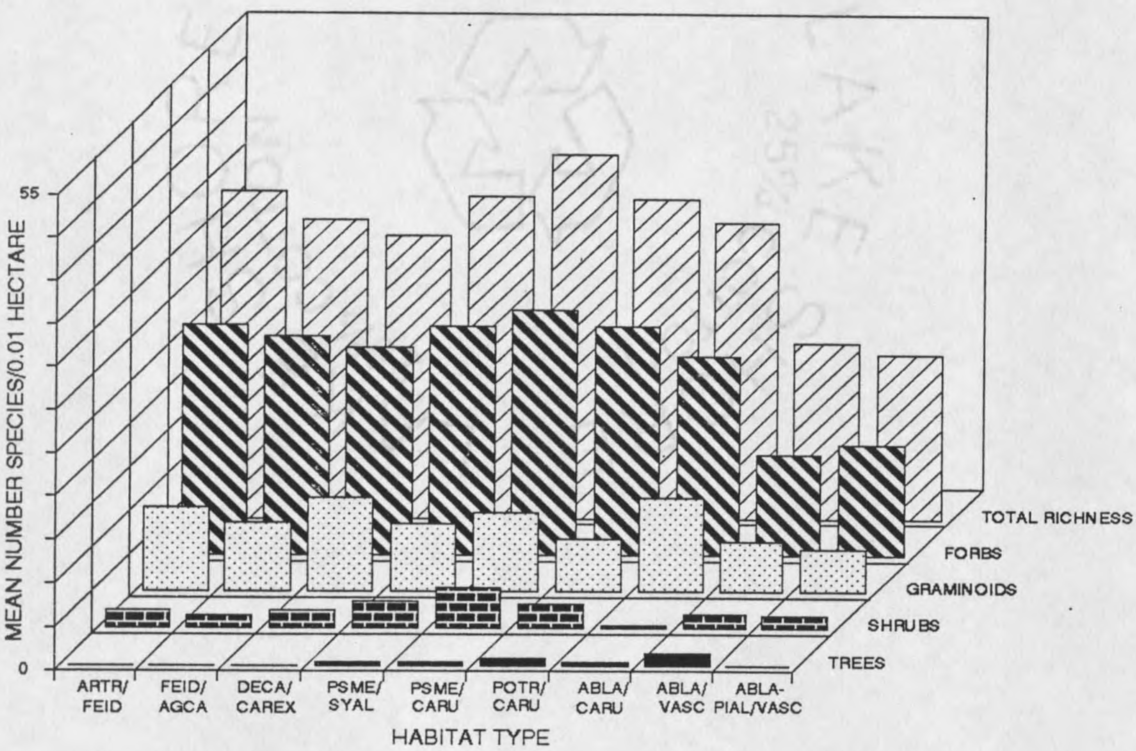

Figure 4. Vascular plant species richness five years after severe fire in mature communities of nine common environments of the Greater Yellowstone Ecosystem. Mean number of species present by life-form and for all species in 0.01 hectare plots (n=3) for each type. Habitat types are arranged in order of increasing elevation: *Artemisia tridentata/Festuca idahoensis* (ARTR/FEID), *Festuca idahoensis/Agropyron caninum* (ARTR/AGCA), *Deschampsia cespitosa/Carex spp.*(DECA/CAREX), *Pseudotsuga menziesia/ Symphoricarpos albus* (PSME/SYAL), *Pseudotsuga menziesia/ Calamagrostis rubescens* (PSME/CARU), *Populus tremuloides/ Calamagrostis rubescens* (PSME/CARU), *Abies lasiocarpa/ Calamagrostis rubescens* (ABLA/CARU), *Abies lasiocarpa/ Vaccinium scoparium* (ABLA/VASC), *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* (ABLA-PIAL/VASC).

Table 8. Mean percent cover and standard deviation (sd) of life-forms and ground cover in pioneer communities of nine environmental types in the Greater Yellowstone Ecosystem five years after severe fire in mature communities.

	Habitat type[1]								
Category[2]	E	J	A	C	B	D	I	N	P
Trees	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.1	0.0
sd	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.1	0.0
Shrubs	1.2	2.1	2.6	10.2	6.2	6.3	0.0	7.1	2.5
sd	1.1	3.6	2.7	10.7	2.1	6.9	0.0	7.5	3.6
Forbs	44.8	35.3	20.9	55.3	41.4	35.4	34.7	17.0	32.2
sd	18.9	14.1	8.5	29.0	21.7	15.3	6.6	4.4	7.3
Grass	43.9	47.5	73.6	9.2	35.9	32.0	30.2	17.1	4.6
sd	13.0	19.2	10.6	6.3	3.9	13.7	17.4	11.4	4.8
Mosses	0.0	0.0	0.1	2.2	5.1	2.0	0.7	10.5	5.1
sd	0.0	0.0	0.1	2.2	5.9	2.1	1.1	9.3	1.0
Litter	2.7	2.9	1.5	5.1	7.6	9.6	10.3	30.6	4.6
sd	1.2	2.4	1.6	7.9	4.9	10.3	2.6	12.8	3.6
C.W.D.	0.0	0.0	0.0	0.8	2.2	3.2	1.0	2.3	1.8
sd	0.0	0.0	0.0	1.4	3.9	3.7	0.4	2.0	0.2
Bare	5.5	11.5	2.6	7.0	4.6	7.7	19.2	16.4	46.9
sd	4.7	4.8	3.1	11.4	4.1	8.3	27.7	20.3	2.6
Total	87.4	99.6	97.0	89.7	102.0	96.7	96.3	100.9	97.4
sd	12.5	3.8	4.2	10.1	19.1	12.4	16.7	5.4	2.3

[1] Habitat types are arranged in order of increasing elevation: E-*Artemisia tridentata/Festuca idahoensis*, J-*Festuca idahoensis/Agropyron caninum*, A-*Deschampsia cespitosa/Carex* species, C-*Pseudotsuga menziesia/ Symphoricarpos albus*, B-*Pseudotsuga menziesia/Calamagrostis rubescens*, D-*Populus tremuloides/Calamagrostis rubescens*, I-*Abies lasiocarpa/Calamagrostis rubescens*, N-*Abies lasiocarpa/Vaccinium scoparium*, P-*Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium*.

[2] First line of each category is mean percent cover. Grasses include all graminoids, Mosses include hornworts, C.W.D.-coarse woody debris greater than 3 inches in diameter, Bare-bare ground, Total-total mean percent cover of all categories. Second line (sd) is standard deviation.

Table 9. Seedling[1] density five years after severe fire in mature or seral stage (cover type) forests of six environments (habitat types) in the Greater Yellowstone Ecosystem.

Habitat Type[3]	Cover Type[4]	Species[2] LPP	DF	SAF	AS	ES	Total	Substr. Ratio[5]
PSME/SYAL		0.67	0.33				1.00	2:1
PSME/CARU		1.67			0.33		2.00	3:0
POTR/CARU		0.33			30.33		30.66	3:0
ABLA/CARU	LP0	1.67					1.67	0:3
ABLA/CARU	LP1	24.67					24.67	0:3
ABLA/CARU	LP2	2.67					2.67	3:0
ABLA/CARU	LP3	5.67					5.67	3:0
ABLA/CARU	All	8.67					8.67	6:6
ABLA/VASC	LP0	17.33				0.33	17.67	1:2
ABLA/VASC	LP1	108.33			0.33		108.67	1:2
ABLA/VASC	LP2	93.00			0.33		93.33	1:2
ABLA/VASC	LP3	3.67			0.33	1.00	5.00	0:3
ABLA/VASC	All	55.58		0.25		0.08	55.91	3:9
ABLA-PIAL	WB2	1.00					1.00	3:0
ABLA-PIAL	WB3						0.00	3:0
ABLA-PIAL	All	0.50					0.50	6:0

[1] Mean number of seedlings per 100 meters squared (n=3). For all sites of ABLA/CARU and ABLA/VASC, n=12. For all ABLA-PIAL sites, n=6.

[2] LPP-lodgepole pine, *Pinus contorta*, DF-Douglas fir, *Pseudotsuga menziesii*, AS-aspen, *Populus tremuloides*, SAF-subalpine fir, *Abies lasiocarpa*, and ES-Englemann spruce, *Picea engelmannii*.

[3] Habitat abbreviations (Steele and others 1983, Mueggler 1988): *Pseudotsuga menziesia/ Symphoricarpos albus* (PSME/SYAL), *Pseudotsuga menziesia/ Calamagrostis rubescens* (PSME/CARU), *Populus tremuloides/ Calamagrostis rubescens* (PSME/CARU), *Abies lasiocarpa/ Calamagrostis rubescens* (ABLA/CARU), *Abies lasiocarpa/ Vaccinium scoparium* (ABLA/VASC), *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* (ABLA-PIAL).

[4] Pre-fire cover types in subalpine forests increase from early seral to mature stand development: LP0, LP1, LP2, LP3. Whitebark pine forests are mid- (WB2) to late (WB3) seral stages (Despain 1990).

[5] Ratio of sample stands on soils derived from relatively fertile andesitic (A) or relatively infertile rhyolitic (R) substrate.

DISCUSSION

Plants Found.

There were 262 vascular plant species identified in the 48 stands sampled. These included five tree, twenty-five shrub, 179 herb, and 53 graminoid species.

Only one plant species new to Yellowstone National Park was found. This was *Silene latifolia* Poir., a perennial catchfly, an exotic herb from Europe. While the Montana State University herbarium did not have a collecion from Montana, it has been collected in various parts of Wyoming (Dorn 1992).

Two species common in first year postfire communities, probably arising from the seed bank, were rarely found five years after the fires. They were *Geranium bicknellii* and *Dracocephalum parviflorum* (Stickney 1990, Anderson and Romme 1993). Of these postfire ephemerals, *G. bicknellii* was found in only two Douglas fir sample stands and *D. parviflorum* was not found in any of the communities sampled.

Pioneer Communities of Major Environmental Types

Fires will continue to occur in all nine environmental types studied. To describe severe fires' initial effects, pioneer communities have been described with a list of colonizing plants and the coverage of each (Tables 5 and 6).

The information has also been compiled to characterize and compare pioneer communities, as a whole, by habitat type, across the elevational gradient (Tables 7 and 8). The underlying individual sample stand data is summarized in Appendix C.

Plants expected in any environmental type are identified by reading down the appropriate column in Table 5. Those represented by a three occurred in 3 of the 3 sample sites and have a high probability of being found. Those represented by a two have a 66.6% probability of occurrence and those represented by a one have an average probability of 33% of being located in pioneer communities of the environmental types considered. These probabilites have a high variance because the sample size was minimal.

Non-ecologists often fear that severely burned sites will revegetate slowly. Table 8 lists the mean percent cover of life-forms and ground cover types of the nine major environmental types. Bare ground cover, five years after fire, was lowest (3%) in the *Deschampsia cespitosa/ Carex spp.* HT and highest (47%) in the *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* habitat type. No other HT exceeded 20% bare ground (Table 8), thus a reasonable amount of vegetative cover appeared in all environments except forests near treeline five years after fire.

Species Distribution Along the Environmental Gradient

Forty-two species appeared in most pioneer communities following severe fire across the entire environmental gradient (Table 5, Sections A and B). These "universal" species are 25% of the 166 species occurring more than once in the sample stands. These species are also present in pioneer communities of forest stands that burned in early to mid-seral stages. Species of this distribution were divided into those that were common (Table 5, Section A) and those that were missing in a few habitat types (Table 5, Section B). If more samples in each habitat type had been taken, the species of weak distribution would probably be found to actually occupy all the environmental types. Of the forty-three species occurring across the environmental gradient only four are exotics.

A variety of adaptations exist for species to be successful pioneers. No single strategy defines those that were successful across the elevational gradient. Some are present vegetatively in mature communties before severe fire and others are not (Pfister and others 1977, Steele and others 1983). Examples of universal species present in the mature communities of these habitat types that resprout after fire are: *Antennaria microphylla*, *Fragaria virginiana*, *Astragalus miser*, *Lupinus spp.*, and *Achillea millefolium* (Table 5). Others are perennials with excellent seed dispersal capabilities, especially by wind: *Epilobium* *angustifolium*, *Agoseris glauca*, *A. aurantiaca*, and *Taraxacum officinale*. Thus, these may colonize from sprouts, the seed bank, or off-site dispersal. Still others are annuals that are rarely present in climax communities, such as *Collinsia parviflora*, *Collomia linearis*, *Epilobium paniculatum*, *Descurainia richardsonii*, and *Polygonum douglassii*. These may colonize from the seed bank or by disperal.

As expected, there are many species with a much narrower ecological amplitude. Twenty-one species occurred in only the shrubland/grassland environments (Table 5, Section C). Constancies of these species were similar to those of rarer universal species (Table 5, Section B) and lower than those of more common universal species (Table 5, Section A). In apparent contrast with climax dominants (grasses), only six grassland/shrubland specialists are graminoids and most of these (four) are from the extremely wet DECA/CAREX habitat type. Most of the grassland pioneers are perennial herbs and shrubs from genera such as *Artimesia*, *Chrysothamnus*, *Erigeron*, and *Eriogonum*.

A third group of species pioneered in both grassland and montane forest environments but were absent in subalpine fir environments (Table 5, Section D). Two-thirds of these species are perennial forbs and only one is a shrub. Several species are common pioneers in both grasslands and montane forests, examples are *Galium boreale*, *Poa juncifolia*, and *Solidago missouriensis*. Others species such as *Trifolium* *hybridum*, *Agropyron spicatum*, and *Phlox hoodii* are common in pioneer grasslands but appear rarely in montane forests. These species may be less shade tolerant than those occupying both environments and therefore may have left a poorer seed bank in the forested environments. In this study, there were no examples of species with the opposite distribution, i.e. species commonly pioneering montane forests and uncommon in the grassland/shrubland environments.

Some species appear in postfire communities of mature stands in mid- and low elevational environments (Table 5, Section D) or mid-elevational montane forests (Table 5, Section E) and high elevational subalpine fir environments burned in early seral stages. They are absent in the postfire communities of mature subalpine fir forests. It could be speculated that such species colonize from on-site sources, vegetative sprouting and seed banks, but that they are absent from the more mature subalpine fir forests.

Nine of the 25 species listed in Table 5, Section E, are annuals or biennials. These species rarely occur in climax communities of subalpine fir or montane environments (Steele and others 1983). Five of the species are shrubs common in climax forests, for example, *Spirea betulifolia* and *Rosa acicularis*. These can resprout after fire. Several species appeared in both low grasslands and high subalpine fir sites after early seral communities burned. The perennials that can resprout, *Danthonia spicata* and *Potentilla diversifolia* are examples. It could be anticipated that the weedy exotics, *Cirsium vulgare* and *Cynoglossum officinale*, would be found in other environments if the sample size were larger.

Nineteen species pioneered after fire in all six forest environments (Table 5, Section F). There were three annuals, *Nemophila breviflora*, *Draba stenoloba*, and *Gayophytum racemosum*. Most are perennials. All were forbs and graminoids, none were shrubs or trees. Some were more common in subalpine fir forests than montane forests. Four examples are *Arnica cordifolia*, *Trisetum spicatum*, *Hieracium albiflorum*, and *Carex rossii*. These all have capabilities to establish either vegetatively or to colonize via the seed bank and seed rain. In contrast, *Poa interior*, a perennial grass, is an example of a species more common in the montane than in the subalpine fir forest environments.

A few species, thirteen, occurred primarily in the subalpine fir environments regardless of pre-fire stand development (Table 5, Section G). Grouse whortleberry, *Vaccinium scoparium* and lodgepole pine, *Pinus contorta*, are examples. Species occurred occasionally in the many (30) postfire stands sampled in these three environments, but never appeared in lower elevational sites. Thus, there is sufficient evidence that these are pioneers restricted to higher elevations.

Thirteen species were found to have a bimodal distribution (Table 5, Section H). These appear after fire in both moist grasslands and subalpine fir environments but not on sites occupied by mid-elevational Douglas fir and aspen forests. It is not clear what excludes them from the montane environments. All are perennials, either forbs or graminoids. Most are present in climax communities of these environments (Steele and others 1983). Thus, all may survive fire and reproduce vegetatively. Some species with bimodal patterns may be artifacts of the small sample size; a larger sample would aid in detecting such species.

Six species occurred in several sample stands, but only in pioneer communities derived from seral subalpine fir forest stands (Table 5, Section I). These species also occur in climax subalpine fir environments (Steele and others 1983). Thus, there is little evidence that they require disturbance to maintain their presence in subalpine fir forest environments.

One hundred and one species appeared in only one pioneer community (Table 6). The bigleaf sagebrush/Idaho fescue HT had only five singletons. The other grasslands had many species occurring only once. The Idaho fescue/bearded wheatgrass HT had fifteen and the tufted hairgrass/sedge HT had eighteeen. Pioneer communities derived from the subalpine fir forests had very few species of single occurrence; ABLA/CARU and ABLA-PIAL/VASC had three singletons each. The lack of species occurring only once at high elevations parallels overall species richness (Table 7) and may indicate stress due to environment.

Species Richness and Cover Along the Environmental Gradient

Species richness of postfire pioneer communities is compared among environmental types along the elevational gradient (Table 7 and Figure 4). Similarly, the mean percent cover by life-form and ground cover type is given in Table 8. Six of the environmental types are forests at maturity before fire. Regeneration of tree species along the gradient is included in the discussion (Table 9). Only postfire communities derived from mature pre-fire vegetation in each of the nine environmental types is characterized, except for tree seedling density.

Very few tree species were present in any of the nine environmental types, partially because few exist in the arboreal flora of the environments studied. No trees occurred in the three grassland/shrubland postfire sample stands. In montane environments, the Douglas fir habitat types had low seedling densities, no greater than 200 seedlings per hectare. These pioneer communities contained both lodgepole pine and Douglas fir cohorts. The aspen forests had over ten times the seedling density of adjacent Douglas fir environments (3,000 seedlings per hectare), most seedlings were aspen resprouts. This low tree seedling density corresponds to cover and species richness values for the montane forests.

The highest diversity in tree species was in the ABLA/VASC HT with a mean of 1.33 tree species/0.01 hectare (Table 7). The most common seedling was the lodgepole pine (Table 9). Values of less than one for tree species richness indicate some of the forested sites had no tree seedlings in the sample site macroplots. Trees are not expected to dominate in the forest environments so soon after severe fire. There was little cover contributed by trees in the pioneer communities (Table 8).

Although tree species diversity and cover was low, some sites in subalpine fir environments had moderate seedling densities. Tree seedling density (Table 9) was highest in the ABLA/VASC HT, 5600 seedlings per hectare, most were lodgepole pine. Very few seedlings appeared in the ABLA-PIAL/VASC HT; there were 500 seedlings per hectare. These harsher timberline environments will be slower to colonize. In a study of lodgepole pine forests two years after the 1988 fires, seedling density varied from 900 to 191,000 seedlings per hectare (Ellis 1993). Thus, the subalpine fir forests from this study are at the lower end of seedling density variability found by Ellis.

For pioneer shrubs, the richest environments were the montane forests (Table 7). The Douglas fir/pinegrass HT had a mean of 5 shrub species/0.01 hectare and 6% shrub cover.

Shrub cover was highest, 10.2 %, in the PSME/SYAL HT and second highest, 7.1% in the ABLA/VASC HT (Table 8). These two environmental types each have an understory dominated by shrubs at climax.

In the grassland/shrubland types, the moist tufted hairgrass/sedge HT had the same amount of shrub species as the bigleaf sagebrush/Idaho fescue shrubland. Thus, the physiognomy of climax communities does not necessarily provide a greater species richness within that life-form in pioneer communities after fire. The moist DECA/CAREX HT may be a more diverse environment than the ARTR/FEID HT which, before fire, is dominated by one species of sagebrush. The DECA/CAREX HT also had more shrub cover in the pioneer communities than the ARTR/FEID habitat type.

Graminoid richness was equally high in the grasslands and the grassy forests, that is, forest environments dominated by pinegrass in the understory in late-seral stages (Table 7). This data suggests both the PSME/CARU and ABLA/CARU HTs are simply moist grasslands with a forest canopy. However, the grassland/shrubland environments had higher graminoid cover than any of the grassy forest environments (Table 8). The aspen stands, although described as having pinegrass as the dominant understory component in mature pre-fire communities, had less graminoid richness in pioneer communities than the coniferous forest pioneer communities, except the two high elevation subalpine fir HTs.

Postfire graminoid richness is relatively constant across the entire environmental gradient, from a low of 5.0 graminoids/0.01 hectare in the ABLA-PIAL/VASC HT to a high of 10.67 graminoids per 0.01 hectare in both the ABLA/CARU and DECA/CAREX habitat types (Table 7). The graminoid cover differs across the elevational gradient, with a low of 4.6% in the subalpine fir-whitebark pine/whorttleberry HT and a high of 73.6% in the DECA/CAREX habitat type (Table 8). Species in combination with their cover, rather than richness of graminoids, defines the differences in climax physiognomy between forests and grasslands.

Forbs dominate species richness in all environmental types (Table 7). Forbs accounted for over half of the species in pioneer communities in all environments except near treeline in the subalpine fir-whitebark pine environments. ARTR/FEID and FEID/AGCA grasslands had at least six more species per sample stand than the wet tufted hairgrass/sedge habitat type. This higher richness of forbs in the drier grasslands accounted for the higher herbaceous cover. The richest part of the environmental gradient for forb diversity in pioneer communities appeared in the mid-elevation Douglas fir/ pinegrass and aspen/pinegrass habitat types. Forb cover was highest, 55 percent, in the slightly lower elevational Douglas fir/snowberry habitat type (Table

8). At these sites over half of the pioneer vegetation was dominated by forbs. Thus, forb species richness and cover are only loosely related.

Differences in diversity become most evident when combining all life-forms into total species richness (Table 7). The diverse pioneer communities of the Douglas fir/pinegrass HT, with 42 species per 0.01 hectare, were over twice as rich as pioneer communities of subalpine fir-whitebark pine/whortleberry HT that had a mean of nineteen species/0.01 hectare. The high elevation subalpine fir HTs, ABLA/VASC and ABLA-PIAL/VASC were clearly the least species rich of the nine environmental types. The lowest seven elevationally - grasslands, montane forests, and the subalpine fir/pinegrass HT were relatively similar in total species richness, varying between means of 32 and 42 species per 0.01 hectare.

The total mean percent cover of vascular plants in pioneer communities of each of the nine environmental types was highest, 97 percent, in the wet grassland, DECA/CAREX habitat type (Table 8). Recovery from fire is rapid in this type, primarily from vegetative regeneration. The lowest vascular plant cover, 39 percent, was in the pioneer communities of the subalpine fir-whitebark pine/whortleberry habitat type. The low vascular plant cover parallels the lack of species richness in this environmental type. This cool, wet environment with a short growing season (Weaver

1990) recovers slowly from disturbance. The three montane forest environments have total mean vascular plant cover, ranging between 74% and 84%, indicating a relationship between high coverage and species richness.

While pioneer communities contain many species, this richness can be expected to decrease as stands mature and competition for resources becomes more intense. Many of the annuals and biennials will become rare or disappear as studies at "climax" indicate (Pfister and others 1977, Mueggler and Stewart 1980, Steele and others 1983). The grassland environments have already recovered much of their pre-fire cover, as expected (Antos 1983). The sagebrush/shrubland pioneer communities will take several more decades to reach climax (Harniss and Murray 1973). Cover of the trees will increase in the forests as the sites develop.

CONCLUSIONS

Pioneer communities following fire in nine major environments of the Greater Yellowstone Ecosystem have been described. Forty-two species occurred in most of the nine environmental types along the elevational gradient. This was 25% of the 166 species identified more than once in the study. These species can be expected to pioneer after future fires in the northern Rocky Mountains regardless of the location of the burned area's position along the environmental gradient.

There were various patterns of distribution for each of the other 122 species, they all have been described. These species were restricted to pioneer communities in assorted portions of the environmental gradient after fire. The distribution patterns could not be summarized by methods of colonization after fire. Each pioneer species had varying strategies in various combinations: vegetative sprouting, canopy seed rain, off-site seed disperal, and the seed bank (Stickney 1990).

Five years after severe fire, pioneer communities across the elevational gradient differed in recovery response and rates. The wet grasslands recovered quickly; their total vascular plant cover is 97 percent. In contrast, communities in subalpine fir environments near treeline have vascular plant cover averaging 39 percent. The six habitat types in the grassland and montane forest environments had an average plant cover between 74 and 97 percent. In the three subalpine fir forest environments, at higher elevations, plant cover averaged less than 66% of a site. Thus, there was a trend for cover to decrease with increasing elevation.

Species richness of pioneer communities five years after severe fire in climax communities along the elevational gradient was highest in the montane forest zone. The highest diversity, a mean of 42 species per 0.01 hectare, was in the Douglas fir/pinegrass habitat type. Mean species richness, from the lowest grasslands/shrublands up to the lowest subalpine fir zone, varied between 32 to 42 species per 0.01 hectare, indicating that the position along the elevational gradient did not exert a great influence on pioneer community richness. The two highest subalpine fir environmental types were distinctively lower in richness, means were 19 and 20 species per 0.01 hectare. These harsher environments have less species capable of establishing after fire.

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PART II

EFFECT OF PRE-FIRE SERAL STAGE ON POSTFIRE PIONEER COMMUNITIES IN SUBALPINE FIR ENVIRONMENTS

INTRODUCTION

In Yellowstone National Park and adjoining lands, a series of fires burned 276,533 hectares (683,305 acres) of various vegetation types during the summer and autumn of 1988 (Rothermal and others 1994). The fires were superimposed over a pre-fire landscape that contained forests of different ages and species composition (Knight and Wallace 1989). Due to the extent of the fires in the Greater Yellowstone Ecosystem, pioneer communities derived from various pre-fire developmental stages were available for comparison.

In this study, the pioneer communities from two subalpine fir environments were the focus of attention. Sites examined were burned in four seral stages, aged forty to over three hundred years. All received severe stand-replacing fire. This type of fire causes total mortality of the tree strata, burns the aerial portions of the understory plants, and consumes most or all of the duff layer on the forest floor.

Objective

This study has one major objective: To test the hypothesis that the pre-fire seral stage determines differences in postfire communities five years after severe fire in an environmental type of the subalpine fir zone.

LITERATURE REVIEW

Community Succession

Fire, insects, wind, and avalanche are major mechanisms of disturbance in the ecosystems of the northern Rocky Mountains (NRM). Most forests in the Rocky Mountains are in some stage of recovery from prior disruption (Peet 1988). These perturbations alter species composition, change rates of processes and modify complexity in the ecosystem. There is a high degree of variability in response by communities as a consequence of the nature of the disturbance, frequency of occurrence, intensity and timing.

Recovery from disturbance in an existing ecosystem is termed "secondary succession". It has been repeatedly defined by ecologists of the twentieth century as new concepts and different approaches to its study have developed. Most definitions describe secondary succession as the sequential change in community or ecosystem properties occurring after disturbance at a given site (McIntosh 1980). The defining aspect of secondary succession is that unlike primary succession it begins with developed soil, organic matter and vegetative propagules that hasten vegetation development (van der Maarel 1988).

The classical view that a succession of plant communities (sere) proceeds from pioneer through various seral stages to a single, mesophytic, stable climax under control of regional climate is often attributed to Clements (1916). This paradigm has undergone extensive critique and has been modified by subsequent studies (McIntosh 1980). Implicit in Clement's view is the assumption that each seral stage modifies the site such that it is less suitable for its own persistence and more favorable for successors (Noble and Slayter 1980). This theory led some to a holistic view such that the series of plant communities grew, maintained, and replaced themselves like a developing organism (supraorganism). Recent ecologists seek a theory which incorporates Clement's observations with the following: different climax-assemblages seem to occur in a climatic region, degradation of assemblages has been observed, often induced by the vegetation itself and cyclic vegetation change processes sometimes occur (Burrows 1990).

Various patterns, models and generalized mechanisms of succession have been studied and described. Clement's holistic concept of succession, although problematic, dominated successional theory for the first half of the twentieth century. Later, proponents of successional development as a community-based property, sought universal explanations of pattern and process. They were widely read but lacked little empirical evidence for their theories. Margalef (1968) applied information theory to explain ecosystem strategies. He argued that trophic levels and populations represented information and succession represented a trend towards the accumulation of greater information in an ecosystem (Glenn-Lewin and others 1992). Odum (1969) suggested that certain successional trends were present in all ecosystems, that most ecosystems tended to develop towards greater homeostasis, diversity and accumulation of biomass. These two authors' synthesis of succession was similar to Clements in that succession was dominated by interactions within the community and external influences such as climate change, immigration of new species and large-scale disturbance created slight variation around monolithic intrinsic change (Glenn-Lewin and others 1992).

Some empirical studies have indicated that the community as an organism concept is inadequate. Eggler (1954) could not find relay floristics--the entry and exit into the community by successive species--in old-field succession in the eastern United States. Instead, his studies demonstrated the importance of the initial floristic composition. His principal point was, after disturbance, colonizing populations change very slowly and restrict invasion by subsequent species as the community develops. Thus, gradual change to a community via the appearance and disappearance of original colonists makes the existence of "organismic" development doubtful. This concept is reinforced by the reductionist viewpoint of Gleason (1926), that it is the individual species that are of interest and community succession is simply the aggregate change of individual species.

Succession has also been described as a population process where community transformation is due to simultaneous establishment and mortality of species populations which determine changes in community composition and structure (Peet and Christiansen 1980). Ecologists recognized mechanisms of succession were not as universal as the holism proponents (Clements 1916, Margalef 1968, Odum 1969) held and thus, a major shift in the last twenty years has been towards mechanistic and reductionistic explanations. Also, the concept that ecosystems tended towards equilibrium (climax) has been de-emphasized.

Predictions of vegetative change are less universal and are now more commonly derived from the knowledge of local habitats and species composition. With the passage of time since a disturbance, shifts of dominance in a community often occur. Due to the extensive studies of succession, the causes and mechanisms of change have been put into a three-tiered hierarchical framework so that confusion can be diminished (Pickett and others 1987). The three levels are: general causes, contributing processes, and defining factors. Within the category of general causes expounded by the authors: site availability, differential species availability and differential species performance are the primary reasons for vegetative change.

Three models of succession have been proposed (Connell and Slayter 1977): facilitation (relay floristics), tolerance (species are successful whether or not other species have preceded them) and inhibition (later species cannot grow in the presence of earlier ones) pathways. These are general models that describe the sequential change observed in plant communities. All fail to recognize the adaptive traits of a species that can persevere after disturbance and the periodicity of the perturbation (Cattelino and others 1979). Several studies in the Rocky Mountains suggest that development in fire-prone plant communities follow the "tolerance pathway" (Lyon and Stickney 1976, Humphrey 1984, Akinsoji 1988).

The mechanisms that allow plant species to occupy a site after perturbation have been attributed to their life-forms (Raunkier 1934), named "plant strategies" (Grime 1977), or "vital attributes" (Nobel and Slayter 1980). Considering fire, specifically, species have various characteristics that allow them to successfully re-establish after various burn intensities (Gill 1975, Noste and Bushey 1987, Stickney 1990). As a consequence of life history traits and other characteristics of the species involved, differing patterns of succession are a result of differing species characteristics (Humphrey 1984).

In forests of the northern Rocky Mountains, physiognomic change is often quite consistent after fire. Early postfire communities are dominated by herbaceous cover. Over time, shrubs assume dominance. Finally, the tree stratum emerges and overtops the other layers. For example, this occurs in Douglas-fir environments (Debyle 1981), western red cedar-hemlock environments (Stickney 1986), Douglas-fir and subalpine fir habitat types in western Montana (Arno and others 1985), as well as larch forests (Shearer and Stickney 1991). The original composition of the fire-established cohort of trees is extremely important in determining the succeeding tree stratum; most recruitment to the climax tree layer is in the first five years after fire (Johnson and Fryer 1989). Further analysis substantiated the absence of recruitment into the overstory by trees not present in the early postfire community of lodgepole pine-Engelmann spruce forests of the southern Canadian Rockies (Johnson and others 1994). They attributed the absence of new overstory trees to low recruitment and high mortality of subsequent cohorts.

The importance of pre-fire vegetation on the course of secondary succession, after fire, is important in several Northern Rocky Mountain environmental types. After severe fire in a western redcedar-hemlock forest, initial floristics, as a result of on-site survivors and off-site colonizers, is a strong determinant of subsequent plant community development (Stickney 1986). This was also the case in lodgepole pine forests following the 1988 Yellowstone fires, two thirds of the individuals present in the first postfire year were from vegetative regrowth (Anderson and Romme 1991). This closely follows similar studies in Douglas-fir forest ecosystems (Lyon 1976). In south-central Idaho virtually all perennial herbaceous species survived prescribed fire as vegetative resprouts. Vegetative resprouts were also important contributors to early post-fire Douglas-fir communities in western Montana (Crane and others 1983).

Postfire communities reflect pre-fire communities due to several other mechanisms. On-site propagules for postfire communities are the seed bank and seeds stored in the tree canopy; these sources are defined as residual colonizers (Stickney 1990). The Yellowstone fires reduced forested site seed bank densities by 80% and species richness by 65 percent (Clark 1991). However, this reduction left significant quantities and a variety of species since the undisturbed seedbanks averaged 4,000 seeds per square meter. The most prominent residual tree colonizer in Yellowstone forests is lodgepole pine. This species is known to have adapted to frequent destructive fires via cone serotiny, a trait that seals and thus protects the seeds in their cones from damaging fires (Wheeler and Critchfield 1985). When fires occur, they destroy the sealant and the seeds are released after fire passes. Early postfire lodgepole seedling densities in surface and crown fires of lodgepole stands after the 1988 Yellowstone fires ranged from 0.09 to 191 per meter squared. They were consistently higher in the moderately burned sites than those receiving severe burns (Ellis 1993). Lodgepole pine seedlings were not greatly affected by competition from the herbaceous species in early seral stands, seedling density was not related to that of its potential competitors (Anderson and Romme 1991).

Off-site colonizers are another important component of the initial postfire community (Stickney 1990). This source is primarily from seeds that are capable of dispersal to the site. Dispersal characteristics indicate distances that a species is capable of traversing, primarily by wind. Other important mechanisms are transport by birds and mammals. Of nine different conifers of the NRM, none, except western hemlock, *Tsuga heterophylla*, are able to disperse more than 30% of their seeds 100 meters by wind (McCaughey and others 1986). A micrometeorological model of winged or plumed seeds adequately characterizes the disperal curve from the source based on six parameters (Greene and Johnson 1989). This experiment used lodgepole pine, two hardwoods, and a common forb with a plumed achene (*Tragopogon dubius*). It showed the importance of wind and release height for disperal distance.

Some plants use animals for seed dispersal. The primary agent for wingless whitebark pine, *Pinus albicaulis* seeds are Clark's nutcrackers, *Nucifraga columbiana* (Tomback and others 1990). These birds are known to cache the seeds thousands of meters from the source. This may give whitebark pine a competitive advantage in large burns where source trees dependent on wind dispersal, such as subalpine fir, are too far away to be as successful. Other species have adaptations, such as hooks and burrs that attach seeds to the coats of animals for dispersal. Another mode of dispersal are seeds that remain viable after passage through the digestive tract of frugivores.

To summarize the preceding, studies of early postfire succession in the NRM indicate that in most environments, from the shrub-steppe to the subalpine, initial floristics are determined by pre-fire vegetation and resprouting remains a strong factor in subsequent stand development. Initial floristics is also dependent on propagules, both residual or off-site colonizers (Stickney 1990). Although pre-fire communities are believed to be an important factor, no studies have determined whether different successional stages lead to differences in early postfire communities within similar environments (habitat types).

Secondary Succession Models

Several models of succession have contemplated the possibility of a wide variety of early seral stages, due to differences in disturbance types and severity (Huschle and

Hironoka 1980). It is hypothesized, in time, these early and mid-seral communities will slowly converge to a more narrowly defined climax community. Convergence theory states that the similarity of different seres in an environment increases as succession proceeds from early to late stages. Therefore, various replacement sequences on the same site create multiple pathways of succession to a narrow compositional climax (Cattelino and others 1979). This concept has also been modeled using a cone as an analogy (Huschle and Hironoka 1980). The wide base of the cone allows for many potential early seral communities but variability in seres decreases to a narrowly defined climax plant community at the apex.

Empirical tests of convergence models have been conducted. In four forested habitat types (subalpine fir and Douglas-fir) in the NRM, predictability was 74% accurate for cover classes of all species (Keane 1987). Multiple pathway community composition was computer modeled for vegetation after wildfire or silvicultural treatment; the model appears fairly successful. The secondary succession cone model after disturbance in grasslands has also been tested and supported in Idaho (Huschle and Hironaka 1980). An ordination of 27 stands within an *Agropyron/Poa* grassland indicates vegetative composition narrows as succession proceeds. Convergence towards the characteristic climax in secondary forest succession in other areas has also been confirmed (Christensen and Peet 1984).

On the other hand, there have been reports that demonstrate that divergence also occurs as a result of chance and historical factors in the stand. It was shown that similar climax communities will maintain considerable differences in composition as a result of stand history in a study of climax forests in the Bitterroot Mountains of western Montana (McCune and Allen 1985). In a syntheses of divergence-convergence examples from around the world, Leps (1991) concluded that many factors influence the successional seres in vegetation and that there isn't one general pattern towards either convergence or divergence. However, it appears from the studies in the NRM that convergence is more prominent and its predictability can be modeled.

METHODS

Study Area

The Greater Yellowstone Ecosystem (GYE) is a mountainous segment of the northern Rocky Mountains shared by the states of Idaho, Wyoming, and Idaho. The center of the ecosystem is Yellowstone National Park. It is surrounded by six National Forests, two National Wildlife Refuges as well as other public and private land holdings. Included in the ecosystem to the south is Grand Teton National Park. The complexity of the land ownership and its changing ecological character make definition of exact boundaries for the ecosystem difficult (Glick and others 1991). The land base is approximately 17 million acres (7 million hectares).

Study Site Selection

Since this study sought to compare pioneer communities occupying sites with different pre-fire vegetation, three replications from each of four pre-fire seral stages in the subalpine fir/pinegrass environmental type were located (n=12) and sampled. To replicate these observations, twelve parallel sites from the subalpine fir/whortleberry habitat type were studied.

A previous project (Clark 1991) had located 21 study sites in subalpine fir environments in the GYE after the 1988 fires. These included all stages of development in subalpine fir/whortleberry and subalpine fir/pinegrass habitat types (HTs). All stands were severely burned in 1988 and all were located within one month after the fires were extinguished. Clark's original selection was aided by the habitat type and seral stage (cover type) map of Yellowstone National Park (Despain and others, unpublished). Each site was located near an unburned portion of the same plant community so that verification of vegetative composition and therefore the environmental type and seral stage could be made.

In the summer of 1993, Clark assisted in relocating the 1988 sampling sites for this study. The metal stakes from the original study were found with the aid of a metal detector. If these could not be found, the exact transect position could not be used. In these cases, the new transect was located in the same stand and in close approximation to the original.

Of the original 21 sample stands in the subalpine fir habitat types, 17 were found to be suitable for this study. Four of the original transects could not be used for the present study due to logging disturbance, improper classification, or they could not be relocated. New sites were identified in the same environmental type and pre-fire seral stage for these four stands.

Three additional sites were established in 1993 so that three replications of each pre-fire seral stage (cover type) for each habitat type could be sampled. The new stands were located in LP0 cover types undersampled in the original study. Use of Despain and others' (unpubl.) Yellowstone National Park habitat type maps aided in finding the appropriate habitat type and cover type for all seven new sampling sites (see Table 11 for new stands).

The code name, location, elevation, and general soil type is listed for all stands (Table 10). All sites sampled for this study were within Yellowstone National Park's boundaries except one, it was located on Gallatin National Forest lands north of the Park. Stand locations in relation to Yellowstone National Park's boundaries are displayed in Figure 5.

Environmental Types

Stands were selected by environmental type (habitat type) both to represent the diversity of climatic factors within the study area and to aid in extrapolating the findings to a larger geographic setting. It is expected that the composition and vegetative characteristics of secondary succession after stand-replacing fire observed in this study will approximate similar responses in other units of the corresponding environmental type throughout the northern Rocky Mountain region.

Table 10. Sample stand location. Stand codes, legal descriptions (Universal Transverse Mercator - Zone 12), elevations and substrate indicating relative fertility.

Code	Site Name	UTM Coordinates	Elevation (meters)	Substrate[1]
F1	Indian Creek	49683 N, 5174 E	2316	A
F2	Heart Junction	48966 N, 5385 E	2245	A
F3	North Indian Creek	49688 N, 5172 E	2316	A
G1	Willow Park North	49681 N, 5208 E	2246	R
G2	North Roaring Mtn.	49598 N, 5208 E	2316	R
G3	Tuff Creek	49441 N, 5132 E	2121	R
H1	Golden Gate	49756 N, 5215 E	2251	R
H2	Madison	49440 N, 5015 E	2238	R
H3	Grotto Geyser	49246 N, 5126 E	2246	R
I1	South Canyon	49495 N, 5401 E	2380	A
I2	Southeast Swan	49716 N, 5221 E	2199	A
I3	Obsidian Creek	49653 N, 5206 E	2253	A
K1	Fan Creek	49781 N, 4967 E	2230	A
K2	Cygnet Lakes	49469 N, 5315 E	2569	R
K3	Canyon - Norris	49521 N, 5372 E	2469	R
L1	Lulu Pass	49865 N, 5866 E	2487	A
L2	Willow Park	49628 N, 5215 E	2254	R
L3	Grizzly Trailhead	49609 N, 5207 E	2322	R
M1	West Thumb	49192 N, 5335 E	2377	A
M2	Lewis Lake	49039 N, 5306 E	2412	R
M3	Lewis Canyon	48974 N, 5275 E	2359	R
N1	Little Thumb	49185 N, 5312 E	2503	R
N2	Canyon - Norris	49522 N, 5374 E	2469	R
N3	Virginia Falls	49507 N, 5282 E	2417	R

[1] Substrate: A - Andesite, basalt, sedimentary (fertile soils); R - Rhyolite, gneiss, granite (infertile, well-drained soils)

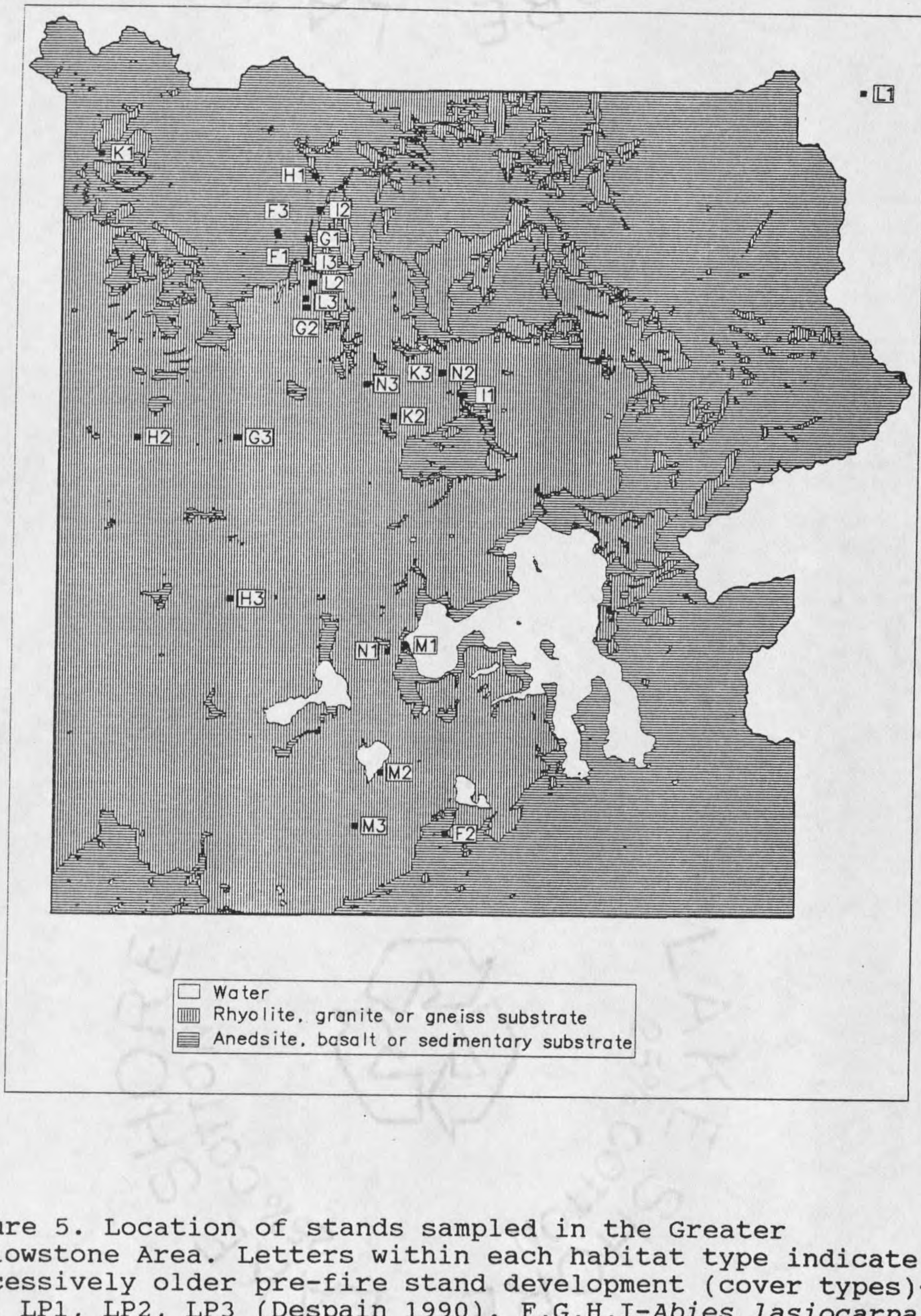

Figure 5. Location of stands sampled in the Greater Yellowstone Area. Letters within each habitat type indicate successively older pre-fire stand development (cover types)- LP0, LP1, LP2, LP3 (Despain 1990). F,G,H,I-*Abies lasiocarpa/ Calamagrostis rubescens*, K,L,M,N-*Abies lasiocarpa/ Vaccinium scoparium*. Numerals indicate replications.

This expectation is based on the assumption that similar environmental and historical constraints are operative throughout all habitat types. The regional system of environmental classification, habitat type, was developed in eastern Washington and northern Idaho (Daubenmire 1952). It was extended to the forests of Montana (Pfister and others 1977) and the forests of eastern Idaho and western Wyoming including the environments of Yellowstone National Park (Steele and others 1983).

In this study environmental type and habitat type are used as synonyms. Environmental type is used to emphasize the concept of climate, other abiotic and biotic factors. Habitat is avoided since it connotates to many, the notion of place, especially for fauna.

This classification system groups land units according to their environmental qualities. In mountainous regions, climax vegetation is the best indicator of environment. As vegetation comes to equilibrium with its environment, influences of all abiotic (climatic and edaphic) and biotic factors are integrated. While some variability between sites exists in a type, this classification system regards each unit of an environmental type to be environmentally similar in the landscape. Thus, units with a similar environment, regardless of the present successional status, are all categorized as the same type.

Because climax vegetation indicates environmental types, the types are named for that vegetation. Two forested environmental types (HTs) were sampled in this study. The environmental types are designated by the dominant overstory tree species followed by the dominant understory species. For brevity, an acronym is used to name each environmental type. This acronym is created from the combination of the first two letters of the genus and the specific epithet for each species.

Abies lasiocarpa/Calamagrostis rubescens (ABLA/CARU)

This environmental type is primarily located east of the continental divide, in Montana (Pfister and others 1977), but in the GYE it occurs on both sides. It is notably absent from the Wind River and Absaroka ranges of Wyoming (Steele and others 1983). It has a relatively warm environment with fertile soils. At climax, dense carpets of pinegrass, *Calamagrotis rubescens* dominate the sites leaving little exposed soil surfaces. During extended dry periods of the year the high graminoid component can carry surface fires under seral lodgepole pine forests (Despain 1990). Soils sampled in the subalpine fir/pinegrass HT were cryoborolls with a very thick dark surface horizon, high water retention, and high fertility (Trettin 1986).

Abies lasiocarpa/Vaccinium scoparium (ABLA/VASC)

Subalpine fir/whortleberry is the most common forested environmental type in Yellowstone National Park, it comprises 52% of the forested areas and is extensive throughout the northern Rocky Mountains (Despain 1990). Subalpine fir is the climax tree species; but, this HT is often dominated by lodgepole pine as fire commonly occurs before *Abies lasiocarpa* becomes dominant. Grouse whortleberry is a small shrub that dominates the understory and often forms a continuous cover. This HT occupies cool, relatively dry sites on mid- to upper mountain slopes and benches (Steele and others 1983).

Seral Stages (Cover Types)

Within an environmental type several different seral stages (cover types) occur. Succession is directional change in vegetation over time and the cover type is a convenient method of expressing a stage in this continuum of vegetation transformation. Despain (1990) has defined cover types for forested stands sampled in this study.

These cover types delineate four phases of forest development common to many forest ecosystems, including those recovering from fire (Peet 1992). The first is an establishment phase. The second is the thinning stage. The third phase marks the transition of the originally established post-fire cohort as subsequent understory trees enter the canopy. The last stage approximates a steady-state, with the forest stand varying around a relatively stable composition (Oliver and Larsen 1990, Peet and Christiansen 1987). This pattern of development is found in many Rocky Mountain coniferous forests, aspen stands, as well as in boreal forests (Peet 1992). The following describes the cover types in more detail (Despain 1990).

LP0 This cover type appears as recently disturbed forests are reoccupied by an early successional community. Tree species, primarily lodgepole pine are in their seedling, sapling and pole size stages. The forb and shrub species are re-establishing themselves and inter- and intra-specific competition for available resources is acute. The vegetation is usually between zero and forty years old.

LP1 The LP1 cover type appears when the first cohorts establishing after stand-initiating disturbance fill the overstory, although their height still isn't equal to neighboring undisturbed forests. The tree understory is undeveloped. In dense stands, canopy cover is complete and understory light quality has decreased. The understory forbs, shrubs, and graminoids are sparse. Remnants of large woody debris from the pre-disturbance stand is still not totally decomposed. Typical ages of this stage are 50 -150 years.

LP2 The original lodgepole pine forest still dominates the overstory, however, regeneration of more shade tolerant species such as subalpine fir, *Abies lasiocarpa* and Engelmann spruce, *Picea engelmannii* is present in the understory. In this cover type, some of the lower limbs of the lodgepole pines remain, the crowns are reduced to the upper half of the tree, and the trees have self-thinned. Mortality of some of the establishment cohorts, by insects, lightning, or other causes opens up forest gaps sporadically throughout the canopy. Lodgepole pine is commonly 150-300 years old.

LP3 This seral stage exhibits a lodgepole pine overstory which shares the canopy with a mix of the younger spruce, subalpine fir, and an occasional whitebark pine, *Pinus albicaulis*. Tree regeneration in the understory consists of the latter three species. The composition of the shrub and herbaceous layer is relatively stable. Canopy openings are more frequent than the previous stage due to more frequent lodgepole pine mortality. Decomposition has not kept pace with dead biomass accumulation so that fuels have built over several centuries. These stands are often over 300 years old, but, can be younger if structural development is quicker.

The habitat type and pre-fire cover type of each of the sample stands are listed (Table 11). The original 1988 stands, as well as each of the newly located sites, are also indicated (Table 11).

Table 11. Sample site environmental types. Stand code, geographic name, habitat type and pre-fire seral stage.

Stand Code	Stand Name[1]	Habitat Type[2]	Pre-Fire[3] Cover Type
F1	Indian Creek	ABLA/CARU	LP0
F2	Heart Junction*	ABLA/CARU	LP0
F3	North Indian Creek*	ABLA/CARU	LP0
G1	Willow Park North**	ABLA/CARU	LP1
G2	North Roaring Mtn.	ABLA/CARU	LP1
G3	Tuff Creek	ABLA/CARU	LP1
H1	Golden Gate	ABLA/CARU	LP2
H2	Madison	ABLA/CARU	LP2
H3	Grotto Geyser	ABLA/CARU	LP2
I1	South Canyon	ABLA/CARU	LP3
I2	Southeast Swan	ABLA/CARU	LP3
I3	Obsidian Creek**	ABLA/CARU	LP3
K1	Fan Creek	ABLA/VASC	LP0
K2	Cygnet Lakes	ABLA/VASC	LP0
K3	Canyon - Norris	ABLA/VASC	LP0
L1	Lulu Pass	ABLA/VASC	LP1
L2	Willow Park	ABLA/VASC	LP1
L3	Grizzly Trailhead**	ABLA/VASC	LP1
M1	West Thumb	ABLA/VASC	LP2
M2	Lewis Lake	ABLA/VASC	LP2
M3	Lewis Canyon	ABLA/VASC	LP2
N1	Little Thumb**	ABLA/VASC	LP3
N2	Canyon - Norris	ABLA/VASC	LP3
N3	Virginia Falls	ABLA/VASC	LP3

1 Asterisks indicate new stands located in 1993, otherwise, stands are from the 1988 study (Clark 1991). New sample stands added for additional replications (*). Original sample stands replaced due to logging, etc. (**).

2 Forested habitat types follow Steele and others (1983): Habitat types are: *Abies lasiocarpa/Calamagrostis rubescens* (ABLA/CARU), *Abies lasiocarpa/Vaccinium scoparium* (ABLA/VASC).

3 Cover types as described by Despain (1990).

Sampling Methods

All stands were sampled between June and September of 1993. Twenty-five meter transects were established between permanent metal stakes. Most transects were relocated from Clark's (1991) project and new transects were similarly marked.

Post-fire pioneer plant community composition sampling used these stakes as reference points for a 25 m. by 4 m. rectangular macroplot (0.01 hectare). The macroplot was two meters on either side of a line projected between the metal stakes that are 25 meters apart.

Two measures of the plant community were used for this study within the macroplot. First, floristic composition was recorded in a species list. Species presence involved the identification to the species level, whenever possible, of all vascular plants in the macroplot. References used for plant identification in the field were Hitchcock and Cronquist (1973) or Dorn (1992).

Several sample sites had species that were in a phenological stage such that the species level of identification was impossible. Non-vascular plants were classified to phylum for bryophyta (mosses) or to genus for the lone identifiable hornwort - Marchantia spp. Differentiating two species of lupine, *Lupinus argenteus* and *L. sericeus* was difficult without flowers or fruit. They have been combined under *L. argenteus* for the analyses because it is the only species listed in climax subalpine forests (Pfister and others 1977, Steele and others 1983). On the other hand, *L. sericeus* is the only species listed in mature grasslands/shrublands (Mueggler 1980).

Voucher specimens were pressed and dried. A list of plant species found and their locations appear as Appendix

A. These specimens reside at the Montana State University Herbarium (MONT). Final determinations of difficult taxa were made at the Montana State University Herbarium and were verified by Dr. J. H. Rumely, associate curator. Nomenclature of plant species follows Hitchcock and Cronquist (1973). Several species, which were either not included in the Pacific Northwest flora or were treated as varieties by Hitchcock and Cronquist and now are treated as species, follow Dorn (1992). Each species identified in the study is listed in Appendix B with its authority.

The second measurement of a sample stand was aerial cover as a measure of performance. Cover is the vertical projection of the crown area of a species to the ground as a percent of the reference area (Daubenmire 1959). It was estimated by sub-sampling the macroplot with twenty quadrats (20 cm. by 50 cm.). The quadrats or microplots were alternately placed along either side of a 25 m. tape measure spaced between the two terminal metal stakes. The quadrats were placed one meter apart on alternate sides of the metric tape starting at meter three and ending at meter twenty-two.

Within each of the twenty quadrats used in each sample stand, cover of each species was estimated using a cover scale. Each species was assigned to a cover class as defined by a range of percent cover (Daubenmire 1959). This method is easily duplicated and the classification is made so that sampling error is minimal. To allow for a finer distinction of cover in the lowest class, a 0-1% class was added (Bailey and Poulton 1968). The classes, their range and midpoints are described (Table 12).

Table 12. Cover classes, cover class ranges and midpoints (Bailey and Poulton 1968).

Cover Class	Range Of Cover (%)	Class Midpoints (%)
7	95-100	97.5
6	75-95	85.0
5	50-75	62.5
4	25-50	37.5
3	5-25	15.0
2	1-5	3.0
1	0-1	0.5

After cover class for each plant species in a quadrat was recorded, the cover of other ground cover types was recorded when appropriate: bare soil, litter, coarse woody debris greater than three inches in diameter, mosses and hornworts. Coarse woody debris greater than three inches (7.5 cm.) has many important physical, chemical and biological functions (Graham and others 1994).

Data from each site were summarized. Each species' cover class midpoints were summed and then divided by twenty. This average is the " mean percent cover" for a species or ground cover type in the stand considered. Total mean percent cover for each sample site, by species and ground cover type, was calculated by summing. These data for each sample stand are listed (Appendix C).

Methods of Analysis

Two methods are used to compare the composition of pioneer communities derived from different pre-fire seral stages (cover types) in an environmental type. The first method is indirect gradient analysis (Kent and Coker 1992), the primary gradient of interest being pre-fire stand development (seral stage). It ordinates each of the pioneer communities in each of the two subalpine fir habitat types, ABLA/VASC and ABLA/CARU. Ordinations were based on species cover data from the microplots. The ordinations located each pioneer community according to its similarity to other stands in a three-dimensional space. Identification of the pre-fire cover type for each stand is provided in each ordination.

The second procedure was direct gradient analysis (Whittaker 1967). It involves construction of releve tables showing pioneer species presence and cover data on a pre-fire, seral stage gradient (LP0 thru LP3). Two statistical tests were used to evaluate species pattern on this gradient. First, Chi-square goodness-of-fitness tests were used to recognize non-random distribution of individual species or groups of species, on the pre-fire gradient. Second, a computer-intensive Monte Carlo method of randomization (Manly 1991) was used to determine whether cover quantity in each of the postfire communities is randomly distributed among pre-fire cover types of an individual species.

Ordination

Many methods have been developed to order or classify plant community data (Orloci 1978). One broad category of multivariate analysis is ordination. In its simplest definition ordination is any technique that "orders" a set of data points. The aim of ordination is to simplify and condense large data sets so that ecological relationships will emerge (Ludwig and Reynolds 1988).

Such ordering of samples is conceptually simple if only two variables are used, the result is a scatter diagram. The "X" axis gives the quantity of the first variable (species) plotted against the "Y" axis containing the quantity of the second variable (species). Similarly, if only three variables are used, a three-dimensional scatter plot is displayed; this, also, is a common method of viewing data. It is impossible to visualize multivariate data sets of four or more variables since an equal number of axes are needed to present the information. Multivariate analysis techniques were developed to reduce large data sets, such as in this study, to a few dimensions. This reduction in dimensionality allows pioneer community similarity to be viewed. These ordination techniques project a swarm of data points from many dimensions and project them into the best three-dimensional space so that they can be viewed. Any pattern which is revealed can then be interpreted (Pielou 1984).

For this study, an ordination of the twelve sample stands originating in four pre-fire seral stages from both the ABLA/VASC HT and the ABLA/CARU HT were evaluated separately. Species' cover values in each stand are the variables used for the subalpine fir/pinegrass environmental type, a narrow environmental segment of the subalpine forests of the NRM. An ordination should determine whether pioneer communities derived from the different pre-fire seral stages are similar or differ. A replicate test was made in the subalpine fir/whortleberry habitat type, a broader segment of the subalpine fir environment.

For the ordination, a data matrix was created that included the cover of the vascular plant species in each stand and environmental type. It had twelve columns representing each of the sample sites in a habitat type. The rows of the matrix are the vascular plant species. The matrix represents "species space" where each stand is a point located in multi-dimensional space defined by all species according to their abundance (Gauch 1982).

The ordination techniques used to analyze the data matrices created for the ABLA/CARU and ABLA/VASC habitat types are known as principal component analysis (PCA) and principal coordinate analysis [(PCoA) or multi-dimensional scaling (MDS)]. PCA and PCoA are two of several multivariate ordination procedures that have evolved since the 1950s. These two multivariate analyses were developed such that the internal structures of the data matrix are maintained (Goodall 1954, Gower 1966).

In a simplistic explanation, PCA partitions either a variance-covariance or correlation matrix of the original data onto a set of axes or components. Each axis has an eigenvalue that explains the amount of overall variance in the data matrix accounted for by that axis. Thus, the original data points (sample units), while retaining their interstand relationship, are recast onto new and fewer axes best fit to describe their relationship. The sample units (stands) located close to each other are more similar and those further apart are more dissimilar on one or more axes (components). This method used to ordinate the stands was based on floristic data alone, although more sophisticated methods have been developed that use environmental and floristic data together (Kent and Coker 1992).

A variation of the PCA is the principle coordinate analysis (PCoA). In this technique, a data matrix is constructed using Euclidean distances (Gower 1966). Euclidean distance is a measure of the dissimilarity of the sample stands (Gauch 1982). Its distance is the square root of the sum of the squared distances (differences in mean percent cover) between each species of a sample stand. Principal coordinate analysis uses a distance (dissimilarity) measure between samples stands, is considered metric, and satisfies certain other conditions (Orloci 1978). These conditions retain internal relationships of the distance matrix during transformation via the PCoA. All distances, when metric, are positive values. In the PCoA for this study, the distance (dissimilarity) between sample stands is a direct measure of the combined differences of all vascular plant species' cover.

An eigenanalysis is conducted on the correlation matrix of the PCA and the transformed distance matrix of the PCoA, each of these are derived via quantitative manipulation of the original data matrices. An eigenvalue of a PCA illustrates the percent of the total variation of the original data matrix explained by each component. For a PCoA, the eigenvalues indicate the proportion of the distance matrix explained by an axis (Mardia and others 1979).

A program (Appendix D) was written in MATHCAD PLUS (v. 5.0) for both PCA and PCoA to ordinate the stands from the two subalpine fir habitat types . The ordinations of the sample stands show the relationships among each of the sample stands in each environmental type. These methods order stands by integrating information of all species and their cover quantities. The ordination of pioneer communities shows similarity which may or may not indicate strong influences of pre-fire seral stage. Thus, PCA and PCoA will test the hypothesis that pre-fire seral stage affects the composition and quantity of the succeeding pioneer communities, by showing, when ordered, similar cover types are near each other.

Releve Tables.

A releve (sample stand) table is a matrix created by listing species down one axis against stands across the other axis and entering presence or cover data in each cell. When the intent is to summarize stand data, groups of similar stands are listed together (Mueller-Dumbois and Ellenberg 1974). When the object is to study the distribution of species on a gradient, stands representing segments of the gradient are ordered (Whittaker 1967). Thus, stands from different pre-fire seral stages (cover types LP0 thru LP3) were ordered for each habitat type along this pre-fire seral (cover type) gradient. Once this master matrix is made, species are grouped to show patterns of success in establishment as related to the pre-fire seral stage. The element of particular interest in this method is the species and its response to stand-replacing fire as opposed to the integrated pioneer communities in the ordinations.

Chi-square tests for species in releve tables.

Three separate Chi-square goodness-of-fit tests were used to evaluate species distribution on the pre-fire seral gradient. That is, this simple non-parametric test is used to determine whether a species or a group of species is randomly distributed in pioneer communities with respect to pre-fire seral stage. It is assumed the sample stands are independent.

The first chi-square test determined whether the distribution of pioneer species presence is random across all four pre-fire cover types (LP0 thru LP3). The second, determines whether the distribution of species presence differs from random with respect to two pre-fire categories: early successional stages (LP0 and LP1 combined) and late successional stages (LP2 and LP3 combined). The results of these two tests are presented for each species in the releve tables (Tables 15 and 20).

A third chi-square goodness-of-fit test for randomness was conducted for groups of species. Pioneer species established from one, two, three, or four pre-fire cover types. This test examined groups of species success in pioneer communities as a consequence of seral stage. For example, within one habitat type's pioneer communities, if twenty species occurred in only one pre-fire cover type, expectations of random distribution would be that 5 would occur in sample stands from each of the four cover types-

LP0, LP1, LP2 and LP3. The chi-square test determines whether this random distribution occurred in postfire communities. These types of chi-square tests are displayed in separate tables for each environmental type (Tables 17 and 22).

Monte Carlo randomization of species in releve tables.

The chi-square tests for species' random distribution along the pre-fire stand age gradient used qualitative data, that is presence or absence data. In contrast, the randomization test identified quantitative differences in distribution on the same gradient. Monte Carlo randomization is a process of resampling the original data to test the null hypothesis, that the pioneer species' quantity and presence is random relative to pre-fire cover types. In this study, patterns in the data were sought for each species having significant cover in more than one stand in either the ABLA/CARU or ABLA/VASC habitat types. Where early post-fire distribution of a species' cover on the seral gradient is not by chance, a relationship to pre-fire seral stage is suggested. The randomization tests only give a probability that the observed distribution pattern might have arisen by chance (Manly 1991).

The degrees of freedom of traditional statistical tests (i.e., t-test, ANOVA, Chi-square) were very low because only three stands were sampled for each of the four pre-fire cover types in the ABLA/CARU or ABLA/VASC habitat types. A randomization test is, therefore, a better analytical method for determining whether a species' cover was related to pre-fire seral stage. Two poles of species distribution occur. The first is that the plant occurs in postfire communities following all pre-fire seral stages and is not dependent on pre-fire stand development. At the other extreme, a species may be present in large quantities in the postfire community following early or late pre-fire seral stages. The null hypothesis that all observed patterns occur merely by chance was tested via randomization.

A program was written in MATHCAD PLUS, v.5.0 (Appendix D) to determine whether the actual distribution of individual species, by their cover, was significantly different from that expected of a random distribution of those same cover values. A convenient way of calculating this pattern is to use the variance of the original cover data among all twelve stands as the test statistic. Each of the cover types are weighted so that the variance is effected by values in each pre-fire cover type. Then, this same cover data for a species is randomly "shuffled" many times by the computer. After each randomization, the variance is recalculated. After one million recalculations, the number of these randomized variance values greater than the original data's variance (test statistic) is calculated. The proportion of the randomized data greater than the test statistic determines how rare the original data was. If the randomized variances rarely exceeded the original data variance, it is suggested that the distribution and quantity of the species is non-random.

A method of signing was used (Appendix E) to indicate which distribution pattern was tested. If a species occurred in pioneer communities from all or most pre-fire seral stages, this was noted with a minus sign. If a species was successful in postfire communities following a particular pre-fire cover type it would be assigned a plus. The randomization test results are included along with two chi-square tests for each species in the releve tables (Tables 15 and 20). There are several species in the releve tables that were not capable of being randomized because they had no quantitative data in the microplots, these are noted with a N/A.

RESULTS

Results from the two environmental types are discussed separately. The subalpine fir/pinegrass, *Abies lasiocarpa/Calamagrostis rubescens* (ABLA/CARU) h.t is considered first. Observations from the subalpine fir/whortleberry, *Abies lasiocarpa/ Vaccinium scoparium* (ABLA/VASC) habitat type are considered second.

Effect of Pre-fire Vegetation on Pioneer Communities in the *Abies lasiocarpa/Calamagrostis rubescens* (ABLA/CARU) Habitat Type.

Species richness of pioneer communities.

A comparison of species richness among pioneer communities derived from the four pre-fire seral stages was completed. Species richness is defined as the mean number of species in a 0.01 hectare macroplot (n=3). It is presented for four life-forms and for all vascular plants. This data is summarized (Table 13) and displayed (Figure 6) for the ABLA/CARU habitat type.

Ordinations of pioneer communities.

To determine whether integrated values of stand similarity show differences between pioneer communities of early versus late seral vegetation, ordinations were conducted.

Table 13. Species Richness[1] of pioneer communities following severe fire in four seral stages (cover types) of the *Abies lasiocarpa/Calamagrostis rubescens* habitat type.

Cover type[2]	Life Form: Trees	Shrubs	Herbs	Graminoids	Total
LP0	0.67	1.33	20.00	10.33	32.33
LP1	1.00	2.33	20.00	8.00	31.33
LP2	0.33	1.00	20.67	7.67	29.67
LP3	0.33	1.00	22.33	10.67	34.33
Average	0.58	1.42	20.75	9.17	31.92

[1] Mean number of species present per 0.01 hectare. Sample size for each cover type was three (n=3).
[2] Seral stages as defined by Despain (1990).

Ordination of the pioneer communities was based on species cover data averaged over 20 microplots in each sample stand in the ABLA/CARU habitat type. This differs from the preceding species richness data where a record of presence/absence data in the 0.01 hectare macroplots was used. Seventy-five species occurred in varying quantities in the postfire pioneer communities of the ABLA/CARU habitat type. Thus, the ordinations arranged the twelve stands in three dimensions, a reduction from the 75-dimensional species space.

Eigenanalyses were conducted on the correlation matrix of the PCA and the transformed distance matrix of the PCoA. The cumulative eigenvalues for each successive component (axis) of a PCA give the percent of the total variation in

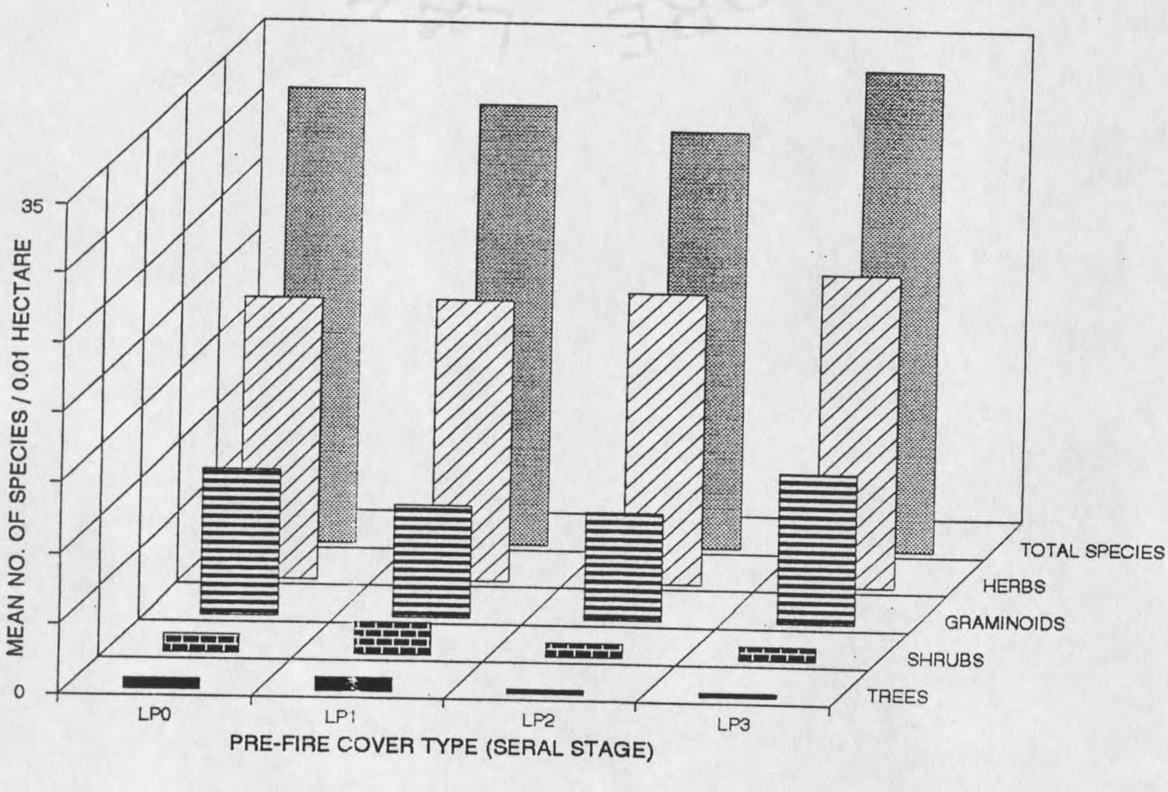

Figure 6. Species Richness[1] of pioneer communities following severe fire in four seral stages (cover types[2]) of the *Abies lasiocarpa/ Calamagrostis rubescens* habitat type.

[1] Average number of species per 0.01 ha macroplot (n=3).
[2] Cover types (LP0 through LP3) as described by Despain (1990).

the correlation matrix explained by the axes (Table 14). For example, the first axis of the PCA for the ABLA/CARU HT accounts for 19 percent of the variation in the original data matrix. The first three axes explain 44 percent of the original data matrix's variation, thus, poor resolution in the reduction of the original data was obtained. The cumulative eigenvalues for the PCA and PCoA for the ABLA/CARU habitat type are listed (Table 14).

The original data points are projected onto axes (components) in a manner that maximizes their separation. This transformation in space, is orthogonal so the original relationships among data points are maintained (Pielou 1984). The ABLA/CARU HT communities are displayed in a three-dimensional diagram, using the first three components

Table 14. Cumulative eigenvalues for principle component analysis (PCA) and principle coordinate analysis (PCoA) of the *Abies lasiocarpa/Calamagrostis rubescens* (ABLA/CARU) habitat type. Values represent cumulative eigenvalues from successive orthogonal axes.

	AXIS										
TYPE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
PCA	19	32	44	55	65	73	81	88	93	98	100
PCoA	33	56	67	77	84	88	93	96	98	100	

(Figure 7). This figure accounts for 44% of the original variability. Different symbols indicate pre-fire seral stages showing the relationship of pioneer community similarity of the twelve sample stands relative to their pre-fire cover types.

The parallel ordination, PCoA, is a composite measure of the differences in the quantities of the 75 species' cover (Figure 8). This ordination reduced the dissimilarity matrix of the twelve stands onto three axes for the ABLA/CARU habitat type. This figure explains 67% of the dissimilarity among the twelve stands. This is better resolution than the PCA, but, still not highly accountable for the variablility in the original data.

Releve tables.

Direct gradient analysis was used to show the effect of pre-fire vegetation on individual species in the subalpine fir/pinegrass habitat type. Species were listed down the first column of a releve table. Pre-fire seral stages, LP0 through LP3 were listed in successive columns across the table from left to right. The matrix was filled with measures of presence or cover. If mean percent cover from the twenty microplots was available, this value was given precedence. If no cover value was available, but the species was present in the macroplot, this was recorded. The species were rearranged to place ones with similar patterns, for example, those following burns in early seral stages only, near one another. This master table was segmented to facilitate discussion.

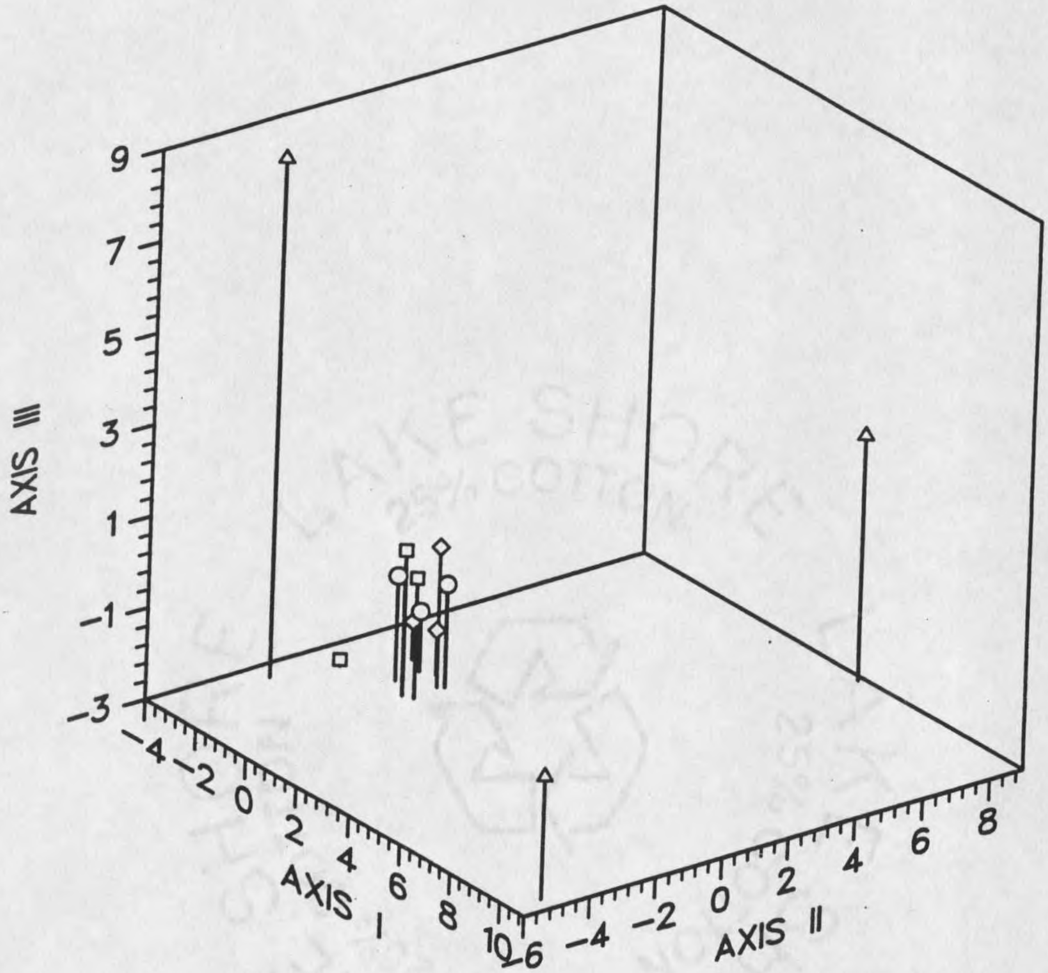

Figure 7. Three major axes of the principle component analysis (PCA) for postfire pioneer communities in the *Abies lasiocarpa/Calamagrostis rubescens* habitat type. Pre-fire stand development is indicated by cover type (Despain 1990): LP0-square, LP1-diamond, LP2-circle, LP3-triangle.

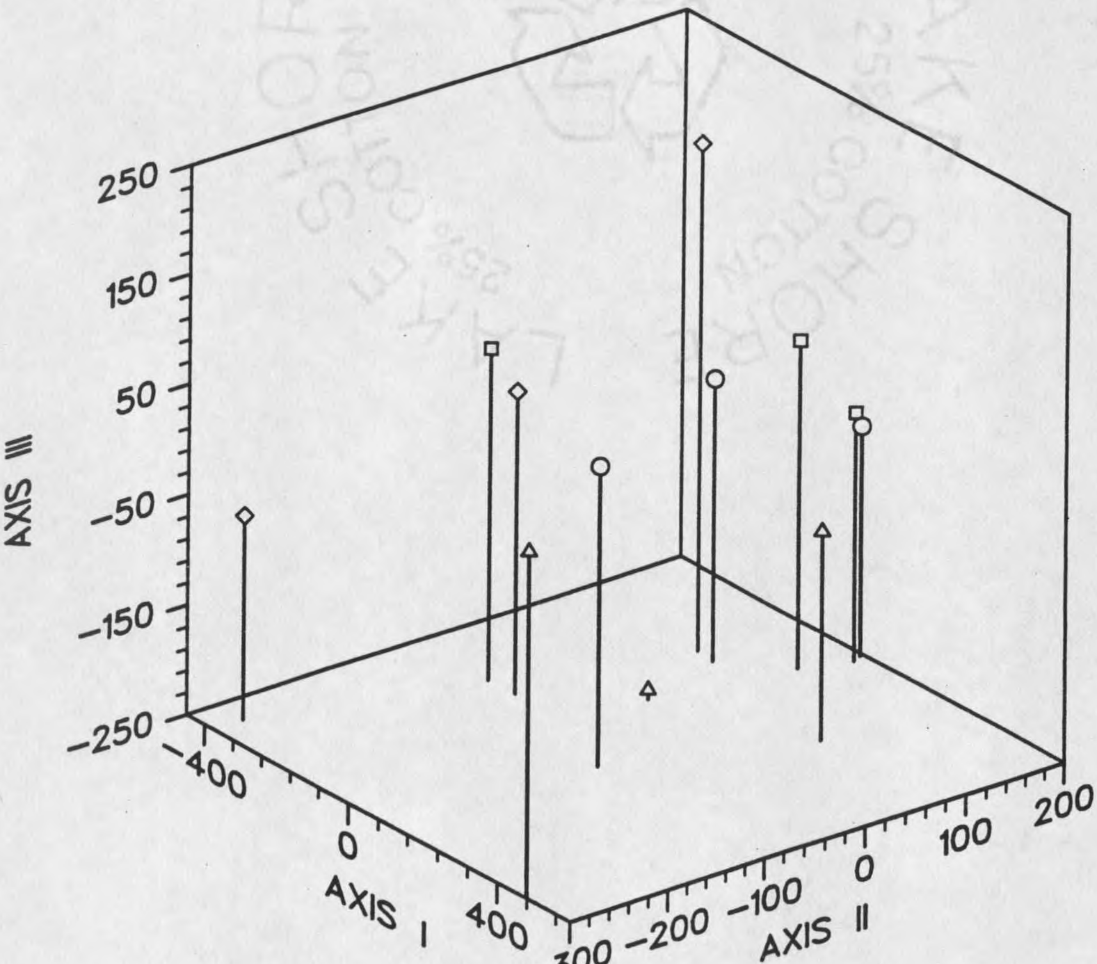

Figure 8. Three major axes of the Principle Coordinate Analysis (PCoA) for postfire pioneer communities in the *Abies lasiocarpa/Calamagrostis rubescens* habitat type. Prefire stand development is indicated by cover type (Despain 1990): LP0-square, LP1-diamond, LP2-circle, LP3-triangle.

Statistical tests were used to evaluate correlation between pioneer species and pre-fire cover types. A chi-square test was used to determine whether a species was correlated with any particular pre-fire cover type (C1 in Table 12). A similar chi-square test (C2) was used to determine if pioneer species established in communities following burns in early (LP0 and LP1) or late (LP2 and LP3) seral stages in a non-random manner. Finally, quantitative species distributions were tested for non-randomness with the Monte Carlo randomization program. The results of the randomization are presented in the releve tables as well as in Appendix E. The signs have been ommitted in the releve tables because it is evident when a species is evenly distributed among the pre-fire cover types or is concentrated in only one or two types.

Table 15. Presence (cover) of pioneer species following fire in early (LP0) to late (LP3) vegetation in the *Abies lasiocarpa/Calamagrostis rubescens* habitat type five years after severe fire. Significance of species pattern is shown in last three columns.

	Seral stage[2]												Test[3]		
Species[4]	F1	F2	F3	G1	G2	G3	H1	H2	H3	I1	I2	I3	C1	C2	R
Section A: Pioneer species common after fire in all four seral stages.															
EPIANG	L	11	2	1	0	2	P	32	2	2	P	4	0.95	0.75	0.41
COLPAR	1	L	L	L	3	L	L	L	L	0	L	1	0.95	0.75	0.47
COLLIN	3	3	1	0	0	L	L	L	1	L	L	3	0.65	0.53	0.48
AGOGLA	4	0	L	L	2	0	2	L	P	6	1	0	0.95	0.72	0.49
ANTMIC	P	0	P	0	0	7	P	P	0	1	L	P	0.80	0.47	0.28
CAMROT	0	L	P	L	0	L	0	P	0	P	P	0	0.92	0.69	0.09
VIONUT	0	L	0	L	L	0	0	0	2	0	L	P	0.88	1.00	0.38
ASTMIS	0	0	2	0	1	0	L	L	0	1	2	0	0.88	0.40	0.29
ARNCOR	0	3	0	P	0	0	P	0	0	0	L	P	0.89	0.65	0.25
ELYGLA	0	7	0	0	P	0	P	0	11	0	0	2	0.89	0.65	0.38
EPIPAN	L	0	L	0	0	L	0	0	1	0	0	4	0.89	0.65	0.18
DANINT	0	P	0	0	0	L	L	0	0	1	2	0	0.89	0.65	0.27
BROCAR	0	0	P	0	0	L	0	0	3	0	1	0	1.00	1.00	0.46
TAROFF	6	3	6	1	1	1	L	2	1	1	P	2	1.00	1.00	0.39
CARROS	2	16	17	10	2	4	16	0	P	L	2	3	0.81	0.39	0.08
POLDOU	8	2	3	L	0	L	0	P	3	0	0	1	0.80	0.47	0.05
LUPARG	P	6	P	1	0	3	L	P	0	L	P	0	0.95	0.72	0.06
AGRSCA	6	P	4	0	0	L	P	0	0	5	0	0	0.57	0.40	0.50
CALRUB	0	4	P	17	7	1	P	12	3	2	2	4	0.95	0.75	0.28
PINCON	0	1	1	L	L	L	0	L	0	1	0	0	0.67	0.25	0.50
SOLMUL	0	P	P	P	P	P	0	0	2	2	0	0	0.67	0.25	0.23
FRAVIR	1	1	4	1	1	3	P	P	2	16	22	4	1.00	1.00	0.08
ACHMIL	P	2	L	2	L	L	P	1	2	3	7	P	1.00	1.00	0.22
AGRCAN	2	0	4	0	0	2	0	L	P	10	5	0	0.92	0.70	0.21
Section B: Pioneer species common after fire in three seral stages.															
POAJUN	.	.	.	L	P	14	L	P	18	15	7	1	0.39	0.31	0.35
STINEL	.	.	.	P	0	2	0	P	L	P	4	0	0.57	0.47	0.47
STINEL	.	.	.	0	0	L	0	0	P	9	L	2	0.27	0.16	0.23
CERFON	.	.	.	0	L	L	0	0	P	0	0	1	0.57	1.00	0.31
POTGLA	.	.	.	0	0	P	P	P	0	1	0	0	0.57	0.31	0.37
SITHYS	.	.	.	0	0	2	1	0	0	P	0	0	0.80	0.58	0.12
CIRARV	0	0	P	.	.	.	0	L	0	0	0	P	0.30	0.58	0.42
CIRSCA	P	0	0	0	0	P	.	.	.	0	P	0	0.30	0.58	N/A
POTGRA	0	P	0	0	L	0	.	.	.	1	0	0	0.30	0.58	0.34
VACSCO	0	P	0	1	0	0	.	.	.	0	0	P	0.30	0.58	0.35

Table 15--Continued.

	Seral stage[2]												Test[3]		
	F1	F2	F3	G1	G2	G3	H1	H2	H3	I1	I2	I3	C1	C2	R
Species[4]															
ARAGLA	L	P	L	0	0	P	P	L	P	.	.	.	0.27	0.70	0.46
ARAHOL	0	0	P	P	0	0	L	P	P	.	.	.	0.27	0.66	0.37
CARGEY	0	1	0	3	P	0	P	0	0	.	.	.	0.39	0.32	0.34
AGOAUR	0	1	0	0	0	1	0	0	2	.	.	.	0.30	0.58	0.49
GAYDIF	L	0	0	1	0	0	L	0	0	.	.	.	0.30	0.58	0.27
Section C: Pioneer species common after fire in two seral stages															
C1: Species occurring in early seral stages															
TRADUB	P	0	P	P	0	0	.	.	.	.	.	.	0.37	0.08	N/A
CARHOO	L	0	0	0	0	9	.	.	.	.	.	.	0.56	0.15	0.34
PHAHAS	0	P	0	P	0	0	.	.	.	.	.	.	0.56	0.15	N/A
C2: Species occurring in mid-seral stages															
ERILAN	.	.	.	P	0	0	P	0	0	.	.	.	0.37	1.00	N/A
LAPRED	.	.	.	0	0	P	P	0	0	.	.	.	0.56	1.00	N/A
RUMACE	.	.	.	0	L	1	0	0	P	.	.	.	0.37	0.58	0.3
C3: Species occurring in late seral stages															
ARECON	.	.	.	.	.	.	L	0	0	L	1	0	0.37	0.08	0.33
PENPRO	.	.	.	.	.	.	0	P	0	2	1	0	0.37	0.08	0.33
CERARV	.	.	.	.	.	.	0	P	0	0	L	0	0.56	0.15	0.40
ARADRU	.	.	.	.	.	.	0	0	P	0	L	0	0.56	0.15	0.40
CAPBUR	.	.	.	.	.	.	0	0	P	0	0	L	0.56	0.15	0.30
C4: Species occurring in the earliest and latest seral stages															
FESIDA	P	0	P	.	.	.	.	.	.	L	3	0	0.26	1.00	0.42
ASTFOL	P	L	P	.	.	.	.	.	.	0	2	0	0.26	1.00	0.35
ANDSEP	P	P	0	.	.	.	.	.	.	0	P	0	0.37	0.58	N/A
ASTINT	0	L	0	.	.	.	.	.	.	0	0	1	0.56	1.00	0.37
PHAFRA	0	0	L	.	.	.	.	.	.	0	P	0	0.56	1.00	0.39

Table 15--Continued.

Species[4]	F1	F2	F3	G1	G2	G3	H1	H2	H3	I1	I2	I3	C1	C2	R
						Seral stage[2]								Test[3]	
			C5: Species occurring in alternate seral stages												
HIEALB	0	L	0	.	.	.	0	L	0	.	.	.	0.56	1.00	0.14
MELBUL	0	L	0	.	.	.	0	0	P	.	.	.	0.56	1.00	N/A
ARTTRI	0	0	P	.	.	.	P	0	0	.	.	.	0.56	1.00	N/A
EPIGLA	.	.	.	1	0	0	.	.	.	P	0	6	0.26	0.60	0.41
GERVIS	.	.	.	1	1	0	.	.	.	0	1	0	0.26	0.60	0.17
VIOADU	.	.	.	0	1	P	.	.	.	2	0	0	0.56	1.00	0.37
PHLLON	.	.	.	P	0	0	.	.	.	0	1	0	0.56	1.00	0.35
SENSER	.	.	.	0	P	0	.	.	.	0	0	P	0.56	1.00	N/A
PHLPRA	.	.	.	0	0	P	.	.	.	0	0	2	0.56	1.00	0.34
Section D: Pioneer species common after fire in one seral stage															
POANER	L	1	P	.	.	.	.	.	.	.	.	.	0.03	0.08	0.42
STINEL	2	0	L	.	.	.	.	.	.	.	.	.	0.11	0.15	0.23
BROCIL	P	P	0	.	.	.	.	.	.	.	.	.	0.11	0.15	N/A
DANSPI	P	0	P	.	.	.	.	.	.	.	.	.	0.11	0.15	N/A
SITHYS	P	0	P	.	.	.	.	.	.	.	.	.	0.11	0.15	N/A
TRISPI	0	P	P	.	.	.	.	.	.	.	.	.	0.11	0.15	N/A
BERREP	.	.	.	P	0	P	.	.	.	.	.	.	0.11	0.15	N/A

[1] Values represent mean percent cover of twenty 0.1 meter squared microplots, L- mean percent cover less than 0.5. P- present in the 0.01 hectare macroplot. Periods replace zeros to emphasize establishment patterns.

[2] Pre-fire stand development corresponds to cover types (Despain 1990). LP0: F1, F2, F3; LP1: G1, G2, G3; LP2: H1, H2, H3; LP3: I1, I2, I3.

[3] Test values are Chi-square or randomization probabilities: C1- Chi-square probability of randomness among communities derived from all four pre-fire seral stages, C2- Chi square probability of randomness for early (LP0 and LP1) versus late (LP2 and LP3) pre-fire seral stages, R-randomization. Methods for probabilities explained in greater detail in methods section.

[4] Species abbreviations as noted in Appendix A.

Table 16. Species present[1] once in pioneer communities in the *Abies lasiocarpa/Calamagrostis rubescens* habitat type five years after severe fire.

	Seral Stage[2]											
Species[3]	F1	F2	F3	G1	G2	G3	H1	H2	H3	I1	I2	I3
SALBEB	P	.	.	.	.	.	.	.	.	.	.	.
ANAMAR	.	L	.	.	.	.	.	.	.	.	.	.
AQUFLA	.	P	.	.	.	.	.	.	.	.	.	.
LOMDIS	.	P	.	.	.	.	.	.	.	.	.	.
PERGAI	.	P	.	.	.	.	.	.	.	.	.	.
THAOCC	.	1	.	.	.	.	.	.	.	.	.	.
RIBCER	.	.	.	1	.	.	.	.	.	.	.	.
SPIBET	.	.	.	P	.	.	.	.	.	.	.	.
ASTSIB	.	.	.	1	.	.	.	.	.	.	.	.
CORAUR	.	.	.	P	.	.	.	.	.	.	.	.
BARORT	.	.	.	.	P	.	.	.	.	.	.	.
EPICIL	.	.	.	.	L	.	.	.	.	.	.	.
LINSEP	.	.	.	.	P	.	.	.	.	.	.	.
OSMDEP	.	.	.	.	P	.	.	.	.	.	.	.
POACOM	.	.	.	.	2	.	.	.	.	.	.	.
MELOFF	.	.	.	.	.	P	.	.	.	.	.	.
STILEM	.	.	.	.	.	1	.	.	.	.	.	.
ASTCON	.	.	.	.	.	.	13	.	.	.	.	.
SOLSPP	.	.	.	.	.	.	5	.	.	.	.	.
CIRSPP	.	.	.	.	.	.	P	.	.	.	.	.
ORYEXI	.	.	.	.	.	.	1	.	.	.	.	.
ERICOM	.	.	.	.	.	.	L	.	.	.	.	.
CREATR	.	.	.	.	.	.	.	P	.	.	.	.
CHEFRE	.	.	.	.	.	.	.	.	L	.	.	.
DESRIC	.	.	.	.	.	.	.	.	P	.	.	.
CIRVUL	.	.	.	.	.	.	.	.	P	.	.	.
SILORE	.	.	.	.	.	.	.	.	P	.	.	.
THLARV	.	.	.	.	.	.	.	.	P	.	.	.
HORBRA	.	.	.	.	.	.	.	.	P	.	.	.
STELON	.	.	.	.	.	.	.	.	.	L	.	.
DRANEM	.	.	.	.	.	.	.	.	.	L	.	.
FRASPE	.	.	.	.	.	.	.	.	.	P	.	.
GAYRAC	.	.	.	.	.	.	.	.	.	P	.	.
GENAMA	.	.	.	.	.	.	.	.	.	1	.	.
HIEGRA	.	.	.	.	.	.	.	.	.	P	.	.
CARPRA	.	.	.	.	.	.	.	.	.	P	.	.
CARRAY	.	.	.	.	.	.	.	.	.	P	.	.
DESCES	.	.	.	.	.	.	.	.	.	P	.	.
PHLALP	.	.	.	.	.	.	.	.	.	P	.	.
POAFEN	.	.	.	.	.	.	.	.	.	.	L	.
DRASTE	.	.	.	.	.	.	.	.	.	.	P	.
ASTCHI	.	.	.	.	.	.	.	.	.	.	.	P
POAPRA	.	.	.	.	.	.	.	.	.	.	.	1
GNASPP	.	.	.	.	.	.	.	.	.	.	.	L

Table 16--Continued.

Species[3]	Seral Stage[2] F1	F2	F3	G1	G2	G3	H1	H2	H3	I1	I2	I3
RORISL	.	.	.	.	.	.	.	.	.	.	.	P
SENCAN	.	.	.	.	.	.	.	.	.	.	.	P

[1] Values represent mean percent cover of twenty 0.1 meter squared microplots, L- mean percent cover less than 0.5. P- present in 0.01 hectare macroplot. Periods replace zeros to emphasize pattern.
[2] Pre-fire stand development corresponds to cover types, from relatively young to old forests (Despain 1990). LP0: F1, F2, F3; LP1: G1, G2, G3; LP2: H1, H2, H3; LP3: I1, I2, I3.
[3] Species abbreviations as noted in Appendix A.

Besides testing for non-random distribution among pre-fire conditions for each pioneer species, chi-square tests were used to detect non-random distribution of species among certain patterns (Table 17). That is, each of the patterns corresponding to the different sections in Table 15, as well as Table 16, might have non-random distribution of pioneer species following the four pre-fire seral stages. For example, if 20 singleton species occur in pioneer communities of one type, such as those in Table 16, random expectation would be for 5 species to occur in each cover type (LP0, LP1, LP2, and LP3). A chi-square test could be used to determine whether this expectation is consistent with occurrences observed among the four cover types. Thus, tests were conducted for species occurring in one, two, or three cover types. These tests were performed on data in Table 15 (Sections B,C, and D) and Table 16.

Table 17. Chi-square goodness-of-fit tests of randomness for pioneer species groups five years after fire in four seral stages (cover types) in the *Abies lasiocarpa/ Calamagrostis rubescens* habitat type.

Groupings Pioneer species present from pre-fire seral stages	Degrees freedom	Chi-square value	Probability
3 cover types	3	3.94	0.27
2 cover types	5	2.11	0.82
1 cover type (common)	3	14.14	0.002
1 cover type (single)	3	6.19	0.10

Effect of Pre-fire Vegetation on Pioneer Communities in the Abies lasiocarpa/Vaccinium scoparium (ABLA/VASC) Habitat Type.

The subalpine fir/whortleberry HT was subjected to the same analyses conducted for the ABLA/CARU habitat type. Therefore, the tables and tests exactly parallel those used for the ABLA/CARU habitat type.

Pioneer community species richness.

Species richness was compared across pre-fire cover types (seral stages) in the ABLA/VASC HT, as in the ABLA/CARU habitat type. Species richness was defined as the mean number of species observed in the 0.01 hectare macroplots. It is presented by both life-form and for all vascular plants. This data is summarized (Table 18) and displayed (Figure 9) for the ABLA/VASC habitat type. ABLA/CARU habitat type.

Table 18. Species richness[1] of pioneer communities following severe fire in four seral stages (cover types) of the *Abies lasiocarpa/ Vaccinium scoparium* (ABLA/VASC) habitat type.

Cover type[2]	Life Form				Total
	Trees	Shrubs	Herbs	Graminoids	
LP0	1.33	1.00	12.67	4.67	19.67
LP1	1.00	1.67	19.00	7.67	29.33
LP2	1.00	1.33	6.67	3.67	12.67
LP3	1.33	1.67	11.67	5.67	20.33
Average	1.17	1.42	12.50	5.42	20.50

[1] Mean number of species present per 0.01 hectare. Sample size for each cover type was three (n=3).
[2] Seral stages as defined by Despain (1990).

Ordinations of pioneer communities.

Ordination was used to determine whether communities following severe fire of early or late seral stages differed on the basis of species cover across all sample sites. Pioneer communities were ordinated by both PCA and PCoA methods for the ABLA/VASC habitat type. The data matrices used the mean species cover from 20 microplots in each of the 12 sample stands. Forty-nine species occurred in varying quantities in the 12 pioneer communities following the severe fire in the four pre-fire cover types.

Eigenanalyses were conducted on the correlation matrix of the PCA and the transformed distance matrix of the PCoA. The cumulative eigenvalues for each successive component (axis) of a PCA gives the percent of the total variation in the correlation matrix explained by the axes (Table 19). The three-dimensional representation of this 49-dimensional space explains 52% of the variability in the data matrix. The ordination is displayed in Figure 10.

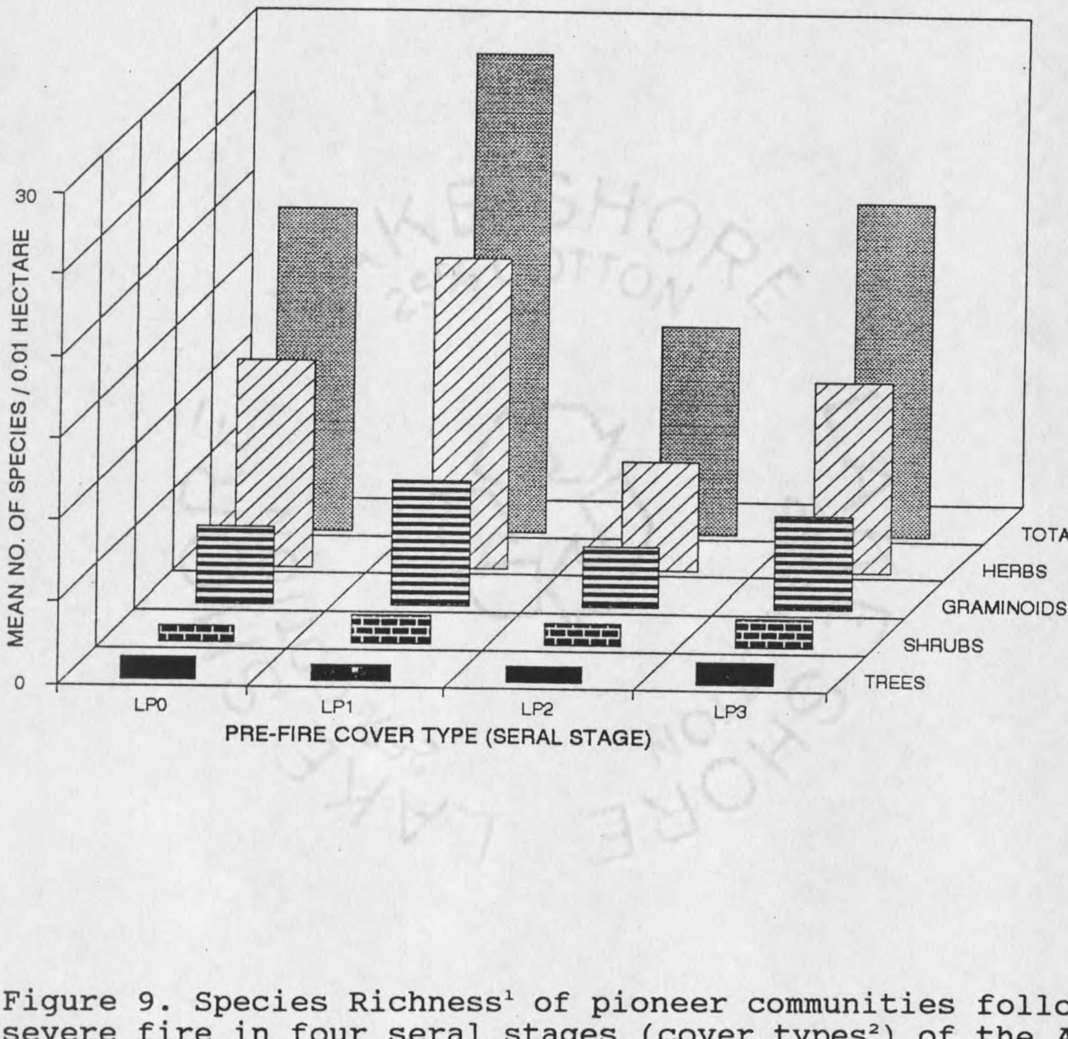

Figure 9. Species Richness[1] of pioneer communities following severe fire in four seral stages (cover types[2]) of the *Abies lasiocarpa/Vaccinium scoparium* habitat type.

[1] Average number of species per 0.01 ha macroplot (n=3).
[2] Cover types (LP0 through LP3) as described by Despain (1990).

In the parallel ordination for the ABLA/VASC HT, the PCoA (Figure 11) is a reduction of the dissimilarity matrix, which is a composite measure of the difference in the quantities of the 49 species' cover. This three-dimensional figure explains 77% of the dissimilarity among the twelve stands (Table 19).

Table 19. Summary of cumulative eigenvalues from multivariate analyses - Principle Component Analysis (PCA) and Principle Coordinate Analysis (PCoA) of the *Abies lasiocarpa/Vaccinium scoparium* (ABLA/VASC) habitat type. Values represent cumulative eigenvalues by successive orthogonal axis.

	AXIS										
Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
PCA	23	39	52	64	73	80	86	91	95	98	100
PCoA	36	61	77	87	93	97	98	99	100		

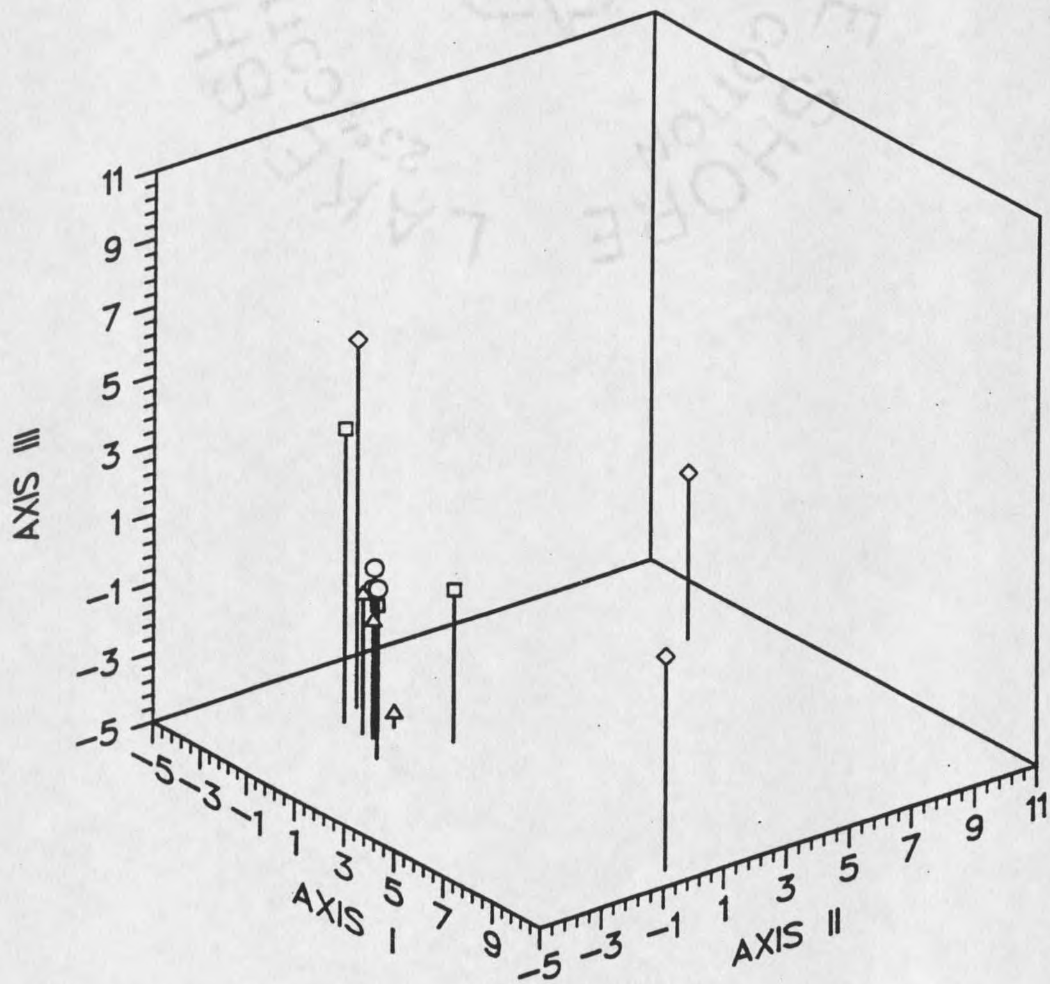

Figure 10. Three major axes of the principle component analysis (PCA) for postfire pioneer communities in the *Abies lasiocarpa/Vaccinium scoparium* habitat type. Pre-fire stand development indicated by cover type (Despain 1990): LP0-square, LP1-diamond, LP2-circle, LP3-triangle.

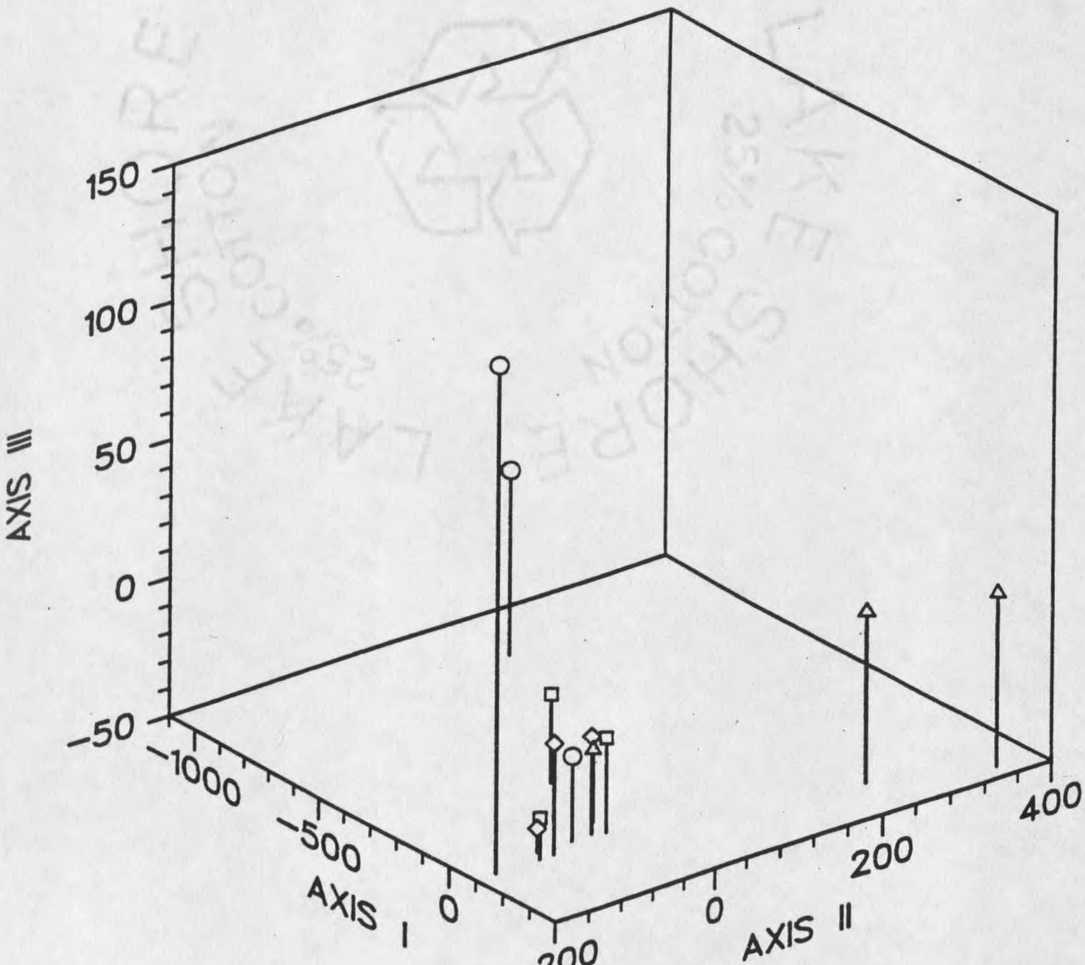

Figure 11. Three major axes of the principle coordinate analysis (PCoA) for postfire pioneer communities in the *Abies lasiocarpa/Vaccinium scoparium* habitat type. Pre-fire stand development indicated by cover type (Despain 1990): LP0-square, LP1-diamond, LP2-circle, LP3-triangle.

Releve tables.

In contrast to ordination, direct gradient analysis identifies the effects of pre-fire vegetation on postfire species. Species patterns and statistical tests for the *Abies lasiocarpa/Vaccinium scoparium*, subalpine fir/ whortleberry habitat type are displayed below. The presentation follows that used for the ABLA/CARU habitat type.

Table 20. Presence (cover) of pioneer species following fire in early (LP0) to late (LP3) vegetation in the *Abies lasiocarpa/Vaccinium scoparium* habitat type five years after severe fire. Significance of species pattern is shown in last three columns.

	Seral stage[2]												Test[3]		
Species[4]	K1	K2	K3	L1	L2	L3	M1	M2	M3	N1	N2	N3	C1	C2	R
Section A: Pioneer species common after fire in all four seral stages.															
VACSCO	P	9	P	15	P	10	4	L	8	5	1	15	1.00	1.00	0.41
CARROS	2	17	1	14	11	14	11	4	3	4	5	1	1.00	1.00	0.02
EPIANG	2	3	8	2	2	5	10	12	1	4	17	12	1.00	1.00	0.11
TAROFF	3	L	L	1	L	3	P	1	P	P	1	L	1.00	1.00	0.08
TRISPI	1	3	3	5	P	1	P	0	P	L	L	L	0.95	0.76	0.09
PINCON	1	1	L	0	5	3	4	L	0	0	L	P	0.96	0.75	0.26
ARNCOR	0	0	P	5	P	L	1	0	0	7	L	4	0.56	1.00	0.24
AGRSCA	2	P	1	0	0	P	P	0	0	0	1	0	0.56	1.00	0.26
EPIGLA	L	P	0	P	0	2	P	0	0	0	L	L	0.92	0.70	0.30
LUPARG	0	L	3	6	P	0	0	2	0	P	3	0	0.92	0.70	0.23
ACHMIL	0	0	P	P	P	0	0	P	0	0	P	P	0.87	0.66	N/A
Section B: Pioneer species common after fire in three seral stages.															
STINEL	.	.	.	P	0	0	0	0	P	P	0	0	0.06	0.58	N/A
CIRARV	.	.	.	0	0	P	1	0	0	P	0	0	0.06	0.58	0.40
GAYRAC	.	.	.	0	0	P	L	0	0	0	P	0	0.06	0.58	0.36
ASTINT	0	0	P	.	.	.	P	P	0	0	1	0	0.56	0.32	0.49
TRADUB	P	0	0	.	.	.	P	0	0	P	0	0	0.30	0.58	N/A
ANTMIC	P	P	L	2	P	P	.	.	.	0	P	0	0.27	0.07	0.35
POANER	P	2	P	1	P	P	.	.	.	0	P	0	0.27	0.07	0.10
HIEALB	L	1	0	1	L	2	.	.	.	P	0	P	0.45	0.27	0.20
COLPAR	L	P	L	P	1	0	.	.	.	0	P	0	0.35	0.07	0.34
FRAVIR	L	0	L	1	P	L	.	.	.	P	P	0	0.45	0.27	0.36
POPTRE	0	0	P	0	0	P	L	0	0	.	.	.	0.80	0.58	0.46
ARAGLA	0	0	L	L	0	0	0	L	0	.	.	.	0.80	0.58	0.08
Section C: Pioneer species common after fire in two seral stages															
C1: Species occurring in early seral stages															
ARAHOL	0	P	P	L	0	0	.	.	.	.	.	.	0.38	0.08	0.39
SITHYS	P	0	0	P	0	0	.	.	.	.	.	.	0.56	0.15	N/A
CIRVUL	L	0	0	0	L	0	.	.	.	.	.	.	0.56	0.15	0.16
SENSER	P	0	0	0	L	0	.	.	.	.	.	.	0.56	0.15	0.38
EPIPAN	1	0	0	0	L	0	.	.	.	.	.	.	0.56	0.15	0.24
AGOAUR	0	0	P	0	0	P	.	.	.	.	.	.	0.56	0.15	0.41

Table 20--Continued.

	K1	K2	K3	L1	L2	L3	M1	M2	M3	N1	N2	N3	C1	C2	R
C2: Species occurring in mid-seral stages															
HIECYN	.	.	.	0	0	1	P	P	P	.	.	.	0.11	0.32	0.39
VACGLO	.	.	.	2	0	0	0	0	P	.	.	.	0.57	1.00	0.45
FESIDA	.	.	.	0	0	1	P	0	0	.	.	.	0.57	1.00	0.36
C3: Species occurring in late seral stages															
MARSPP	.	.	.	.	.	.	7	0	0	0	0	1	0.56	0.15	0.45
C4: Species occurring in the earliest and latest seral stages															
GAYDIF	0	1	3	.	.	.	.	.	.	P	0	0	0.38	1.00	0.20
COLLIN	L	0	0	.	.	.	.	.	.	0	P	0	0.57	1.00	0.37
C5: Species occurring in alternate seral stages															
ELYGLA	.	.	.	L	8	0	.	.	.	P	0	P	0.26	1.00	0.31
SOLMUL	.	.	.	P	P	0	.	.	.	2	0	0	0.30	0.58	0.37
ANTRAC	.	.	.	0	P	L	.	.	.	0	0	1	0.30	0.58	0.45
FRAVES	.	.	.	0	0	P	.	.	.	0	P	0	0.56	1.00	N/A
Section D: Pioneer species common after fire in one seral stage															
DRANEM	P	P	0	.	.	.	.	.	.	.	.	.	0.11	0.15	N/A
PHLALP	.	.	.	P	P	0	.	.	.	.	.	.	0.11	0.15	N/A
GNAVIS	.	.	.	.	.	.	.	.	.	P	0	P	0.11	0.15	N/A
CARPRA	.	.	.	.	.	.	.	.	.	P	0	1	0.11	0.15	0.34

[1] Values represent mean percent cover of twenty 0.1 meter squared microplots, L- mean percent cover less than 0.5. P- present in the 0.01 hectare macroplot. Periods replace zeros to emphasize establishment patterns.
[2] Pre-fire stand development corresponds to cover types (Despain 1990). LP0: K1, K2, K3; LP1: L1, L2, L3; LP2: M1, M2, M3; LP3: N1, N2, N3.
[3] Test values are Chi-square or randomization probabilities: C1- Chi-square probability of randomness among communities derived from all four pre-fire seral stages, C2- Chi square probability of randomness for early (LP0 and LP1) versus late (LP2 and LP3) pre-fire seral stages, R-randomization. Methods for probabilities explained in greater detail in methods section.
[4] Species abbreviations as noted in Appendix A.

Table 21. Species present[1] once in pioneer communities in the *Abies lasiocarpa/Vaccinium scoparium* habitat type five years after severe fire.

Species[3]	Seral Stage[2]											
	K1	K2	K3	L1	L2	L3	M1	M2	M3	N1	N2	N3
DESRIC	P	.	.	.	.	.	.	.	.	.	.	.
BROCAR	L	.	.	.	.	.	.	.	.	.	.	.
SENCRA	.	P	.	.	.	.	.	.	.	.	.	.
SPERUB	.	.	L	.	.	.	.	.	.	.	.	.
PENPRO	.	.	P	.	.	.	.	.	.	.	.	.
SPIBET	.	.	.	7	.	.	.	.	.	.	.	.
ARNLAT	.	.	.	P	.	.	.	.	.	.	.	.
ARNPAR	.	.	.	P	.	.	.	.	.	.	.	.
ASTSIB	.	.	.	12	.	.	.	.	.	.	.	.
GERVIS	.	.	.	L	.	.	.	.	.	.	.	.
PENFRU	.	.	.	P	.	.	.	.	.	.	.	.
PERGAI	.	.	.	P	.	.	.	.	.	.	.	.
SEDLAN	.	.	.	P	.	.	.	.	.	.	.	.
PHLPRA	.	.	.	L	.	.	.	.	.	.	.	.
ARADRU	.	.	.	.	P	.	.	.	.	.	.	.
CIRSCA	.	.	.	.	P	.	.	.	.	.	.	.
EPIAN	.	.	.	.	2	.	.	.	.	.	.	.
GNASPP	.	.	.	.	P	.	.	.	.	.	.	.
LAPRED	.	.	.	.	P	.	.	.	.	.	.	.
RUMACE	.	.	.	.	P	.	.	.	.	.	.	.
DESELO	.	.	.	.	7	.	.	.	.	.	.	.
CAMROT	.	.	.	.	.	P	.	.	.	.	.	.
CERARV	.	.	.	.	.	P	.	.	.	.	.	.
HIEGRA	.	.	.	.	.	L	.	.	.	.	.	.
TARLAE	.	.	.	.	.	1	.	.	.	.	.	.
CALRUB	.	.	.	.	.	L	.	.	.	.	.	.
CARHOO	.	.	.	.	.	P	.	.	.	.	.	.
AGOGLA	.	.	.	.	.	.	.	L	.	.	.	.
ORYEXI	.	.	.	.	.	.	.	.	L	.	.	.
PICENG	.	.	.	.	.	.	.	.	.	.	P	.
ABILAS	.	.	.	.	.	.	.	.	.	.	P	.
DRASTE	.	.	.	.	.	.	.	.	.	.	P	.
CALCAN	.	.	.	.	.	.	.	.	.	.	P	.
RIBLAC	.	.	.	.	.	.	.	.	.	.	.	P
VACMEM	.	.	.	.	.	.	.	.	.	.	.	L
AQUFLA	.	.	.	.	.	.	.	.	.	.	.	P
OSMDEP	.	.	.	.	.	.	.	.	.	.	.	P
MUHRAC	.	.	.	.	.	.	.	.	.	.	.	4

[1] Values represent mean percent cover. L- mean percent cover less than 0.5. P- present. Periods replace zeros.
[2] Pre-fire stand development corresponds to cover types, from relatively young to old forests (Despain 1990). LP0: K1, K2, K3; LP1: L1, L2, L3; LP2: M1, M2, M3; LP3: N1, N2, N3.
[3] Species abbreviations as noted in Appendix A.

Table 22. Chi-square goodness-of-fit tests of randomness for pioneer species groups five years after fire in four seral stages (cover types) in the *Abies lasiocarpa/ Vaccinium scoparium* habitat type.

Groupings Pioneer species present from pre-fire seral stages	Degrees freedom	Chi-square value	Probability
3 seral stages	3	2.00	0.56
2 seral stages	5	8.73	0.12
1 seral stage (common)	3	5.00	0.13
1 seral stage (single)	3	6.85	0.09

DISCUSSION

The environmental types will be discussed separately. First, the subalpine fir/pinegrass HT, then, the subalpine fir/whortleberry HT will be presented.

Abies lasiocarpa/Calamagrostis rubescens Habitat Type.

Postfire species richness as a consequence of pre-fire cover types.

Immediately after the 1988 fires the study sites had no understory. One year later, in another study of early postfire lodgepole pine forests, two-thirds of the individuals present in pioneer communities were a result of vegetative regrowth (Anderson and Romme 1991). Almost one-third were from serotinous lodgepole pine cones and only 2% of the individuals were from the seed bank or off-site seed dispersal (Anderson and Romme 1991).

Five years after the fires, this study found an average of 32 species per 0.01 hectare, involving both on-site and off-site colonizers (Table 18). Average species richness by life-form in the ABLA/CARU HT was: herbs (21), graminoids (9), shrubs (1), and trees (1) [Figure 6]. Pre-fire cover types in the ABLA/CARU HT had no measurable effect on pioneer species richness five years after fire. One slight trend was that herbs increased slightly from LP0 through LP3 (Figure 6), the change is from a low mean of 20 herbs/0.01 hectare in LP0 increasing to 22.33 herbs/0.01 hectare in the LP3 pre-fire cover type.

As the stands mature the species richness is expected to decline. Taylor (1973) found that after canopy closure, which would correspond with the LP1 cover type, there was a 65% decrease in plant and animal species richness.

Our observations that total species richness in the postfire communities was not affected by pre-fire cover type in the ABLA/CARU habitat type is contrary to our expectations. Taylor (1974) found that pre-fire seral stages of LP0 and LP1 are more species rich than the LP2 and early LP3 cover types. Thus, we expected that pioneer communities established from early seral cover types would have especially high species richness in early postfire communities. In the first postfire year study vegetative resprouting made this true (Anderson and Romme 1991). However, after five years, seed bank and off-site colonizers were able to establish such that species richness does not differ among postfire communities regardless of pre-fire seral stage. Thus, differences in pre-fire species richness disappear after stand-replacing fire.

Ordination of postfire communities as a function of pre-fire cover types.

Ordination was used to test the hypothesis that pre-fire vegetation affects postfire communities. Principle component analysis (PCA) and principle coordinate analysis (PCoA) used each species' cover to order the 12 stands in the ABLA/CARU habitat type. These ordinations of vegetation indicate whether each of the pre-fire seral stages' postfire communities are similar in composition after severe fire. Early secondary successional community composition is a result of many factors bearing on species success and persistence; resource availability, competition, seed rain, seed bank, vegetative propagation, etc. (van der Valk 1992). The PCA and PCoA, by ordinating with respect to 75 species, integrate all of these factors indirectly as a means of determining whether pre-fire vegetation is a major factor effecting pioneer communities.

Similarity among stands is expressed by relative distances along each axis in both analyses. The two ordination techniques, PCA and PCoA, were used to determine whether pre-fire cover types affect pioneer communities. If the effect is strong, the two ordination techniques should show the same pioneer community response to pre-fire vegetation. Since these analyses are not statistical, a second ordination method provides a non-statistical test of the first ordination's results.

The cumulative eigenvalues represent the relative contribution of each component to the explanation of the total variability of the original data matrix (Table 14).

Jackson (1993) discusses eight methods for determining the number of axes necessary for a PCA ordination. The simplest approach is to use enough axes to explain 95% of the total variance. Two other methods for determining the number of axes required are a scree plot of the eigenvalues and the use of all eigenvalues greater than one (Kaiser-Guttman criteria). All three were included in the PCA program written in MATHCAD PLUS and reported here.

With only three axes, the PCA ordination accounts for less than half, 44%, of the integrated variation (Table 14). Using the simplest approach, ten axes are required to explain 95% of the variance for the PCA. A scree plot of the ABLA/CARU HT's eigenvalues indicated five axes are needed. The Kaiser-Guttman method required eleven axes. These rules, used to ascertain the number of axes necessary to display the PCA, indicate the PCA ordination of postfire stands in the ABLA/CARU HT should be viewed with caution. The reduction of the 49-dimensional species space to 3 was not entirely satisfactory.

Nevertheless, a three component display of the PCA plot (Figure 7) is examined to look for an effect of the pre-fire vegetation's effect on subsequent pioneer communities. Postfire communities derived from the three earliest pre-fire cover types were very similar. Pioneer stands following the LP3 pre-fire cover type were somewhat distinct, but do not cluster in one direction from stands burned at earlier seral stages. They do not differ from the other nine stands in any consistent way. It can be concluded that there is no dominate axis and since the sample stands were carefully allocated among pre-fire cover types (LP0 through LP3) there is no indication of a pre-fire effect on pioneer communities.

The second ordination, PCoA accounts for more of the total variation of the original data matrix than the PCA in the first three axes. The cumulative eigenvalues for the PCoA indicate that the first three axes explain 67% of the dissimilarity (distance) between the twelve stands. Thus, this ordination is expected to be better than the PCA, but still not ideal.

The PCoA of the ABLA/VASC data matrix (Figure 8) demonstrates an equitable scattering of the sample stands regardless of pre-fire cover types. This suggests little influence of pre-fire cover types on post-fire communities.

The PCA ordination of the ABLA/CARU HT, Figure 7, suggests that communities establishing from the LP3 pre-fire cover type are slightly different from those establishing from younger pre-fire seral stages. However, they do not differ consistently along the three axes. Thus, there is little evidence that they respond to a single factor, whether pre-fire seral stage or some other environmental variable. The PCoA of the ABLA/VASC data matrix (Figure 8) demonstrates an equitable scattering of the sample stands regardless of pre-fire cover type. These two ordinations indicate there is little influence of pre-fire cover types on post-fire communities in the ABLA/CARU environmental type.

Gradient analysis with Chi-square goodness-of-fit and randomization tests

The releve table was divided into two tables. Table 15 has four sections to facilitate discussion of species responses to severe fire in the ABLA/CARU habitat type. Table 16 is a list of species that occurred only once in the twelve sites organized by pre-fire seral stage and thus, deserves little discussion. These tables indicate the relationship pioneer species have to pre-fire cover types. The tables are arranged in order of species ubiquity. The first species appear in postfire communities of all four pre-fire cover types. Then those that succeed in three, two, and only one pre-fire seral stage. Those that appear from only one cover type can be common (occur in more than one sample stand) or rare (were identified only once).

Twenty-four species established after the fires in all four pre-fire cover types (Table 15, Section A). Most of these species are capable of vegetative regrowth as noted in the vital attributes (Noble and Slayter 1980) listed by

Anderson and Romme (1991). A notable exception is *Pinus contorta*, which arrives from seed stored in the tree canopy. Other species that commonly establish via their seed from either the seed bank or as off-site colonizers are the annuals: *Collomia linearis, Collinsia parviflora, and Polygonum douglassii*. Some species are perennials that may establish by either vegetative regrowth or seed dispersal: *Epilobium angustifolium, Carex rossii, Arnica cordifolia, Agrostis scabra, Agoseris glauca* and *Epilobium paniculatum*. The chi-square tests for non-random presence-absence distribution among the four pre-fire cover types (C1) or between early and late seral stages (C2) show no correlation between these species and pre-fire vegetation.

The more quantitative test, randomization (R), indicates that five species in the pioneer communities (Table 15, Section A) tend to have higher cover when following early seral vegetation. The five species, *Campanula rotundifolia* (P=0.09), *Carex rossii* (P=0.08), *Fragaria virginiana* (P=0.08), *Lupinus argenteus* (P=0.06), and *Polygonum douglassii* (P=0.05) have cover values and distribution among the four pre-fire cover types that indicate non-random distribution. Nevertheless, these species are very successful in this environmental type when stands burn, regardless of pre-fire seral stage.

Fifteen species established in postfire communities from three of the four possible pre-fire cover types (Table

15, Section B). The chi-square and the randomization tests give no indication that the distributions are non-random. If sample size were increased, it is likely all might be found after all four pre-fire seral stages burned.

Twenty five species established in pioneer communities from two pre-fire seral stages of forest development. This could have happened in six possible ways (Table 15, Subsections C1 to C5). All three species that occur in pioneer communities following the two earliest seral stages, approach significance, *Trogopogon dubius* (P=0.08), *Carex hoodii* (P=0.15), and *Phacelia hastata* (P=0.15). Chi-square tests comparing presence after the two earliest pre-fire seral stages compared to the last two (C2) gave these probabilities.

There was no parallel indication of species that establish from mid-seral vegetation. Species that seem to follow only mid-seral vegetation (LP1 and LP2) are listed in Table 15, Subsection C2. The pioneer communities derived from these pre-fire stands had reached canopy closure before the fires. Two of the species are annuals and probably are off-site colonizers, *Lappula redowskii* and *Rumex acetosella*, since all three tests indicate randomness for the three species.

There were five species that occurred five years after fire from only the two latest seral stages, LP2 and LP3 cover types (Table 12, Subsection C3). Two, *Penstemon* *procerus* and *Arenaria congesta* occurred in three pioneer communities of the six late seral sites and the chi-square test (C2) gives weak evidence that these perennial herbs may reappear primarily from older forested stands (P=0.08). The same test indicates a weaker (P=0.15) tendency of the remaining species to follow fire in mature vegetation.

Species sometimes appear after fire in two unrelated seral stages, i.e. LP0 and LP2 cover types (Table 15, Subsections C4 and C5). Such distributions may best be explained as random occurrences. None of the three tests indicated non-random tendencies for any of the species.

Seven pioneer species established after severe fire from only one pre-fire cover type (Table 15, Section D). *Poa nervosa*, occurred in three stands, all from the LP0 pre-fire cover type. The chi-square test (C1) for this distribution indicates this is not random (P=0.03). The remaining six species also pioneered after fire in an early seral community, their presence-absence patterns were all nearly significant (P=0.11).

The second releve table for the *Abies lasiocarpa/ Calamagrostis rubescens* habitat type is a list of 46 species that occurred only once in any of the twelve sample stands (Table 16). It was expected that these would be evenly distributed among communities establishing from the four pre-fire seral stages. Six established in the LP0, eleven in the LP1, twelve in the LP2, and seventeen in the LP3 pre-fire cover types. This may suggest that pioneer communities derived from early seral stages are lacking and late seral stages are rich in singletons. The chi-square test for this distribution (P=0.10), Table 17, indicates a weak non-random distribution of singletons among the four pre-fire types.

Chi-square goodness-of-fit tests for distribution within each of the four patterns from Tables 15 and 16 were calculated (Table 17). Species that occurred in pioneer communities from three of the four cover types (Table 15, Section B) were not significantly missing from any particular pre-fire cover type (P=0.27).

Among species present following fire in two cover types (Table 15, Section B) only those following early or late seral stages approached significance. Mid-seral or alternating distributions were completely insignificant. The chi-square test for randomness among the six possibilities for species present in two cover types (Table 17) indicates a random occurrence (P=0.82) between the six possibilities. Thus, there is no evidence for groups of species likely to establish from any combination of two particular pre-fire cover types, even after the earliest two or latest two seral stages.

Of the seven species common in pioneer communities following only one pre-fire seral stage, six established in the LP0 cover type. The other occurred in LP1 and there were none in the LP2 or LP3 pre-fire cover types. The test of randomness in this pattern (Table 17) indicates that the probability for six of the seven species to be in one pre-fire cover type is rare (0.002). All six species are grasses and vegetatively resprout. This type of vegetative resprouting is common in grasslands after fire. The pre-fire LP0 stands had not reached canopy closure, so many of these grass species had not been excluded from the communities and survived the 1988 fires.

The various tables and tests of each species in the ABLA/CARU habitat type indicated that only one pioneer species, *Poa nervosa*, was clearly correlated with a pre-fire cover type (P=0.03). The LP0 cover type also contributed an unusually high number (six grasses) of the total seven species occurring in pioneer communities from only one pre-fire seral stage (Table 15, Section D). Otherwise, postfire communities appearing five years after stand-replacing fire appear to be a result of random establishment rather than pre-fire cover type. Although the PCA indicated some separation of communities establishing from the LP1 pre-fire cover type, the releve tables suggested few species likely to be responsible for that separation.

Abies lasiocarpa/Vaccinium scoparium Habitat Type.

The discussion for the subalpine fir/whortleberry HT is parallel to that of the previous ABLA/CARU habitat type.

Postfire species richness as a consequence of pre-fire cover types.

The species richness by life-form in ABLA/VASC HT postfire communities progressively decreased from herbs (12), graminoids (5), shrubs (1), and trees (1) regardless of pre-fire cover types (Table 18). The lone exception was a higher mean tree than shrub richness in communities derived from the LP0 cover type. The same pattern was observed in the *Abies lasiocarpa/ Calamagrostis rubescens* (ABLA/CARU) habitat type.

Pioneer communities originating in the richest pre-fire forests (LP0) were expected to have the most diverse postfire communities. In the ABLA/VASC HT, richness following LP1 forests was highest, it was lowest in postfire stands from the LP2 pre-fire cover type (Figure 9). The LP0 and LP3 have similar results for richness although they are slightly less rich than LP1 seral stage. The difference between LP2 and LP1 may be significantly lower for overall species richness, 12.67 species/0.01 hectare versus 29.33 species/0.01 hectare, respectively. The herbs and the graminoids account for most of this difference. One possible explanation for the low species richness in the LP2 postfire communities is that two of the sample sites were in parts of

Yellowstone Park where the lodgepole pine forests are often depauperate due to deep rhyolitic soils.

Ordinations of postfire sample stands as a function of pre-fire cover types in the ABLA/VASC habitat type.

Ordination was used to test the hypothesis that pre-fire vegetation effects postfire communities. Principle component analysis (PCA) and principle coordinate analysis (PCoA) used each species' cover to order the 12 stands in the ABLA/CARU habitat type. These ordinations of vegetation indicate whether each of the pre-fire seral stages' postfire communities are similar in composition after severe fire.

The cumulative eigenvalues underlying the two ordinations have been tabulated (Table 19). The three axes presented for the PCA explain 52% of the variability in the data matrix, well short of the 95% needed in the simplest evaluation of axes essential for a PCA (Jackson 1993). This criterion would necessitate the use of ten axes. The two other methods used for this study, the scree plot of the eigenvalues and the use of all eigenvalues greater than one (Kaiser-Guttman criteria), both indicated the use of three components. Thus, the latter criteria indicate that the three axes used in the PCA (Figure 10) may adequately explain the original data matrix.

The PCA of the ABLA/VASC HT, Figure 10, suggests that postfire communities following LP1 cover types differ slightly from other pioneer communities, but, the difference is not consistent. The deviation of the three stands is on different axes for each one. They are not clustered, so each stand is apparently responding to a different environmental factor. Data from the species richness section (above), indicated that postfire communities derived from LP1 cover types are especially rich; this may explain some of the differentiation in the ordination.

The cumulative eigenvalues of the PCoA for the first three axes is 77 percent (Table 19). This value that is well below 95% and indicates the display of the twelve sample stands in the PCoA for ABLA/VASC HT (Figure 11) should be viewed cautiously. The criteria used for indicating the number of axes required in a PCA have not been verified for use in a PCoA.

The PCoA of the ABLA/VASC data matrix (Figure 11) indicates two stands following fire in the LP2 cover type and two in the LP3 cover type are somewhat distinct from the other eight pioneer communities. For these two late-seral cover types, the third replication for each is in the main cluster. This suggests that pioneer communities of each of the late seral stages, as a whole, are not distinctly different as a result of pre-fire vegetation.

There is no evidence from the two ordinations that ABLA/VASC HT postfire communities are dissimilar as a consequence of pre-fire stand development. There was separation of LP0 in the PCA and the late-seral stages (LP2 and LP3) in the PCoA. Thus, the different ordinations were not consistent in differentiating communites as a consequence of pre-fire cover type. Neither the PCA nor the PCoA separated postfire communities in a consistent manner with respect to pre-fire seral stage. When there was separation, the three replications of a cover type were not distinct as a cluster along the same axes. This evidence gives little support that the developmental stage of pre-fire vegetation influences postfire communities.

Huschle and Hironoka (1980) argue that the early seral communities differ greatly and then converge as succession proceeds. Sources of original variation might be previous vegetation (via resprouts or seed banks), seed rain, and the nature of the disturbance. This study examined the effects of one source--previous vegetation--after a relatively uniform treatment (severe fire). The ordinations gave little evidence that pre-fire vegetative condition (seral stage) has any effect on the re-establishing pioneer communities. On the contrary, such communities are very similar.

Gradient analysis with Chi-square goodness-of-fit and randomization tests

The releve table for the ABLA/VASC HT was divided into two tables. Table 20 has four sections to facilitate discussion of species responses to severe fire. Table 21 is a list of species that occurred only once in the twelve sites organized by pre-fire seral stage and thus, deserves little discussion. These tables indicate the relationship a pioneer species can have to pre-fire cover type. The tables are arranged in order of species ubiquity and are parallel to those of the ABLA/CARU habitat type.

Pioneer communities in the ABLA/VASC HT have fewer species than those in the ABLA/CARU habitat type. The ABLA/VASC HT had eleven species which followed all four pre-fire cover types and twelve which followed in three pre-fire cover types (Table 20, Sections A and B). Universal species (Section A) and nearly universal species (Section B) have random distributions of presence. The randomization test, which considers quantity as much as presence, indicates that *Carex rossii*, which has high cover values, may favor early seral stages (P=0.02). This species is known to re-establish successfully, both vegetatively and via propagules, after fire in these forests. Low probability values for the cover distribution of *Taraxacum officinale* (P=0.08) and *Trisetum spicatum* (P=0.09) suggests that these two species tend to follow early seral communities.

The species present in pioneer communities derived from all four pre-fire cover types that occurred in the ABLA/VASC HT were usually in the ABLA/CARU HT as well. Thus, seven species occurred in pioneer communities from all four seral stages in both environmental types. These species were discussed in the ABLA/CARU HT (above). Of the two species unique to the ABLA/VASC HT, one was *Vaccinium scoparium*, the dominant shrub of climax communities for which the HT is named. It maintains its presence by vegetatively resprouting. The other was *Trisetum spicatum*, a perennial grass that also resprouts.

Most species occurring in postfire stands following fire in three cover types might well occur in all four if the sample size were increased. Two of these occurred in pioneer communities of all four pre-fire cover types in the ABLA/CARU HT - *Collinsia parviflora*, an annual herb and *Antennaria microphylla*, a perennial herb.

Due to large differences in competition (light, water, nutrients) it might be predicted that some species would specialize in early or late seral communities. Pioneer species establish in communities from many on-site sources (sprouting, seed bank, seed canopy) so differences in pre-fire vegetation might affect the early postfire communities. Table 20 (Subsection C1), lists the species present in pioneer communities from only two pre-fire seral stages. There were six species that established after fire from the LP0 and LP1 cover types. They never occurred in more than half of the six sample stands, thus, chi-square tests (C2) gave weak support (P=0.08 and P=0.15) to the hypothesis they follow early stages (are not random).

Only one species, *Marchantia spp.*, a hornwort, pioneered from the last two seral stages, LP2 and LP3 (Table 20, Subsection C4). There was only slight evidence (P=0.15) that it followed late seral stages in non-random manner.

Species sometimes appear after fire in two temporally unrelated seral stages, i.e. LP0 and LP2 pre-fire cover types (Table 20, Subsections C4 and C5). Statistical tests ($P>0.30$) gave no indication of significant pattern in these distributions.

Four species occurred more than once in postfire stands following one pre-fire cover type (Table 20, Section D). The possibility of a weak non-random pattern is indicated ($P=0.11-0.15$). These species follow three different pre-fire seral stages. This equitibility among types ($P=0.57$) supports the hypothesis of random pattern for species occurring more than once in one cover type (Table 22).

Thirty-eight species were found only once in the twelve sample stands (Table 21). They were distributed such that 5 species occurred in communities following fire in the LP0 cover type, 22 following LP1, two following LP2, and nine after fire in LP3 cover types. The 22 species occurring in LP1 pioneer communities accounts for much of the species richness in these postfire communities (Table 18).

The chi-square test of singleton species in pioneer communities distributed among the four pre-fire cover types, Table 22, suggests that too many follow LP1 ($P=0.09$). A similar test ($P=0.10$) suggested that species richness was high in pioneer communities following later seral stages (LP3) for singletons in the ABLA/CARU environmental type

(Table 17). Thus, there is no consistent pattern for singletons in postfire communities of both environmental types.

Overall, there is little evidence that the composition of postfire communities in the ABLA/VASC habitat type is affected significantly by pre-fire seral stage. It appears that vascular plant species that are successful after severe fire are randomly distributed among the various pre-fire cover types.

CONCLUSIONS

There was little evidence that pre-fire vegetation affects postfire pioneer communities. Ordinations of both the ABLA/CARU HT and ABLA/VASC HT pioneer communities show no affiliation of pioneer communities relative to either early or late seral pre-fire vegetation.

Similarly, gradient analysis allows recognition of some species which seem to follow early or late seral communities, although tests for concentration of presence-absence (chi-square goodness-of-fit) or cover (Monte Carlo randomization) rarely showed significance. Only two species were significant at the 0.05 level or below in the ABLA/CARU HT, *Poa nervosa* and *Polygonum douglasii*. Only one species was significant in the ABLA/VASC habitat type, *Carex rossii*. All three were strongly represented by presence or cover in pioneer communities derived from early seral stages.

With only three replications, the sample size is small enough to yield either false acceptance or rejection of randomness in pattern (i.e. pioneer species associated with particular pre-fire seral stages). False rejection is more dangerous if managing for diversity. Thus, species which show pattern at higher probabilities, those slightly greater than P=0.05, may indicate they deserve further study. These slightly higher values may be due to true rareness of the species and not low sample size. It also indicates a reliance on certain pre-fire seral stages for these postfire pioneers. There were 18 species that had probabilities that were between 0.06 and 0.15 in the ABLA/CARU HT and 18 in the ABLA/VASC environmental type (Tables 15 and 20).

Fire-prone subalpine fir ecosystems have evolved under an unpredictable disturbance pattern. The necessity of re-establishment after severe fire at any point in time of seral development up to 300 years may have selected for species adapted to establishment after any fire interval. Thus, it appears that the dispersal and establishment capabilities of all pioneer species assured their success within five years after the fires of 1988. Such adaptations involve colonization capacities from both off-site and on-site vegetation.

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APPENDIX A

VOUCHER SPECIMENS AND SPECIES ACRONYMS

Table 23. Vascular plant voucher specimens collected by sample stand. Species abbreviations (acronyms) used in text and tables. Specimens stored at Montana State University Herbarium (MONT), Bozeman, MT.

Species	Sample stand[1]	Acronym
Trees		
Abies lasiocarpa		ABILAS
Picea engelmannii		PICENG
Pinus contorta		PINCON
Populus tremuloides		POPTRE
Pseudotsuga menziesia		PSEMEN
Shrubs		
Arctostyphalos uva-ursi	G3	ARCUVA
Artemisia cana	E2	ARTCAN
Artemisia frigida		ARTFRI
Artemisia tridentata		ARTTRI
Berberis repens		BERREP
Ceanothus velutinus	B2	CEAVEL
Chrysothamnus nauseosus		CHRNAU
Chrysothamnus viscidiflorus		CHRVIS
Iliamna rivularis	B2	ILIRIV
Linnaea borealis		LINBOR
Potentilla arguta	A3	POTARG
Potentilla diversifolia	O2	POTDIV
Potentilla fruticosa	A1	POTFRU
Potentilla glandulosa	C3 H2	POTGLA
Potentilla gracilis	A3 C3 E3	POTGRA
Ribes cereum	G1	RIBCER
Ribes lacustre	N3	RIBLAC
Rosa acicularis		ROSACI
Rubus idaeus		RUBIDA
Salix bebbiana	A1 A3	SALBEB
Salix geyeriana		SALGEY
Salix wolfii	A3	SALWOL
Sheperdia canadensis		SHECAN
Spiraea betulifolia		SPIBET
Symphoricarpos albus	D2	SYMALB
Symphoricarpos oreophilus		SYMORE
Vaccinium globulare		VACGLO
Vaccinium membranaceum	N3	VACMEM
Vaccinium scoparium		VACSCO
Forbs		
Achillea millefolium		ACHMIL
Agoseris glauca	H1	AGOGLA
Agoseris aurantiaca	G3	AGOAUR
Allium brevistylum	D2	ALLBRE
Allium cernuum		ALLCER
Anaphalis margaritacea	M1	ANAMAR

Table 23--Continued.

Androsace septentrionalis	I2	ANDSEP
Anemone parviflora		ANEPAR
Antennaria microphylla	H1 K1 K3	ANTMIC
Antennaria racemosa	L2	ANTRAC
Aquilegia flavescens	N3	AQUFLA
Arabis drummondii	H2 P3	ARADRU
Arabis glabra	C3 E3 H1 K1	ARAGLA
Arabis holboellii	C1 H1	ARAHOL
Arabis lyallii	P3	ARALYA
Arenaria congesta	C3 I1 I2	ARECON
Arenaria laterifolia	D3	ARELAT
Arnica cordifolia	O1	ARNCOR
Arnica latifolia	L1	ARNLAT
Arnica longifolia	A2	ARNLON
Arnica mollis	A3	ARNMOL
Arnica parryi	L1	ARNPAR
Aster chilensis var. adscendens	D1 E3 I3	ASTCHI
Aster campestris	D1 E2 E3	ASTCAM
Aster conspicuus	B2 C2 H1	ASTCON
Aster foliaceus	C2 E3 I2 O2	ASTFOL
Aster hesperius	A1 A2 D2	ASTHES
Aster integrifolius	M1 K3	ASTINT
Aster occidentalis	A3 E1	ASTOCC
Aster pereglans	B1	ASTPER
Aster sibiricus var. meritus	G1 L1	ASTSIB
Astragalus adsurgens	B3	ASTADS
Astragalus agrestis	B3 D3 E1	ASTAGR
Astragalus alpinus	P2	ASTALP
Astragalus eucosmus	D2	ASTEUC
Astragalus kentrophyta		ASTKEN
Astragalus leptaleus	O1	ASTLEP
Astragalus miser	B2	ASTMIS
Astragalus purshii	B3	ASTPUR
Astragalus vexiflexis	J3	ASTVEX
Atriplex fremontii	C3	ATRFRE
Atriplex nuttallii	J2	ATRNUT
Balsamorhiza sagittata		BALSAG
Barbarea orthoceras	A2	BARORT
Besseya wyomingensis	J2	BESWYO
Camelina microcarpa	J2	CAMMIC
Campanula rotundifolia	L3	CAMROT
Capsella bursa-pastoris	H3	CAPBUR
Castilleja lutescens	J1	CASLUT
Castilleja miniata	B3	CASMIN
Cerastium arvense	C3 H2 I2	CERARV
Cerastium fontanum	H3	CERFON
Cerastium vulgatum	G3	CERVUL
Chaenactis douglasii	E2	CHADOU
Chenopodium fremontii	H3	CHEFRE
Cirsium arvense	L3	CIRARV

Table 23--Continued.

Cirsium scariosum		CIRSCA
Cirsium vulgare		CIRVUL
Cirsium spp.	H1	CIRSPP
Collinsia parviflora		COLPAR
Collomia linearis	H2	COLLIN
Conmitella williamsii	C3	CONWIL
Corralorhiza trifida	D3	CORTRI
Corydalis aureum	B2	CORAUR
Crepis atrabarba	H2	CREATR
Cynoglossum officinale		CYNOFF
Descurainia richardsonii	C3 H3 O2 P2	DESRIC
Draba nemorosa	K1	DRANEM
Draba stenoloba	I2 J1 N2 P3	DRASTE
Epilobium anagalladium		EPIANA
Epilobium angustifolium		EPIANG
Epilobium ciliatum	G2 P2	EPICIL
Epilobium glaberrimum	M1	EPIGLA
Epilobium paniculatum		EPIPAN
Equisetum arvense		EQUARV
Erigeron acris	A3	ERIACR
Erigeron gracilis	B3 E2	ERIGRA
Erigeron compositus		ERICOM
Erigeron speciosus	C2 E3 P2	ERISPE
Eriogonum umbellatum	E2 J1	ERIUMB
Eriophyllum lanatum	E3 G1 H1	ERILAN
Erysimum cheiranthoides	C3	ERYCHE
Erysimum conspicuus	B2 D2	ERYCON
Erythronium grandiflorum	C3 O2	ERYGRA
Fragaria vesca		FRAVES
Fragaria virginiana		FRAVIR
Frasera speciosa		FRASPE
Galium bifolium	C1	GALBIF
Galium boreale	E3	GALBOR
Galium trifidum	A3	GALTRI
Gayophytum diffusum	G1	GAYDIF
Gayophytum racemosum	M1	GAYRAC
Gentiana detonsa	A3	GENDET
Gentiana amarella	D2 I1 O2	GENAMA
Geranium bicknellii	C1	GERBIC
Geranium richardsonii		GERRIC
Geranium viscossisimum		GERVIS
Geum triflorum		GEUTRI
Gnaphalium viscosum	N1	GNAVIS
Gnaphalium spp.		GNASPP
Hackelia deflexa		HACDEF
Hackelia floribunda	B2	HACFLO
Hackelia micrantha		HACMIC
Hieracium albiflorum	L3	HIEALB
Hieracium cynoglossoides	M3	HIECYN
Hieracium gracile	L3	HIEGRA

Table 23--Continued.

Lactuca seriola	B2	LACSER
Lappula redowskii	E2	LAPRED
Lepidium virginicum var. pubescens	C2	LEPVIR
Linanthus septentrionalis	G2	LINSEP
Linnaria dalmatica		LINDAL
Linum lewisii		LINLEW
Lithospermum ruderale	E3	LITRUD
Lomatium cous	J1	LOMCOU
Lomatium dissectum		LOMDIS
Lupinus argenteus	L2	LUPARG
Lupinus lepidus	O2	LUPLEP
Lupinus sericeus		LUPSER
Melilotus officinalis		MELOFF
Mentha arvensis var. canadensis		MENARV
Microsteris gracilis	G3	MICGRA
Myosotis sylvatica (=alpestris)	E3 J1	MYOSYL
Nemophila breviflora		NEMBRE
Orthocarpus luteus	E1	ORTLUT
Ozmorhiza chilensis	C1	OSMCHI
Osmorhiza depauperata	N3	OSMDEP
Oxytropis deflexa	J3	OXYDEF
Penstemon procerus	C3 E2 H2 I1	PENPRO
Penstemon fruticosus	L1	PENFRU
Perideridia gairdneri	E3	PERGAI
Phacelia franklinii	C3 I2	PHAFRA
Phacelia hastata		PHAHAS
Phacelia sericea	O1	PHASER
Phlox hoodii		PHLHOO
Phlox longifolia	I2 J1	PHLLON
Phlox multiflora	C3	PHLMUL
Polygonum douglassii	H2	POLDOU
Polygonum bistortoides	A3	POLBIS
Polemonium pulcherrimum	O1	POLPUL
Rorippa islandica	I3	RORISL
Rumex acetosella	E2 G2 L2	RUMACE
Rumex paucifolius	O3	PUMPAU
Saxifraga rhomboidea	A3 J1	SAXRHO
Sedum lanceolatum	L1	SEDLAN
Senecio canus		SENCAN
Senecio crassulus	O2	SENCRA
Senecio cymbalarioides	A3	SENCYM
Senecio pseudaureus	D2	SENPSE
Senecio sphaerocephalus		SENSPH
Senecio streptanthifolius	A2 E2	SENSTR
Senecio serra	E3 G2 P2 P3	SENSER
Sibbaldia procumbens	O2	SIBPRO
Silene alba		SILALB
Silene latifolia		SILLAT
Silene oregana		SILORE
Solidago canadensis var. salebrosa	A1	SOLCAN

Table 23--Continued.

Solidago missouriensis	E1 K3	SOLMIS
Solidago multiradiata	G1 I1 L1 L2 O2	SOLMUL
Solidago spp.	H1	SOLSPP
Spergula arvensis		SPEARV
Spergularia rubra	K3	SPERUB
Stellaria longipes var. altocaulis	A3 I1	STELON
Swertia perennis	A3	SWEPER
Taraxacum laevigatum		TARLAE
Taraxacum officinale		TAROFF
Thalictrum occidentalis		THAOCC
Thalspi arvense	H3	THAARV
Tragopogon dubius	M1	TRADUB
Trifolium longipes	D2	TRILON
Trifolium hybridum	E3	TRIHYB
Trifolium pratense		TRIPRA
Trifolium repens	B2	TRIREP
Valeriana dioica		VALDIO
Veronica serpyllifolia	A3	VERSER
Veronica wormskjoldii	O2	VERWOR
Viola adunca	A1	VIOADU
Viola canadensis	C3	VIOCAN
Viola nuttallii		VIONUT
<u>Grasses/Graminoids</u>		
Agrostis scabra	A3	AGRSCA
Agropyron caninum	D3 E2 O1	AGRCAN
Agropyron spicatum		AGRSPI
Bromus carinatus	E2	BROCAR
Bromus ciliatus	B3 E1	BROCIL
Bromus inermis	O3	BROINE
Calamagrostis canadensis	A1 A2	CALCAN
Calamagrostis rubescens	A3	CALRUB
Carex aquatilis	A3	CARAQU
Carex geyeri	N2	CARGEY
Carex hoodii	A1 G3 L3 O2	CARHOO
Carex lanuginosa	A1	CARLAN
Carex micropteris	A2	CARMIC
Carex praticola	C3 E3 J1 N3	CARPRA
Carex raynoldsii	E3 I1 P2	CARRAY
Carex rostrata		CARROS2
Carex rossii	H1	CARROS
Carex sartwellii	A1	CARSAR
Carex vallicola	E2	CARVAL
Dactylis glomerata		DACGLO
Danthonia intermedia	H1 I2	DANINT
Danthonia spicata	A3	DANSPI
Deschampsia caespitosa	A3	DESCAE
Deschampsia elongata	L2	DESELO
Elymus cinereus		ELYCIN
Elymus glaucus	D2 D3 L2 O2	ELYGLA

Table 23--Continued.

Festuca idahoensis	E2	FESIDA
Hordeum brachyantherum	H3	HORBRA
Juncus balticus	A1	JUNBAL
Koelaria cristata	E2 E3 J1	KOECRI
Luzula campestris	A3	LUZCAM
Melica bulbosa	H3	MELBUL
Muhlenbergia racemosa	N3	MUHRAC
Muhlenbergia richardsonii	A1	MUHRIC
Phleum alpinum	I1 L2	PHLALP
Phleum pratense	A1	PHLPRA
Oryzopsis exigua	C3 M3	ORYEXI
Poa compressa	G2	POACOM
Poa cusickii	J1	POACUS
Poa fendleriana	I2	POAFEN
Poa interior	D2	POAINT
Poa juncifolia	A3 E2 E3	POAJUN
Poa nervosa	B2 C2 C3 E2 G3	POANER
Poa palustris	A1 A3	POAPAL
Poa scabrella	I3 O1 P2	POASCR
Poa trivialis	A2	POATRI
Sitanion hysterix		SITHYS
Stipa lemonnii	J3	STILEM
Stipa occidentalis		STIOCC
Stipa occidentalis var. nelsonii	E2 B2	STINEL
Stipa richardsonii	E1	STIRIC
Trisetum spicatum	L2	TRISPI

[1] Sample stand codes listed in Table 2.

APPENDIX B

VASCULAR PLANT NOMENCLATURE AND AUTHORITY

Table 24. Plant species list and authority. Nomenclature follows Hitchcock and Cronquist (1973), otherwise Dorn (1992).

<u>Trees</u>
Abies lasiocarpa (Hook.) Nutt.
Picea engelmannii Parry ex Engelm.
Pinus contorta Dougl. var. latifolia Engelm.
Populus tremuloides Michx.
Pseudotsuga menziesia (Mirbel) Franco

<u>Shrubs</u>
Arctostaphylos uva-ursi (L.) Spreng.
Artemisia cana Pursh
Artemisia frigida Willd.
Artemisia tridentata Nutt.
Berberis repens Lindl.
Ceanothus velutinus Dougl.
Chrysothamnus nauseosus (Pall.) Britt.
Chrysothamnus viscidiflorus (Hook.) Nutt.
Iliamna rivularis (Dougl.) Greene
Linnaea borealis L.
Potentilla fruticosa L.
Ribes cereum Dougl.
Ribes lacustre (Pers.) Poir.
Rubus idaeus L.
Rosa acicularis Lindl.
Salix bebbiana Sarg.
Salix geyeriana Anderss.
Salix wolfii Bebb
Sheperdia canadensis (L.) Nutt.
Spiraea betulifolia Pall.
Symphoricarpos albus (L.) Blake
Symphoricarpos oreophilus Gray
Vaccinium globulare Rydb.
Vaccinium membranaceum Dougl.
Vaccinium scoparium Leiberg

<u>Forbs</u>
Achillea millefolium L.
Agoseris aurantiaca (Hook.) Greene
Agoseris glauca (Pursh) Raf.
Allium brevistylum Wats.
Allium cernuum Roth
Anaphalis margaritacea (L.) B. & H.
Androsace septentrionalis L.
Anemone parviflora Michx.
Anemone spp. L.
Antennaria microphylla Rydb.
Antennaria racemosa Hook.
Aquilegia flavescens Wats.

Table 24--Continued.

Arabis drummondii Gray
Arabis glabra (L.) Bernh.
Arabis holboellii Hornem.
Arabis lemmonii Wats.
Arabis lyallii Wats.
Arenaria congesta Nutt.
Arenaria laterifolia L.
Arnica cordifolia Hook.
Arnica latifolia Bong.
Arnica longifolia D. C. Eat.
Arnica mollis Hook.
Arnica parryi Gray
Aster adscendens Lindl.
Aster campestris Nutt.
Aster conspicuus Lindl.
Aster foliaceus Lindl.
Aster hesperius Gray
Aster integrifolius Nutt.
Aster occidentalis (Nutt.) T. & G.
Aster pereglans Nels. & Macbr.
Aster meritus A. Nels.
Astragalus adsurgens Hook.
Astragalus agrestis Dougl.
Astragalus alpinus L.
Astragalus eucosmus Robins.
Astragalus kentrophyta Gray
Astragalus miser Dougl.
Astragalus purshii Dougl.
Astragalus vexilliflexis Sheld.
Atriplex nuttallii Wats.
Balsamorhiza sagittata (Pursh) Nutt.
Barbarea orthoceras Ledeb.
Besseya wyomingensis (A. Nels.) Rydb.
Camelina microcarpa Andrz.
Campanula rotundifolia L.
Capsella bursa-pastoris (L.) Crantz
Castilleja miniata Dougl.
Castilleja pallescens (Gray) Greenm.
Cerastium arvense L.
Cerastium fontanum Baumg.
Chaenactis douglasii (Hook.) H. & A.
Chenopodium fremontii Wats.
Cirsium arvense (L.) Scop.
Cirsium scariosum Nutt.
Cirsium vulgare (Savi) Tenore
Cirsium spp. Mill.
Collinsia parviflora Lindl.
Collomia linearis Nutt.
Conimitella williamsii (Eaton) Rydb.
Corallorhiza trifida Chat.

Table 24--Continued.

Corydalis aurea Willd.
Crepis atrabarba Heller
Cynoglossum officinale L.
Delphenium nuttallianum Pritzel ex Walpers
Descurainia richardsonii (Sweet) Schulz
Draba nemorosa L.
Draba stenoloba Ledeb.
Epilobium anagallidifolium Lam.
Epilobium angustifolium L.
Epilobium ciliatum Raf.
Epilobium glaberrimum Barbey
Epilobium paniculatum Nutt.
Equisetum arvense L.
Erigeron acris L.
Erigeron compositus Pursh
Erigeron gracilis Rydb.
Erigeron speciosus (Lindl.) DC.
Eriogonum umbellatum Torr.
Eriophyllum lanatum (Pursh) Forbes
Erysimum cheiranthoides L.
Erysimum inconspicuum (Wats.) MacM.
Erythronium grandiflorum Pursh
Fragaria vesca L.
Fragaria virginiana Duchesne
Frasera speciosa Dougl.
Galium bifolium Wats.
Galium boreale L.
Galium trifidum L.
Gayophytum diffusum T. & G.
Gayophytum racemosum T. & G.
Gentiana detonsa Rottb.
Gentiana amarella L. (= Gentianella amarella L. (Borner))
Geranium bicknellii Britt.
Geranium richardsonii Fisch. & Trautv.
Geranium viscosissimum F. & M.
Geum triflorum Pursh
Gnaphalium viscosum H. B. K.
Gnaphalium spp. L.
Hackelia deflexa (Wahlenb.) Opiz
Hackelia floribunda (Lehm.) Johnst.
Hackelia micrantha (Eastw.) J. L. Gentry
Hieracium albiflorum Hook.
Hieracium cynoglossoides Arv.-Touv.
Hieracium gracile Hook.
Lactuca seriola L.
Lappula redowskii (Hoernem.) Greene
Lepidium virginicum L. var. pubescens (Greene) Hitchc.
Lewisia rediviva Pursh
Linanthus septentrionalis Mason
Linaria dalmatica (L.) Mill.

Table 24--Continued.

Linum lewisii Pursh.
Lithospermum ruderale Dougl.
Lomatium cous (Wats.) Coult. & Rose
Lomatium dissectum (Nutt.) Math. & Const.
Lupinus argenteus Pursh
Lupinus lepidus Dougl.
Lupinus sericeus Pursh
Melilotus officinalis (L.) Lam.
Mentha arvensis L. var. canadensis (Benth.) Fern
Microsteris gracilis (Hook.) Greene
Myosotis sylvatica Hoffm. (=M. alpestris Schmidt)
Nemophila breviflora Gray
Orthocarpus luteus Nutt.
Osmorhiza chilensis H. & A.
Osmorhiza depauperata Phil.
Oxytropis deflexa (Pall.) DC.
Penstemon fruticosus (Pursh) Greene
Penstemon procerus Dougl.
Perideridia gairdneri (H. & A.) Math.
Phacelia franklinii (R. Br.) Gray
Phacelia hastata Dougl.
Phacelia sericea (Grah.) Gray
Phlox hoodii Rich.
Phlox longifolia Nutt.
Phlox multiflora A. Nels.
Polemonium pulcherrimum Hook.
Polygonum bistortoides Pursh
Polygonum douglasii Greene
Potentilla arguta Pursh
Potentilla diversifolia Lehm.
Potentilla glandulosa Lindl.
Potentilla gracilis Dougl.
Rorippa islandica (Oed.)
Rumex acetosella L.
Rumex paucifolius Nutt.
Saxifraga rhomboidea Greene
Sedum lanceolatum Torr.
Senecio canus Hook.
Senecio crassulus Gray
Senecio cymbalarioides Buck
Senecio hydrophilus Nutt.
Senecio integerrimus Nutt.
Senecio pseudaureus Rydb.
Senecio sphaerocephalus Greene
Senecio streptanthifolius Greene
Senecio serra Hook.
Sibbaldia procumbens L.
Silene latifolia Poir.
Silene oregana Wats.
Solidago canadensis L.

Table 24--Continued.

Solidago missouriensis Nutt.
Solidago multiradiata Ait.
Solidago spp. L.
Spergularia rubra (L.) Presl.
Stellaria longipes Goldie var. altocaulis(Hulten) Hitchc.
Taraxacum laevigatum (Willd.) DC.
Taraxacum officinale Weber
Thalictrum occidentale Gray
Thlaspi arvense L.
Tragopogon dubius Scop.
Trifolium longipes Nutt.
Trifolium hybridum L.
Trifolium pratense L.
Trifolium repens L.
Valeriana dioica L.
Verbascum thapsus L.
Veronica serpyllifolia L.
Veronica wormskjoldii Roem. & Schult.
Viola adunca Sm.
Viola canadensis L.
Viola nuttallii Pursh
Zigadenus venenosus Wats.

Grasses/Graminoids
Agrostis scabra Willd.
Agropyron caninum (L.) Beauv.
Agropyron spicatum (Pursh) Scribn. & Smith
Bromus carinatus H. & A.
Bromus carinatus H. & A. var. carinatus (= B. marginatus)
Bromus ciliatus L.
Bromus inermis Leys.
Calamagrostis canadensis (Michx.) Beauv.
Calamagrostis rubescens Buckl.
Carex geyeri Boott
Carex hoodii Boott
Carex lanuginosa Michx.
Carex microptera Mack.
Carex praticola Rydb.
Carex raynoldsii Dewey
Carex rossii Boott
Carex rostrata Stokes
Carex sartwellii Dewey
Carex vallicola Dewey
Carex spp. L.
Dactylis glomerata L.
Danthonia intermedia Vasey
Danthonia spicata (L.) Beauv.
Deschampsia cespitosa (L.) Beauv.
Deschampsia elongata (Hook.) Munro
Elymus cinereus Scribn. & Merr.

Table 24--Continued.

Elymus glaucus Buckl.
Festuca idahoensis Elmer
Hordeum brachyantherum Nevski
Juncus balticus Willd.
Koelaria cristata Pers.
Luzula campestris (L.) DC.
Melica bulbosa Geyer
Muhlenbergia racemosa (Michx.) B.S.P.
Muhlenbergia richardsonis (Thurb.) Rydb.
Oryzopsis exigua Thurb.
Phleum alpinum L.
Phleum pratense L.
Poa compressa L.
Poa cusickii Vasey
Poa fendleriana (Steud.) Vasey
Poa interior Rydb.
Poa juncifolia Scribn.
Poa nervosa (Hook.) Vasey
Poa palustris L.
Poa scabrella (Thurb.) Benth.
Poa trivialis L.
Sitanion hystrix (Nutt.) Smith
Stipa lemmonii (Vasey) Scribn.
Stipa occidentalis Thurb.
Stipa nelsonii Scribn.
Stipa richardsonii Link
Trisetum spicatum (L.) Richter

APPENDIX C

SUMMARY DATA OF SAMPLE STANDS BY HABITAT TYPE

Table 25. Species presence and cover in three stands in the *Deschampsia cespitosa/Carex spp.* habitat type. Numeric values give mean percent cover in twenty 20 cm. by 50 cm. quadrats. P indicates presence of species not found in quadrats but appearing in the 4 m. by 25 m. macroplot.

Species	Transect A1	Transect A2	Transect A3
Shrubs			
Artemisia tridentata Nutt.	P	P	0.00
Potentilla fruticosa L.	1.95	0.00	0.00
Salix geyeriana Anderss.	0.15	0.00	5.25
Salix wolfii Bebb	0.00	0.00	P
Forbs			
Achillea millefolium L.	0.75	0.30	P
Agoseris glauca (Pursh) Raf.	0.00	0.75	P
Antennaria microphylla Rydb.	0.00	0.00	0.75
Arabis glabra (L.) Bernh.	0.00	0.00	0.15
Arenaria laterifolia L.	0.00	4.20	0.00
Arnica mollis Hook.	0.00	0.00	P
Aster hesperius Gray	1.20	0.90	0.00
Aster occidentalis (Nutt.) T. & G.	0.00	P	P
Campanula rotundifolia L.	P	0.00	0.00
Cirsium scariosum Nutt.	P	P	P
Collinsia parviflora Lindl.	0.00	P	0.00
Collomia linearis Nutt.	0.00	P	0.03
Epilobium angustifolium L.	0.75	0.00	0.00
Epilobium ciliatum Raf.	1.23	1.95	0.05
Epilobium paniculatum Nutt.	0.00	P	0.00
Equisetum arvense L.	0.18	0.00	0.00
Erigeron acris L.	0.00	0.00	P
Fragaria virginiana Duchesne	0.90	0.00	P
Galium boreale L.	1.55	0.00	0.00
Galium trifidum L.	0.00	0.00	0.15
Gentiana detonsa Rottb.	0.00	0.00	0.15
Geranium viscosissimum F. & M.	0.30	0.00	0.00
Mentha arvensis L. var. canadensis	0.15	0.00	0.00
Penstemon procerus Dougl.	0.00	0.00	P
Polygonum douglasii Greene	0.00	P	P
Potentilla arguta Pursh	0.45	P	0.15
Potentilla diversifolia Lehm.	0.00	0.00	1.70
Potentilla gracilis Dougl.	0.15	0.00	0.00
Saxifraga rhomboidea Greene	0.00	0.00	P
Senecio cymbalarioides Buck	0.00	0.00	P
Senecio sphaerocephalus Greene	6.70	0.00	0.00
Senecio streptanthifolius Greene	0.00	P	0.00
Solidago canadensis L.	11.55	0.00	0.00
Stellaria longipes var.altocaulis	0.00	0.00	0.03
Taraxacum officinale Weber	0.03	5.25	0.30
Thalictrum occidentale Gray	4.43	0.00	0.00

Table 25--Continued.

Thlaspi arvense L.	0.00	P	0.00
Trifolium longipes Nutt.	0.00	0.00	0.15
Trifolium hybridum L.	0.00	P	0.00
Veronica serpyllifolia L.	0.00	0.00	P
Viola adunca Sm.	0.30	0.15	0.15
Viola canadensis L.	0.03	0.00	0.00
<u>Graminoids</u>			
Agrostis scabra Willd.	0.00	0.00	P
Agropyron caninum (L.) Beauv.	1.20	P	0.00
Bromus carinatus H. & A.	0.15	0.00	0.00
Calamagrostis canadensis (Michx.) Beauv	2.15	3.00	0.00
Calamagrostis rubescens Buckl.	0.00	0.00	4.20
Carex aquatilis Wahl.	0.00	0.00	36.29
Carex hoodii Boott	P	0.00	0.00
Carex lanuginosa Michx.	P	21.05	0.00
Carex microptera Mack.	0.00	0.15	0.00
Carex praticola Rydb.	P	0.00	0.00
Carex rostrata Stokes	0.00	0.00	29.28
Carex sartwellii Dewey	20.28	0.00	0.00
Danthonia spicata (L.) Beauv.	0.00	0.00	0.15
Deschampsia cespitosa (L.) Beauv.	6.43	5.15	8.55
Juncus balticus Willd.	28.55	0.15	0.00
Luzula campestris (L.) DC.	0.00	0.00	P
Muhlenbergia richardsonis (Thurb.) Rydb	2.43	0.00	0.00
Phleum pratense L.	P	2.25	P
Poa juncifolia Scribn.	0.00	0.00	0.15
Poa pratensis L.	0.20	49.00	P
Poa trivialis L.	0.00	0.03	0.00
Stipa nelsonii Scribn.	P	0.00	0.00
<u>Non-Vascular Plants</u>			
Mosses	0.00	0.00	0.15
Litter	0.15	3.30	1.05
Woody Debris > 3" Diameter	0.00	0.00	0.00
Bare Ground	0.00	1.65	6.08
Total	94.25	101.78	94.89

Table 26. Species presence and cover in three stands in the *Pseudotsuga menziesii/Calamagrostis rubescens* habitat type. Numeric values give mean percent cover in twenty 20 cm. by 50 cm. quadrats. P indicates presence of species not found in quadrats but appearing in the 4 m. by 25 m. macroplot.

Species	Transect		
	B1	B2	B3
Trees			
Populus tremuloides Michx.	0.00	0.00	P
Shrubs			
Artemisia tridentata Nutt.	0.00	0.18	0.00
Berberis repens Lindl.	0.00	0.20	0.00
Ceanothus velutinus Dougl.	2.25	0.00	0.00
Chrysothamnus nauseosus (Pall.) Britt.	0.00	P	0.00
Iliamna rivularis (Dougl.) Greene	0.15	1.35	0.00
Rosa acicularis Lindl.	1.50	3.55	0.00
Sheperdia canadensis (L.) Nutt.	0.00	P	0.00
Spiraea betulifolia Pall.	1.65	P	0.00
Symphoricarpos albus (L.) Blake	0.00	0.00	3.00
Symphoricarpos oreophilus Gray	1.68	P	0.00
Forbs			
Achillea millefolium L.	5.88	4.08	2.10
Agoseris aurantiaca (Hook.) Greene	0.00	P	0.00
Agoseris glauca (Pursh) Raf.	0.15	P	0.75
Androsace septentrionalis L.	P	0.00	0.00
Antennaria microphylla Rydb.	P	0.00	0.00
Arabis glabra (L.) Bernh.	0.78	P	0.15
Arabis holboellii Hornem.	P	0.00	0.03
Arnica cordifolia Hook.	0.00	0.75	P
Aster adscendens Lindl.	P	0.00	0.00
Aster conspicuus Lindl.	1.20	7.88	0.00
Aster pereglans Nels. & Macbr.	P	0.00	0.00
Astragalus miser Dougl.	0.15	1.53	0.00
Balsamorhiza sagittata (Pursh) Nutt.	0.00	2.25	0.00
Campanula rotundifolia L.	0.00	0.00	P
Capsella bursa-pastoris (L.) Crantz	0.00	P	0.00
Castilleja miniata Dougl.	0.00	0.00	0.75
Cerastium arvense L.	0.00	0.00	0.90
Cirsium arvense (L.) Scop.	0.00	P	0.00
Cirsium vulgare (Savi) Tenore	0.00	1.68	0.00
Collinsia parviflora Lindl.	0.00	0.15	0.00
Collomia linearis Nutt.	0.10	P	0.15
Corydalis aurea Willd.	0.00	P	0.00
Cynoglossum officinale L.	0.00	2.08	0.00
Epilobium angustifolium L.	3.68	0.15	45.88
Epilobium ciliatum Raf.	P	0.00	0.15
Epilobium glaberrimum Barbey	0.00	P	0.00
Epilobium paniculatum Nutt.	0.18	0.00	0.00
Erigeron speciosus (Lindl.) DC.	P	0.00	1.50

Table 26.--Continued.

Erysimum inconspicuum (Wats.) MacM.	0.00	P	0.00
Fragaria vesca L.	0.00	0.00	1.95
Fragaria virginiana Duchesne	P	0.00	1.50
Galium boreale L.	0.00	2.55	1.05
Gayophytum racemosum T. & G.	0.00	0.20	0.00
Geranium richardsonii Fisch. & Trautv.	0.03	0.00	0.00
Geranium viscosissimum F. & M.	0.00	2.93	0.75
Hackelia floribunda (Lehm.) Johnst.	0.00	0.15	0.00
Hackelia micrantha (Eastw.) J. L. Gentry	0.00	0.00	P
Lactuca seriola L.	0.95	0.63	0.00
Linaria dalmatica (L.) Mill.	0.00	P	0.00
Lupinus spp. L.	6.00	0.33	P
Melilotus officinalis (L.) Lam.	P	1.65	0.00
Myosotis sylvatica Hoffm.	0.00	P	0.00
Osmorhiza depauperata Phil.	0.00	0.00	P
Perideridia gairdneri (H. & A.) Math.	0.00	P	0.00
Polygonum douglasii Greene	0.50	0.00	0.00
Potentilla glandulosa Lindl.	0.00	0.00	0.30
Senecio serra Hook.	0.75	P	6.53
Silene latifolia Poir.	P	0.00	0.00
Solidago missouriensis Nutt.	1.65	P	0.00
Solidago spp. L.	0.00	0.15	0.00
Taraxacum officinale Weber	P	3.65	0.15
Thalictrum occidentale Gray	0.00	0.00	0.90
Tragopogon dubius Scop.	0.90	0.00	0.00
Trifolium hybridum L.	0.00	2.70	0.00
Viola canadensis L.	0.00	P	0.00
Zigadenus venonosus Wats.	P	0.50	0.00
<u>Graminoids</u>			
Agropyron caninum (L.) Beauv.	0.90	0.00	0.30
Bromus carinatus H. & A.	0.00	0.75	0.00
Bromus ciliatus L.	P	0.00	4.65
Calamagrostis rubescens Buckl.	34.15	0.15	28.30
Carex geyeri Boott	0.00	0.00	P
Carex hoodii Boott	P	0.00	1.88
Carex rossii Boott	0.75	0.00	0.00
Dactylis glomerata L.	0.00	P	0.00
Elymus cinereus Scribn. & Merr.	0.15	P	0.00
Elymus glaucus Buckl.	0.00	0.00	0.75
Phleum pratense L.	P	24.35	0.15
Poa interior Rydb.	0.00	0.00	0.45
Poa juncifolia Scribn.	P	0.00	0.00
Poa nervosa (Hook.) Vasey	0.75	6.43	P
Stipa occidentalis var. nelsonii	2.78	P	0.30
<u>Non-Vascular Plants</u>			
Mosses	11.53	P	3.68

Table 26.--Continued.

Litter	8.78	2.30	11.75
Woody Debris > 3" Diameter	6.65	0.00	0.00
Bare Ground	6.00	7.88	P
Total	102.83	82.58	120.68

Table 27. Species presence and cover in three stands in the *Pseudotsuga menziesii/Symphoricarpos albus* habitat type. Numeric values give mean percent cover in twenty 20 cm. X 50 cm. quadrats. P indicates presence of species not found in quadrats but appearing in the 4 m. X 25 m. macroplot.

Species	Transect C1	Transect C2	Transect C3
__Trees__			
Pseudotsuga menziesia (Mirbel) Franco	0.00	P	0.00
__Shrubs__			
Artemisia tridentata Nutt.	P	0.00	P
Iliamna rivularis (Dougl.) Greene	21.88	0.00	0.00
Linnaea borealis L.	0.00	0.00	P
Rubus idaeus L.	0.00	0.00	2.03
Rosa acicularis Lindl.	0.00	0.75	5.83
Spiraea betulifolia Pall.	0.00	0.00	P
Symphoricarpos albus (L.) Blake	0.00	P	0.00
__Forbs__			
Achillea millefolium L.	0.90	2.88	3.93
Agoseris glauca (Pursh) Raf.	P	0.00	0.75
Allium cernuum Roth	0.00	0.00	0.15
Antennaria microphylla Rydb.	0.00	0.00	0.78
Arabis drummondii Gray	0.00	0.00	P
Arabis glabra (L.) Bernh.	P	P	P
Aster conspicuus Lindl.	0.00	2.25	2.63
Aster foliaceus Lindl.	0.00	P	0.00
Astragalus miser Dougl.	0.00	0.00	1.68
Cerastium arvense L.	0.00	0.00	P
Chenopodium fremontii Wats.	1.08	0.00	P
Cirsium scariosum Nutt.	0.00	0.75	0.00
Cirsium vulgare (Savi) Tenore	0.00	0.00	P
Collinsia parviflora Lindl.	0.23	0.00	0.08
Collomia linearis Nutt.	6.18	0.00	P
Conimitella williamsii (Eaton) Rydb.	0.00	0.00	0.30
Cynoglossum officinale L.	P	0.00	0.00
Descurainia richardsonii (Sweet) Schulz	0.20	0.00	2.63
Epilobium angustifolium L.	1.50	63.50	6.93
Epilobium ciliatum Raf.	0.30	2.40	0.00
Epilobium paniculatum Nutt.	P	0.00	P
Erigeron compositus Pursh	0.00	0.00	P
Erigeron speciosus (Lindl.) DC.	0.00	P	0.00
Erysimum inconspicuum (Wats.) MacM.	0.00	0.00	0.15
Erythronium grandiflorum Pursh	0.00	0.00	P
Fragaria vesca L.	0.15	0.00	0.00
Fragaria virginiana Duchesne	0.75	2.10	5.58
Galium bifolium Wats.	0.90	0.00	0.00
Galium boreale L.	P	0.15	5.20
Geranium bicknellii Britt.	P	0.00	0.00

Table 27--Continued.

Geranium richardsonii Fisch. & Trautv.	0.00	0.90	0.00
Geranium viscosissimum F. & M.	0.00	P	0.03
Geum triflorum Pursh	0.00	0.00	0.30
Hackelia deflexa (Wahlenb.) Opiz	0.00	P	0.00
Hieracium albiflorum Hook.	0.00	0.00	0.75
Lepidium virginicum L. var. pubescens	0.00	P	0.00
Linanthus septentrionalis Mason	P	0.00	0.00
Lomatium dissectum (Nutt.) Math. & Const	0.00	0.00	P
Nemophila breviflora Gray	1.20	P	0.00
Osmorhiza chilensis H. & A.	0.30	0.00	0.00
Penstemon procerus Dougl.	P	0.00	0.75
Phacelia franklinii (R. Br.) Gray	0.00	0.00	0.30
Phlox hoodii Rich.	0.00	0.00	P
Phlox multiflora A. Nels.	0.00	0.00	0.15
Potentilla arguta Pursh	0.00	0.15	0.00
Potentilla glandulosa Lindl.	0.00	0.00	0.75
Potentilla gracilis Dougl.	0.00	P	P
Senecio serra Hook.	21.75	7.28	2.78
Taraxacum officinale Weber	1.50	4.80	2.85
Thlaspi arvense L.	P	0.00	0.00
Tragopogon dubius Scop.	0.00	1.65	0.00
Valeriana dioica L.	0.00	0.00	P
Viola canadensis L.	0.00	0.00	0.75
<u>Graminoids</u>			
Agropyron caninum (L.) Beauv.	0.95	0.75	0.30
Agropyron spicatum Scribn. & Smith	0.00	0.00	1.83
Bromus carinatus H. & A.	P	1.65	0.00
Calamagrostis rubescens Buckl.	0.00	1.65	0.00
Carex geyeri Boott	0.00	0.00	P
Carex praticola Rydb.	0.00	0.00	0.75
Elymus glaucus Buckl.	0.03	P	0.00
Festuca idahoensis Elmer	0.00	0.00	0.75
Oryzopsis exigua Thurb.	0.00	0.00	P
Phleum pratense L.	1.08	4.43	0.00
Poa interior Rydb.	0.00	P	0.00
Poa nervosa (Hook.) Vasey	P	2.10	9.63
Stipa occidentalis var. nelsonii	0.00	0.75	0.75
Stipa richardsonii Link	0.00	0.00	0.15
Trisetum spicatum (L.) Richter	0.00	0.00	P
<u>Non-Vascular Plants</u>			
Mosses	2.25	0.00	4.33
Litter	0.93	0.15	14.23
Woody Debris > 3" Diameter	2.40	0.00	0.00
Bare Ground	20.18	0.00	0.75
Total	86.60	101.03	81.63

Table 28. Species presence and cover in three stands in the *Populus tremuloides/Calamagrostis rubescens* habitat type. Numeric values give mean percent cover in twenty 20 cm. by 50 cm. quadrats. P indicates presence of species not found in quadrats but appearing in the 4 m. by 25 m. macroplot.

Species	Transect		
	D1	D2	D3
Trees			
Populus tremuloides Michx.	0.00	0.00	0.75
Pseudotsuga menziesia (Mirbel) Franco	0.00	0.00	P
Shrubs			
Artemisia tridentata Nutt.	0.00	P	0.00
Berberis repens Lindl.	0.00	P	0.75
Iliamna rivularis (Dougl.) Greene	0.00	0.00	0.00
Potentilla gracilis Dougl.	0.00	1.50	P
Rosa acicularis Lindl.	0.00	1.65	2.73
Spiraea betulifolia Pall.	0.00	0.00	4.98
Symphoricarpos albus (L.) Blake	0.00	3.68	5.25
Forbs			
Achillea millefolium L.	4.55	0.90	3.48
Agoseris glauca (Pursh) Raf.	1.80	0.15	0.00
Allium brevistylum Wats.	0.00	P	0.00
Anemone parviflora Michx.	0.00	0.00	P
Arabis drummondii Gray	0.00	P	0.00
Arenaria laterifolia L.	0.00	0.00	P
Aster chilensis Nees var. adscendens	0.00	0.00	0.75
Aster campestris Nutt.	0.15	0.90	0.00
Aster conspicuus Lindl.	0.00	0.00	1.05
Aster hesperius Gray	0.00	2.85	0.00
Aster integrifolius Nutt.	0.00	5.03	0.00
Astragalus agrestis Dougl.	0.00	0.00	0.75
Astragalus eucosmus Robins.	0.00	4.03	0.00
Astragalus miser Dougl.	0.15	1.23	2.43
Balsamorhiza sagittata (Pursh) Nutt.	0.00	0.00	1.05
Campanula rotundifolia L.	0.00	0.15	0.15
Chenopodium fremontii Wats.	0.03	0.00	0.00
Cirsium scariosum Nutt.	0.00	P	0.00
Cirsium vulgare (Savi) Tenore	0.00	0.00	2.25
Collinsia parviflora Lindl.	0.03	0.00	0.00
Collomia linearis Nutt.	0.45	P	0.00
Corallorhiza trifida Chat.	0.00	0.00	P
Cynoglossum officinale L.	0.00	0.00	0.03
Draba stenoloba Ledeb.	0.03	0.00	0.00
Epilobium angustifolium L.	6.90	4.88	0.00
Epilobium paniculatum Nutt.	2.33	0.00	0.03
Erysimum inconspicuum (Wats.) MacM.	0.00	P	0.00
Fragaria virginiana Duchesne	2.55	1.05	P
Frasera speciosa Dougl.	0.00	0.75	0.00

Table 28--Continued.

Galium boreale L.	0.00	1.05	0.03
Gayophytum diffusum T. & G.	P	0.00	0.00
Gentiana amarella L.	0.00	P	0.00
Geranium richardsonii Fisch. & Trautv.	0.00	10.85	0.00
Geranium viscosissimum F. & M.	0.90	2.25	1.65
Hackelia floribunda (Lehm.) Johnst.	0.15	0.00	0.00
Lactuca seriola L.	0.00	0.00	0.03
Linanthus septentrionalis Mason	P	0.00	0.00
Lithospermum ruderale Dougl.	0.00	0.00	0.78
Lupinus spp. L.	7.50	4.38	2.58
Melilotus officinalis (L.) Lam.	0.00	0.00	0.15
Myosotis sylvatica Hoffm.	0.00	P	0.00
Osmorhiza depauperata Phil.	0.00	0.00	0.18
Perideridia gairdneri (H. & A.) Math.	0.15	0.15	P
Polygonum douglasii Greene	0.60	P	0.00
Senecio pseudaureus Rydb.	0.00	P	0.00
Senecio serra Hook.	P	6.50	P
Solidago missouriensis Nutt.	0.00	0.00	P
Solidago multiradiata Ait.	P	0.00	0.93
Taraxacum officinale Weber	0.75	3.00	4.55
Thalictrum occidentale Gray	0.00	0.15	0.00
Thlaspi arvense L.	0.05	0.00	0.00
Tragopogon dubius Scop.	0.15	0.00	0.30
Trifolium longipes Nutt.	0.00	2.55	0.00
Trifolium pratense L.	0.00	0.00	P
Trifolium repens L.	0.00	0.00	0.90
Verbascum thapsus L.	0.00	0.00	P
Viola adunca Sm.	0.00	0.00	0.03
<u>Graminoids</u>			
Agropyron caninum (L.) Beauv.	36.13	0.18	0.00
Bromus carinatus H. & A.	0.00	0.60	0.53
Calamagrostis rubescens Buckl.	8.30	0.00	0.93
Carex hoodii Boott	0.00	P	0.00
Carex praticola Rydb.	0.00	0.15	P
Elymus cinereus Scribn. & Merr.	0.00	0.00	P
Elymus glaucus Buckl.	0.00	1.05	0.00
Phleum pratense L.	0.00	30.53	12.93
Poa interior Rydb.	0.00	1.68	0.00
Poa juncifolia Scribn.	0.00	P	0.00
Poa nervosa (Hook.) Vasey	0.00	0.15	2.83
Stipa nelsonii Scribn.	P	0.00	0.00
<u>Non-Vascular Plants</u>			
Mosses	4.15	1.65	0.00
Litter	5.78	1.65	21.33
Woody Debris > 3" Diameter	7.25	2.18	0.00
Bare Ground	16.55	0.15	6.23
Total	107.35	99.55	83.23

Table 29. Species presence and cover in three stands of the *Artemesia tridentata\Festuca idahoensis* habitat type. Numeric values give mean percent cover in twenty 20 cm. by 50 cm. quadrats. P indicates presence of species not found in quadrats but appearing in the 4 m. by 25 m. macroplot.

Species	Transect		
	E1	E2	E3
Shrubs			
Artemisia cana Pursh	0.00	0.03	0.00
Artemisia frigida Willd.	0.00	P	0.00
Artemesia tridentata Nutt.	1.65	P	2.03
Chrysothamnus viscidiflorus (Hook.) Nutt.	P	0.00	0.00
Forbs			
Achillea millefolium L.	1.53	0.05	4.53
Agoseris aurantiaca (Hook.) Greene	0.00	0.00	0.30
Agoseris glauca (Pursh) Raf.	2.70	0.00	1.80
Androsace septentrionalis L.	0.00	0.00	P
Antennaria microphylla Rydb.	2.73	0.15	0.00
Arabis drummondii Gray	0.00	0.00	P
Arabis glabra (L.) Bernh.	0.00	0.00	P
Aster adscendens Lindl.	0.00	0.00	P
Aster campestris Nutt.	0.00	1.00	P
Aster foliaceus Lindl.	0.00	0.00	32.85
Aster occidentalis (Nutt.) T. & G.	7.20	0.00	0.00
Astragalus agrestis Dougl.	0.30	0.00	0.00
Astragalus kentrophyta Gray	0.00	0.00	P
Astragalus miser Dougl.	0.00	0.00	1.65
Atriplex nuttallii Wats.	0.00	0.00	P
Campanula rotundifolia L.	0.45	0.00	P
Chaenactis douglasii (Hook.) H. & A.	0.00	P	0.00
Cirsium scariosum Nutt.	0.00	0.00	P
Collomia linearis Nutt.	0.00	0.00	0.53
Epilobium glaberrimum Barbey	0.00	0.00	P
Erigeron gracilis Rydb.	0.00	0.03	0.00
Erigeron speciosus (Lindl.) DC.	0.00	0.00	P
Eriogonum umbellatum Torr.	0.90	P	1.88
Eriophyllum lanatum (Pursh) Forbes	0.00	0.00	1.50
Erysimum inconspicuum (Wats.) MacM.	0.00	P	0.00
Fragaria virginiana Duchesne	0.00	0.00	4.65
Galium boreale L.	P	0.00	P
Geranium viscosissimum F. & M.	0.00	0.00	4.80
Geum triflorum Pursh	0.00	0.00	P
Lappula redowskii (Hoernem.) Greene	0.00	P	0.00
Lewisia rediviva Pursh	0.00	P	0.00
Linum perennne L. var. lewisii (Pursh)	P	0.00	0.00
Lithospermum ruderale Dougl.	0.00	0.00	P
Lupinus spp. L.	7.75	30.68	2.03
Microseris nutans (Geyer) Schultz-Bip.	0.00	P	0.00
Myosotis sylvatica Hoffm.	0.00	0.00	P
Orthocarpus luteus Nutt.	0.15	0.00	0.00

Table 29--Continued.

Oxytropis deflexa (Pall.) DC.	5.30	0.00	0.00
Penstemon procerus Dougl.	2.43	P	0.00
Perideridia gairdneri (H. & A.) Math.	0.00	0.00	P
Phlox hoodii Rich.	0.00	0.15	P
Phlox longifolia Nutt.	0.00	0.00	P
Polygonum douglasii Greene	0.15	0.00	0.63
Potentilla glandulosa Lindl.	0.00	0.00	0.90
Potentilla gracilis Dougl.	P	0.00	6.30
Rumex acetosella L.	0.00	0.10	0.00
Senecio canus Hook.	0.00	0.00	P
Senecio streptanthifolius Greene	P	0.03	0.00
Senecio serra Hook.	0.00	0.00	P
Solidago missouriensis Nutt.	P	0.00	0.00
Stellaria longipes Goldie var.altocaulis	0.00	0.00	P
Taraxacum laevigatum (Willd.) DC.	P	0.00	P
Taraxacum officinale Weber	3.78	0.00	1.88
Thlaspi arvense L.	0.00	0.00	0.08
Tragopogon dubius Scop.	0.00	0.00	P
Trifolium longipes Nutt.	P	0.00	0.00
Trifolium hybridum L.	0.15	0.00	P
Viola nuttallii Pursh	0.15	0.03	0.15
<u>Graminoids</u>			
Agrostis scabra Willd.	0.00	0.03	0.00
Agropyron caninum (L.) Beauv.	0.30	19.55	1.20
Agropyron spicatum (Pursh) Scribn. & Sm.	0.00	2.78	0.00
Bromus carinatus H. & A.	0.00	0.00	6.83
Bromus ciliatus L.	0.60	0.00	0.00
Carex praticola Rydb.	0.15	0.00	0.45
Carex raynoldsii Dewey	0.00	0.00	0.03
Carex vallicola Dewey	0.00	P	0.00
Danthonia spicata (L.) Beauv.	4.28	0.00	0.00
Festuca idahoensis Elmer	16.80	3.68	1.08
Koelaria cristata Pers.	1.80	0.08	P
Phleum pratense L.	7.73	0.00	10.93
Poa juncifolia Scribn.	5.70	2.28	4.60
Poa nervosa (Hook.) Vasey	P	0.18	0.00
Stipa nelsonii Scribn.	0.90	3.35	0.75
Stipa richardsonii Link	3.68	0.00	0.00
Litter	3.15	1.38	3.60
Bare Ground	8.25	8.05	0.00
Total	90.63	73.55	97.90

Table 30. Species presence and cover in three stands in the *Abies lasiocarpa/Calamagrostis rubescens* habitat type, LPO pre-fire cover type. Numeric values give mean percent cover in twenty 20 cm. by 50 cm. quadrats. P indicates presence of species not found in quadrats but appearing in the 4 m. by 25 m. macroplot.

Species	Transect F1	F2	F3
Trees			
Pinus contorta Dougl.	0.00	0.75	0.78
Shrubs			
Artemisia tridentata Nutt.	0.00	0.00	P
Salix bebbiana Sarg.	P	0.00	0.00
Vaccinium scoparium Leiberg	0.00	P	0.00
Forbs			
Achillea millefolium L.	P	2.05	0.03
Agoseris aurantiaca (Hook.) Greene	0.00	0.60	0.00
Agoseris glauca (Pursh) Raf.	3.66	0.00	0.15
Anaphalis margaritacea (l.) B. & H.	0.00	0.15	0.00
Androsace septentrionalis L.	0.00	P	0.00
Anemone parviflora Michx.	0.00	0.00	0.00
Antennaria microphylla Rydb.	P	0.00	P
Aquilegia flavescens Wats.	0.00	P	0.00
Arabis drummondii Gray	0.00	0.00	0.00
Arabis glabra (L.) Bernh.	0.30	P	0.15
Arabis holboellii Hornem.	0.00	0.00	P
Arnica cordifolia Hook.	0.00	2.73	0.00
Aster foliaceus Lindl.	P	0.15	P
Aster integrifolius Nutt.	0.00	0.15	0.00
Astragalus miser Dougl.	0.00	0.00	1.53
Campanula rotundifolia L.	0.00	0.30	P
Cirsium arvense (L.) Scop.	0.00	0.00	P
Cirsium scariosum Nutt.	P	0.00	0.00
Collinsia parviflora Lindl.	0.65	0.15	0.08
Collomia linearis Nutt.	2.63	2.90	1.10
Epilobium angustifolium L.	0.15	11.03	1.95
Epilobium paniculatum Nutt.	0.48	0.00	0.45
Fragaria virginiana Duchesne	0.80	1.35	3.98
Gayophytum diffusum T. & G.	0.38	0.00	0.00
Hieracium albiflorum Hook.	0.00	0.15	0.00
Lomatium dissectum (Nutt.) Math. & Cons.	0.00	P	0.00
Lupinus sericeus Pursh	P	5.55	P
Perideridia gairdneri (H. & A.) Math.	0.00	P	0.00
Phacelia franklinii (R. Br.) Gray	0.00	0.00	0.48
Phacelia hastata Dougl.	0.00	P	0.00
Polygonum douglasii Greene	7.85	2.05	2.88
Potentilla gracilis Dougl.	0.00	P	0.00
Solidago multiradiata Ait.	0.00	P	P

Table 30--Continued.

Taraxacum officinale Weber	6.15	3.15	6.18
Thalictrum occidentale Gray	0.00	0.75	0.00
Tragopogon dubius Scop.	P	0.00	P
Viola nuttallii Pursh	0.00	0.30	0.00
<u>Graminoids</u>			
Agrostis scabra Willd.	6.03	P	3.75
Agropyron caninum (L.) Beauv.	1.68	0.00	3.90
Bromus carinatus H. & A.	0.00	0.00	P
Bromus ciliatus L.	P	P	0.00
Calamagrostis rubescens Buckl.	0.00	4.20	P
Carex geyeri Boott	0.00	1.05	0.00
Carex hoodii Boott	0.15	0.00	0.00
Carex rossii Boott	2.25	16.25	16.95
Danthonia intermedia Vasey	0.00	P	0.00
Danthonia spicata (L.) Beauv.	P	0.00	P
Elymus glaucus Buckl.	0.00	7.28	0.00
Festuca idahoensis Elmer	P	0.00	P
Melica bulbosa Geyer	0.00	0.03	0.00
Poa nervosa (Hook.) Vasey	0.15	0.75	P
Sitanion hystrix (Nutt.) Smith	P	0.00	P
Stipa nelsonii Scribn.	2.40	0.00	0.15
Trisetum spicatum (L.) Richter	0.00	P	P
<u>Non-vascular plants</u>			
Mosses	P	3.00	3.95
Litter	6.98	9.98	4.50
Woody Debris > 3" Diameter	2.63	2.25	15.53
Bare Ground	60.63	17.93	35.65
Total	105.91	96.95	104.08

Table 31. Species presence and cover in three stands in the *Abies lasiocarpa/Calamagrostis rubescens* habitat type, LP1 pre-fire cover type. Numeric values give mean percent cover in twenty 20 cm. by 50 cm. quadrats. P indicates presence of species not found in quadrats but appearing in the 4 m. by 25 m. macroplot.

Species	Transect		
	G1	G2	G3
Trees			
Pinus contorta Dougl.	0.15	0.45	0.05
Shrubs			
Arctostyphalos uva-ursi (L.) Spreng.	0.00	0.00	P
Berberis repens Lindl.	P	0.00	P
Potentilla glandulosa Lindl.	0.00	0.00	P
Potentilla gracilis Dougl.	0.00	0.03	0.00
Ribes cereum Dougl.	0.90	0.00	0.00
Spiraea betulifolia Pall.	P	0.00	0.00
Vaccinium scoparium Leiberg	0.75	0.00	0.00
Forbs			
Achillea millefolium L.	1.53	0.18	0.03
Agoseris aurantiaca (Hook.) Greene	0.00	0.00	0.60
Agoseris glauca (Pursh) Raf.	0.15	2.00	0.00
Antennaria microphylla Rydb.	0.00	0.00	6.80
Arabis glabra (L.) Bernh.	0.00	0.00	P
Arabis holboellii Hornem.	P	0.00	0.00
Arnica cordifolia Hook.	P	0.00	0.00
Aster meritus A. Nels.	10.20	0.00	0.00
Astragalus miser Dougl.	0.00	0.78	0.00
Barbarea orthoceras Ledeb.	0.00	P	0.00
Campanula rotundifolia L.	0.15	0.00	0.03
Cerastium fontanum Baumg.	0.00	0.33	0.15
Cirsium scariosum Nutt.	0.00	0.00	P
Collinsia parviflora Lindl.	0.45	3.25	0.18
Collomia linearis Nutt.	0.00	0.00	0.05
Corydalis aurea Willd.	P	0.00	0.00
Epilobium angustifolium L.	1.20	0.00	2.00
Epilobium ciliatum Raf.	0.00	0.18	0.00
Epilobium glaberrimum Barbey	0.63	0.00	0.00
Epilobium paniculatum Nutt.	0.00	0.00	0.38
Eriophyllum lanatum (Pursh) Forbes	P	0.00	0.00
Fragaria virginiana Duchesne	0.75	0.75	3.15
Gayophytum diffusum T. & G.	1.18	0.00	0.00
Geranium viscosissimum F. & M.	0.75	0.90	0.00
Lappula redowskii (Hoernem.) Greene	0.00	0.00	P
Linanthus septentrionalis Mason	0.00	P	0.00
Lupinus spp. L.	0.75	0.00	3.25
Melilotus officinalis (L.) Lam.	0.00	0.00	P
Microsteris gracilis (Hook.) Greene	0.00	0.00	0.20

Table 31--Continued.

Osmorhiza depauperata Phil.	0.00	P	0.00
Phacelia hastata Dougl.	P	0.00	0.00
Phlox longifolia Nutt.	P	0.00	0.00
Polygonum douglasii Greene	0.30	0.00	0.02
Rumex acetosella L.	0.00	0.15	0.60
Senecio serra Hook.	0.00	P	0.00
Solidago multiradiata Ait.	P	P	P
Taraxacum officinale Weber	1.35	0.83	0.78
Tragopogon dubius Scop.	P	0.00	0.00
Viola adunca Sm.	0.00	0.60	P
Viola nuttallii Pursh	0.15	0.05	0.00
<u>Graminoids</u>			
Agrostis scabra Willd.	0.00	0.00	0.23
Agropyron caninum (L.) Beauv.	0.00	0.00	1.65
Bromus carinatus H. & A.	0.00	0.00	0.18
Calamagrostis rubescens Buckl.	16.58	6.93	0.75
Carex geyeri Boott	3.13	P	0.00
Carex hoodii Boott	0.00	0.00	9.05
Carex rossii Boott	9.53	1.50	4.43
Danthonia intermedia Vasey	0.00	0.00	0.03
Elymus glaucus Buckl.	0.00	P	0.00
Phleum pratense L.	0.00	0.00	P
Poa compressa L.	0.00	2.00	0.00
Poa nervosa (Hook.) Vasey	0.18	P	13.70
Sitanion hystrix (Nutt.) Smith	0.00	0.00	1.80
Stipa occidentalis Thurb.	0.00	0.00	1.10
Stipa nelsonii Scribn.	P	0.00	1.98
Trisetum spicatum (L.) Richter	0.00	0.00	0.03
<u>Non-vascular plants</u>			
Mosses	0.00	0.00	0.45
Litter	4.65	1.08	11.83
Woody Debris > 3" Diameter	0.00	5.15	7.05
Bare Ground	42.53	36.45	22.53
Total	97.90	63.55	95.00

Table 32. Species presence and cover in three stands in the *Abies lasiocarpa/Calamagrostis rubescens* habitat type, LP2 pre-fire cover type. Numeric values give mean percent cover in twenty 20 cm. by 50 cm. quadrats. P indicates presence of species not found in quadrats but appearing in the 4 m. by 25 m. macroplot.

Species	Transcect H1	H2	H3
<u>Trees</u>			
Pinus contorta Dougl.	0.00	0.33	0.00
<u>Shrubs</u>			
Artemisia tridentata Nutt.	P	0.00	0.00
<u>Forbs</u>			
Achillea millefolium L.	P	0.71	2.40
Agoseris aurantiaca (Hook.) Greene	0.00	0.00	1.50
Agoseris glauca (Pursh) Raf.	1.55	0.03	P
Antennaria microphylla Rydb.	P	P	0.00
Arabis drummondii Gray	0.00	0.00	P
Arabis glabra (L.) Bernh.	P	0.48	P
Arabis holboellii Hornem.	0.20	P	P
Arenaria congesta Nutt.	0.15	0.00	0.00
Arnica cordifolia Hook.	P	0.00	0.00
Aster conspicuus Lindl.	12.83	0.00	0.00
Astragalus miser Dougl.	0.40	0.05	0.00
Campanula rotundifolia L.	0.00	P	0.00
Capsella bursa-pastoris (L.) Crantz	0.00	0.00	P
Cerastium arvense L.	0.00	P	0.00
Cerastium fontanum Baumg.	0.00	0.00	P
Chenopodium fremontii Wats.	0.00	0.00	0.18
Cirsium arvense (L.) Scop.	0.00	0.15	0.00
Cirsium vulgare (Savi) Tenore	0.00	0.00	P
Cirsium spp. Mill.	P	0.00	0.00
Collinsia parviflora Lindl.	0.43	0.28	0.03
Collomia linearis Nutt.	0.03	0.35	0.68
Crepis atrabarba Heller	0.00	P	0.00
Descurainia richardsonii (Sweet) Schulz	0.00	0.00	P
Epilobium angustifolium L.	P	32.30	1.50
Epilobium paniculatum Nutt.	0.00	0.00	0.70
Erigeron compositus Pursh	0.03	0.00	0.00
Eriophyllum lanatum (Pursh) Forbes	P	0.00	0.00
Fragaria virginiana Duchesne	P	P	1.65
Gayophytum diffusum T. & G.	0.03	0.00	0.00
Hieracium albiflorum Hook.	0.00	0.03	0.00
Lupinus spp. L.	0.15	P	0.00
Penstemon procerus Dougl.	0.00	P	0.00
Polygonum douglasii Greene	0.00	P	2.80
Potentilla glandulosa Lindl.	P	P	0.00

Table 32--Continued.

Rumex acetosella L.	0.00	0.00	P
Silene oregana Wats.	0.00	0.00	P
Solidago multiradiata Ait.	0.00	0.00	1.65
Solidago spp. L.	4.95	0.00	0.00
Taraxacum officinale Weber	0.15	1.93	0.50
Thlaspi arvense L.	0.00	0.00	P
Viola nuttallii Pursh	0.00	0.00	2.00
Graminoids			
Agrostis scabra Willd.	P	0.00	0.00
Agropyron caninum (L.) Beauv.	0.00	0.03	P
Bromus carinatus H. & A.	0.00	0.00	2.95
Calamagrostis rubescens Buckl.	P	11.95	2.70
Carex geyeri Boott	P	0.00	0.00
Carex rossii Boott	15.90	0.00	P
Danthonia intermedia Vasey	0.03	0.00	0.00
Elymus glaucus Buckl.	P	0.00	11.08
Hordeum brachyantherum Nevski	0.00	0.00	P
Melica bulbosa Geyer	0.00	0.00	P
Oryzopsis exigua Thurb.	0.75	0.00	0.00
Poa nervosa (Hook.) Vasey	0.15	P	18.25
Sitanion hystrix (Nutt.) Smith	1.10	0.00	0.00
Stipa nelsonii Scribn.	0.00	P	0.38
Trisetum spicatum (L.) Richter	0.00	0.00	P
Non-vascular plants			
Mosses	0.18	7.95	0.60
Litter	1.65	7.05	4.68
Woody Debris > 3" Diameter	0.75	6.73	1.50
Bare Ground	39.13	4.05	19.90
Total	80.50	74.36	77.60

Table 33. Species presence and cover in three stands in the *Abies lasiocarpa/Calamagrostis rubescens* habitat type, LP3 pre-fire cover type. Numeric values give mean percent cover in twenty 20 cm. by 50 cm. quadrats. P indicates presence of species not found in quadrats but appearing in the 4 m. by 25 m. macroplot.

Species	Transect I1	Transect I2	Transect I3
<u>Trees</u>			
Pinus contorta Dougl.	0.90	0.00	0.00
<u>Shrubs</u>			
Vaccinium scoparium Leiberg	0.00	0.00	P
<u>Forbs</u>			
Achillea millefolium L.	2.73	7.25	P
Agoseris glauca (Pursh) Raf.	6.23	1.45	0.00
Androsace septentrionalis L.	0.00	P	0.00
Antennaria microphylla Rydb.	0.75	0.15	P
Antennaria racemosa Hook.	0.00	P	0.00
Arabis drummondii Gray	0.00	0.18	0.00
Arenaria congesta Nutt.	0.18	1.38	0.00
Arnica cordifolia Hook.	0.00	0.30	P
Aster adscendens Lindl.	0.00	0.00	P
Aster foliaceus Lindl.	0.00	2.40	0.00
Aster integrifolius Nutt.	0.00	0.00	0.75
Astragalus miser Dougl.	0.78	2.13	0.00
Campanula rotundifolia L.	P	P	0.00
Capsella bursa-pastoris (L.) Crantz	0.00	0.00	0.15
Cerastium arvense L.	0.00	0.15	0.00
Cerastium fontanum Baumg.	0.00	0.00	1.05
Cirsium arvense (L.) Scop.	0.00	0.00	P
Cirsium scariosum Nutt.	0.00	P	0.00
Collinsia parviflora Lindl.	0.00	0.20	0.78
Collomia linearis Nutt.	0.03	0.05	3.45
Draba nemorosa L.	0.18	0.00	0.00
Draba stenoloba Ledeb.	0.00	P	0.00
Epilobium angustifolium L.	1.65	P	3.90
Epilobium glaberrimum Barbey	P	0.00	6.30
Epilobium paniculatum Nutt.	0.00	0.00	3.60
Fragaria virginiana Duchesne	15.80	21.50	3.68
Frasera speciosa Dougl.	P	0.00	0.00
Gayophytum racemosum T. & G.	P	0.00	0.00
Gentianella amarella L. (Borner)	0.75	0.00	0.00
Geranium viscosissimum F. & M.	0.00	0.75	0.00
Gnaphalium spp. L.	0.00	0.00	0.15
Hieracium gracile Hook.	P	0.00	0.00
Lupinus spp. L.	0.30	P	0.00
Penstemon procerus Dougl.	1.50	0.75	0.00
Phacelia franklinii (R. Br.) Gray	0.00	P	0.00

Table 33--Continued.

Phlox longifolia Nutt.	0.00	0.60	0.00
Polygonum douglasii Greene	0.00	0.00	1.05
Potentilla glandulosa Lindl.	0.75	0.00	0.00
Potentilla gracilis Dougl.	0.75	0.00	0.00
Rorippa islandica (Oed.) Borbas	0.00	0.00	P
Senecio canus Hook.	0.00	0.00	P
Senecio serra Hook.	0.00	0.00	P
Solidago multiradiata Ait.	1.65	0.00	0.00
Stellaria longipes Goldie var.altocaulis	0.18	0.00	0.00
Taraxacum officinale Weber	1.35	P	2.28
Viola adunca Sm.	1.98	0.00	0.00
Viola nuttallii Pursh	0.00	0.15	P
Graminoids			
Agrostis scabra Willd.	5.40	0.00	0.00
Agropyron caninum (L.) Beauv.	9.75	4.75	0.00
Bromus carinatus H. & A.	0.00	1.08	0.00
Calamagrostis canadensis (Michx.) Beauv.	6.25	0.00	0.00
Calamagrostis rubescens Buckl.	2.03	2.43	3.88
Carex praticola Rydb.	P	0.00	0.00
Carex raynoldsii Dewey	P	0.00	0.00
Carex rossii Boott	0.15	1.65	3.38
Danthonia intermedia Vasey	0.90	2.28	0.00
Danthonia spicata (L.) Beauv.	0.00	0.00	0.00
Deschampsia cespitosa (L.) Beauv.	P	0.00	0.00
Elymus glaucus Buckl.	0.00	0.00	1.88
Festuca idahoensis Elmer	0.15	3.33	0.00
Phleum alpinum L.	P	0.00	0.00
Phleum pratense L.	0.00	0.00	1.90
Poa fendleriana (Steud.) Vasey	0.00	0.03	0.00
Poa nervosa (Hook.) Vasey	14.93	6.88	0.90
Poa scabrella (Thurb.) Benth.	0.00	0.00	0.90
Sitanion hystrix (Nutt.) Smith	P	0.00	0.00
Stipa nelsonii Scribn.	P	4.28	0.00
Trisetum spicatum (L.) Richter	9.30	0.48	1.65
Non-vascular plants			
Mosses	0.00	0.15	1.98
Litter	9.98	7.93	13.00
Woody Debris > 3" Diameter	1.50	0.75	0.75
Bare Ground	4.43	1.95	51.13
Total	103.15	77.30	108.45

Table 34. Species presence and cover in three stands of the *Festuca idahoensis/Agropyron caninum* habitat type. Numeric values give mean percent cover in twenty 20 cm. by 50 cm. quadrats. P indicates presence of species not found in quadrats but appearing in the 4 m. by 25 m. macroplot.

Species	Transect		
	J1	J2	J3
<u>Shrubs</u>			
Artemisia cana Pursh	0.00	P	0.00
Artemisia frigida Willd.	0.00	P	0.00
Chrysothamnus viscidiflorus (Hook.) Nutt	0.00	6.28	0.00
Symphoricarpos albus (L.) Blake	0.00	P	0.00
<u>Forbs</u>			
Achillea millefolium L.	1.05	0.78	2.73
Agoseris glauca (Pursh) Raf.	3.93	3.03	0.15
Allium cernuum Roth	0.00	0.00	0.00
Androsace septentrionalis L.	0.03	0.00	0.00
Anemone spp. L.	0.03	0.00	P
Antennaria microphylla Rydb.	1.98	0.00	P
Arabis drummondii Gray	0.00	P	0.00
Arabis glabra (L.) Bernh.	0.00	0.00	0.15
Arabis holboellii Hornem.	P	0.45	0.00
Arenaria congesta Nutt.	0.18	0.00	0.00
Aster occidentalis (Nutt.) T. & G.	0.00	0.00	6.90
Astragalus adsurgens Hook.	0.00	P	0.00
Astragalus agrestis Dougl.	0.00	0.60	P
Astragalus miser Dougl.	0.15	1.05	0.00
Astragalus purshii Dougl.	0.00	P	0.00
Astragalus vexilliflexis Sheld.	0.00	0.00	P
Besseya wyomingensis (A. Nels.) Rydb.	2.13	0.00	0.00
Camelina microcarpa Andrz.	0.00	0.03	0.00
Campanula rotundifolia L.	0.00	0.00	P
Castilleja pallescens (Gray) Greenm.	0.15	0.00	0.00
Cerastium arvense L.	1.35	9.03	0.30
Chenopodium fremontii Wats.	0.00	P	0.00
Cirsium scariosum Nutt.	0.00	0.00	P
Collomia linearis Nutt.	2.70	P	0.00
Descurainia richardsonii (Sweet) Schulz	0.18	0.00	0.00
Draba nemorosa L.	0.48	0.05	0.00
Delphenium nuttallianum Pritzl	1.53	0.00	0.00
Epilobium paniculatum Nutt.	0.00	P	0.00
Erigeron gracilis Rydb.	0.00	1.20	0.03
Erigeron speciosus (Lindl.) DC.	0.75	0.00	0.00
Eriogonum umbellatum Torr.	3.85	1.50	0.15
Erysimum cheiranthoides L.	0.00	0.00	P
Erythronium grandiflorum Pursh	0.03	0.00	0.00
Gayophytum diffusum T. & G.	0.00	0.00	0.00
Geum triflorum Pursh	16.20	0.00	0.00
Linum perennne L. var. lewisii (Pursh)	0.00	0.90	1.53

Table 34--Continued.

Lomatium cous (Wats.) Coult. & Rose	0.03	0.00	0.00
Lupinus spp. L.	0.00	4.80	4.35
Myosotis sylvatica Hoffm.	0.35	0.00	0.00
Oxytropis deflexa (Pall.) DC.	0.00	0.00	0.15
Penstemon procerus Dougl.	0.00	0.00	0.60
Phlox hoodii Rich.	0.00	P	0.00
Phlox longifolia Nutt.	5.88	0.00	0.00
Polygonum bistortoides Pursh	0.80	0.00	0.00
Polygonum douglasii Greene	0.00	0.45	0.00
Potentilla diversifolia Lehm.	2.43	0.00	0.00
Potentilla gracilis Dougl.	0.00	0.00	1.05
Saxifraga rhomboidea Greene	1.08	0.00	0.00
Senecio integerrimus Nutt.	1.68	0.00	0.00
Senecio serra Hook.	0.00	0.00	P
Silene oregana Wats.	0.00	0.15	0.00
Solidago missouriensis Nutt.	0.00	0.00	0.15
Taraxacum laevigatum (Willd.) DC.	0.15	0.00	0.00
Taraxacum officinale Weber	0.00	2.70	6.90
Thlaspi arvense L.	2.10	P	P
Tragopogon dubius Scop.	0.00	3.45	0.00
Trifolium hybridum L.	0.00	0.00	0.30
Viola adunca Sm.	0.00	0.00	0.15
<u>Graminoids</u>			
Agropyron caninum (L.) Beauv.	7.33	0.00	15.20
Agropyron spicatum (Pursh)	0.15	4.20	0.00
Bromus carinatus Hooker & Arnott	0.00	0.00	0.75
Calamagrostis rubescens Buckl.	2.13	0.00	0.00
Carex praticola Rydb.	0.30	0.00	0.00
Carex spp. L.	P	0.00	0.00
Danthonia intermedia Vasey	0.00	0.00	0.00
Danthonia spicata (L.) Beauv.	0.00	0.00	P
Festuca idahoensis Elmer	16.88	13.55	17.55
Koelaria cristata Pers.	0.00	2.55	1.35
Phleum pratense L.	0.00	1.50	8.40
Poa cusickii Vasey	0.30	0.00	0.00
Poa juncifolia Scribn.	0.90	26.25	19.65
Poa nervosa (Hook.) Vasey	0.00	0.00	0.00
Stipa lemmonii (Vasey) Scribn.	0.00	0.00	P
Stipa nelsonii Scribn.	0.00	0.15	1.20
Stipa richardsonii Link	0.00	0.00	2.25
Litter	4.48	4.05	0.15
Bare Ground	13.18	15.18	6.00
Total	96.75	103.85	98.08

Table 35. Species presence and cover in three stands in the *Abies lasiocarpa/Vaccinium scoparium* habitat type, LP0 pre-fire cover type. Numeric values give mean percent cover in twenty 20 cm. X 50 cm. quadrats. P indicates presence of species not found in quadrats but appearing in the 4 m. X 25 m. macroplot.

Species	Transect		
	K1	K2	K3
<u>Trees</u>			
Pinus contorta Dougl.	0.75	0.90	0.15
Populus tremuloides Michx.	0.00	0.00	P
<u>Shrubs</u>			
Vaccinium scoparium Leiberg	P	8.93	P
<u>Forbs</u>			
Achillea millefolium L.	0.00	0.00	P
Agoseris aurantiaca (Hook.) Greene	0.00	0.00	P
Antennaria microphylla Rydb.	P	P	0.15
Arabis glabra (L.) Bernh.	0.00	0.00	0.30
Arabis holboellii Hornem.	0.00	P	P
Arnica cordifolia Hook.	0.00	0.00	P
Aster integrifolius Nutt.	0.00	0.00	P
Cirsium vulgare (Savi) Tenore	0.45	0.00	0.00
Collinsia parviflora Lindl.	0.35	P	0.03
Collomia linearis Nutt.	0.05	0.00	0.00
Descurainia richardsonii (Sweet) Schulz	P	0.00	0.00
Draba nemorosa L.	P	P	0.00
Epilobium angustifolium L.	2.13	3.48	7.80
Epilobium glaberrimum Barbey	0.10	P	0.00
Epilobium paniculatum Nutt.	0.93	0.00	0.00
Fragaria virginiana Duchesne	0.20	0.00	0.15
Gayophytum diffusum T. & G.	0.00	1.25	2.80
Lupinus sericeus Pursh	0.00	0.15	2.73
Penstemon procerus Dougl.	0.00	0.00	P
Senecio crassulus Gray	0.00	P	0.00
Senecio serra Hook.	P	0.00	0.00
Spergularia rubra (L.) Presl.	0.00	0.00	0.03
Taraxacum officinale Weber	2.93	0.18	0.03
Tragopogon dubius Scop.	P	0.00	0.00
<u>Graminoids</u>			
Agrostis scabra Willd.	1.98	P	0.55
Bromus carinatus H. & A.	0.15	0.00	0.00
Carex rossii Boott	1.50	16.63	0.78
Poa nervosa (Hook.) Vasey	P	1.50	P
Sitanion hystrix (Nutt.) Smith	P	0.00	0.00
Trisetum spicatum (L.) Richter	0.98	3.48	2.58

Table 35--Continued.

<u>Non-vascular plants</u>			
Mosses	1.45	6.30	9.63
Litter	0.98	9.98	3.10
Woody Debris > 3" Diameter	4.80	5.03	6.00
Bare Ground	67.13	40.18	46.03
Total	86.85	98.85	82.80

Table 36. Species presence and cover in three stands in the *Abies lasiocarpa/Vaccinium scoparium* habitat type, LP1 pre-fire cover type. Numeric values give mean percent cover in twenty 20 cm. by 50 cm. quadrats. P indicates presence of species not found in quadrats but appearing in the 4 m. by 25 m. macroplot.

Species	Transect		
	L1	L2	L3
Trees			
Pinus contorta Dougl.	0.00	5.05	3.38
Populus tremuloides Michx.	0.00	0.00	P
Shrubs			
Spiraea betulifolia Pall.	7.30	0.00	0.00
Vaccinium globulare Rydb.	1.50	0.00	0.00
Vaccinium scoparium Leiberg	14.53	P	9.83
Forbs			
Achillea millefolium L.	P	P	0.00
Agoseris aurantiaca (Hook.) Greene	0.00	0.00	P
Antennaria microphylla Rydb.	1.50	P	P
Antennaria racemosa Hook.	0.00	P	0.30
Arabis drummondii Gray	0.00	P	0.00
Arabis glabra (L.) Bernh.	0.15	0.00	0.00
Arabis holboellii Hornem.	0.30	0.00	0.00
Arnica cordifolia Hook.	4.83	P	0.35
Arnica latifolia Bong.	P	0.00	0.00
Arnica parryi Gray	P	0.00	0.00
Aster meritus A. Nels.	11.65	0.00	0.00
Campanula rotundifolia L.	0.00	0.00	P
Cerastium arvense L.	0.00	0.00	P
Cirsium arvense (L.) Scop.	0.00	0.00	P
Cirsium scariosum Nutt.	0.00	P	0.00
Cirsium vulgare (Savi) Tenore	0.00	0.16	0.00
Collinsia parviflora Lindl.	P	1.47	0.00
Epilobium anagallidifolium Lam.	0.00	2.25	0.00
Epilobium angustifolium L.	1.50	1.76	4.83
Epilobium glaberrimum Barbey	P	0.00	1.73
Epilobium paniculatum Nutt.	0.00	0.08	0.00
Fragaria vesca L.	0.00	0.00	P
Fragaria virginiana Duchesne	0.93	P	0.03
Gayophytum racemosum T. & G.	0.00	0.00	P
Geranium viscosissimum F. & M.	0.15	0.00	0.00
Gnaphalium spp. L.	0.00	P	0.00
Hieracium albiflorum Hook.	1.05	0.24	1.95
Hieracium cynoglossoides Arv.-Touv.	0.00	0.00	0.75
Hieracium gracile Hook.	0.00	0.00	0.45
Lappula redowskii (Hoernem.) Greene	0.00	P	0.00
Lupinus spp. L.	5.55	P	0.00
Penstemon fruticosus (Pursh) Greene	P	0.00	0.00

Table 36--Continued.

Perideridia gairdneri (H. & A.) Math.	P	0.00	0.00
Rumex acetosella L.	0.00	P	0.00
Sedum lanceolatum Torr.	P	0.00	0.00
Senecio serra Hook.	0.00	0.16	0.00
Solidago multiradiata Ait.	P	P	0.00
Taraxacum laevigatum (Willd.) DC.	0.00	0.00	1.05
Taraxacum officinale Weber	0.75	0.24	2.58
<u>Graminoids</u>			
Agrostis scabra Willd.	0.00	0.00	P
Calamagrostis rubescens Buckl.	0.00	0.00	0.15
Carex geyeri Boott	0.00	P	1.65
Carex hoodii Boott	0.00	0.00	P
Carex rossii Boott	14.10	11.32	13.93
Deschampsia elongata (Hook.) Munro	0.00	7.37	0.00
Elymus glaucus Buckl.	0.15	8.00	0.00
Festuca idahoensis Elmer	0.00	0.00	0.75
Phleum alpinum L.	P	P	0.00
Phleum pratense L.	0.15	0.00	0.00
Poa nervosa (Hook.) Vasey	0.78	P	P
Sitanion hystrix (Nutt.) Smith	P	0.00	0.00
Stipa nelsonii Scribn.	P	0.00	0.00
Trisetum spicatum (L.) Richter	5.28	P	1.35
<u>Non-vascular plants</u>			
Mosses	0.00	4.32	13.73
Litter	5.70	9.11	11.40
Woody Debris > 3" Diameter	0.75	4.13	0.75
Bare Ground	26.88	27.40	19.03
Total	105.50	83.12	89.93

Table 37. Species presence and cover in three stands in the *Abies lasiocarpa/Vaccinium scoparium* habitat type, LP2 pre-fire cover type. Numeric values give mean percent cover in twenty 20 cm. by 50 cm. quadrats. P indicates presence of species not found in quadrats but appearing in the 4 m. by 25 m. macroplot.

Species	Transect M1	M2	M3
Trees			
Pinus contorta Dougl.	3.60	0.15	0.00
Populus tremuloides Michx.	0.03	0.00	0.00
Shrubs			
Vaccinium globulare Rydb.	0.00	0.00	P
Vaccinium scoparium Leiberg	3.50	0.20	7.58
Forbs			
Achillea millefolium L.	0.00	P	0.00
Agoseris glauca (Pursh) Raf.	0.00	0.03	0.00
Arabis glabra (L.) Bernh.	0.00	0.03	0.00
Arnica cordifolia Hook.	0.93	0.00	0.00
Aster integrifolius Nutt.	P	P	0.00
Cirsium arvense (L.) Scop.	0.75	0.00	0.00
Epilobium angustifolium L.	9.93	12.03	0.75
Epilobium glaberrimum Barbey	P	0.00	0.00
Gayophytum racemosum T. & G.	0.15	0.00	0.00
Hieracium cynoglossoides Arv.-Touv.	P	P	P
Lupinus spp. L.	0.00	2.03	0.00
Taraxacum officinale Weber	P	0.75	P
Tragopogon dubius Scop.	P	0.00	0.00
Graminoids			
Agrostis scabra Willd.	P	0.00	0.00
Carex geyeri Boott	0.00	0.15	9.25
Carex rossii Boott	10.70	4.20	2.88
Festuca idahoensis Elmer	P	0.00	0.00
Oryzopsis exigua Thurb.	0.00	0.00	0.15
Stipa nelsonii Scribn.	0.00	0.00	P
Trisetum spicatum (L.) Richter	P	0.00	P
Non-vascular plants			
Marchantia spp.	7.45	0.00	0.00
Mosses	8.93	9.55	0.93
Litter	29.23	34.88	23.60
Woody Debris > 3" Diameter	3.38	9.53	9.40
Bare Ground	26.53	27.40	46.65
Total	105.10	100.90	101.18

Table 38. Species presence and cover in three stands in the *Abies lasiocarpa/Vaccinium scoparium* habitat type, LP3 pre-fire cover type. Numeric values give mean percent cover in twenty 20 cm. by 50 cm. quadrats. P indicates presence of species not found in quadrats but appearing in the 4 m. by 25 m. macroplot.

Species	Transect		
	N1	N2	N3
<u>Trees</u>			
Abies lasiocarpa (Hook.) Nutt.	0.00	P	0.00
Picea engelmannii Parry ex. Engelm.	0.00	P	0.00
Pinus contorta Dougl.	0.00	0.15	P
<u>Shrubs</u>			
Ribes lacustre (Pers.) Poir.	0.00	0.00	P
Vaccinium membranaceum Dougl.	0.00	0.00	0.15
Vaccinium scoparium Leiberg	4.73	1.05	15.48
<u>Forbs</u>			
Achillea millefolium L.	0.00	P	P
Antennaria microphylla Rydb.	0.00	P	0.00
Antennaria racemosa Hook.	0.00	0.00	0.75
Aquilegia flavescens Wats.	0.00	0.00	P
Arnica cordifolia Hook.	6.75	0.15	4.20
Aster integrifolius Nutt.	0.00	0.90	0.00
Cirsium arvense (L.) Scop.	P	0.00	0.00
Collinsia parviflora Lindl.	0.00	P	0.00
Collomia linearis Nutt.	0.00	P	0.00
Draba stenoloba Ledeb.	0.00	P	0.00
Epilobium angustifolium L.	3.75	16.58	12.03
Epilobium glaberrimum Barbey	0.00	0.03	0.18
Fragaria vesca L.	0.00	P	0.00
Fragaria virginiana Duchesne	P	P	0.00
Gayophytum diffusum T. & G.	P	0.00	0.00
Gayophytum racemosum T. & G.	0.00	P	0.00
Gnaphalium vicosum H. B. K.	P	0.00	P
Hieracium albiflorum Hook.	P	0.00	P
Lupinus spp. L.	P	2.60	0.00
Osmorhiza depauperata Phil.	0.00	0.00	P
Solidago multiradiata Ait.	1.88	0.00	0.00
Taraxacum officinale Weber	P	0.90	0.15
Tragopogon dubius Scop.	P	0.00	0.00
<u>Graminoids</u>			
Agrostis scabra Willd.	0.00	0.90	0.00
Calamagrostis canadensis (Michx.) Beauv.	0.00	P	0.00
Carex geyeri Boott	24.38	10.90	0.00
Carex praticola Rydb.	P	0.00	0.78
Carex rossii Boott	4.20	4.50	0.75
Elymus glaucus Buckl.	P	0.00	P

Table 38--Continued.

Muhlenbergia racemosa (Michx.) B.S.P.	0.00	0.00	4.28
Poa nervosa (Hook.) Vasey	0.00	P	0.00
Stipa nelsonii Scribn.	P	0.00	0.00
Trisetum spicatum (L.) Richter	0.15	0.16	0.15
<u>Non-vascular plants</u>			
Marchantia spp.	0.00	0.00	0.90
Mosses	0.30	18.63	11.70
Litter	19.20	28.05	44.53
Woody Debris> 3" Diameter	0.00	3.75	3.00
Bare Ground	39.78	5.55	3.83
Total	105.10	94.78	102.83

Table 39. Species presence and cover in three stands in the *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* habitat type, WB2 pre-fire cover type. Numeric values give mean percent cover in twenty 20 cm. by 50 cm. quadrats.
P indicates presence of species not found in quadrats but appearing in the 4 m. by 25 m. macroplot.

Species	Transect 01	02	03
Shrubs			
Vaccinium scoparium Leiberg	0.00	P	1.50
Forbs			
Achillea millefolium L.	1.00	0.48	1.25
Agoseris glauca (Pursh) Raf.	P	3.90	P
Androsace septentrionalis L.	0.00	0.00	0.15
Antennaria microphylla Rydb.	P	P	0.00
Arabis drummondii Gray	0.00	0.00	P
Arabis glabra (L.) Bernh.	0.00	P	0.00
Arabis holboellii Hornem.	P	0.00	0.00
Arnica cordifolia Hook.	1.60	2.13	0.75
Arnica parryi Gray	0.00	P	0.00
Aster foliaceus Lindl.	0.00	3.88	0.00
Astragalus miser Dougl.	P	0.00	0.00
Cerastium arvense L.	P	0.00	0.00
Chenopodium fremontii Wats.	0.00	0.00	0.30
Collinsia parviflora Lindl.	P	0.00	0.35
Descurainia richardsonii (Sweet) Schulz	P	P	0.15
Epilobium angustifolium L.	63.63	16.58	48.88
Erythronium grandiflorum Pursh	0.00	P	0.00
Frasera speciosa Dougl.	0.00	P	0.00
Gayophytum racemosum T. & G.	0.00	0.00	P
Gentiana amarella L.	0.00	P	0.00
Hieracium cynoglossoides Arv.-Touv.	0.00	0.15	0.00
Hieracium gracile Hook.	0.00	P	0.00
Lepidium virginicum L. var. pubescens	0.00	0.00	0.30
Lupinus argenteus Pursh	0.00	P	P
Lupinus lepidus Dougl.	0.00	0.48	0.00
Phacelia sericea (Grah.) Gray	P	0.00	0.00
Polemonium pulcherrimum Hook.	P	0.00	0.78
Polygonum douglasii Greene	0.00	0.00	0.20
Potentilla diversifolia Lehm.	0.00	P	0.00
Rumex paucifolius Nutt.	0.00	0.00	P
Senecio crassulus Gray	0.00	P	0.00
Sibbaldia procumbens L.	0.00	0.90	0.00
Solidago multiradiata Ait.	0.00	0.15	0.00
Taraxacum officinale Weber	0.00	P	P
Thalictrum occidentale Gray	0.00	0.00	0.00
Veronica wormskjoldii Roem. & Schult.	0.00	P	0.00
Viola nuttallii Pursh	0.00	0.00	P

Table 39--Continued.

<u>Graminoids</u>			
Agrostis scabra Willd.	P	0.15	0.00
Agropyron caninum (L.) Beauv.	0.15	0.00	0.15
Bromus inermis Leys.	0.00	0.00	P
Calamagrostis rubescens Buckl.	P	0.00	0.00
Carex hoodii Boott	0.00	P	0.00
Carex rossii Boott	P	17.58	P
Elymus glaucus Buckl.	P	0.75	0.00
Festuca idahoensis Elmer	0.00	0.00	P
Poa nervosa (Hook.) Vasey	P	P	1.25
Poa scabrella (Thurb.) Benth.	0.33	P	0.30
Sitanion hystrix (Nutt.) Smith	0.00	0.15	0.00
Stipa occidentalis var. nelsonii	0.00	P	0.00
Trisetum spicatum (L.) Richter	P	2.63	1.50
<u>Non-Vascular Plants</u>			
Mosses	0.00	12.25	0.00
Litter	P	17.65	11.10
Woody Debris > 3" Diameter	0.75	0.75	2.25
Bare Ground	31.75	26.45	35.93
Total	99.20	106.98	107.08

Table 40. Species presence and cover in three stands in the *Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* habitat type, WB3 pre-fire cover type. Numeric values give mean percent cover in twenty 20 cm. by 50 cm. quadrats.
P indicates presence of species not found in quadrats but appearing in the 4 m. by 25 m. macroplot.

Species	Transect		
	P1	P2	P3
<u>Shrubs</u>			
Vaccinium globulare Rydb.	0.00	P	0.00
Vaccinium scoparium Leiberg	6.68	P	0.90
<u>Forbs</u>			
Achillea millefolium L.	0.90	P	0.83
Agoseris glauca (Pursh) Raf.	0.15	0.00	0.00
Antennaria microphylla Rydb.	0.00	0.00	P
Arabis drummondii Gray	0.00	0.00	P
Arabis glabra (L.) Bernh.	0.75	0.00	0.00
Arabis lemonii	0.00	0.00	P
Arabis lyallii	0.00	P	0.00
Arnica cordifolia Hook.	0.15	17.55	0.00
Astragalus alpinus L.	0.00	P	0.00
Aster foliaceus Lindl.	P	0.00	0.00
Collinsia parviflora Lindl.	1.25	0.00	0.58
Descurainia richardsonii (Sweet) Schulz	0.00	P	0.00
Draba stenoloba Ledeb.	0.00	0.00	P
Epilobium angustifolium L.	21.40	21.85	25.30
Epilobium glaberrimum Barbey	P	0.15	1.55
Epilobium paniculatum Nutt.	P	0.00	0.00
Hieracium albiflorum Hook.	0.00	P	P
Hieracium gracile Hook.	1.88	0.00	0.00
Lupinus argenteus Pursh	P	0.00	0.00
Nemophila breviflora Gray	0.00	0.18	0.00
Polygonum douglasii Greene	0.15	0.00	0.20
Sedum lanceolatum Torr.	0.15	0.00	0.00
Senecio serra Hook.	0.00	P	0.15
Taraxacum officinale Weber	0.75	0.93	0.15
Tragopogon dubius Scop.	P	0.00	0.00
<u>Graminoids</u>			
Agrostis scabra Willd.	0.00	0.00	0.20
Agropyron caninum (L.) Beauv.	0.00	P	0.03
Calamagrostis canadensis (Michx.) Beauv.	0.00	P	0.00
Carex rossii Boott	2.95	0.75	7.48
Poa interior Rydb.	0.00	0.00	P
Poa nervosa (Hook.) Vasey	P	0.00	0.00
Poa scabrella (Thurb.) Benth.	0.00	P	0.05
Sitanion hystrix (Nutt.) Smith	P	0.00	0.00
Trisetum spicatum (L.) Richter	0.18	P	2.25

Table 40--Continued.

Species	Transect P1	P2	P3
<u>Non-vascular plants</u>			
Mosses	4.45	6.23	4.50
Litter	8.48	3.80	1.40
Woody Debris > 3" Diameter	1.50	1.88	1.88
Bare Ground	48.28	42.88	48.50
Total	100.03	96.18	95.95

APPENDIX D

MATHCAD PLUS (v. 5.0) COMPUTER PROGRAMS:

PRINCIPAL COMPONENT ANALYSIS

PRINCIPAL COORDINATE ANALYSIS

MONTE CARLO RANDOMIZATION

Program written in MATHCAD PLUS (v. 5.0) for Principle Component Analysis.

$A := \mathrm{READPRN}(data)$

$B := \mathrm{READPRN}(data)$

$C := \mathrm{augment}(A, B)$

$i := 0..\mathrm{rows}(C) - 1 \quad j := 0..\mathrm{cols}(C) - 1$

$$cmean_j := \frac{1}{\mathrm{rows}(C)} \cdot \sum C^{<j>}$$

$$CC_{i,j} := C_{i,j} - cmean_j$$

$$CSUM := CC^T \cdot CC$$

$$CCOV := \frac{1}{\mathrm{rows}(C)} \cdot CSUM$$

$$V(x) := \mathrm{var}(x) \cdot \frac{\mathrm{length}(x)}{\mathrm{length}(x) - 1}$$

$$CVAR_j := V\left(C^{<j>}\right)$$

$$CVAR^T =$$

$$CSTD_{i,j} := \frac{CC_{i,j}}{\sqrt{V\left(C^{<j>}\right)}}$$

$$CCOR := \frac{CSTD^T \cdot CSTD}{\mathrm{rows}(C) - 1}$$

$$\lambda orig := \mathrm{eigenvals}(CCOR)$$

$$\lambda orig^T =$$

$$\lambda := \mathrm{reverse}(\mathrm{sort}(\mathrm{eigenvals}(CCOR)))$$

$$E^{<j>} := \mathrm{eigenvec}\left(CCOR, \lambda_j\right)$$

$$lngth_j := \sqrt{\sum \overrightarrow{\left(E^{<j>}\right)^2}}$$

$$scores := CSTD \cdot E$$

Principle Component Analysis Program--Continued.

$$vscores_j := V\left(scores^{\langle j\rangle}\right)$$

$$prop\lambda := \frac{\lambda}{\sum\lambda}$$

$$cumprop\lambda_j := \frac{\sum_{k=0}^{j} \lambda_k}{\sum\lambda}$$

Program written in MATHCAD PLUS (v. 5.0) for Principle Coordinate Analysis.

$A := \mathrm{READPRN}(data)$

$B := \mathrm{READPRN}(data)$

$C := \mathrm{augment}(A,B)^T$

$$V(x) := \mathrm{var}(x)\cdot\frac{\mathrm{length}(x)}{\mathrm{length}(x)-1}$$

$i := 0..\mathrm{rows}(C)-1 \quad r := 0..\mathrm{rows}(C)-1 \quad p := 0..\mathrm{cols}(C)-1$

$j := 0..\mathrm{cols}(C)-1 \quad s := 0..\mathrm{rows}(C)-1 \quad k := 0..\mathrm{cols}(C)-1$

$$d(x,r,s) := \sqrt{\sum_{k=0}^{48}\left(C_{r,k}-C_{s,k}\right)^2}$$

$D_{i,j} := d(C,i,j)$

$$F(x) := \left(-\frac{1}{2}\right)\cdot\overrightarrow{\left(x^2\right)}$$

$$G_{r,s} := F_{r,s} - \underbrace{\left(\frac{1}{n}\cdot\sum_{k=0}^{n-1}F_{r,k}\right)}_{\text{row mean}} - \underbrace{\left(\frac{1}{n}\cdot\sum_{k=0}^{n-1}F_{k,s}\right)}_{\text{column mean}} + \underbrace{\left(\frac{1}{n^2}\cdot\sum_{k=0}^{n-1}\sum_{h=0}^{n-1}F_{k,h}\right)}_{\text{grand mean}}$$

$I(x) \equiv \mathrm{identity}(\mathrm{rows}(x))$

$$H(x) := I(x) - \frac{1}{\mathrm{rows}(x)}$$

$G(x) := H(x)\cdot F(x)\cdot H(x)$

$\lambda orig := \mathrm{eigenvals}(G(D))$

$\lambda := \mathrm{reverse}(\mathrm{sort}(\mathrm{eigenvals}(G(D))))$

$E^{<j>} := \mathrm{eigenvec}\left(G(D),\lambda_j\right)$

$$lngth_j := \sqrt{\sum\overrightarrow{\left(E^{<j>}\right)^2}}$$

Principle Coordinate Analysis Program--Continued.

$$\mathrm{prop}\lambda := \frac{\lambda}{\sum \lambda}$$

$$\mathrm{cumprop}\lambda_j := \frac{\sum_{k=0}^{j} \lambda_k}{\sum \lambda}$$

$$\mathrm{scores} := G(D) \cdot E$$

$$V(x) := \mathrm{var}(x) \cdot \frac{\mathrm{length}(x)}{\mathrm{length}(x) - 1}$$

$$\mathrm{vscores}_j := V\left(\mathrm{scores}^{<j>}\right)$$

Program written in MATHCAD PLUS (v. 5.0) for Monte Carlo Randomization.

$DAT1 := READPRN(data)$

$DAT2 := READPRN(data)$

$A := augment(DAT1, DAT2)$

$B := (1\ \ 1\ \ 1\ \ 2\ \ 2\ \ 2\ \ 3\ \ 3\ \ 3\ \ 4\ \ 4\ \ 4)^T$

$j := 0 .. cols(A) - 1 \qquad i := 0 .. rows(C) - 1$

$\alpha := 0.1$

$$SS(x) := \sum_j if\left(x_j > 0, 1, 0\right)$$

$$Mn(x) := \frac{\sum_j x_j \cdot B_j}{SS(x)}$$

$$C(x, M) := \overrightarrow{((x \cdot B - M) \cdot \Phi(x - .00000000000001))}$$

$$CNT(x) := C(x, Mn(x))$$

$$Var(x) := \frac{\sum_j \left[\left(CNT(x)_j\right)^2\right]}{SS(x)}$$

$$V0_i := Var\left[\left(A^T\right)^{<i>}\right]$$

$NTS := 2000$

$L := 0 .. NTS - 1$

$tstsdum_L := 1$

$rndpertst := 20$

$one_j := 1$

$$x := \left(A^T\right)^{<i>}$$

$$RandO(x) := csort\left(augment\left(\overrightarrow{rnd(one)}, x\right), 0\right)^{<1>}$$

Monte Carlo Randomization Program--Continued.

$$Z := \mathrm{RandO}\left[\left(A^{T}\right)^{<i>}\right]$$

$$\mathrm{RMn}(x) := \frac{\sum_{j} \mathrm{RandO}(x)_j \cdot B_j}{\mathrm{SS}(x)}$$

$$\mathrm{RMn}\left[\left(A^{T}\right)^{<i>}\right]$$

$$\mathrm{RC}(x,M) := \overrightarrow{((x \cdot B - M) \cdot \Phi(x - .00000000000001))}$$

$$\mathrm{RC1}(x) := \mathrm{RC}(x, \mathrm{RMn}(x))$$

$$\mathrm{RCNT}(x) := \mathrm{RC1}(\mathrm{RandO}(x))$$

$$\mathrm{RVar}(x) := \frac{\sum_{j} \left[\left(\mathrm{RCNT}(x)_j\right)^2\right]}{\mathrm{SS}(x)}$$

$$\mathrm{LoR}(x, V0) := \mathrm{if}(V0 < \mathrm{RVar}(x), 0, 1)$$

$$\mathrm{Min}(a,b) := \mathrm{if}(a < b, a, b)$$

$$\mathrm{tailP}(x) := \mathrm{Min}(x, 1 - x)$$

$$\mathrm{TP}(x, V0) := \mathrm{tailP}\left[\frac{\sum_{i=1}^{\mathrm{rndpertst}} \mathrm{LoR}(x, V0)}{\mathrm{rndpertst}}\right]$$

$$Q(x, V0) := \frac{\sum_{i=1}^{\mathrm{rndpertst}} \mathrm{LoR}(x, V0)}{\mathrm{rndpertst}}$$

$$f(x) := \begin{pmatrix} \mathrm{tailP}(x) \\ \mathrm{if}(x<0.5, -1, 1) \end{pmatrix}$$

$$\mathrm{PROP}^{<i>} := f\left[Q\left[\left(A^{T}\right)^{<i>}, V0_i\right]\right]$$

APPENDIX E

PROBABILITIES VIA RANDOMIZATION TEST

Table 41. Monte Carlo randomization[1] results, probabilities for random distribution of plant species presence and cover quantity in pioneer communities as a consequence of pre-fire seral stage (cover type) in the ABLA/CARU habitat type after severe fire (n=12).

Species	Probability	Tail[2]
Trees		
Pinus contorta Dougl. var. latifolia Eng	0.495	1
Shrubs		
Ribes cereum Dougl.	0.405	-1
Vaccinium scoparium Leiberg	0.35	-1
Forbs		
Achillea millefolium L.	0.215	1
Agoseris glauca (Pursh) Raf.	0.485	-1
Agoseris aurantiaca (Hook.) Greene	0.195	1
Anaphalis margaritacea (l.) B. & H.	0.43	-1
Antennaria microphylla Rydb.	0.275	-1
Arabis drummondii Gray	0.395	-1
Arabis glabra (L.) Bernh.	0.46	-1
Arabis holboellii Hornem.	0.365	-1
Arenaria congesta Nutt.	0.3	1
Arnica cordifolia Hook.	0.25	-1
Aster conspicuus Lindl.	0.36	-1
Aster foliaceus Lindl.	0.345	1
Aster integrifolius Nutt.	0.365	1
Aster sibiricus L. var. meritus (A. Nels.)	0.33	-1
Astragalus miser Dougl.	0.285	1
Campanula rotundifolia L.	0.09	-1
Capsella bursa-pastoris (L.) Crantz	0.385	-1
Cerastium arvense L.	0.415	-1
Cerastium fontanum Baumg.	0.31	1
Chenopodium fremontii Wats.	0.385	-1
Cirsium arvense (L.) Scop.	0.42	-1
Collinsia parviflora Lindl.	0.465	-1
Collomia linearis Nutt.	0.475	1
Draba nemorosa L.	0.385	-1
Epilobium angustifolium L.	0.41	1
Epilobium ciliatum Raf.	0.355	-1
Epilobium glaberrimum Barbey	0.405	1
Epilobium paniculatum Nutt.	0.175	1
Erigeron compositus Pursh	0.42	-1
Fragaria virginiana Duchesne	0.08	1
Gayophytum diffusum T. & G.	0.265	-1
Gentiana amarella L.	0.34	-1
Geranium viscosissimum F. & M.	0.165	-1
Gnaphalium spp. L.	0.42	-1
Hieracium albiflorum Hook.	0.135	-1
Lupinus argenteus Pursh	0.335	-1
Lupinus sericeus Pursh	0.06	-1

Table 41--Continued.

Microsteris gracilis (Hook.) Greene	0.335	-1
Penstemon procerus Dougl.	0.325	-1
Phacelia franklinii (R. Br.) Gray	0.385	-1
Phlox longifolia Nutt.	0.345	-1
Polygonum douglasii Greene	0.05	-1
Potentilla glandulosa Lindl.	0.365	-1
Potentilla gracilis Dougl.	0.34	1
Rumex acetosella L.	0.3	-1
Solidago multiradiata Ait.	0.225	-1
Solidago spp. L.	0.39	-1
Stellaria longipes Goldie var. altocaulis	0.405	-1
Taraxacum officinale Weber	0.0	-1
Thalictrum occidentale Gray	0.385	-1
Viola adunca Sm.	0.37	1
Viola nuttallii Pursh	0.38	1
<u>Graminoids</u>		
Agrostis scabra Willd.	0.5	1
Agropyron caninum (L.) Beauv.	0.205	1
Bromus carinatus H. & A.	0.455	-1
Calamagrostis canadensis (Michx.) Beauv.	0.445	-1
Calamagrostis rubescens Buckl.	0.28	-1
Carex geyeri Boott	0.34	-1
Carex hoodii Boott	0.34	-1
Carex rossii Boott	0.08	-1
Danthonia intermedia Vasey	0.265	1
Elymus glaucus Buckl.	0.38	-1
Festuca idahoensis Elmer	0.415	1
Oryzopsis exigua Thurb.	0.345	-1
Phleum pratense L.	0.335	-1
Poa compressa L.	0.46	-1
Poa nervosa (Hook.) Vasey	0.415	1
Poa scabrella (Thurb.) Benth.	0.4	-1
Sitanion hystrix (Nutt.) Smith	0.115	-1
Stipa occidentalis Thurb.	0.465	-1
Stipa occidentalis var. nelsonii (Scribn.)	0.225	1
Trisetum spicatum (L.) Richter	0.23	1

[1] Monte Carlo randomization program results from Appendix C.
[2] Positive values represent tests of species establishing in postfire communities of many pre-fire seral stages (cover types). Negative values represent tests of species distribution by presence and cover quantity in postfire communities of only one or two pre-fire seral stages.

Table 42. Monte Carlo randomization[1] results, probabilities for random distribution of plant species presence and cover quantity in pioneer communities as a consequence of pre-fire seral stage (cover type) in the ABLA/CARU habitat type after severe fire (n=12).

Species	Probability	Tail[2]
Trees		
Pinus contorta Dougl.	0.255	-1
Populus tremuloides Michx.	0.46	-1
Shrubs		
Spiraea betulifolia Pall.	0.455	-1
Vaccinium globulare Rydb.	0.45	-1
Vaccinium membranaceum Dougl.	0.39	-1
Vaccinium scoparium Leiberg	0.405	1
Forbs		
Agoseris glauca (Pursh) Raf.	0.41	-1
Antennaria microphylla Rydb.	0.345	-1
Antennaria racemosa Hook.	0.445	1
Arabis glabra (L.) Bernh.	0.08	-1
Arabis holboellii Hornem.	0.39	-1
Arnica cordifolia Hook.	0.24	1
Aster integrifolius Nutt.	0.49	-1
Aster sibiricus L. var. meritus (A. Nels.)	0.48	-1
Cirsium arvense (L.) Scop.	0.4	-1
Cirsium vulgare (Savi) Tenore	0.155	-1
Collinsia parviflora Lindl.	0.335	-1
Collomia linearis Nutt.	0.365	-1
Epilobium anagallidifolium Lam.	0.395	-1
Epilobium angustifolium L.	0.105	1
Epilobium glaberrimum Barbey	0.295	-1
Epilobium paniculatum Nutt.	0.24	-1
Fragaria virginiana Duchesne	0.355	-1
Gayophytum diffusum T. & G.	0.195	-1
Gayophytum racemosum T. & G.	0.36	-1
Geranium viscosissimum F. & M.	0.375	-1
Hieracium albiflorum Hook.	0.195	-1
Hieracium cynoglossoides Arv.-Touv.	0.385	-1
Hieracium gracile Hook.	0.39	-1
Lupinus argenteus Pursh	0.23	-1
Senecio serra Hook.	0.38	-1
Solidago multiradiata Ait.	0.365	-1
Spergularia rubra (L.) Presl.	0.39	-1
Taraxacum laevigatum (Willd.) DC.	0.375	-1
Taraxacum officinale Weber	0.075	-1
Graminoids		
Agrostis scabra Willd.	0.26	-1
Bromus carinatus H. & A.	0.425	-1
Calamagrostis rubescens Buckl.	0.415	-1

Table 42--Continued.

Carex geyeri Boott	0.28	1
Carex praticola Rydb.	0.335	-1
Carex rossii Boott	0.015	-1
Deschampsia elongata (Hook.) Munro	0.45	-1
Elymus glaucus Buckl.	0.305	-1
Festuca idahoensis Elmer	0.355	-1
Muhlenbergia racemosa (Michx.) B.S.P.	0.41	-1
Oryzopsis exigua Thurb.	0.41	-1
Phleum pratense L.	0.435	-1
Poa nervosa (Hook.) Vasey	0.1	-1
Trisetum spicatum (L.) Richter	0.09	-1

[1] Monte Carlo randomization program results from Appendix C.
[2] Positive values represent tests of species establishing in postfire communities of many pre-fire seral stages (cover types). Negative values represent tests of species distribution by presence and cover quantity in postfire communities of only one or two pre-fire seral stages.