(16) Barmore

#16109 11/6/91

ECOLOGICAL EFFECTS AND BIOTIC SUCCESSION FOLLOWING THE 1974 WATERFALLS CANYON FIRE IN GRAND TETON NATIONAL PARK

Research Progress Report

1974 - 1975

William J. Barmore Jr., Dale Taylor, and Peter Hayden

Research Biologist, Seasonal Biologist, and
Aquatic Research Biologist, respectively

Grand Teton National Park

September 1976

Not For Publication

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Since the 1960's there has been a growing awareness of the vital role that fire played in the dynamics of many pristine ecosystems (see Baker 1975 for a partial bibliography). Prior to this time National Park Service policy was to completely suppress all natural and man-caused fires in western national parks. However, recommendations by the Secretary of the Interior's Advisory Board on Wildlife Management (Leopold 1963) resulted in new management policies that recognized the role of fire in many natural ecosystems and that provided for the use of natural and/or prescribed fire as management tools (National Park Service 1970). Fire management plans using natural and/or prescribed fire were implemented in several national parks (Hendrickson 1973), and management policies have been further revised to reflect rapidly increasing scientific knowledge and management expertise regarding fire in park ecosystems (National Park Service 1975).

Scientific research during the 1960's and early 1970's documented the importance of fire in ecosystems in northwestern Wyoming (Oswald 1966; Taylor 1969, 1973b, 1974; Loope 1971; Loope and Gruell 1973; Houston 1973; Gruell and Loope 1974). This research provided the scientific foundation for a fire vegetation management plan for Grand Teton National Park that was implemented in 1972 and updated in 1973 following preparation of an environmental assessment, draft environmental impact statement, and a public hearing in Jackson, Wyoming (Grand Teton National Park 1973).

After implementation of this plan in 1972 and prior to the Waterfalls Canyon Fire in 1974, only two lightning-caused fires occurred in that portion of the Park zoned for letting natural fires run their course. These fires attracted little attention. However, the Waterfalls Canyon Fire that started from a lightning strike on July 17, 1974 was not declared out until December 1, 1974 after burning over about 3,500 acres (1,414 ha). This sizeable and long enduring fire attracted national as well as local attention and created considerable controversy (Loope and Wood (In Press) provide a brief description of the fire).

As part of ongoing research on fire ecology and in response to strong public interest in the Waterfalls Canyon Fire, studies were initiated in 1974 to document effects of the fire and long term successional changes following it. The study design provides for repetitive measurements of several ecological parameters over a long time period. This report summarizes research accomplished during the summers of 1974 and 1975. Some aspects such as weather conditions during the fire will be presented elsewhere. No attempt has been made to utilize all the scientific literature that might relate to the analysis and interpretation of data obtained to date.

METHODS

Mapping the Burn

Park Ranger Dick Guilmette mapped the daily progress of the fire on a 1:24,000 U. S. Geological Survey, Colter Bay, Wyoming quadrangle.

In 1975 the burn was mapped into the following categories on black and white aerial photos taken in September, 1969. Photos varied in scale from about 1:14,000 to 1:22,000 (U. S. Forest Service series TNP).

1. Severe burn - most trees (90 percent or more) were killed, usually by crown fire, with foliage and branches consumed to varying degrees. Above ground portions of herbs and shrubs were largely consumed, but in some instances rapidly moving crown fire killed most trees but not all understory vegetation.
2. Moderate burn - much of the tree overstory (40 percent or more) was alive one year postfire. Individual trees and/or small groups of taller trees were killed by crown fire, and heat from nearby burning trees or creeping ground fire killed others. A higher percentage of understory trees may have been killed, but ground fire typically created a complex mosaic of burned and unburned understory vegetation.
3. Unburned - areas where neither trees nor understory vegetation was burned.

Two broad vegetation types were mapped: coniferous forest and meadow-shrub. The latter type included some avalanche paths with dense, scrubby conifers and/or aspen.

Mapping was done by systematically covering the burn on foot and from a boat on Jackson Lake. Differences in topography, vegetation types, density and/or height of the tree overstory, and other characteristics apparent when viewing the 1969 photos stereoscopically and reference to large scale color photos taken in October 1974 permitted fairly accurate delineation of the three burn intensity classes. Acreage was estimated with dot grids (64 or 256 dots/in^2) directly from the 1969 aerial photos after they had been stratified into as many as three elevation zones to reduce errors from variations in photo scale.

Four slope classes were mapped by inspection of topographic variation on the Colter Bay, Wyoming quadrangle (contour interval 40 feet (12.2 m)). Acreage in slope classes was estimated with a dot grid (64 dots/in^2), and mean percent slope was estimated from 41 measurements on the quadrangle.

Fire Effects and Successional Changes

Four fire "treatments" were selected and permanent study plots were established at each site (see Figure 1 for locations):

1. Severely burned in 1974 - This site of about 89 acres (36 ha) was the largest contiguous area on a fairly uniform site that was uniformly severely burned in 1974; partly on July 28 and partly on August 28. Slope was 0-5 percent east. Essentially all above ground vegetation was killed and most was consumed by the fire (Figure 2). Before the fire the site was covered by spruce-fir forest similar in species composition and successional status to the unburned site described below. A small stream that dried up by the end of July in 1975 flowed through the site.
2. Moderately burned in 1974 - This site (Figure 3) included about

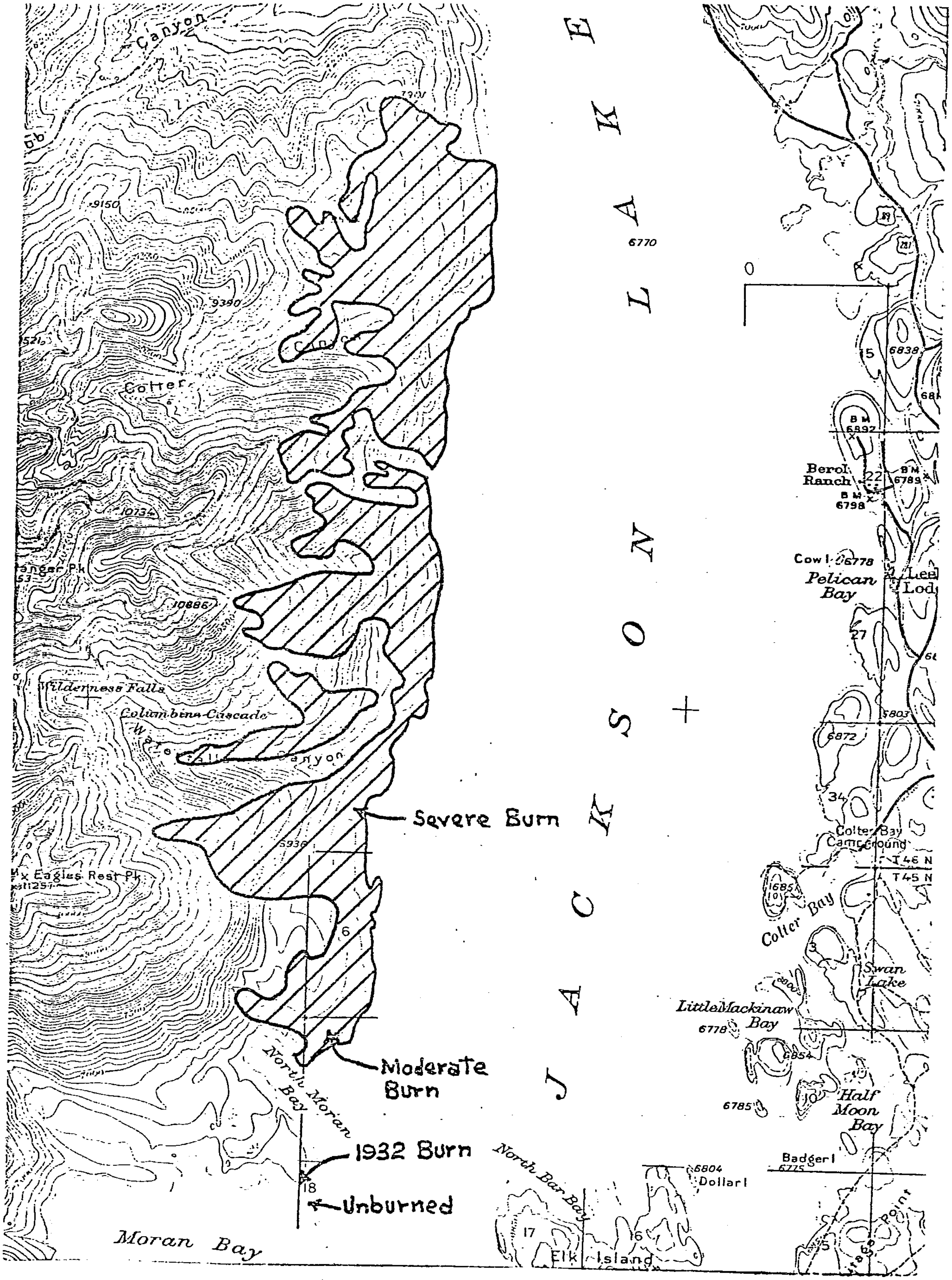


Figure 1. Location of the Waterfalls Canyon Burn and study sites.

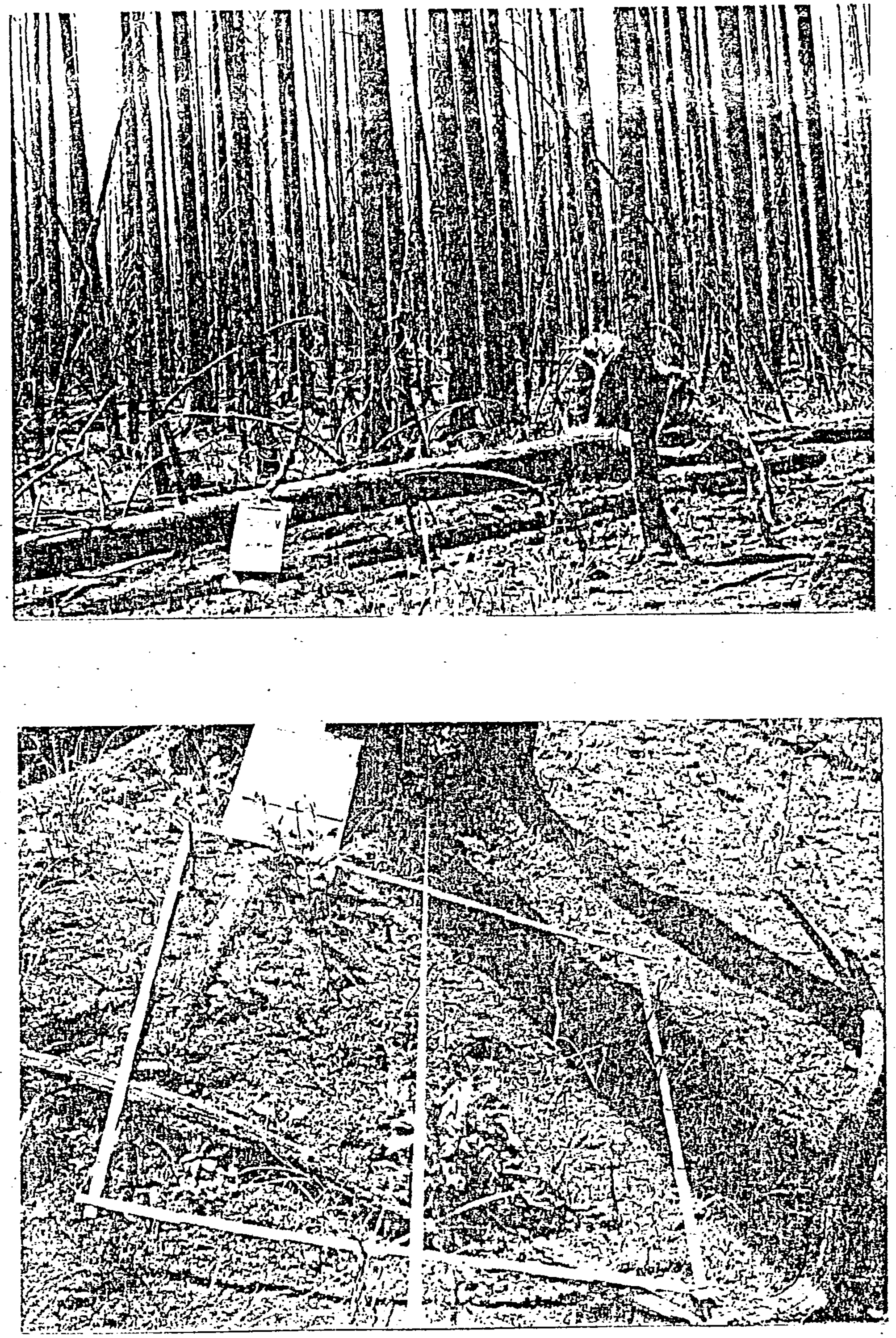
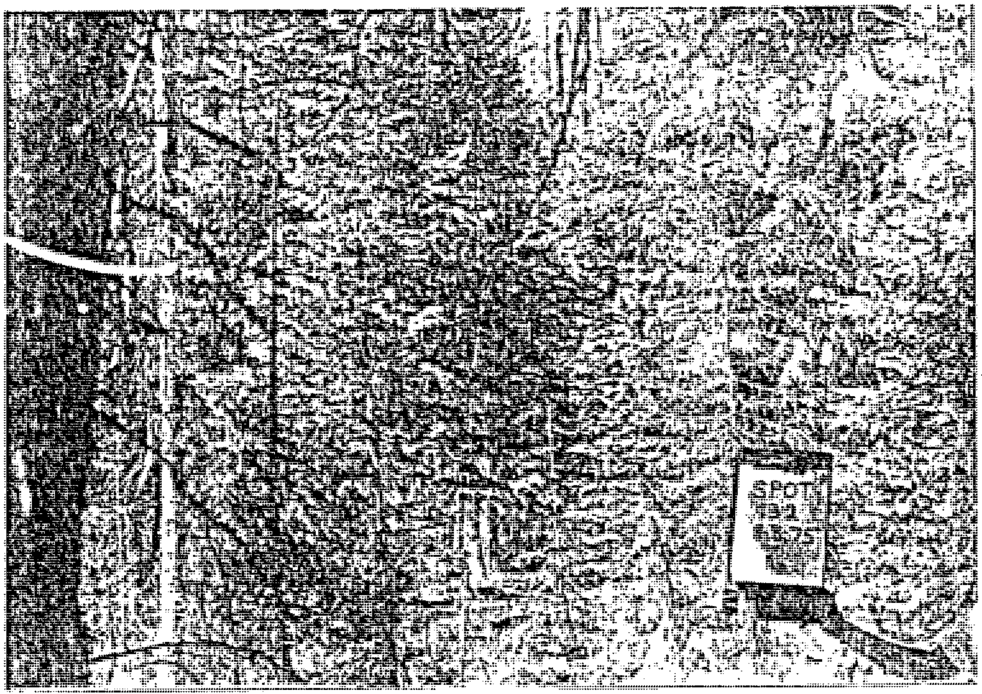


Figure 2. Fire effects on the severely burned site, summer 1975.



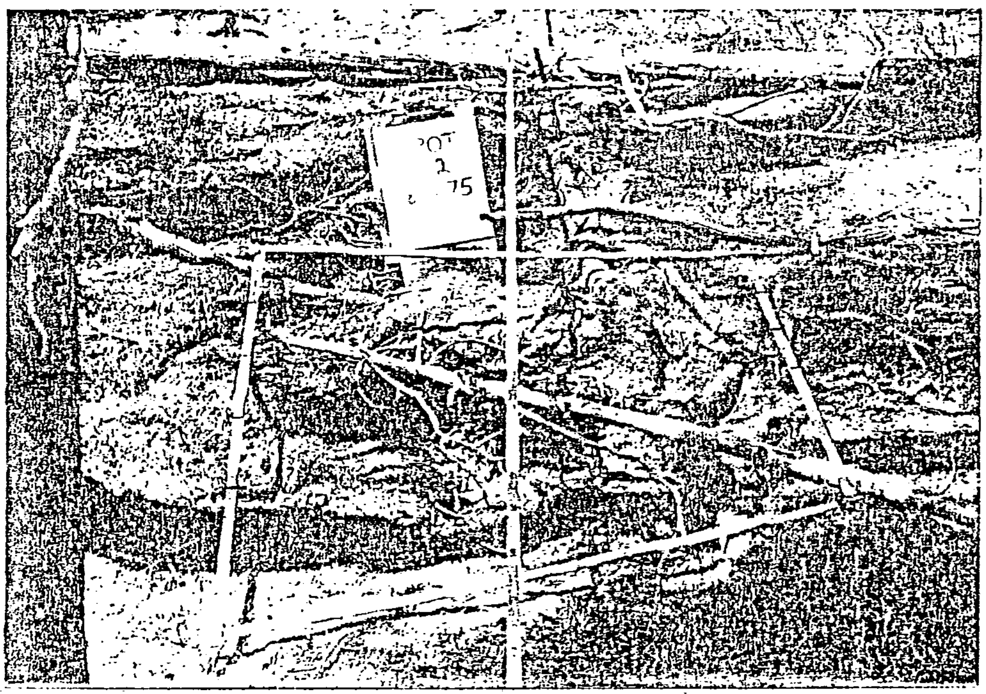


Figure 3. Fire effects on the moderately burned site, summer 1975.

116 acres (47 ha) on a 0-5 percent east slope and was typical of moderately burned spruce-fir forest on similar sites throughout the burn. The area burned or reburned on August 1 and 28 and September 8 and 18. The permanent study plots probably burned on the 18th. Prefire vegetation was spruce-fir forest similar to that on the unburned site but somewhat more advanced successionally than that on the severely burned site.

3. Severely burned in 1932 - This area of about 100 acres (40.5 ha) was a man-caused fire. The site was swept by a severe crown fire with results very similar to those on sites severely burned in 1974 (Figure 4). Topography was somewhat more varied on this site than on the other three. It included several small knolls and low ridges with slopes that varied from 10 percent northeast to 3-6 percent south and 4 percent southwest. Prior to the 1932 fire, vegetation was probably the same as on the unburned site immediately to the southeast. Although the prefire spruce-fir forest was probably fairly uniform, vegetation in 1975 varied from open grass-forb-shrub (Figure 5) to dense lodgepole pine forest (Figure 6).

4. Unburned - This site (Figure 7) of about 42 acres (17 ha) was immediately adjacent to the area severely burned in 1932 on a 0-3 percent south slope. In 1975 the vegetation was spruce-fir forest (see detailed vegetation description below).

Figure 4. Fire effects on the 1932 burn 3 or 4 years after the fire.

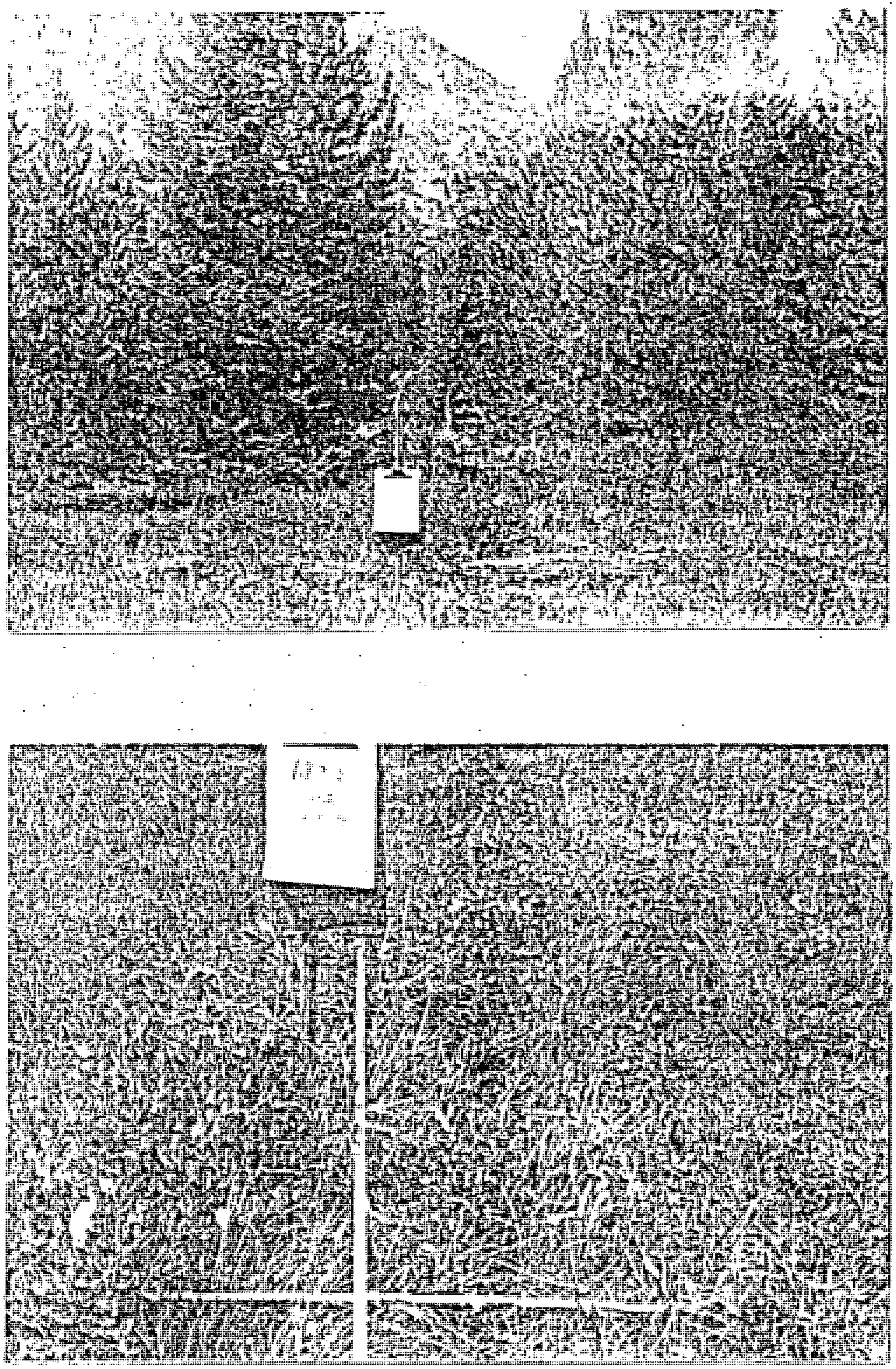


Figure 5. Grass-forb-shrub vegetation on the 1932 burn in summer 1975.

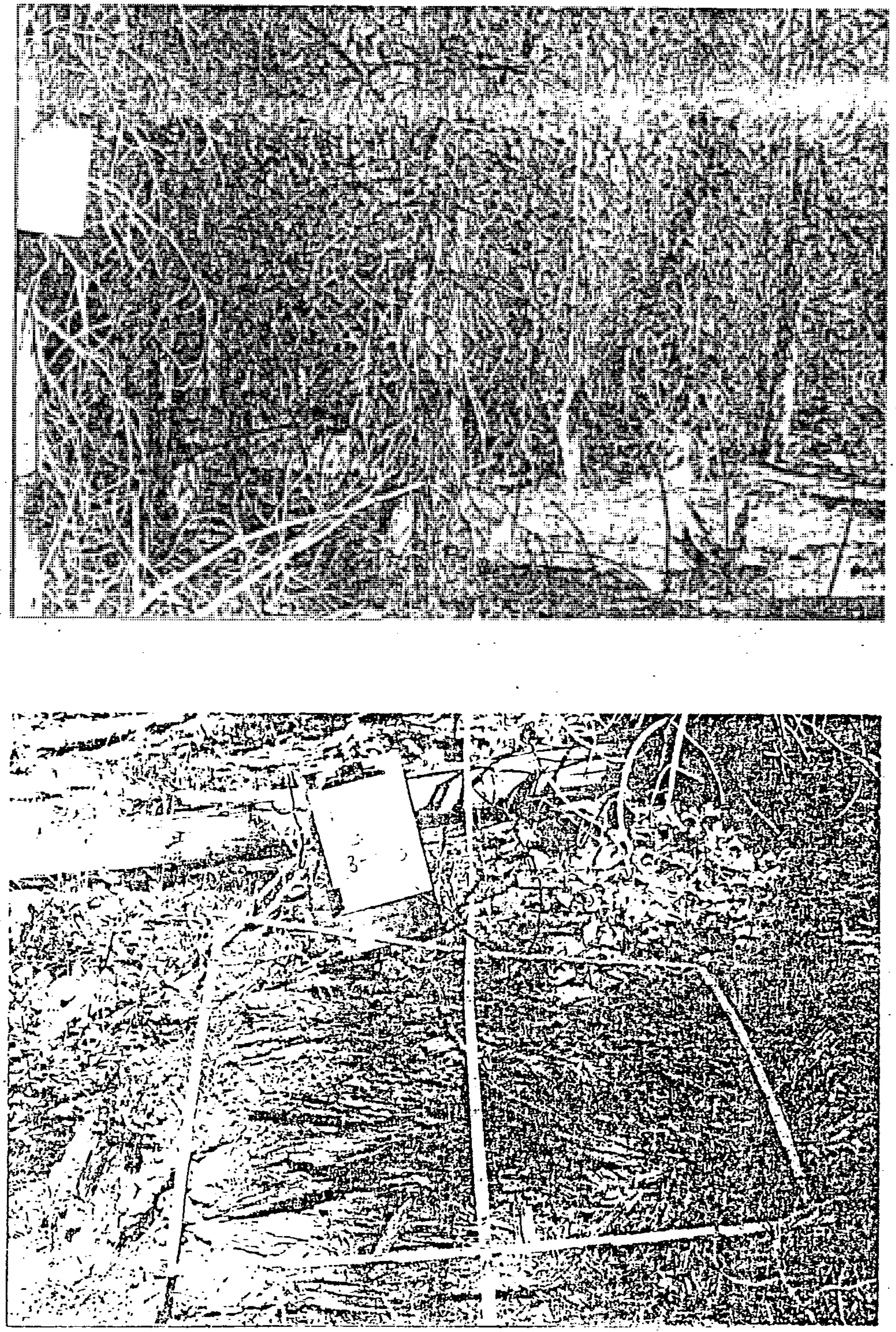


Figure 6. Dense lodgepole pine stand on the 1932 burn in summer 1975.

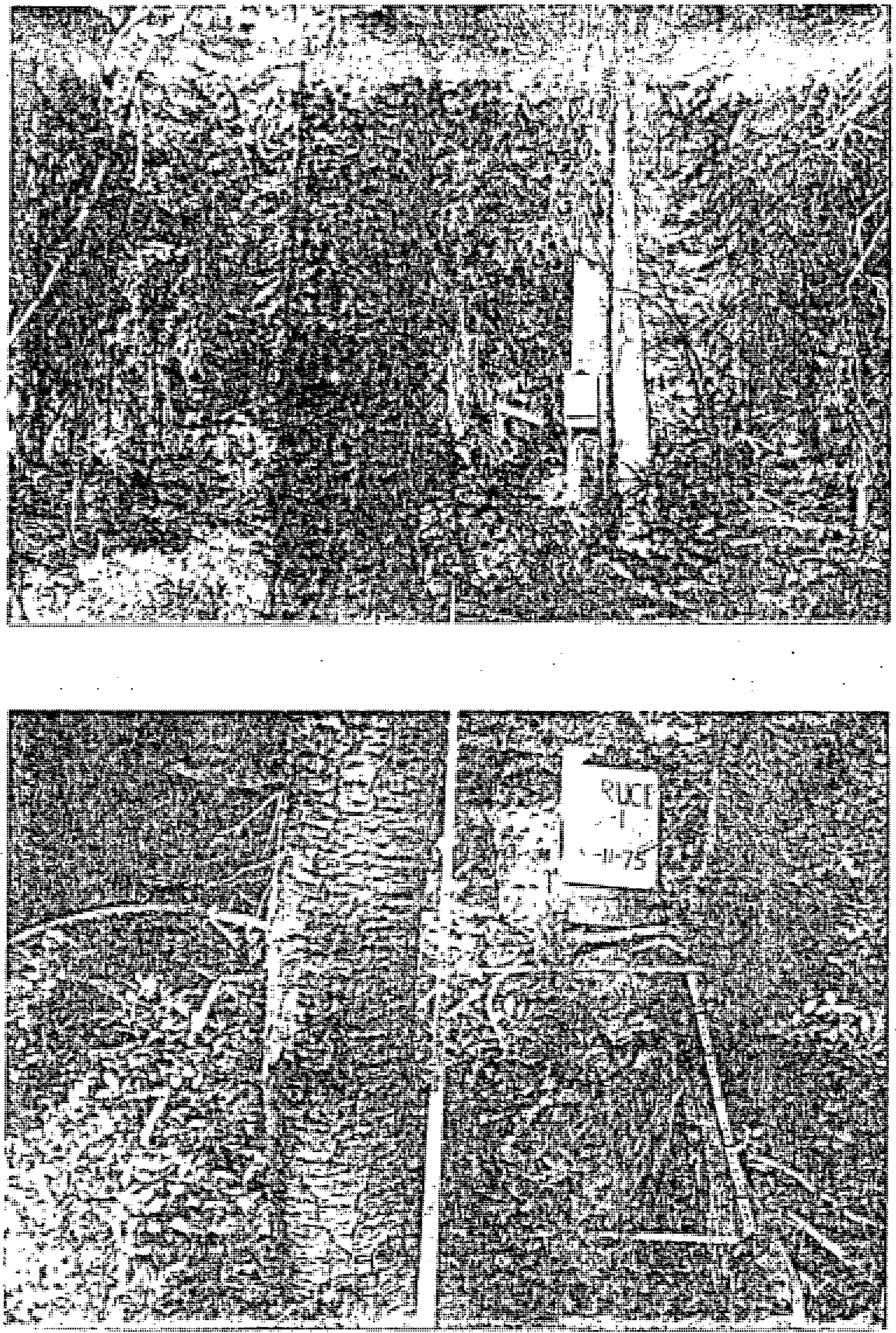


Figure 7. Vegetation on the unburned site in summer 1975.

Plants

Three 15 m x 25 m macroplots were permanently established with steel fence posts at each of the four study sites (Figure 8). In all but the 1932 burn the first macroplot on each site was located by pacing a predetermined distance into the site on a predetermined compass bearing. The other two macroplots were then located sequentially 150-164 feet (45.8-50.2 m) from each other on a predetermined compass bearing. Distances and compass bearings were selected to keep macroplots within an area of maximum homogeneity of burn, vegetation, and topography. On the 1932 burn a single macroplot was established as described above in each of three strata that reflected differences in tree density. The objective was to sample the full range of variation in successional responses to the 1932 fire.

Height to the nearest foot and diameter at breast height (DBH) to the nearest 0.1 inch were recorded by species for all live and dead trees two feet (0.6 m) or taller on each of three 5 m x 25 m belts within each macroplot. Tree height was measured with a 10 foot pole or a Suunto PM5 clinometer. DBH was measured with a diameter tape. Trees less than 1 inch in DBH were given a DBH of 0.5 inch. The presence of lichens, dead tops, broken out tops, and leaning trees was also recorded as appropriate for each tree. Current year's growth of terminal leaders and of one randomly selected lateral leader was measured to the nearest 0.5 cm for all trees where terminal leaders were within reach.

The following data on understory herbs, shrubs, and trees up to 2 ft. (0.6 m) tall were recorded by species on each of ten 2 dm x 5 dm

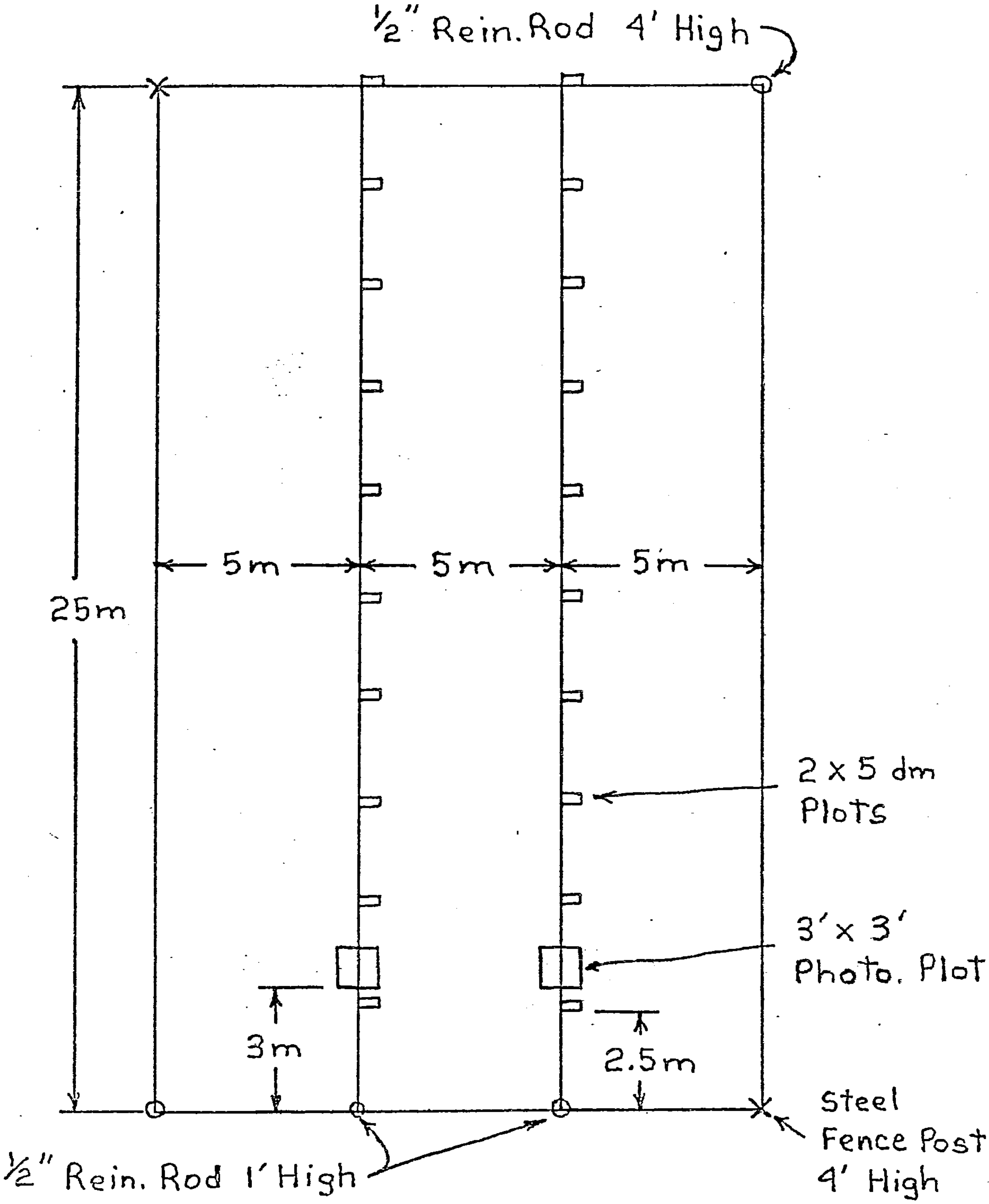


Figure 8. Layout of vegetation study plots, Waterfalls Canyon Burn, 1975.

plots at 2.5 m intervals on the right side of each of two transects extending from permanent stakes at the 5 m and 10 m marks along one end of each macroplot (Figure 8). (1) number of tree seedlings produced during the current year, (2) number and height of trees up to 2 ft. (0.6 m) tall, (3) aerial coverage as defined by Daubenmire (1959) for herbs and shrubs estimated to the nearest percent, (4) number of single-stemmed and/or individually recognizable herbs rooted in the plot, (5) number of individual shrub stems rooted within the plot, (6) maximum height of shrubs rooted within the plot, and (7) percentage of ground surface not covered by aerial plant growth.

Ground surface characteristics (Table 1) were determined from categories hit by each sharpened corner leg of the 2 dm x 5 dm plots (80 points per macroplot).

A close up and two distant color photographs (3.5 in x 5.0 in prints, Pentax Spotmatic 35 mm camera, 55 mm lens), Kodak Vericolor II Professional Film Type S) were taken along each transect used to describe understory vegetation. Closeups were of 3 ft x 3 ft quadrats 2 m from the permanent transect stake over which the camera was centered 54 inches above the ground on a tripod. Distance photos were taken along the transect tape to show general characteristics of the understory and the tree canopy. Prints became part of the permanent data file for each macroplot. These photographs (and slides if needed) provide visual documentation of successional changes.

Animals

Insects. Airborne and foliage insects were collected only from the 1974 severe burn at bi-weekly intervals during July and August, 1975. Each collection consisted of three samples of 48 strokes each with a standard sweep net (Kendeigh 1974). Samples were sorted into insect orders.

Birds. Bird density was estimated by the transect survey method (Haapanen 1965, Kendeigh 1944) during four censuses on each study site and another climax spruce-fir forest site (Spruce-Fir II) between June 25 and July 10, 1975. Breeding birds were considered to be those within a 75 ft (22.9 m) wide belt on each side of a 1,000 yd (914 m) paced transect (census area=10.3 acres (4.2 ha)). Birds outside the transect were also recorded as were mammals within the transects.

Small Mammals. Part of the severe burn that burned on July 26, 1974 was snaptrapped for 3 consecutive days (360 trap nights) in early August, 1974 using methods described by Calhoun and Casby (1958).

In 1975 each study site was livetrapped for five consecutive nights between July 1-18 and between August 6-23 using a 50 m x 100 m (0.5 ha) grid with a small (2 x 2.5 x 6.5 in) and a large (3 x 3.5 x 9 in) Sherman folding livetrap at each 10 m x 10 m grid intersection (50 small and 50 large traps/grid). Bait was a mixture of peanut butter, rolled oats, and bacon grease. Cotton batting inside the traps provided protection. Captured mammals were identified to species, toe-clipped for individual identification, weighed, sexed, aged (young, adult), examined for reproductive condition, and released at the capture point. Population estimates were made by the Schnabel method as described by Overton and Davis (1969). Known mortality was taken into consideration.

Soils

Soil Conservation Service (SCS) personnel made detailed soil profile descriptions at the severely burned, 1932 burn, and unburned sites using standard SCS techniques. Twelve, 5, and 3 soil samples were taken from the severe burn, 1932 burn, and unburned sites, respectively to be analyzed for pH, moisture tension (15 bar), organic carbon, and organic nitrogen at the SCS Soil Investigation Laboratory, Riverside, California. Analyses were not available when this report was written.

Water Quality

Water samples were obtained on October 24 and November 27, 1974 and at about weekly intervals (8 times) between June 11 and August 20, 1975 from two streams that drained unburned watersheds (Moran Creek and North Moran Creek) and from three that drained partially burned watersheds; streams in Waterfalls Canyon and Colter Canyon called Waterfalls Creek and Colter Creek, respectively, and a stream flowing east from Ranger Peak called Falcon Creek. An additional intermittent stream (called Burn Creek) that flowed through the severe burn study site with most of its watershed severely burned was sampled in 1975.

pH, turbidity, and nitrate concentration were determined at the time of collection by colorimetry (Hack Company DR-EL photometer and reagents); stream temperature was measured and volume of flow was estimated. Filtered and frozen samples were later analyzed for phosphorus by the standard molybdate method (American Public Health Association

1962) in the laboratory at Park Headquarters. Turbidity was measured only if coloration or cloudiness was visible.

An additional set of samples collected July 24, 1975 was analyzed by personnel at the Forest Sciences Laboratory, U. S. Forest Service, Logan, Utah as a check against analyses done in the Park.

RESULTS AND DISCUSSION

Description of the Burn

The fire perimeter enclosed 3,492 acres (1,414 ha), extended about 6.7 miles (10.8 km) along the west side of Jackson Lake, had a maximum width of about 1.6 miles (2.6 km), and ranged in elevation from about 6,770 feet (2,065 m) on the lake shore to 9,500 feet (2,898 m) on the east ridge of Ranger Peak (Figure 1).

About 25, 16, 34, and 26 percent of the burn was on slopes of 0-10, 11-20, 21-40, and over 40 percent, respectively, with east to southeast exposures. Maximum mean slope was 64 percent.

Soils on gentler slopes between Jackson Lake and the steeply rising mountains were mostly derived from morainal deposits of Pinedale glaciers and Paleozoic sediments (north of Colter Canyon) with small inclusions derived from alluvium and talus. Soils on steeper mountain slopes were derived from basement granite, gneiss, and schist except north of Colter Canyon where Paleozoic sediments occur (Love and Reed 1968).

Prior to the fire the 3,492 acres (1,414 ha) within the burn perimeter was 82 percent coniferous forest and 18 percent meadow-shrub. Of the 387 acres (157 ha) of unburned vegetation within the perimeter (11 percent), 75 percent was meadow-shrub and 25 percent was coniferous forest. *Picea engelmanni* and *Abies lasiocarpa* were the dominant trees on gentler slopes of most exposures and on steeper slopes with an east exposure, except north of Colter Canyon where *Pseudotsuga menziessii* became more important. (Common and scientific plant names are in Table 34). This species and *Pinus contorta* were more important on steeper slopes with a more southern exposure. Pinus albicaulis was a minor component at low elevations but became more important at higher elevations on steep east slopes and ridges. Lush grass-forb meadows occurred in mesic areas and in avalanche paths. The latter sites also often contained scrubby conifers and/or Populus tremuloides. Small, remnant stands of more mature P. tremuloides occurred on the lower margins of avalanche paths between Falcon Creek and Colter Canyon. Otherwise, P. tremuloides was very sparse or absent from the burned area.

Of the 3,106 acres (1,258 ha) actually burned, 89 percent was coniferous forest and 11 percent was meadow-shrub. Of the 2,763 acres (1,119 ha) of coniferous forest burned, 57 percent was severely burned and 43 percent was moderately to lightly burned. Within the fire perimeter proportionately more coniferous forest (96 percent) than meadow-shrub (54 percent) was burned. Further indication that meadow-shrub vegetation was less prone to burn is the fact that 75 percent of the unburned acreage within the burn perimeter was meadow-shrub.

Ground Surface Characteristics

One year after the 1974 fire the relative frequency of hits was similar on all sites for plants (3-6 percent) and for logs (9-16 percent). Even severe fire apparently did not reduce understory plant basal area (Table 1). More hits on mosses and lichens on the unburned site (15 percent) than on sites burned in 1974 (1 percent or less) suggests that most mosses and lichens were killed by the fire with no replacement by one year postfire. Mosses and lichens covered only 4 percent of the 1932 burn which suggests that post fire recovery will be slow and may depend upon reestablishment of a dense tree canopy.

Table 1. Ground surface characheristics, Waterfalls Canyon Burn, 1975

	Mean percent[a]				Coefficient of variation (%)			
	Unburned	1932 Burn	1974 Burn Moderate	1974 Burn Severe	Unburned	1932 Burn	1974 Burn Moderate	1974 Burn Severe
Rocks[c]		1		1		169		175
Gravel[d]								
Soil[e]		4	2	1		149	112	169
Ash			2	7			171	97
Burned Litter			8	73			43	6
Unburned Litter	71	70	74	1	8	12	0	100
Logs	9	16	12	11	70	47	32	33
Moss & Lichens	15	4	T[b]	1	56	149		88
Plant basal area	5	6	3	5	74	71	90	48

[a] n=3 macroplots/site, 80 points/macroplot
[b] T-less than 0.5%
[c] Greater than 3/4" in diameter
[d] 1/8" - 3/4" in diameter
[e] Less than 1/8" in diameter

Bare soil was sparse on all sites (0-4 percent), as was ash on the moderate (2 percent) and severe (7 percent) burns.

Comparison with the unburned site suggests that fire effects on soil surface characteristics of moderately burned sites were minor one year postfire. Mosses and lichens were still absent and 10 percent of the soil surface was covered by ash and burned litter, but unburned litter was nearly the same on the two sites. However, immediate postfire effects were obscured by profuse needle fall from trees that were killed by the fire but that did not have their foliage consumed. By summer, 1975, needle fall on the moderate burn covered burned litter, ash, and bare soil to the extent that unburned litter equalled that on the unburned site and 1932 burn.

Comparison with the unburned site indicates major fire-caused changes on severely burned sites that lasted throughout the first post-fire year. Essentially all litter was charred but not consumed and replaced by bare soil or ash which, combined, covered only 8 percent of the ground surface. Essentially all tree foliage was consumed during the fire on the severely burned site; thus litter was not re-established by postfire needle fall as occurred on the moderately burned site.

Even on the severely burned site most of the ground surface (92 percent) was fairly well protected from erosion throughout the first postfire year. General observations suggested that this was true of most burned areas on gentle to moderately steep slopes, but that the fire increased bare soil and/or ash and susceptibility to erosion proportionately more on very steep slopes. Even on these sites much of the soil surface was still protected by burned and unburned organic matter and higher proportions of rock and gravel. Needle fall from fire-killed trees created considerable litter that reduced erosion potential even on many very steep slopes.

Vegetation

The Tree Stratum

The prefire density and basal area of live trees and the extent of fire-caused tree mortality on the moderate burn are unknown but some estimates can be made from data in Tables 2, 3, and 4 and by assuming that (1) in 1974 the stand consisted of those live and dead trees still standing in 1975, (2) the prefire percentage of dead trees on the moderate burn was the same as for the unburned site in 1975 (Table 5), (3) no trees on the unburned site died between 1974 and 1975, (4) no trees two feet tall or taller were completely consumed by the 1974 fire, and (5) proportionately the same number of trees fell over on the moderate and unburned sites between 1974 and 1975. This approach provides minimum estimates, since some trees were no doubt consumed by the fire and proportionately more trees probably fell over on the moderate than on the unburned site.

Picea engelmanni and *Abies lasiocarpa* combined probably made up about 97 percent of the prefire live tree density and basal area on the moderate burn. *Pinus contorta* and *P. albicaulis* were of minor importance (Table 5). Trees less than 19 feet (5.7 m) tall accounted for 73, 90, 34, and 100 percent of the prefire tree density for *P. engelmanni*, *A. lasiocarpa*, *Pinus contorta*, and *P. albicaulis*, respectively. Sixty

Table 2. Relative density by height classes of living plus dead standing trees on three sites, Waterfalls Canyon Burn, 1975.

Height (feet)	*Picea engelmanni* Unb.	Mod.	1932	*Abies lasiocarpa* Unb.	Mod.	1932	*Pinus contorta* Unb.	Mod.	1932	*Pinus albicaulis* Unb.	Mod.	1932	All species Unb.	Mod.	1932
	Percent														
2-6	36	40	80	68	59	58	44	17	29	87	91	86	63	57	42
7-12	26	19		9	22	21	6		14	13	9	14	11	19	15
13-18	7	14	10	4	9	12	11	17	9				5	10	10
19-24	6	8	10	4	2	6			2				4	3	3
25-30	6	5		4	1	2			7				4	2	5
31-36	4	1		1	1				10				1	1	6
37-42	2	1		2	1		6		6				2	1	4
43-48	4	2		3	1		6		8				3	1	5
49-54	6			2	1				7				2	1	5
55-60				2	T[a]		6		6				2	T	4
61-66		1		1	T		22						2	1	
67-72	6			T	1			50					1	1	
73-78		4		1	T								1	1	
79-84								17						T	
85-90		1			T									T	
91-96															
97-102		1			T									T	
+		1												T	
Density[b]	198	302	36	1104	1543	173	65	22	392	54	40	25	1421	1906	626
C.V.[c]	46	21	76	12	32	97	60	173	73	53	87	176	14	29	63
Comp.[d]	14	16	6	78	81	28	5	1	63	4	2	4			
Max. Ht.[e]	72	117	20	78	98	29	66	83	58	9	9	10			

[a] T= less than 0.5%
[b] Mean No. trees/acre, n=3 macroplots
[c] Coefficient of variation in percent
[d] Percent composition
[e] Feet

Table 3. Relative basal area by diameter classes of living plus dead standing trees on three sites, Waterfalls Canyon Burn, 1975

DBH (inches)	Picea engelmanni Unb.	Picea engelmanni Mod.	Picea engelmanni 1932	Abies lasiocarpa Unb.	Abies lasiocarpa Mod.	Abies lasiocarpa 1932	Pinus contorta Unb.	Pinus contorta Mod.	Pinus contorta 1932	Pinus albicaulis Unb.	Pinus albicaulis Mod.	Pinus albicaulis 1932	All species Unb.	All species Mod.	All species 1932
	Percent														
0.5	T[a]	T	8	1	2	5	T	T	1	100	32	36	1	1	1
1.5	1	1		1	5	9	1		T		68	64	1	2	1
2.5	2	2		2	7	18	1	1	2				2	4	3
3.5	5	2	92	4	3	14			4				4	2	6
4.5	1	4		4	2	12			9				3	3	9
5.5	2	2		9	7	18			10				6	4	10
6.5	8	3		10	4	25	5		17				9	3	18
7.5	11			15	3				28				12	1	26
8.5				4	8				20				2	4	18
9.5	11	2		5	10		11		8				7	6	8
10.5	7			14	16		39						16	7	
11.5	8	3		10				17					8	3	
12.5	20	4		4			19	20					10	4	
13.5		9		9									6	4	
14.5							25	27					3	3	
15.5					7									3	
16.5					16			35						10	
+	24	68		8	9								11	37	
Total[b]	100	100	100	100	99	101	101	100	99	100	100	100	101	101	100
B.A.[c]	4493	11154	75	10895	9722	485	2380	2197	6201	11	19	11	17779	23092	6772
Comp.[d]	25	48	1	61	42	7	13	10	92	T	T	T			
Max DBH[e]	19.5	30.5	3.5	17.5	17.5	6.5	14.5	16.5	9.5	0.5	1.5	1.5			

a T=less than 0.5%
b Man not total 100 due to rounding
c Basal area in inches^2/acre
d Percent composition
e Inches

Table 4. Pre and postfire relative density, relative basal area and importance values for live trees, Waterfalls Canyon Burn, 1975.[a]

	Unburned			Moderate burn			1932 burn		
	Relative Density	Relative B.A.	Importance	Relative Density	Relative B.A.	Importance	Relative Density	Relative B.A.	Importance
Picea engelmanni									
Prefire	14.8	29.6	44.4	16.9	53.9	70.8	6.5	1.3	7.8
Postfire	14.8	29.6	44.4	21.4	56.9	78.3	6.5	1.3	7.8
Abies lasiocarpa									
Prefire	77.7	66.4	144.1	80.0	43.5	123.5	30.7	8.9	39.6
Postfire	77.7	66.4	144.1	73.9	37.1	111.0	30.7	8.9	39.6
Pinus contorta									
Prefire	3.4	3.9	7.3	0.9	2.5	3.4	58.5	89.6	148.1
Postfire	3.4	3.9	7.3	1.1	6.0	7.1	58.5	89.6	148.1
Pinus albicaulis									
Prefire	4.0	0.1	4.1	2.2	0.1	2.3	4.5	0.2	4.7
Postfire	4.0	0.1	4.1	3.5	0.1	3.6	4.5	0.2	4.7

[a] See text for an explanation of how pre and postfire estimates were obtained

Table 5. Estimated prefire density and basal area of live trees on the moderate burn, Waterfalls Canyon Burn, 1975.

	P. engelmanni		*A. lasiocarpa*		*P. contorta*		*P. albicaulis*		All species	
	Unb.	Mod.	Unb.	Mod.	Unb.	Mod.	Unb.	Mod.	Unb.	Mod.
Density										
Live & dead	205	317	1119	1554	65	22	54	40		
Live	198		1040		47		54			
Percent alive	96.5		92.9		72.3		100.0			
Prefire density of live trees[a]	198	306	1040	1444	47	16	54	40	1339	1806
Basal area										
Live & dead	4493	11,154	10,895	9722	2380	2197	11	19		
Live	3808		8569		467		11			
Percent alive	84.8		78.6		19.6		100.0			
Prefire basal area of live trees[a]	3808	9459	8569	7641	467	431	11	19	12,855	17,550

[a] Computed for the moderate burn as: Live & dead on moderate burn X percent alive on the unburned site.

seven percent of the P. contorta were taller than 66 feet (20.1 m). Trees greater than 13.5 inches (34.3 cm) DBH may have accounted for 68, 32, and 62 percent of the prefire basal area of Picea engelmanni, A. lasiocarpa, and Pinus contorta, respectively. Maximum height was 117, 98, 83, and 9 feet (35.1, 29.4, 24.9, and 2.7 m) and maximum DBH was 30.5, 17.5, 16.5, and 1.5 inches (77.5, 44.4, 41.9, and 3.8 cm) for Picea engelmanni, A. lasiocarpa, Pinus contorta, and P. albicaulis, respectively.

Some differences between the unburned site and the moderate burn in prefire characteristics of the live tree stratum are suggested. Prefire density of all species combined, of Picea engelmanni, and of A. lasiocarpa was probably greater on the moderate burn than on the unburned site. Pinus contorta and P. albicaulis densities were low on both sites but lowest on the moderate burn (Table 2). Prefire basal area of all live trees combined and of Picea engelmanni was probably greater on the moderate burn, but basal area of A. lasiocarpa, Pinus contorta, and P. albicaulis was similar on both sites (Table 3). Prefire live tree composition based on density was very similar for both sites, but P. engelmanni and A. lasiocarpa comprised about 54 and 44 percent, respectively, of the basal area on the moderate burn compared to 30 and 66 percent, respectively on the unburned site. Taller and larger diameter P. engelmanni and A. lasiocarpa were probably more numerous on the moderate burn than on the unburned site. Small Pinus Contorta were more abundant on the unburned site, and large P. contorta were more abundant on the moderate burn prior to the fire, all of which suggests that forest succession was more advanced on the moderate burn than on the unburned site prior to the 1974 fire.

All trees on the severely burned site were killed and many were consumed by the 1974 fire, but prefire characteristics of this stand were probably more similar to the moderately burned than to the unburned site.

Approximately 56 percent of the trees but only 10 percent of the basal area may have been killed during the fire and/or during the first postfire year (Tables 6 and 7). Most fire-caused mortality was of trees less than 19 feet (5.7 m) tall (Figure 9), which explains the relatively high tree mortality in terms of density but not in terms of basal area. However, percentages of standing dead trees greater than 19 feet (5.7 m) tall were from 15 to 50 percent greater for trees up to 50 to 60 feet (15.0 m to 18.0 m) tall on the moderate burn than on the unburned site indicating that some taller trees were killed by the fire (Figure 10).

Fire-caused mortality of A. lasiocarpa may have been proportionately greater than of Picea engelmanni in terms of both basal area and density, but primarily the latter (Tables 6 and 7). Importance values decreased for A. lasiocarpa and increased for P. engelmanni following the fire (Table 4), probably because proportionately more of the prefire density of A. lasiocarpa (90 percent) than of P. engelmanni (74 percent) was less than 19 feet (5.7 m) tall; the height class most susceptible to fire.

In 1975 live tree density on the unburned site was 1.9 and 2.4 times greater than on the moderate burn and 1932 burn, respectively, but basal area was similar on the unburned site and moderate burn and about 2.4 times greater on these sites as on the 1932 burn (Table 8). The

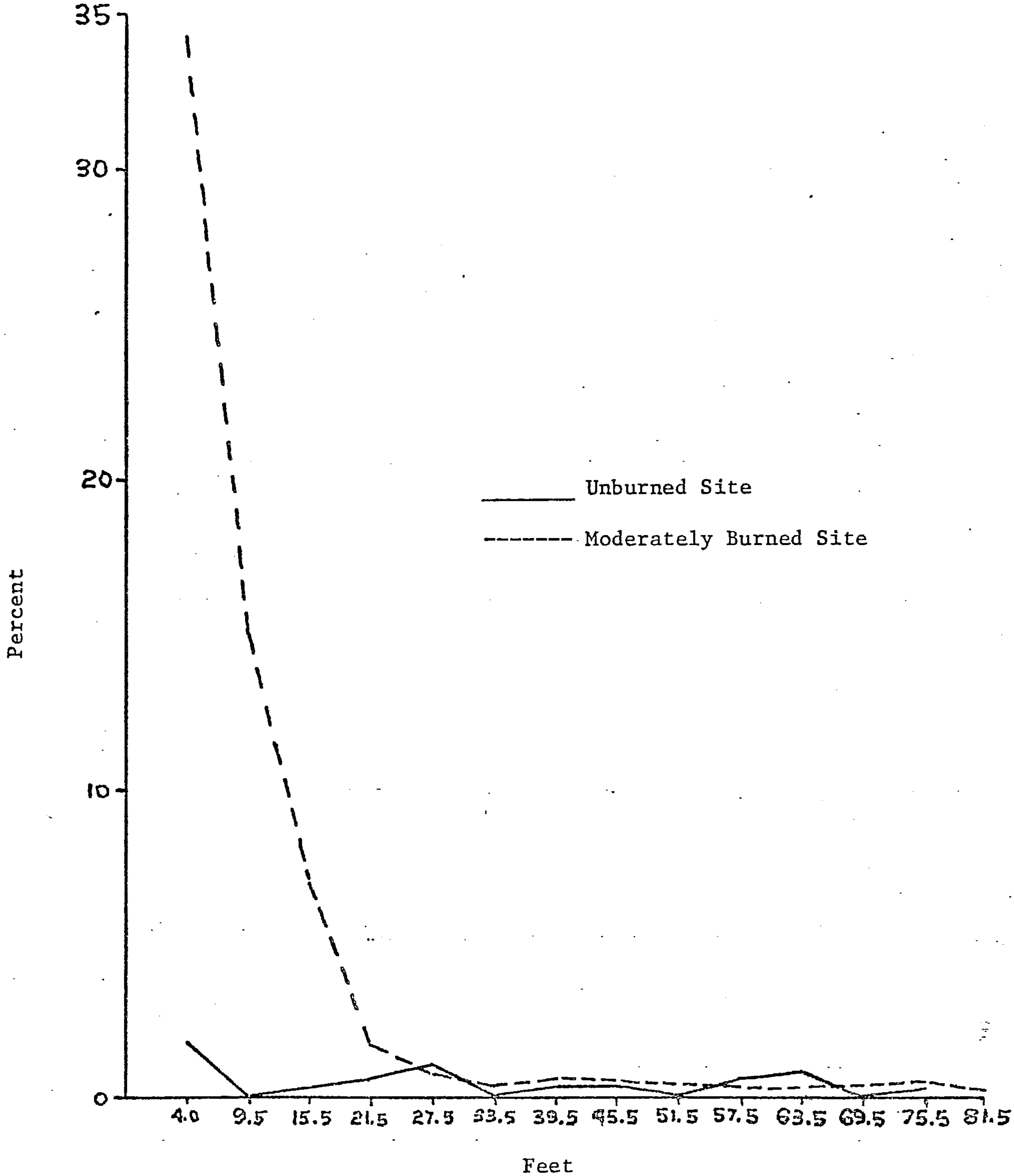


Figure 9. Percentages by height of total standing trees that were dead on the moderately burned and unburned sites, Waterfalls Canyon Burn, 1975.

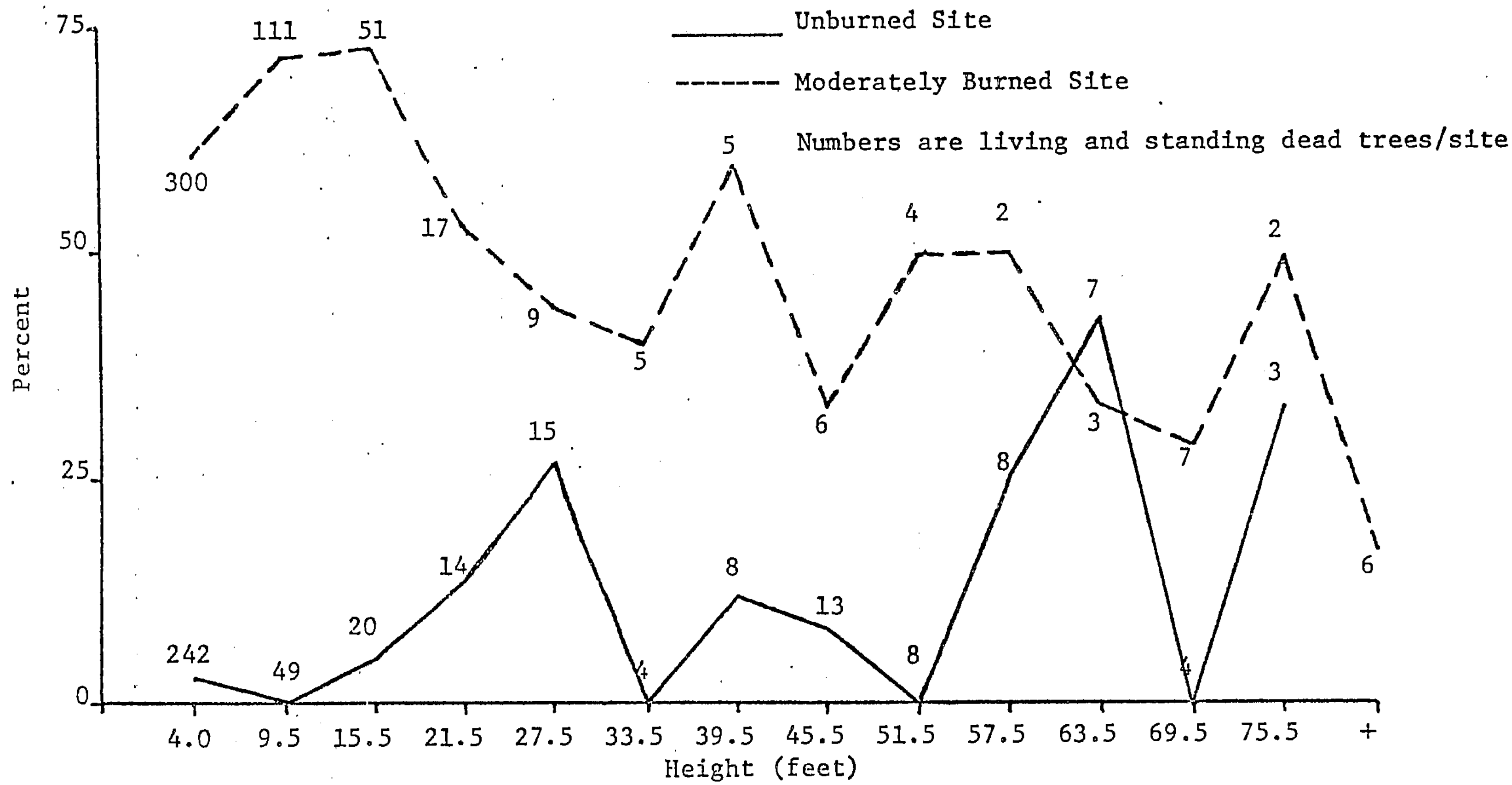


Figure 10. Percentages by height classes of living plus standing dead trees that were dead on the unburned and moderately burned sites, Waterfalls Canyon Burn, 1975.

Table 6. Estimated reduction by fire in the prefire density of live trees on the moderate burn site, Waterfalls Canyon Burn, 1975

	Unburned Site			Moderate Burn				
	Density[a]		Percent	Postfire Density		Prefire Dead	Killed by Fire	
	Total	Dead	Dead	Total	Dead	Density[b]	Density[c]	Percent
Picea engelmanni	205	7	3	317	106	10	150	47
Abies lasiocarpa	1119	79	7	1554	1022	109	913	59
Pinus contorta	65	18	28	22	14	6	8	36
Pinus albicaulis	54	0	0	40	14	0	14	35
All species	1443	104	7	1933	1210	125	1085	56

[a] Trees/acre
[b] Total prefire density on moderate burn X percent dead on unburned site
[c] Postfire dead density - prefire dead density
[d] Percent of total postfire density

Table 7. Estimated reduction due to fire in the prefire basal area of live trees on the moderate burn site, Waterfalls Canyon Burn, 1975.

	Unburned Site			Moderate Burn				
	Basal Area[a]		Percent	Postfire B.A.		Prefire	Killed by fire	
	Total	Dead	Dead	Total	Dead	Dead B.A.[b]	B.A.[c]	Percent[d]
Picea engelmanni	4493	685	15	11,154	3333	1673	1660	15
Abies lasiocarpa	10,895	2326	21	9722	4113	2042	2071	21
Pinus contorta	2380	1913	80	2197	1382	1758	None	None
Pinus albicaulis	11	0	0	19	8	0	8	42
All species	17,779	4924	28	23,092	8836	6466	2370	10

[a] Inches^2/acre
[b] Total B.A. on moderate burn X percent dead on unburned site
[c] Postfire dead B.A. - Prefire dead B.A.
[d] Percent of total postfire B.A.

Table 8. Relative basal area of live trees by diameter classes on three sites, Waterfalls Canyon Burn, 1975.

DBH	*P. engelmanni*			*A. lasiocarpa*			*P. contorta*			*P. albicaulis*			Total		
	Percent														
(inches)	Unb.	Mod.	1932	Unb.	Mod.	1932	Unb.	Mod.	1932	Unb.	Mod.	1932	Unb.	Mod.	1932
0.5	1	T[a]	8	2	1	5	1		1	100	36	36	1	1	1
1.5	1	1		2	3	9	3		1		64	64	1	1	1
2.5	2	1		2	2	18	4		2				2	2	4
3.5	6	2	92	4	2	14			4				5	2	6
4.5	2	3		3		12			9				3	2	9
5.5	2	1		11	5	18			7				8	2	7
6.5	9	5		10	4	24	26		16				10	4	17
7.5	12	3		15					28				14		25
8.5				2	7				24				2	3	21
9.5	13	3		3	14				10				6	7	9
10.5				14	22		67						12	8	
11.5		5		4				46					3	5	
12.5	23			5				54					10	3	
13.5				12									8		
14.5															
15.5					12									5	
16.5					27									10	
+	28	79		10									15	43	
B.A.[b]															
Mean[c]	3808	7821	75	8569	5609	485	467	815	5184	11	11	11	12855	14256	5753
C.V.[d]	52	102	157	51	74	86	92	173	106	27	123	172	27	73	87
Density[e]															
Mean[c]	199	157	36	1042	532	170	48	8	323	54	26	26	1343	723	555
C.V.[d]	46	53	76	13	58	96	75	165	64	53	90	176	16	54	61

[a]T = less than 0.5%
[b]B.A. = basal area in inches 2/acre
[c]n = 3 macroplots
[d]C.V. = coefficient of variation in %
[e]Trees/acre

greater variation between macroplots in both live tree density and basal area on both the moderate and the 1932 burns than on the unburned site is probably due mostly to the mosaic pattern of fire effects but may also partly reflect variation in topography and/or soils on the 1932 burn. Portions of the 1932 burn were still largely in a grass-forb or grass-forb-shrub stage in 1975. Tree re-establishment on these areas has been very slow, although the pattern of fallen trees apparent on aerial photographs suggests that tree cover was fairly uniform prior to the 1932 fire.

In terms of live trees one year postfire, A. lasiocarpa had the highest importance values on both the unburned (144.1) and moderately burned (111.0) sites followed by Picea engelmanni (44.4 and 78.3 on the unburned and moderately burned sites, respectively). Pinus contorta and P. albicaulis were of minor importance (3.6-7.3) on both sites. In contrast, on the 1932 burn P. contorta was by far the most important (148.1), A. lasiocarpa was less important (39.6), and Picea engelmanni and Pinus albicaulis were unimportant (7.8 and 4.7, respectively). (Table 4).

In 1975 live tree density of both P. engelmanni and A. lasiocarpa was greater on the unburned (199 and 1,042 trees /acre (491 and 2,573/ha), respectively) than on the moderately burned site (157 and 532 trees/acre (388 and 1,314/ha), respectively) (Table 9), but relative density of both species was similar on both sites (14.8 and 21.4 percent for P. engelmanni and 77.7 and 73.9 percent for A. lasiocarpa on the unburned and moderately burned sites, respectively) (Table 4). P. engelmanni had both the highest absolute and relative basal area on the moderate burn (7,821 in ^{2}/acre (12.5 m^2/ha) and 56.9 percent, respectively), while

Table 9. Relative dnesity of live trees by height classes on three sites, Waterfalls Canyon Burn, 1975.

Height (feet)	Picea engelmanni Unb.	Picea engelmanni Mod.	Picea engelmanni 1932	Abies lasiocarpa Unb.	Abies lasiocarpa Mod.	Abies lasiocarpa 1932	Percent Pinus contorta Unb.	Pinus contorta Mod.	Pinus contorta 1932	Pinus albicaulis Unb.	Pinus albicaulis Mod.	Pinus albicaulis 1932	Total Unb.	Total Mod.	Total 1932
2- 6	35	32	78	70	64	57	60		32	87	100	85	65	58	45
7-12	25	14		9	17	21	8		12	13		15	12	16	14
13-18	7	14	11	4	5	13	15		9				5	7	10
19-24	6	14	11	3	1	6			2				3	4	4
25-30	6	7		3	1	2			8				3	2	5
31-36	4	2		1	1				8				1	2	4
37-42	2	2		2	1				4				2	1	2
43-48	4	4		3	1		8		9				3	2	5
49-54	6			2	1				9				2	1	5
55-60				2	1				7				1	1	4
61-66				1	1		8						1	1	
67-72	6			T[a]	2			100					1	2	
73-78		2		1	1								1	1	
79-84														1	
85-90		2			1									1	
91-96															
97-102		2			1									1	
+		2												1	
Density[b]	198	158	37	1039	534	170	48	7	324	54	25	26	1339	724	557
Height															
Mean[c]	19	20	6	11	10	8	18	23[e]	24	4	2[f]	2[e]	13	14	18
C.V.[d]	30	32	101	52	30	48	53	173	60	25	90	177	36	10	49
Max.	72	117	20	73	98	29	66	68	58	9	9	10	73	117	58

[a]T = less than 0.5%
[b]Mean Number of trees/acre, n = 3 macroplots
[c]Weighted means calculated from data arrayed in three foot height class intervals, n = 3 macroplots
[d]Coefficient of variation in percent
[e]Present on only one macroplot
[f]Present on only two macroplots

A. lasiocarpa was highest in both categories (8,569 in ^{2}/acre (13.7 m^2/ha) and 66.4 percent) on the unburned site.

On the 1932 burn Pinus contorta was by far the most important species in terms of both absolute and relative density and basal area.

In 1975 a greater proportion of the live tree basal area of both Picea engelmanni (79 percent) and A. lasiocarpa (41 percent) was in large diameter trees (greater than 14.5 inches (36.8 cm) DBH) on the moderate burn than on the unburned site (28 and 10 percent for P. engelmanni and A. lasiocarpa, respectively). Large diameter trees (10.5-12.5 inches (26.7-31.8 cm) DBH) accounted for most of the live tree basal area of Pinus contorta on both the unburned (67 percent) and moderately burned (100 percent) sites (Table 8).

On the 1932 burn trees 6.5-9.5 inches (16.5-24.1 cm) DBH accounted for 78 percent of the live basal area of P. contorta and trees were up to 58 feet (17.7 m) tall. In contrast, all the live basal area was in trees less than 4.5 inches (11.4 cm) DBH and 20 feet (6.1 m) tall for Picea engelmanni and less than 6.5 inches (16.5 cm) DBH and 29 feet (8.8 m) tall for A. lasiocarpa. The live basal area of Pinus albicaulis on all three sites was accounted for by trees less than 2.5 inches (6.4 cm) DBH and 11 feet (3.4 m) tall (Tables 8 and 9).

Terminal leaders of A. lasiocarpa and P. engelmanni were significantly longer on the 1932 burn than on the unburned and moderately burned sites. Lateral leaders of P. engelmanni were significantly longer on the 1932 burn than on the moderate burn and longer (but not significantly so) on the 1932 burn than on the unburned site (Tables 10 and 11). Both

Table 10. Current growth of terminal and lateral leaders for understory trees, Waterfalls Canyon Burn, 1975.

	Mean Length and (n)[a]				Coefficient of Variation[b]			
	Unburned	1932 Burn	1974 Moderate	Overall	Unburned	1932 Burn	1974 Mod.	Overall
Abies lasiocarpa								
Terminal	2.5 (57)	4.7 (27)	3.1 (53)	3.2 (137)	64	70	78	77
Lateral	2.8 (119)	3.2 (30)	3.0 (88)	2.9 (237)	49	42	48	48
Picea engelmanni								
Terminal	2.5 (16)	4.9 (8)	2.4 (10)	3.1 (34)	75	58	30	69
Lateral	2.8 (18)	3.8 (8)	2.2 (12)	2.8 (38)	50	34	26	46
Pinus contorta								
Terminal	5.2 (5)	11.1 (31)		10.2 (36)	62	64		69
Lateral	3.8 (6)	6.8 (33)		6.3 (39)	41	54		57
Pinus albicaulis								
Terminal	3.7 (3)		2.4 (5)	2.9 (8)	81		18	61
Lateral	3.2 (5)		2.1 (7)	2.6 (12)	64		40	57

[a]Length in cm; n = sample size
[b]Percent

Table 11. Analysis of variance in mean current annual growth of terminal and lateral leaders on understory trees, Waterfalls Canyon Burn, 1975.[a]

Source	d.f.		M.S.[c]		Significant Differences Between Means[b]	
	Ter.	Lat.	Terminal	Lateral	Terminal	Lateral
<u>Picea engelmanni</u>						
Among sites	2	2	17.28*	6.18*	1932 > Moderate	1932 > Moderate
Within sites	31	35	3.69	1.39	1932 > Unburned	
<u>Abies lasiocarpa</u>						
Among sites	2	2	41.56**	1.54	1932 > Moderate	
Within sites	134	234	5.43	1.96	1932 > Unburned	
<u>Pinus contorta</u>						
Among sites	1	1	149.09	46.85		
Within sites	34	37	45.98	12.17		
<u>Pinus albicaulis</u>						
Among sites	1	1	3.01	3.26		
Within sites	6	10	3.15	2.12		

[a]Sites were: Unburned, 1932 Burn, 1974 Moderate Burn except <u>P. contorta</u> and <u>P. albicaulis</u> were not measured on the 1974 Moderate Burn and the 1932 Burn, respectively.
[b]Determined by the student-Newman-Keuls Test at $\alpha = 0.05$ (Sokal and Rohlf 1969, Rohlf and Sokal 1969)
[c]Significance level, * = P less than 0.05, ** = P less than 0.01.

terminal and lateral leaders of *P. contorta* were longer on the 1932 burn than on the unburned site but not significantly so. No understory *P. contorta* were encountered on macroplots in the moderate burn. Both terminal and lateral leaders of *P. albicaulis* were longer on the unburned than on the moderate burn but not significantly so. This species was not encountered on macroplots in the 1932 burn. Current growth of both terminal and lateral leaders of all species except *P. albicaulis* (not measured) was greatest on the 1932 burn (Table 10). This was associated with lower tree density and less than half the basal area on the 1932 burn as on the other two sites (Table 8). There was no evidence that the 1974 fire significantly affected terminal or lateral leader growth of understory trees one year postfire.

Frequency of occurrence and density of all tree seedlings produced in 1975 was greater on the moderate burn than on other sites (Table 12). Only seedlings of *P. engelmanni* and *A. lasiocarpa* were encountered on the moderate burn. Moderately severe fire which reduced live tree density and basal area about 56 and 10 percent, respectively, which reduced aerial coverage of herbs and shrubs, and which altered ground surface characteristics, apparently enhanced tree seedling production the first postfire summer. The species of seedlings produced were the same as those that dominated the pre and postfire tree overstory. Total production of tree seedlings on the severely burned site was very low and similar to unburned sites.

Seedlings of both *P. engelmanni* and *A. lasiocarpa* were more abundant on the moderate burn than on the unburned site. Only *P. engelmanni*

Table 12. Frequency of occurrence and density of tree seedlings produced during 1975, Waterfalls Canyon Burn.

	Frequency and (Density)[a]							
	Means[b]				Coefficient of Variation[c]			
	Unburned	1932 Burn	1974 Burn Moderate	1974 Burn Severe	Unburned	1932 Burn	1974 Burn Moderate	1974 Burn Severe
Abies lasiocarpa	3 (T)[d]		20 (3)		88		114 (120)	
Pica engelmanni			30 (7)	13 (2)			44 (46)	58 (62)
Pinus contorta		5 (1)				174 (175)		
Pinus albicaulis								
Unidentified	2 (T)	2 (T)			170	145		
Total	5 (T)	7 (1)	45 (10)	13 (2)	100	109 (160)	33 (26)	58 (62)

[a] Frequency in percent, density = number/m^2
[b] n = 3 macroplots/site
[c] Percent
[d] T = mean of less than $0.5/m^2$

seedlings were encountered on the severe burn, and only A. lasiocarpa seedlings were encountered on the unburned site. This suggests that factors associated with moderately severe fire enhanced the first year postfire production of both A. lasiocarpa and P. engelmanni compared to production on unburned sites, and that both moderate and severe fire may have disproportionately favored production of P. engelmanni seedlings compared to A. lasiocarpa.

The specific factors responsible for these differences in seedling production are not known, but on the moderate burn most seedlings became established only where the soil surface had been disturbed by fire. This combined with a still abundant seed source in the partially intact tree overstory may explain why seedlings were more abundant on the moderate burn compared to the severe burn where the soil surface was disturbed by fire but where most seed may have been destroyed when the tree overstory was consumed.

The Herb and Shrub Stratum

Although plant basal area was similar on all sites (Table 1), total canopy coverage was similar only on the unburned and 1932 burn sites and was about 3.5 times greater on those sites as on those burned in 1974 (Table 13). Shrubs accounted for most of the greater coverage on the unburned site than on those burned in 1974, but all three plant categories (grasses and grasslike, forbs and shrubs) had considerably more coverage on the 1932 burn than on sites burned in 1974. Coverage of grasses and grasslike plants and of forbs on the 1932 burn were considerably higher than on the other sites.

Mushrooms (Morchella angusticeps) were abundant on the moderate and,

Table 13. Frequency of occurrence and canopy coverage of herbs and shrubs, Waterfalls Canyon Burn, 1975.

	Mean frequency and (coverage)[a]				Coefficient of Variation (%)			
		1932	1974 Burn			1932	1974 Burn	
	Unburned	Burn	Moderate	Severe	Unburned	Burn	Moderate	Severe
Totals	(72)	(69)	(19)	(17)	(10)	(45)	(35)	(17)
Grasses and grasslike	72 (12)	87 (24)	53 (10)	73 (5)	22 (36)	14 (62)	6 (35)	22 (44)
Forbs	54 (7)	73 (20)	22 (1)	67 (10)	24 (45)	28 (119)	73 (50)	19 (36)
Shrubs	95 (53)	53 (25)	40 (8)	28 (2)	5 (5)	6 (36)	33 (36)	45 (111)
Grasses and grasslike								
Agropyron sp.		7 (T)[b]				164		
Calamagrostis rubescens	42 (6)	78 (12)	7 (1)	15 (1)	38 (66)	24 (84)	41 (150)	67 (88)
Carex geyeri	47 (6)	58 (11)	50 (9)	67 (4)	53 (111)	35 (72)	0 (57)	16 (58)
Melica spectabilis				12 (T)				63
Phleum alpinum		2 (T)				145		
Stipa sp.	3 (T)	13 (1)		2 (T)	175	178 (182)		145
Trisetum spicatum		2 (T)				145		
Forbs								
Achillia millefolium		2 (T)				145		
Aconitum columbianum				3 (T)				193
Agoseris aurantiaca		2 (T)				145		
A. glauca		3 (T)				97		
Antennaria microphylla		7 (T)				109		
Arnica cordifolia	18 (2)	15 (1)	2 (T)	38 (4)	42 (86)	120 (138)	145	27 (60)
Aster sp.		17 (2)		2 (T)		145 (138)		145
Astragalus sp.				10 (1)				50 (136)
Campanula rotundifolia		13 (1)				118 (133)		
Chenopodium sp.				2 (T)				145
Epilobium sp.				2 (T)				145
E. angustifolium			15 (T)	20 (1)			67	25 (11)
Frageria sp.		7 (2)				164 (172)		
Galium boreale		7 (T)		7 (T)		164		109
Geranium sp.		3 (T)				193		

Table 13. Continued

	Mean frequency and (coverage)				Coefficient of Variation (%)			
		1932	1974 Burn			1932	1974 Burn	
	Unburned	Burn	Moderate	Severe	Unburned	Burn	Moderate	Severe
Goodyera oblongifolia	10 (T)		3 (T)		87		193	
Hieracium albiflorum	10 (T)	28 (2)	5 (T)		50	88 (88)	100	
Iliamna rivularis				10 (1)				50 (141)
Lactuca sp.				2 (T)				145
Lupinus sp.		17 (6)				170 (173)		
Dracocephalum parviflorum				22 (2)				13 (26)
Osmorhiza chilensis	15 (1)	3 (T)			58 (100)	97		
Pedicularis sp.	12 (T)				89			
Perideridia gairdneri		13 (1)				178 (180)		
Polygonum sp.		5 (T)				174		
Pyrola asarifolia	13 (T)				95			
Taraxacum officinale		37 (4)				109 (124)		
Thalictrum fendleri	10 (2)			2 (T)	50 (34)			145
Viola sp.		13 (1)		2 (T)		118 (117)		145
Shrubs								
Amelanchier alnifolia	2 (1)				170 (164)			
Berberis repens	7 (T)	12 (1)	2 (T)	2 (T)	114	168 (169)	145	145
Ceanothus velutinus		23 (12)				88 (116)		
Chimaphila umbellata	52 (5)	2 (T)	17 (1)		39 (22)	145	104 (86)	
Lonicera utahensis	27 (9)	2 (1)	5 (1)	3 (1)	22 (29)	145 (164)	174 (167)	97 (128)
Sorbus scopulina	2 (T)				170			
Spirea betulifolia	27 (4)	22 (3)	7 (1)	8 (1)	66 (82)	80 (109)	83 (100)	95 (112)
Symphoricarpus oreophilus		8 (2)				180 (175)		
Vaccinium membranaceum	80 (33)	15 (4)	30 (6)	23 (1)	16 (18)	115 (136)	17 (48)	55 (92)
V. scoparium	2 (T)	3 (T)			170	193		

[a]Expressed as precent, n = 3 macroplots/site
[b]T = less than 0.5%

particularly, the severe burn one year postfire but were not observed on the unburned site or the 1932 burn. On the severe burn 79 M. angusticeps were counted in a belt 100 paces long by 3 feet wide one year postfire.

Canopy coverage of grasses and grasslike plants was greatest on the 1932 burn (24 percent compared to 5-12 percent on other sites) but varied more between macroplots than on other sites. The 1974 fire may have reduced canopy coverage of grasses and grasslike plants on the severely burned site but apparently had little influence on frequency of occurrence. Calamagrostis rubescens and Carex geyeri made up essentially all the coverage and had the highest frequency of occurrence on all sites and were most important on the 1932 burn. Canopy coverage and frequency of occurrence of C. geyeri were similar on all sites, but the 1974 fire may have reduced both coverage and frequency of occurrence for C. rubescens on both moderately and severely burned sites. Melica spectabilis was sparse on the severe burn but absent on other sites.

Forb canopy coverage and frequency of occurrence were highest on the 1932 burn, but coverage varied greatly between macroplots. Frequency and coverage were next highest on the severe burn and were lowest on the moderate burn. Individual species of forbs had relatively low frequency of occurrence and coverage on all sites. No species had a frequency higher than 37-38 percent (Taraxacum officinale on the 1932 burn and Arnica cordifolia on the severe burn) or coverage greater than 4-6 percent (Lupinus sp. and T. officinale on the 1932 burn and A. cordifolia on the severe burn). A. cordifolia, the only forb encountered on all four sites, had highest frequency of occurrence and coverage on the severe burn.

Frequency and coverage of shrubs were by far the highest on the unburned site, were next highest on the 1932 burn, and were lowest on the severe burn. Vaccinium membranaceum was the most important shrub on the unburned site and retained its relative importance on both sites burned in 1974, though at much lower frequency and coverage. Chimaphila umbellata and Lonicera utahensis were also relatively important on the unburned site but not the others. In contrast, Ceanothus velutinus was the most important shrub on the 1932 burn but was not encountered on the other sites.

More species of shrubs (4) were common to all sites than of grasses and grasslike plants (2) or forbs (1).

Assuming that prefire plant composition on the burned and unburned sites was similar, the following fire effects and postfire successional processes can be tentatively suggested.

Shrubs were the most dominant component of the herb and shrub stratum in unburned spruce-fir forest and least dominant on the severe burn. The 1974 fire destroyed most of the shrub canopy on the severe burn and reduced it greatly on the moderate burn. Vaccinium membranaceum was particularly hard hit. Chimaphila umbellata which was common on the unburned site was not encountered on the severe burn. Most shrub coverage on the severe burn and much of it on the moderate burn one year postfire was from root sprouts. Mean height of V. membranaceum was 38, 34, 23, and only 3 cm on the unburned, 1932 burn, moderate

Table 14. Mean maximum height of shrubs, Waterfalls Canyon Burn, 1975.[a]

	Means and (n)				Coefficient of Variation (%)			
	Unburned	1932 Burn	1974 Burn		Unburned	1932 Burn	1974 Burn	
			Moderate	Severe			Moderate	Severe
Berberis repens		12 (7)				39		
Ceanothus velutinus		68 (14)				22		
Chimaphila umbellata	11 (31)		11 (8)		55		51	
Lonicera Utahensis	45 (16)				36			
Spirea betulifolia	25 (16)	32 (15)	24 (4)	15 (4)	46	62	57	69
Vaccinium membranaceum	38 (44)	34 (9)	23 (18)	3 (13)	37	64	82	81

[a]Height in cm.

burn, and severe burn, respectively (Table 14).

Compared to unburned spruce-fir forest, no new shrub species were encountered one year postfire. By 43 years postfire, shrub coverage and frequency were about half that of unburned spruce-fir forest but differed considerably in species composition. Ceanothus velutinus was the most important shrub on the 1932 burn, and Symphoricarpus oreophilus was encountered there but neither species was encountered on other sites. On the severe burn and perhaps on the moderate burn, Ceanothus velutinus and Symphoricarpus oreophilus may become more abundant and remain so for at least 43 years postfire, and then disapper as succession to spruce-fir forest proceeds.

Following severe fire, Vaccinium membranaceum may remain relatively unimportant at least for 43 years postfire but increase greatly as succession proceeds to spruce-fir forest. Chimaphila umbellata and Lonicera utahensis also may remain relatively unimportant for at least 43 years postfire but increase sometime thereafter. Spirea betulifolia may increase somewhat by 43 years postfire and change little thereafter as succession proceeds to mature spruce-fir forest. Berberis repens may remain a minor component of the herb and shrub stratum throughout succession to spruce-fir forest. These successional processes will probably be accelerated on the moderate burn as compared to the severe burn.

Forbs that may be relatively important in early postfire succession but that may decrease or disappear before 43 years postfire include:

Astragalus sp.
Epilobium angustifolium
Iliamna rivularis
Dracocephalum parviflorum

Forbs that may increase in importance from early postfire at least through 43 years postfire and then decrease as succession proceeds to spruce-fir forest include:

Aster sp.
Campanula rotundifolia
Frageria sp.
Lupinus sp.
Perideridia gairdneri
Taraxacum officinale
Viola sp.

Some forbs characteristic of spruce-fir forest may have been largely eliminated by severe but not moderately intense fire. These include *Goodyera oblongifolia* and *Hieracium alfiflorum*. *Osmorhiza chilensis*, *Pedicularis* sp., and *Pyrola asarifolia* may have been eliminated by both moderate and severe fire.

The relative importance of grasses and grasslike plants may change little from one year postfire through succession to spruce-fir forest. The 1974 fire apparently had little impact on *Carex geyeri* but considerably reduced both coverage and frequency of *Calamagrostis rubescens*. Both species may increase at least through 43 years postfire and then decline somewhat in more mature spruce-fir forest.

Species diversity was greatest on the 1932 burn (31 species) and least on the moderate burn (11 species). Forbs were more numerous on the 1932 burn (17 species) and the severe burn (13 species). From the first year through at least 43 years postfire, severe fire in spruce-fir forest apparently increases plant diversity, particularly the number of forb species (Table 15).

Table 15. Number of plant species, Waterfalls Canyon Burn, 1975.

	Unburned	1932 Burn	1974 Burn	
			Moderate	Severe
Grasses and Grasslike	3	6	2	4
Forbs	7	17	4	13
Shrubs	8	8	5	4
Total	18	31	11	21

Animals

Insects

Large woodwasps (Urocerus gigas flavicornus and Sirex juvencus californicus; SIRICIDAE) known to fire fighters as the "fire bug", oviposited at the base of still smoldering trees in the severe burn but disappeared within five days after it burned (nomenclature follows Borror and Delong 1971).

During summer, 1975, prodigious numbers of roundheaded borers (Monochamus sp. and Xylotrechus longitarsis; CERAMBYCIDAE) were under the bark of fire-killed trees. The borer's noisy chewing was one of the more prominent sounds throughout the burn. Woodpeckers fed extensively on these borers in 1975. One woodpecker captured seven borers/minute during a five minute period.

Most insects collected in 1975 were Diptera (flies), Hymenoptera (bees, wasps, and ants), and Hemiptera (true bugs). Coleptera (beetles) and Trichoptera (caddis flies) were also present, and 14 percent of the samples (larvae, etc.) were not classified to order.

Birds

Summer 1974. On July 25 immediately after fire had swept through the severe burn site, hundreds of pine siskins were observed in the tops of fire-killed trees apparently feeding on seeds released from cones. Numerous pine siskins were still present when the area was last visited three weeks later. Cassin's finches, hairy woodpeckers, northern three-toed woodpeckers, western tanagers and robins were also present immediately after the fire, but pine siskins and Clark's nutcrackers were more abundant (common and scientific names of birds are in Table 35). Two western tanagers were observed feeding near flames, and Clark's nutcrackers fed on large wood-wasps ovipositing in the bases of fire-killed trees.

Summer 1975. Both the number of breeding species and total density of breeding pairs were highest on the unburned and moderately burned sites, somewhat lower on the 1932 burn, and by far the lowest on the severe burn. Differences in total species observed were less pronounced and suggested that some species may have fed on the severe burn but did not nest there (Table 16). Severe but not moderate fire in spruce-fir forest resulted in lower total breeding bird density and diversity one year postfire that may persist for at least 43 years.

Golden-crowned kinglets, mountain chickadees, and Audubon's warblers were the most abundant breeding species on the two unburned sites; Swainson's thrushes and chipping sparrows on the moderate burn; chipping sparrows on the 1932 burn; and northern three-toed woodpeckers on the severe burn.

Northern three-toed woodpeckers (listed as rare in the Park, Anonymous 1973) concentrated on the severe burn and to a lesser extent on the moderate burn compared to other sites. Their density on the severe burn (34/100 acres) was second only to that of chipping sparrows on the 1932 burn (39/100 acres). Work by Taylor (1969) in Yellowstone National Park suggests that the nesting density of this fire-associated species will decline to none by about seven years postfire.

Table 16. Density of breeding pairs of birds, Waterfalls Canyon Burn, June 25 to July 8, 1975.

	Mean Breeding Pairs/100 Acres[a]				
	Unburned		1932 Burn	1974 Burn	
	Spruce Fir I	Spruce Fir II		Moderate	Severe
Tetraonidae					
Ruffed Grouse			2 (200)		
Picidae					
Northern Three-toed Woodpecker	P1[b]	2 (200)		7 (67)	34 (29)
Black-backed Woodpecker				2 (200)	5 (115)
Hairy Woodpecker	2 (200)	P1	2 (200)	5 (200)	
Yellow-bellied Sapsucker			2 (200)		
Tyrannidae					
Western Wood Pewee		P1		5 (200)	P3
Hirundinidae					
Tree Swallow			P1		
Corvidae					
Gray Jay	10 (141)	7 (200)	15 (159)	7 (200)	2 (200)
Paridae					
Mountain Chickadee	15 (86)	24 (69)	5 (115)	15 (67)	P1
Sittidae					
Red-breasted Nuthatch	7 (67)	2 (200)		P2	
Certhiidae					
Brown Creeper		2 (200)		5 (115)	
Turdidae					
Robin	P1	P1		P1	P3
Swainson's Thrush	10 (115)	12 (40)	P2	19 (41)	P3
Mountain Bluebird					P1

Table 16. Continued.

	Mean Breeding Pairs/100 Acres[a]				
	Unburned		1932 Burn	1974 Burn	
	Spruce Fir I	Spruce Fir II		Moderate	Severe
Sylviidae					
Ruby-crowned Kinglet	12 (101)	2 (200	P1	2 (200)	P1
Golden-crowned Kinglet	22 (76)	29 (54)		P1	
Parulidae					
Audubon's Warbler	24 (69)	P3	5 (115)	5 (115)	
Thraupidae					
Western Tanager	15 (86)	5 (115)		10 (0)	
Fringillidae					
Pine Grosbeak	2 (200)		2 (200)		
Pine Siskin	2 (200)	10 (141)		P3	P1
Red Crossbill	P1	P1	P1	P1	
Oregon Junco	10 (141)	2 (200)	2 (200)	12 (77)	10 (82)
Chipping Sparrow	10 (82)	2 (200)	39 (20)	19 (100)	P3
Total Breeding Pairs	141 (35)	102 (37)	75 (40)	114 (16)	51 (36)
Number of species in transects	13	12	9	13	4
Number of species on the site	16	17	13	18	12

[a]n = 4 censuses per site, coefficient of variation in parenthesis.
[b]P = present on the site but not within the census transect. Following P is the number of censuses during which the species was present.

Black-backed three-toed woodpeckers also nested on the severe and moderate burns but were not observed on other sites. This species is not on the Park's bird list (Anonymous 1973), although Salt (1957) recorded 0.7 breeding pairs/100 acres in spruce-fir forest west of String Lake.

Taylor (1973a) described a "tree hole cycle" initiated by forest fires that leave standing fire-killed trees in their wake. Woodpeckers concentrate on burned areas to nest in the dead trees and to feed on the abundant insect larvae that attack the trees. Mountain bluebirds, tree swallows, and some other birds later nest in these holes. Mountain bluebird population levels may be partially dependent on forest fires and nesting sites created by woodpeckers in fire-killed trees. Taylor (1973a) believed that hairy woodpeckers initiated the tree hole cycle in burned lodgepole pine forest in Yellowstone National Park where northern three-toed woodpeckers were rarely seen. However, the youngest stand he examined was five years postfire. In the burned spruce-fir forest described here, the cycle was initated by northern and black-backed three-toed woodpeckers in place of or in combination with hairy woodpeckers. Five successful three-toed woodpecker nests were observed. Although present on the severe burn, mountain bluebirds apparently did not nest and eventually left.

Mean total breeding bird density for the two unburned spruce-fir stands sampled during this study was similar to that for a spruce-fir stand sampled by Salt (1957), but the diversity of breeding species was lower than he found (Table 17). Breeding pair density for individual species and for these grouped by similar feeding habitats varied greatly

Table 17. Density of breeding birds in lodgepole pine and spruce-fir vegetation types, Grand Teton National Park.[a]

	Number of Breeding Pairs/100 Acres					
	Lodgepole Pine		Spruce Fir			
	Salt (1957) n=6	This Study 1932 Burn	Salt (1957) n=11	This Study: Spruce Fir I	This Study: Spruce-Fir II	This Study: Moderate
Air Perching			1		P1[b]	5
Olive-sided Flycatcher			1			
Western Wood Pewee					P1	5
Foliage-Insect	12	5	41	73	36	17
Audubon's Warbler	7	5	8	24	P3	5
Western Tanager	5		13	15	5	10
Ruby-crowned Kinglet			8	12	2	2
Golden-crowned Kinglet			12	22	29	P1
Foliage-Seed	7	17	25	14	17	7
Gray Jay	3	15		10	7	7
Clark's Nutcracker	2		20			
Pine Siskin	2	P1	1	2	10	P3
Pine Grosbeak		2	4	2		
Red Crossbill		P1		P1	P1	P1
Timber Searching	7	5	15	22	28	20
Mountain Chickadee	7	5	7	15	24	15
Brown Creeper			4		2	5
Red-Breasted Nuthatch			4	7	2	P2
Timber-Drilling		4	4	2	2	14
Hairy Woodpecker		2	3	2	P1[b]	5
B.-backed 3-toed Woodpecker			1			2
Northern three-toed Woodpecker				P1	2	7
Yellow-bellied Sapsucker		2				

Table 17. Continued.

	Number of Breeding Pairs/100 Acres					
	Lodgepole Pine		Spruce Fir			
	Salt (1957) n=6	This Study 1932 Burn	Salt (1957) n=11	This Study		
				Spruce-Fir I	Spruce-Fir II	Moderate
Ground-Insect	2	39	14	20	14	38
Chipping Sparrow	2	39	3	10	2	19
Robin			4	P1	P1	P1
Hermit Thrush			4			
Swainson's Thrush		P2	3	10	12	19
Ground-Seed	10	2	8	10	2	12
Oregon Junco	10	2	7	10	2	12
Cassin's Finch			1			
Total Breeding Pairs	38	72	108	141	102	114
Breeding Species	8	9	19	13	12	13

[a] Data from Salt (1957) are rounded to the nearest breeding pair
[b] P = present on the site but not in census transect. Following P is the number of censuses that the species was present
[c] n = 4 censuses on each site during this study

between the two spruce-fir stands sampled in this study and were quite different from densities reported by Salt. The Clark's Nutcracker was the most abundant breeding bird in the spruce-fir stand sampled by Salt but was not present in either stand sampled during this study.

Mean total breeding bird density in the open and highly variable lodgepole pine stand sampled during this study (1932 burn) was greater and species diversity was similar to that for a dense, even-aged lodgepole pine stand sampled by Salt (1957) (Table 17). The most notable differences were much larger numbers of gray jays and chipping sparrows in the more open stand and greater numbers of Oregon juncos in the dense, even-aged stand.

Wide variation in counts within and between stands sampled during this study and lack of a measure of within stand variation in counts by Salt preclude more detailed comparisons. This variation may reflect actual population differences between study periods, differences in environmental and/or stand characteristics, inadequacies of census techniques or any combination of these and other factors with inadequate census techniques probably responsible for much of the variation.

Mammals

Summer 1974. There was little evidence of immediate and direct mortality of mammals from the fire. Only one red-backed vole that apparently suffocated near the entrance to its burrow was found during a search of a severely burned area two days after it burned (common and scientific names of mammals are in Table 35). Other studies have shown that direct mortality of mammals from fire may vary greatly but is usually low (Bendell 1974).

Although some small mammals were probably killed directly by fire in severely burned areas (mostly by suffocation, Bendell 1974), many may have survived underground or by moving to less severely burned or unburned peripheral areas. Most mammals probably survived direct mortality by fire in moderately burned areas where clumps of vegetation, logs, and litter were unburned, temperatures were lower, oxygen reduction and persistence of noxious gasses was less, and where the slower rate of fire spread permitted escape.

Part of the severely burned study site that burned on July 26, 1974 was snap-trapped August 8-10, 1974. During 360 trap nights seven red-backed voles and 8 deer mice were taken at least 200 yards from any unburned vegetation. Abundant conifer seeds on the soil surface that were released from fire-killed trees may have attracted these small mammals. Moose, elk, and probably other large mammals were present throughout the burn in areas that were still smoldering and they remained there after the fire was out.

Summer 1975. During the July 1-18, 1975 trapping period about twice as many individual small mammals (all species combined) were trapped on the severely and moderately burned sites as on the 1932 burn and unburned site. Yellow pine chipmunks and deer mice accounted for most of the difference. Numbers of individual red-backed voles were similar on all areas (Table 18).

By August 16-23, 1975 the total number of individual small mammals trapped was similar on all sites and from 2 to 5 times greater than during the July 1-18 period (Table 19), largely due to young animals, but

Table 18. Small mammal live trapping results, July 1-18, 1975, Waterfalls Canyon Burn

	Number of Individuals (Percent Mortality) Number of Recaptures				
	1974 Severe	1974 Moderate	1932 Burn	Unburned	Totals
Yellow Pine Chipmunk					
Young			1(100)0		1(0) 0
Adults	2(0) 0	8(50) 5			10(50) 5
Total	2(0) 0	8(50) 5	1(100)0		11(45) 5
Deer Mouse					
Young		2(0) 1			2(0) 1
Adults	4(0) 6	2(50) 5	1(0)1	2(0)0	9(11)12
Total	4(0) 6	4(25) 6	1(0)1	2(0)0	11(9)13
Red-backed Vole					
Young		1(0) 0		1(100)0	2(50) 0
Adults	3(0) 4	1(0) 0	3(100)1	3(33)2	10(40) 7
Total	3(0) 4	2(0) 0	3(100)1	4(50)2	12(42) 7
Mountain Vole					
Young					
Adult	1(100) 0				1(100) 0
Total	1(100) 0				1(100) 0
Totals					
Young		3(0) 1	1(100)0	1(100)0	5(40) 1
Adult	10(10)10	11(55)10	4(75)2	5(40)2	30(37)24
Total	10(10)10	14(43)11	5(80)2	6(33)2	35(37)25

Table 19. Small mammal live trapping results, August 16-23, 1975, Waterfalls Canyon Burn.

	Number of Individuals (Percent Mortality) Number of Recaptures				
	1974 Severe	1974 Moderate	1932 Burn	Unburned	Totals
Yellow Pine Chipmunk					
Young		2(0) 0	2(100) 0		4(50) 0
Adults	1(0) 0	4(50) 6	6(83) 2		11(64) 8
Total	1(0) 0	6(33) 6	8(88) 2		15(60) 8
Deer Mouse					
Young	17(24)13	8(25)10	7(14) 8		32(21)31
Adults	5(0)14	3(25) 5	5(0) 3	1(0) 1	14(7)23
Total	22(18)27	11(27)15	12(9)11	1(0) 1	47(17)54
Red-backed Vole					
Young	5(40) 1	7(57) 5	1(0) 0	12(42) 2	25(44) 8
Adults	3(67) 7	2(100) 2	6(33) 2	13(38) 8	24(46)19
Total	8(50) 8	9(67) 7	7(29) 2	25(40)10	49(45)27
Totals					
Young	22(28)14	17(35)15	10(30) 8	12(42) 2	61(33)39
Adults	9(22)21	9(56)13	17(44) 7	14(36) 9	50(38)50
Total	31(26)35	26(44)28	27(38)15	26(38)11	111(35)89

more adults were also present on the 1932 burn and unburned site in August than in July.

Cold, rainy weather influenced trapping results on the 1932 burn and unburned site during the August 16-23 period, but trap mortality was high on other areas as well and varied markedly between areas, species, and trapping periods (Tables 18 and 19). Population estimates and confidence intervals are presented in Table 20.

Totals of 4, 3, 3, and 2 species of small mammals were trapped on the severe burn, moderate burn, 1932 burn, and unburned site, respectively. Red squirrels were observed on all but the severely burned site; thus small mammal species diversity was similar for all sites. Negus and Findley (1959) trapped three species in spruce-fir-whitebark pine forest (vagrant shrew, deer mouse, and red-backed vole) but only one species (vagrant shrew) in lodgepole pine forest.

Yellow pine chipmunks were trapped on all but the unburned area during both trapping periods. Negus and Findley (1959) found that the center of abundance for this species was in aspen stands and lodgepole pine forest, especially more open sites with shrub and forb ground cover, but that Uinta chipmunks replaced yellow pine chipmunks in spruce-fir forest. Neither yellow pine or Uinta chipmunks were trapped or observed in unburned spruce-fir forest in 1975.

The presence of yellow pine chipmunks in the 1932 burn but not the adjacent unburned site indicates their apparent preference for more open and/or earlier succession forest types as noted by Negus and Findley (1959). Their presence one year postfire in the moderately and severely burned sites suggests early dispersal into formerly dense spruce-fir forest

Table 20. Estimated density of small mammals, Waterfalls Canyon Burn, 1975[a].

	Number/0.5 hectare				
	1974 Severe	1974 Moderate	1932 Burn	Spruce-Fir I	Spruce-Fir II
July 1-18					
Yellow Pine Chipmunk		8 (2.7-21.5)			8 (0.6-152.4)
Deer Mouse	3 (1.0- 6.6)	4 (1.3- 8.2)	1 (0.1-19.5)		1 (0.1- 19.5)
Red-backed Vole	3 (0.8- 8.9)		3 (0.2-58.5)	3 (0.5-19.5)	10 (3.2- 25.7)
Total	9 (4.4-17.6)	13 (6.2-23.3)	6 (0.9-33.4)	6 (0.9-34.5)	18 (7.3- 40.0)
August 16-23					
Yellow Pine Chipmunk		7 (2.6-16.5)	6 (1.0-35.0)		
Deer Mouse	19 (12.1-27.0)	11 (6.3-19.1)	10 (4.8-18.0)		
Red-backed Vole	10 (4.0-19.2)	7 (0.7-15.3)	11 (1.6-60.5)	32 (14.9-59.8)	
Total	29 (20.0-40.2)	27 (17.4-38.4)	28 (15.1-50.0)	35 (16.2-65.0)	

[a] Population estimate and 95 percent confidence interval in parentheses calculated according to methods described in Overton and Davis (1969).

opened up by fire.

Deer mice and red-backed voles were trapped on all sites during both trapping periods, and similarly low numbers of each species were trapped on each site in July. However, in August many more deer mice were trapped on the three burned sites (particularly the severe burn) than on the unburned site, and many more red-backed voles were trapped on the unburned than on the three burned sites where numbers trapped were similar (Tables 19 and 20). Negus and Findley (1959) found red-backed voles common in spruce-fir forest but absent from lodgepole pine forest.

Several small mammal species that might have been expected on one or more of the study sites were not trapped or observed in 1975 (Table 21). Elk and moose tracks and droppings were abundant throughout the burn in 1975. These species plus mule deer and black bear were summer and fall residents. Extensive browsing of understory _Abies lasiocarpa_ indicated winter and/or spring use by moose which may have been reduced by extensive fire-caused mortality of _A. lasiocarpa_ throughout the burn.

Total small mammal biomass (first captures) in July was about 2 and 4 times greater on the severely burned and moderately burned sites, respectively, than on the 1932 burn and unburned sites which were quite similar (Table 22). In August total biomass was somewhat lower on the unburned site than on the three burned sites which were similar. Yellow pine chipmunk biomass was much greater on the moderate burn than on other sites in July, but in August their biomass was similar on the moderate burn and 1932 burn and much higher there than on the severe

Table 21. Small mammal species collected from lodgepole pine and spruce forests within or near Grand Teton National Park.

	Negus and Findley (1959)		Taylor (unpublished)	
	Lodgepole Pine (Signal Mt.)	Spruce (Togwotee Pass)	Lodgepole Pine (Signal Mt.)	Lodgepole Pine (Beaver Creek)
Masked Shrew				X
Vagrant Shrew	X			
Uinta Chipmunk		X		
Least Chipmunk	X			
Yellow Pine Chipmunk	X		X	X
Red Squirrel	X	X	X	X
Northern Flying Squirrel	X	?	?	?
Deer Mouse			X	
Meadow Vole			X	
Mountain Phenacomys			X	
Red-backed Vole		X	X	X
Western Jumping Mouse				X

Table 22. Biomass of live trapped small mammals, Waterfalls Canyon Burn, 1975.

	Total Biomass of Individuals (gm/ha)									
	1974 Severe		1974 Moderate		1932 Burn		Unburned		Total	
	July	Aug.	July	Aug.	July	Aug.	July	Aug.	July	Aug.
Yellow Pine Chipmunk										
Young				134	80	158			80	364
Adults	166	120	770	394		536			936	1094
Total	166	120	770	528	80	694			1016	1458
Deer Mouse										
Young		464	40	212		188			38	864
Adults	182	224	100	174	44	200	82	42	408	672
Total	182	688	140	386	44	388	82	42	446	1536
Red-backed Vole										
Young		72	22	214		20	20	282	42	588
Adult	144	150	42	86	112	272	123	644	442	1300
Total	144	222	64	300	112	292	143	926	484	1888
Mountain Vole										
Adult	72								72	
Total										
Young		536	62	560	80	366	20	282	160	1816
Adult	564	494	912	654	156	1008	205	686	1858	3066
Total	564	1030	974	1214	236	1374	225	968	2018	4882

burn. Deer mice biomass was highest on the severe burn in July and particularly during August when it was 2 to 8 times higher on the severe burn than on other sites. In August no young deer mice were captured on the unburned site, and deer mice biomass there was only 6-11 percent as high as on other sites. In July biomass of red-backed voles on the moderate burn was about half that on other sites, but in August their biomass was 3-4 times greater on the unburned site than on other sites.

Mean weights of live trapped small mammals are summarized in Tables 23 and 24.

Preliminary interpretation of live trapping data (primarily for August) suggests that the 1974 Waterfalls Canyon Fire changed the species composition and relative abundance of small mammals characteristic of spruce-fir forest. Compared to their probable prefire status, yellow pine chipmunks and deer mice were more numerous and red-backed voles were less numerous one year postfire, total biomass of small mammals may have been increased somewhat by fire, and these changes may persist up to 43 years postfire.

Water Quality

All sample streams except Burn Creek drain highlands exceeding 10,000 ft. (3,048 m) elevation that contain permanent snowfields on some northfacing slopes. Drainage basins vary considerably in size (Table 25). They are underlain by Precambrian granites, gneisses and schists in the higher, western portions except for Colter Creek where some Paleozoic beds are exposed. Substrates in the lower portions of the drainages consist of weathered and/or alluvial material and some glacial debris.

Table 23. Mean weights of live trapped small mammals, July 1-18, 1975, Waterfalls Canyon Burn.

	Weight (gms)									
	1974 Severe		1974 Moderate		1932 Burn		Unburned		Total	
	Young	Adult	Young	Adult	Young	Adult	Young	Adult	Young	Adult
Yellow Pine Chipmunk										
Mean		41.5		48.1						46.8
S.D.[a]		2.83		7.22						7.02
n[b]		2		8						10
Deer Mouse										
Mean		22.6	9.5	25.0				20.2	9.5	22.6
S.D.		4.15	0.71	8.48				0.35	0.71	4.28
n		4	2	2				2	2	9
Red-backed Vole										
Mean		23.8	11.0			18.7	10.0	20.5	10.5	21.0
S.D.		3.01	--			2.08	--	2.60	0.71	3.01
n		3	1			3	1	3	2	10

[a] S.D. = plus and minus one standard deviation
[b] n - sample size

Table 24. Mean Weights of live trapped small mammals, August 16-23, 1975, Waterfalls Canyon Burn.

	Weight (gms)									
	1974 Severe		1974 Moderate		1932 Burn		Unburned		Total	
	Young	Adult	Young	Adult	Young	Adult	Young	Adult	Young	Adult
Yellow Pine Chipmunk										
Mean			33.5	51.0	38.3	46.4			36.4	49.7
S.D.[a]			0.71	6.40	4.93	5.55			4.39	6.75
n[b]			2	5	3	5			5	11
Deer Mouse										
Mean	13.9	22.1	13.2	21.4	14.2	20.0			13.8	21.3
S.D.	2.69	3.18	2.54	3.58	2.33	1.22			2.53	2.83
n	19	9	9	5	9	5			37	20
Red-backed Vole										
Mean	7.2	23.3	15.3	20.3		22.7	11.3	22.3	11.9	22.4
S.D.	1.10	2.80	1.42	2.52		4.13	2.46	2.96	3.43	3.09
n	5	6	10	3		6	13	18	29	33

[a] S.D. = plus or minus one standard deviation
[b] n - sample size

Table 25. Chemical characteristics of streams in and near the 1974 Waterfalls Canyon Burn, July 24, 1975. [a]

	Moran Creek	North Moran Creek	Waterfalls Creek	Burn Creek	Falcon Creek	Colter Creek
pH	6.58	6.61	6.81	7.41	6.65	6.83
Conductivity [b]	20	22	37	215	27	43
Turbidity [c]	1.8	0.7	0.5	0.1	0.0	0.7
Total Dissolved Solids [c]	6.1	5.9	14.6	114.5	8.5	18.1
Calcium [c]	3.00	4.06	5.00	29.00	3.75	6.75
Magnesium [c]	0.34	0.35	1.40	9.32	0.65	1.15
Sodium [c]	0.52	0.52	0.62	1.18	0.52	0.62
Potassium [c]	0.60	0.40	0.80	0.80	0.40	0.60
Chloride [c]	0.42	0.42	1.06	1.81	0.53	0.53
Sulfate [c]	1.10	0.70	1.10	9.40	1.10	1.50
Orthophosphate [c]	0.00	0.00	0.00	0.00	0.00	0.00
Nitrate [c]	0.04	0.05	0.06	0.00	0.01	0.09
Carbonate (phth) Aklalinity [c]	0.0	0.0	0.0	0.0	0.0	0.0
Bicarbonate (MO) Alkalinity [c]	6.4	9.0	17.0	98.8	10.2	18.0
Total Hardness [c]	8.9	11.4	18.2	110.8	12.0	21.6
Drainage Area (acres)	10,300	7,000	3,200	90	1,800	2,500

[a] Analysis was done by Mr. Ezra Hookano, U.S. Forest Service, Forest Sciences Laboratory, Logan, Utah.

[b] Micromhos/cm at 25°C.

[c] mg/liter

Most of the flow of these perennial streams originates from snowmelt and is highest in late June and early July. Estimated flows in late summer 1975 were: Moran Creek, 50 cfs (1.4 cms); North Moran Creek, 30 cfs (0.8 cms); Waterfalls Creek 15 cfs (0.4 cms); Falcon Creek and Colter Creek, 5 cfs (0.1 cms). Winter flows are much less and probably originate from underground sources.

Burn Creek originates from springs and seepage within the perimeter of the Waterfalls Canyon Burn at about 7,200 ft. (2,200 m) elevation and flows east through a small watershed (Table 25) about 0.5 mile (1 km) to Jackson Lake. Maximum flow of about 2 cfs (0.05 cms) in early June resulted from snowmelt, and the creek dried up by August 1, 1975. Burn Creek was sampled because it drained a severely burned area where fire-caused changes in water quality should have been greatest. All streams except Burn Creek contained low concentrations of dissolved minerals (Table 25), probably because most minerals in rocks of the drainage basins are relatively insoluble and most stream flow is runoff from snowfields. Burn Creek contained higher concentrations of minerals and total dissolved solids probably because it originates from underground sources in an area of relatively well-developed soils. Because of large inherent differences in chemical characteristics, comparisons of Burn Creek with the other streams in terms of fire effects on water quality cannot be made.

Nitrate content did not appear to differ between streams draining unburned and partially burned watersheds except for Burn Creek (Table 26). Higher nitrate concentrations on June 11, 1975 probably reflect moderate water flows. Lower concentrations through July probably reflect dilu-

Table 26. Nitrate Content of streams in and near the 1974 Waterfalls Canyon Burn.

Date	Parts/million					
	Moran Creek	North Moran Creek	Waterfalls Creek	Burn Creek	Falcon Creek	Colter Creek
10/24/74	0.10	0.09	0.11	a	0.08	0.12
6/11/75	0.16	0.20	0.19	0.12	0.22	0.22
6/17/75	0.08	0.10	0.12	0.00	0.13	0.13
6/26/75	0.10	0.12	0.18	0.02	0.16	0.15
7/10/75	0.07	0.09	0.14	0.02	0.09	0.15
7/16/75	0.06	0.08	0.13	a	0.11	0.05
7/22/75	0.06	0.08	0.09	0.02	0.04	0.12
7/31/75	0.07	0.09	0.11	0.03	0.06	0.14
8/20/75	0.08	0.06	0.09	a	0.03	0.09
Mean	0.09	0.10	0.13	0.04	0.11	0.13
Standard Deviation	0.03	0.04	0.04	0.04	0.06	0.05
Coefficient of Variation	0.37	0.39	0.27	1.20	0.58	0.36

[a] Stream not sampled

Table 27. Total Phosphate content of streams in and nea
Waterfalls Canyon Burn.

Date	Parts/million				
	Moran Creek	North Moran Creek	Waterfalls Creek	Burn Creek	Fal Cre
10/24/74	0.024	0.008	0.031	a	0.0
11/27/74	0.012	a	0.019	a	0.0
6/11/75	0.027	0.006	0.016	0.073	0.0
6/17/75	0.010	0.002	0.006	0.032	0.0
6/26/75	0.007	0.005	0.016	0.025	0.0
7/10/75	0.008	0.102	b	0.017	0.00
7/16/75	0.012	0.047	0.009	a	0.01
7/22/75	0.012	0.004	0.007	0.025	0.03
7/31/75	0.013	0.010	0.029	0.010	0.00
8/20/75	0.050	0.026	0.026	a	0.02
Mean	0.018	0.025	0.016	0.030	0.01
Standard Deviation	0.014	0.033	0.010	0.022	0.01
Coefficient of Variation	0.78	1.32	0.63	0.73	0.93

a Stream not sampled

b Sample lost

Table 28. Orthophosphate content of streams in and near the 1974 Waterfalls Canyon Burn

Date	Parts/million					
	Moran Creek	North Moran Creek	Waterfalls Creek	Burn Creek	Falcon Creek	Colter Creek
10/24/74	0.004	*	0.015	a	0.002	0.006
11/27/74	*	a	0.008	a	*	b
6/11/75	0.003	0.002	0.006	0.061	0.019	0.014
6/17/75	*	*	0.003	0.024	0.002	0.010
6/26/75	*	0.002	*	0.015	0.002	b
7/10/75	0.003	0.054	0.004	0.061	*	b
7/16/75	0.003	b	0.013	a	0.005	0.003
7/22/75	*	*	0.001	0.003	*	0.002
7/31/75	*	*	*	*	*	*
8/20/75	0.012	0.015	0.015	a	0.006	0.008

No mean values were calculated due to many analyses below test sensitivity.

* Less than 0.001 parts per million

a Stream not sampled

b Sample insufficient for analysis

differences in the chemical characteristics of Burn Creek cc the other streams rather than fire effects. Preburn data fc would be needed to detect fire effects on this stream. Incı phorus in overland flow and ground water following fire woul (McColl and Grigal 1975) as would a decrease in soil phosphc 1974). Increases in waterborne phosphorus are most pronounc year following fire and then decline, while soil phosphorus increase after about 10 years (Viro 1974).

Colter Creek and Burn Creek were both slightly turbid o (5 Jackson Turbidity Units), but no suspended material was v any other time in any of the streams. This is not surprisin little soil movement was observed anywhere within the fire p No intense rain storms occurred in the area during 1975, alt storms were numerous. Striffler and Mogren (1971) found tha of rock on the soil surface was more important than slope in particle movement during low intensity storms, but slope was trolling factor during high intensity storms. They also obs most eroded particles were re-deposited downslope where the flattened or behind obstructions. Except for Burn Creek, no stream bottoms were severely burned, and a strip of intact ve remains along stream banks. The fuels in these locations ap contained enough moisture to retard burning. Snyder, et al. observed that such buffer strips in Idaho were efficient in suspended sediment.

Burn Creek was generally 2-3 degrees C warmer than the for the same dates and time periods.

The 1975 data suggest no direct influence of the fire on the water quality of Waterfalls, Falcon and Colter Creeks. The fire may have reduced nitrates in Burn Creek, but this cannot be confirmed at this time. Presumably, nitrates will increase in Burn Creek within a few years if the low concentrations observed are fire related. McColl and Grigal (1975) found that increased phosphorus in ground and runoff water from burned areas had negligible effects on phosphorus content in adjoining lakes or streams. They ascribed this to the great dilution factor and losses of phosphorus in ground water by adsorption. Likewise, Striffler and Mogren (1971) detected no direct influence of fire on a small stream in Colorado. They ascribed this to a lack of severe storms during the sampling period and the small size of the burned area involving the creek.

SUMMARY

This report summarizes research accomplished during the summers of 1974 and 1975 on the ecological effects and first postfire year successional processes following the lightning-caused Waterfalls Canyon Fire in Grand Teton National Park. This fire occurred in that portion of the Park zoned for letting naturally-caused fires run their course. It burned from July 17, 1974 to about December 1, 1974 and covered about 3,492 acres (1,414 ha) on the west side of Jackson Lake. Most of the area burned during September. Prior to the fire, about 82 percent of the burn was coniferous forest, and 18 percent was meadow-shrub. About 387 acres (157 ha) within the burn perimeter was unburned meadow-shrub (75 percent) and coniferous forest (25 percent). Of the 3,106 acres (1,258 ha) actually burned, 89 percent was coniferous forest, of which 57 percent was severely burned and 43 percent was lightly to moderately burned.

Even severe fire apparently did not reduce the basal area of herbs and shrubs, which was low (3-6 percent) on all sites one year postfire. Most mosses and lichens were apparently killed by both moderate and severe fire and were still sparse 43 years postfire when compared to the unburned site. Recovery may require re-establishment of a dense tree canopy.

Only 2 and 7 percent of the soil surface on the moderate and severe burns, respectively, was covered by ash, and only 1, 2, 4, and 0 percent of the surface on the severe, moderate, 1932 burn and unburned sites, respectively, was bare soil.

The main effect of the fire on soil surface characteristics was to char but not destroy organic litter. One year postfire, charred litter covered 73 percent of the soil surface on the severe burn compared to a similar percentage of unburned litter on other sites. The percentage of burned litter on the moderate burn was much higher (but still less than on the severe burn) immediately after the fire, but profuse needle fall from the foliage killed but not consumed by the fire covered much of the ground surface between 1974 and 1975. This did not occur on the severe burn because the fire consumed all tree foliage.

The prefire forest on all sites but the 1932 burn was dominated by Picea engelmanni and Abies lasiocarpa with Pinus contorta and P. albicaulis minor components, but forest succession may have been somewhat more advanced on the moderately and severely burned sites than on the unburned site.

All trees on the severe burn were killed and many were consumed by the fire. About 56 percent of the trees but only 10 percent of the basal area may have been killed on the moderate burn. About 60 percent of the trees killed were less than 19 feet (5.7 m) tall. Proportionately more A. lasiocarpa than P. engelmanni may have been killed because proportionately more of the prefire density and basal area of A. lasiocarpa than of P. engelmanni was less than 19 feet (5.7 m) tall; the height class most susceptible to fire.

Live tree density one year postfire on the unburned site was 1.9 times greater than on the moderate burn and 2.4 times greater than on the 1932 burn, but tree basal area was similar on the unburned and moderately burned sites and about 2.4 times greater on these sites as on the 1932 burn. A. lasiocarpa had the highest postfire importance values on both the unburned (144.1) and moderately burned (111.0) sites followed by P. engelmanni (44.4 and 78.3 on the unburned and moderately burned sites respectively). Pinus contorta and P. albicaulis had low importance valu (3.6-7.3) on both sites. In contrast, P. contorta had by far the highes importance value on the 1932 burn (148.1), followed by A. lasiocarpa (39.6), Picea engelmanni (7.8) and Pinus albicaulis (4.7).

Pinus contorta will probably dominate postfire succession on the severe burn at least through 43 years postfire and probably longer, but Picea engelmanni and Abies lasiocarpa will be present in lesser numbers. Pinus contorta will probably also be more important in postfire succession on the moderate burn than it was in the prefire stand but will probably remain subordinate to A. lasiocarpa and P. engelmanni. Pinus albicaulis will probably be of minor importance in postfire succession on all sites.

Mean current year's growth of terminal and lateral leaders of P. engelmanni, A. lasiocarpa and P. contorta was greatest on the 1932 burn, but significantly so only for terminal leaders of A. lasiocarpa and P. engelmanni and for lateral leaders of P. engelmanni. The 1974 fire did not significantly affect leader growth on the moderate burn during the first postfire growing season. Greater leader growth for all tree species seemed to be associated with lower tree density and basal area.

Tree seedlings were sparse on all sites but density and frequency of occurrence were highest on the moderate burn and similarly lower on the other three sites one year postfire. Only A. lasiocarpa and P. engelmanni seedlings were encountered on the burn, only A. lasiocarpa on the unburned site, only P. engelmanni on the severe burn, and only Pinus contorta on the 1932 burn. Moderate and severe fire may have favored production and/or survival of P. engelmanni seedlings over those of A. lasiocarpa.

Total canopy coverage of herbs and shrubs was similar on the unburned site and the 1932 burn and about 3.5 times greater on these sites as on those burned in 1974. Shrubs accounted for most of the difference between the unburned site and those burned in 1974. Mushrooms (Morchella angusticeps) were abundant on the moderate and particularly on the severe burn one year postfire but were not observed on the other sites.

Canopy coverage of grasses and grasslike plants was 24, 12, 10, and 5 percent on the 1932 burn, the unburned site, the moderate burn, and the severe burn, respectively. Low canopy coverage but relatively high frequency of occurrence (compared to the unburned site) suggests that few grasses and grasslike plants were killed even by severe fire. The main initial effect of fire on grasses and sedges was to reduce the amount and vigor of their aerial growth. Calamagrostis rubescens and Carex geyeri combined made up 92-100 percent of the total canopy coverage of grasses and sedges on all sites, were the only species frequently encountered, and were most abundant on the 1932 burn. The 1974 fire may have disproportionately reduced the number and size of C. rubescens plants, but apparently had little effect on C. geyeri.

Canopy coverage and frequency of occurrence of forbs in 1975 were also highest on the 1932 burn, next highest on the severe burn, slightly lower on the unburned site, and lowest on the moderate burn. Severe but not moderate fire may have stimulated production and/or survival of forbs one year postfire, and forbs may remain more prominant on severely burned sites for at least 43 years postfire. Individual forb species had low canopy coverage and frequency of occurrence on all sites. *Arnica cordifolia* and *Thalictrum fendleri* had the highest canopy coverage (2 percent) on the unburned site, *Lupinus* sp. (6 percent) on the 1932 burn, *A. cordifolia* (4 percent) on the severe burn, and no forb was present in more than trace amounts on the moderate burn. *A. cordifolia* was the only forb encountered on all four sites.

Canopy coverage and frequency of occurrence of shrubs were by far the highest on the unburned site and were next highest on the 1932 burn. Fire destroyed most of the shrub canopy on the severe burn and greatly reduced it on the moderate burn. The much lower frequency of occurrence of shrubs on both the moderate and severe burns than on the unburned site suggests that many shrubs were killed by the fire. *Vaccinium membranaceum* was the dominant shrub on the unburned site and retained its relative importance on both sites burned in 1974, though at much lower frequency of occurrence and canopy coverage. In contrast, *Ceanothus velutinus* was the dominant shrub on the 1932 burn but was not encountered on other sites. Most shrubs on the severe burn and many on the moderate burn one year postfire were root sprouts.

The data suggest the following changes in the herb and shrub stratum may occur as postfire succession proceeds toward spruce-fir forest. Ceanothus velutinus and Symphoricarpus oreophilus will probably become more abundant on the severe burn and perhaps on the moderate burn, will remain prominent until at least 43 years postfire, and will gradually be replaced by Vaccinium membranaceum. Forbs that may be relatively important in early postfire succession and that may decrease in abundance or disappear before 43 years postfire include: Astragulus sp., Epilobium angustifolium, Iliamna rivularis, and Dracocephalum parviflorum. Forbs that may increase in importance from early postfire at least through 43 years postfire and then decrease include: Aster sp., Campanula rotundifolia, Frageria sp., Lupinus sp., Perideridia gairdneri, Taraxacum officinale, and Viola sp. Grasses and grasslike plants may change little through postfire succession to spruce-fir forest. Carex geyeri and,particularly, Calamagrostis rubescens may increase at least through 43 years postfire and then decline somewhat, but will remain the dominant species of grasses and sedges throughout postfire succession to spruce-fir forest. Severe fire in spruce-fir forest resulted in increased diversity of herbs and shrubs (particularly forbs) one year postfire that may persist for at least 43 years postfire.

Most insects collected from the severe burn one year postfire were Diptera (flies), Hymenoptera (bees, wasps and ants), and Hemiptera (true bugs). Coleoptera (beetles) and Trichoptera (caddis flies) were also present. Prodigious numbers of roundheaded borers (Monochamus sp. and Xylotrechus longitarsus) under the bark of fire-killed trees provided food for woodpeckers in 1975.

Small mammal species diversity (trapped or observed) was similarly low (3-4 species) on all sites in 1975. About twice as many small mammals were trapped on the severely and moderately burned sites as on other sites in July, but by August numbers were similar on all sites and 2-5 times greater than during July; largely due to the production of young. Estimated small mammal densities were 54, 56, 58 and 70 animals/ha (21.9, 22.7, 23.5 and 28.3/acre) for the moderate, 1932, severe and unburned sites, respectively; however, confidence intervals were broad and overlapping, and density differences may have been more apparent than real.

Data are presented on the biomass and mean weights of live trapped small mammals.

In 1975 deer mice and red-backed voles were trapped on all sites, yellow pine chipmunks on all but the unburned site, and one mountain vole was trapped only on the severe burn. Red squirrels were observed on all but the severely burned site.

The 1974 fire changed the abundance and species composition of small mammals characteristic of unburned spruce-fir forest. Yellow pine chipmunks and deer mice were more numerous, red-backed voles were less numerous, and total small mammal biomass was somewhat greater (due to yellow pine chipmunks) on burned areas one year postfire. These changes may persist for at least 43 years postfire.

Moose, elk, mule deer and black bear were summer and fall residents of the burn one year postfire as they were prior to the 1974 fire. Extensive browsing of <u>Abies lasiocarpa</u> and abundant moose droppings indicated winter and/or spring use by moose. Extensive fire-caused mortality of *A. lasiocarpa* may result in less winter and/or spring use by moose.

Drainage basin characteristics for six streams that flowed through burned and unburned areas are described. One year postfire, all streams except Burn Creek (an intermittent stream that flows through the severe burn) contained low concentrations of dissolved minerals, probably because minerals in the rocks of their drainage basins are relatively insoluble and most flow is runoff from snowfields. There was no evidence that the 1974 Waterfalls Canyon Fire altered nitrate or phosphate content of streams. Lack of turbidity in all samples indicated that, if soil movement occurred (there was little evidence of this), sediments did not reach the streams.

Special thanks are due JoAnn Byrd, Grand Teton National Park, for typing the manuscript and some of the tables. Sue Kylander, Barbara Ralph, Rosemary McIntosh, Lanette Haun, and Nancy Fedell of the Park staff all helped type various tables.

LITERATURE CITED

American Public Health Association. 1962. Standard methods for the examination of water, wastewaters.

Anonymous. 1973. Birds and mammals of Grand Teton National Park. Grand Teton Natural History Association.

Baker, J. O. Jr. 1975. A selected and annotated bibliography for wilderness fire managers. U.S.D.A., Forest Service, Washington, D. C., 36 p.

Bendell, J. F. 1974. Effects of fire on birds and mammals. Pages 73-138. in T. T. Zozlowski and C. E. Ahlgren, eds. Fire and ecosystems. Academic Press, New York, San Francisco, London.

Blair, W. F., A. P. Blair, P. Brodkorb, F. R. Cagle, and G. A. Moore. 1957. Vertebrates of the United States. McGraw-Hill Book Company, Inc., New York, Toronto, London, 819 p.

Borror, D. and D. Delong. 1971. An introduction to the study of insects. Third edition. Holt, Rinehart, and Winston, New York, 812 p.

Calhoun, J. B. and J. Casby. 1958. Calculation of home range and density of small mammals. U. S. Dept. Health, Education and Welfare, Public Health mono. 55, 24 p.

Daubenmire, R. 1959. A canopy-coverage method of vegetation analysis. Northwest Science 33:43-64.

Despain, D. G. 1975. Field key to the flora of Yellowstone National Park. Yellowstone Library and Museum Association xxxii + 257 p.

Grand Teton National Park. 1973. Fire-Vegetation Management Plan: 1974-1978, Grand Teton National Park Files, 17 p.

Gruell, G. E. and L. L. Loope. 1974. Relationships among aspen, fire, and ungulate browsing in Jackson Hole, Wyoming. USDA, Forest Service and USDI, National Park Service, 33 p.

Haapanen, A. 1965. Bird fauna of Finish forests in relation to forest succession. I. Annales Zoologici Finnici 2:153-196.

Hendrickson, W. H. (chairman). 1973. Fire in the national parks symposium. Pages 339-488. in Proceedings of the Annual Tall Timbers fire ecology conference, June 8-9, 1972, Lubbock, Texas, Volume 12. Tall Timbers Research Station, Tallahassee, Florida.

Houston, D. B. 1973. Wildfires in northern Yellowstone National Park. Ecology 54:1111-1117.

Kendeigh, S. C. 1944. Measurement of bird populations. Ecol. Mono. 14:67-106.

Kendeigh, S. C. 1974. Ecology. Prentice-Hall, Englewood Cliffs, New Jersey, 474 p.

Leopold, A. S. 1963. Study of wildlife problems in national parks. Twenty Eighth North American Wildlife and Natural Resources Conf., Trans. 28-45.

Loope, L. L. 1971. Dynamics of forest communities in Grand Teton National Park. Naturalist 22(1):39-47.

Loope, L. L. and G. E. Gruell. 1973. The ecological role of fire in the Jackson Hole area of northwestern Wyoming. Quaternary Res. 3(3):425-443.

Loope, L. L. and R. P. Wood. (In press). Fire management in Grand Teton National Park. Proc. Tall Timbers Fire Ecology Conf. volume 14 (Fire and Land Management Symp. October 1974, Missoula, Montana).

Love, J. D. and J. C. Reed Jr. 1968. Creation of the Teton landscape. The geologic story of Grand Teton National Park. Grand Teton Natural History Association, 120 p.

McColl, J. G. and D. F. Grigal. 1975. Forest fire: Effects on phosphorus movement to lakes. Science 188:109-113.

National Park Service. 1970. Administrative policies for the national parks and national monuments of scientific significance (natural area category). (Revised). USDI, Nat'l. Park Serv., Washington, D. C., 147 p.

National Park Service. 1975. Management Policies. USDI, Nat'l. Park Service, Washington, D. C.

Negus, N. C. and J. Findley. 1959. Mammals of Jackson Hole, Wyoming. J. Mammal. 40(3):371-381.

Oswald, E. T. 1966. A synecological study of the forested moraines of the valley floor of Grand Teton National Park, Wyoming. Unpubl. PhD Dissertation, Montana State University, Bozeman, 101 p.

Overton, W. S. and D. E. Davis. 1969. Estimating the numbers of animals in wildlife populations. Pages 403-455. in Robert H. Giles, ed. Wildlife Management Techniques, third edition, revised. The Wildlife Society, Washington, D. C.

Rohlf, F. J. and R. R. Sokal. 1969. Statistical Tables. W. H. Freeman and Company, San Francisco, 253 p.

Salt, G. W. 1957. An analysis of avifaunas in the Teton Mountains and Jackson Hole, Wyoming. The Condor 59(6):373-393.

Shaw, R. J. 1976. Field guide to the vascular plants of Grand Teton National Park and Teton County, Wyoming. Utah State University Press, Logan, 301 p.

Snyder, G. G., H. F. Haupt, and G. H. Belt, Jr. 1975. Clearcutting and burning slash alter quality of stream water in northern Idaho. USDA, Forest Service Research Paper. Int-168, 34 p.

Sokal, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Company, San Francisco, 776 p.

Striffler, W. D. and E. W. Mogren. 1971. Erosion, soil properties and revegetation following a severe burn in the Colorado Rockies. Pages 25-35. in C. W. Slaughter, R. J. Barney, and G. M. Hansen, eds. Fire in the northern environment - a symposium. U.S.D.A., Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Taylor, D. L. 1969. Biotic succession of lodgepole pine forests of fire origin in Yellowstone National Park. PhD Dissertation, University of Wyoming, 320 p.

Taylor, D. L. 1973a. Competitive exclusion between tree swallows and mountain bluebirds in Yellowstone National Park. Report to the National Geographic Society, Washington, D. C.

Taylor, D. L. 1973b. Some ecological implications of forest fire control in Yellowstone National Park. Ecology 54(6):1394-1396.

Taylor, D. L. 1974. Forest fires in Yellowstone National Park. J. Forest History 18(3):68-73, 75, 77.

Viro, P. J. 1974. Effects of forest fire on soil. Pages 7-45. in T. T. Kozlowski and C. E. Ahlgren, eds. Fire and ecosystems. Academic Press, New York, San Francisco, London.

APPENDIX

Table 29. Basal area by diameter classes of live plus dead standing trees on three sites, Waterfalls Canyon Burn, 1975.

DBH (inches)	Basal Area (inches ^{2}/acre) Picea engelmanni Unb.	Mod.	1932	Abies lasiocarpa Unb.	Mod.	1932	Pinus contorta Unb.	Mod.	1932	Pinus albicaulis Unb.	Mod.	1932	Total Unb.	Mod.	1932
0.5	19	26	6	153	201	22	6	1	31	11	6	4	189	234	63
1.5	32	89		140	439	45	13		25		13	7	185	541	77
2.5	71	212		194	706	88	18	18	141				283	936	229
3.5	242	173	69	415	311	69			277				657	484	415
4.5	57	401		458	229	57			572				515	630	629
5.5	85	171		940	684	85			598				1025	855	683
6.5	358	358		1074	358	119	119		1074				1551	716	1193
7.5	477			1589	318				1748				2066	318	1748
8.5				408	817				1225				408	817	1225
9.5	510	255		510	1020		255		510				1275	1275	510
10.5	311			1557	1557		934						2802	1557	
11.5	374	374		1121				374					1495	748	
12.5	883	441		441			441	441					1765	882	
13.5		1029		1029									1029	1029	
14.5							594	594					594	594	
15.5					679									679	
16.5					1538			769						2307	
+	1074	7625		866	865								1940	8490	
Total	4493	11154	75	10895	9722	485	2380	2197	6201	11	19	11	17779	23092	6772

Table 30. Density by diameter classes of live trees on three sites, Waterfalls Canyon Burn, 1975.

DBH (inches)	Picea engelmanni Unb.	Picea engelmanni Mod.	Picea engelmanni 1932	Abies lasiocarpa Unb.	Abies lasiocarpa Mod.	Abies lasiocarpa 1932	Pinus contorta Unb.	Pinus contorta Mod.	Pinus contorta 1932	Pinus albicaulis Unb.	Pinus albicaulis Mod.	Pinus albicaulis 1932	Total Unb.	Total Mod.	Total 1932
	Number of Trees/Acre														
0.5	94	47	29	741	349	108	29		133	54	22	22	918	418	292
1.5	18	22		76	83	25	7		14		4	4	101	109	43
2.5	14	22		32	25	18	4		25				50	47	43
3.5	25	18	7	40	14	7			22				65	32	36
4.5	4	14		18		4			29				22	14	33
5.5	4	4		40	11	4			14				44	15	18
6.5	11	11		25	7	4	4		25				40	18	29
7.5	11			29					32				40		32
8.5				4	7				22				4	7	22
9.5	7	4		4	11				7				11	15	7
10.5				14	14		4						18	14	
11.5		4		4				4					4	8	
12.5	7			4				4					11	4	
13.5				7									7		
14.5															
15.5					4									4	
16.5					7									7	
+	4[a]	11[b]		4[c]									8	11	
Totals	199	157	36	1042	532	170	48	8	323	54	26	26	1343	723	555
Mean DBH (c.v.)[d]	3.4 (46)	3.7 (58)	1.2 (100)	1.8 (46)	1.7 (31)	1.4 (68)	2.8 (55)	4.0 (173)	4.1 (60)	0.5 (0)	0.4 (100)	0.2 (173)	2.0 (32)	2.4 (17)	3.0 (50)

a Maximum DBH = 19.5
b Maximum DBH = 30.5
c Maximum DBH = 17.5
d Mean and (Coefficient of Variation in percent), n=3 macroplots

Table 31. Basal area by diameter classes of live trees on three sites, Waterfalls Canyon Burn, 1975.

DBH (inches)	Basal Area (inches ^{2}/acre) Spruce Unb.	Spruce Mod.	Spruce 1932	Subalpine Fir Unb.	Subalpine Fir Mod.	Subalpine Fir 1932	Lodgepole Pine Unb.	Lodgepole Pine Mod.	Lodgepole Pine 1932	Whitebark Pine Unb.	Whitebark Pine Mod.	Whitebark Pine 1932	Totals Unb.	Totals Mod.	Totals 1932
0.5	19	9	6	148	70	22	6		27	11	4	4	184	83	59
1.5	32	38		134	147	45	13		25		7	7	179	192	77
2.5	71	106		159	123	88	18		124				248	229	212
3.5	242	173	69	381	138	69			208				623	311	346
4.5	57	229		286		57			458				343	229	515
5.5	85	85		940	256	85			342				1025	341	427
6.5	358	358		835	239	119	119		835				1312	597	954
7.5	477			1271					1430				1748		1430
8.5				204	408				1225				204	408	1225
9.5	510	255		255	765				510				765	1020	510
10.5				1246	1246		311						1557	1246	
11.5		374		374				374					374	748	
12.5	883			441				441					1324	441	
13.5				1029									1029		
14.5															
15.5					679									679	
16.5					1538									1538	
+	1074	6194		866									1940	6194	
Totals	3808	7821	75	8569	5609	485	467	815	5184	11	11	11	12855	14256	5755
Mean B.A. (c.v.)[a]	269 (52)	2607 (102)	25 (157)	2857 (51)	1870 (74)	162 (86)	156 (92)	272 (173)	1728 (106)	4 (27)	4 (123)	4 (172)	4284 (27)	4752 (73)	1918 (87)

[a] Mean basal area and (Coefficient of Variation in percent), n=3 macroplots

Table 32. Density by height classes of live trees on three sites, Waterfalls Canyon Burn, 1975.

Height (feet)	Number of Trees/Acre														
	Spruce			Subalpine Fir			Lodgepole Pine			Whitebark Pine			Totals		
	Unb.	Mod.	1932	Unb.	Mod.	1932	Unb.	Mod.	1932	Unb.	Mod.	1932	Unb.	Mod.	1932
2-6	72	50	29	722	342	97	29		104	47	25	22	870	417	252
7-12	50	22		97	90	36	4		40	7		4	158	112	80
13-18	14	22	4	40	29	22	7		29				61	51	55
19-24	11	22	4	32	7	11			7				43	29	22
25-30	11	11		29	7	4			25				40	18	29
31-36	7	4		7	7				25				14	11	25
37-42	4	4		22	4				14				26	8	14
43-48	7	7		32	7		4		29				43	14	29
49-54	11			18	7				29				29	7	29
55-60				18	4				22				18	4	22
61-66				11	7		4						15	7	
67-72	11			4	11			7					15	18	
73-78		4		7	4								7	8	
79-84		4												4	
85-90					4									4	
91-96															
97-102		4			4									8	
+		4												4	
Totals	198	158	37	1039	534	170	48	7	324	54	25	26	1339	724	557
Mean Ht. (c.v.)[a]	19 (30)	20 (32)	6 (101)	11 (52)	10 (30)	8 (48)	18 (53)	23 (173)	24 (60)	4 (25)	2 (90)	2 (177)	13 (36)	14 (10)	18 (49)
Max. Ht.	72	117	19	73	98	29	66	68	58	9	9	10	73	117	58

[a] Mean and (Coefficient of Variation in percent), n=3 macroplots

Table 33. Relative density of live trees by diameter classes on three sites, Waterfalls Canyon Burn, 1975.

DBH	Percent														
	Spruce			Subalpine Fir			Lodgepole Pine			Whitebark Pine			Totals		
(inches)	Unb.	Mod.	1932	Unb.	Mod.	1932	Unb.	Mod.	1932	Unb.	Mod.	1932	Unb.	Mod.	1932
0.5	47	30	81	71	66	64	60		41	100	85	85	68	58	53
1.5	9	14		7	16	15	15		4		15	15	8	15	8
2.5	7	14		3	5	11	8		8				4	6	8
3.5	13	12	19	4	3	4			7				5	4	6
4.5	2	9		2		2			9				2	2	6
5.5	2	2		4	2	2	8		4				3	2	3
6.5	6	7		2	1	2			8				3	2	5
7.5	6			3					10				3		6
8.5				T[a]	1				7				T	1	4
9.5	4	2		T	2				2				1	2	1
10.5				1	3		8						1	2	
11.5		2		T				50					T	1	
12.5	4			T				50					1	1	
13.5				1									1		
14.5															
15.5					1									1	
16.5					1									1	
+	2[b]	7[c]		T[d]									1	2	
Density[e]	199	157	36	1042	532	170	48	8	323	54	26	26	1343	723	555
Comp.[f]	15	22	6	78	74	31	4	1	58	4	4	5			
DBH															
Mean[g]	3.4	3.7	1.2	1.8	1.7	1.4	2.8	4.0[i]	4.1	0.5	0.4[j]	0.2[i]	2.0	2.4	3.0
c.v.[h]	46	58	100	46	31	68	55	173	60	0	100	173	32	17	50

a T = <0.5%

b Max. DBH = 19.5 inches

c Max. DBH = 30.5 inches

d Max. DBH = 17.5 inches

e Mean number of trees/acre, n=3 macroplots

f Percent composition

g Weighted mean calculated from data arrayed in 1 inch diameter classes, n=3 macroplots.

h Coefficient of variation in percent

i Present on only one plot

j Present on only two plots

Table 34. Common and Scientific names of plants. [a]

TREES	
Abies lasiocarpa	subalpine fir
Picea engelmannii	engelmann spruce
Pinus albicaulis	whitebark pine
Pinus contorta	lodgepole pine
Populus tremuloides	aspen
Pseudotsuga menziesii	douglas fir
GRASSES AND GRASSLIKE	
Agropyron sp.	wheatgrass
Calamagrostis rubescens	pinegrass
Carex geyeri	elk sedge
Melica spectabilis	oniongrass
Phleum alpinum	alpine timothy
Stipa sp.	needlegrass
Trisetum spicatum	spike trisetum
FORBS	
Achillea millefolium	yarrow
Aconitum columbianum	columbian monkshood
Agoseris aurantiaca	orange agoseris
Agoseris glauca	pale agoseris
Antennaria microphylla	rosy pussytoes
Arnica cordifolia	heartleafed arnica
Aster sp.	aster
Astragalus sp.	milk vetch
Campanula rotundifolia	harebell
Chenopodium sp.	goosefoot
Dracocephalum parviflorum	american dragonhead
Epilobium sp.	willow herb
Epilobium angustifolium	fireweed
Frageria sp.	strawberry
Galium boreale	northern bedstraw
Geranium sp.	geranium
Goodyera oblongifolia	western rattlesnake plantain
Hieracium albiflorum	whiteflowered hawkweed
Iliamna rivularis	streambank globemallow
Lactuca sp.	lettuce
Lupinus sp.	lupine
Osmorhiza chilensis	mountain sweetroot
Pedicularis sp.	lousewort
Perideridia gairdneri	gardner's yampah
Polygonum sp.	smartweed
Pyrola asarifolia	alpine pyrola

FORBS (Cont'd)

Taraxacum officinale	common dandelion
Thalictrum fendleri	meadowrue
Viola sp.	violet

SHRUBS

Amelanchier alnifolia	western serviceberry
Berberis repens	oregongrape
Ceanothus velutinus	buckbrush
Chimaphila umbellata	pipsissewa
Lonicera utahensis	utah honeysuckle
Sorbus scopulina	cascade mountain ash
Spirea betulifolia	shinyleaf spirea
Symphoricarpus oreophilus	mountain snowberry
Vaccinium membranaceum	huckleberry
Vaccinium scoparium	grouseberry

[a] Scientific names are from Shaw (1976), common names are according to Despain (1975)

Table 35. Common and scientific names of birds and mammals.[a]

BIRDS

Dendroica auduboni	Audubon's warbler
Picoides arcticus	Black-backed three-toed woodpecker
Certhia familiaris	Brown creeper
Carpodacus cassinii	Cassin's finch
Spizella passerina	Chipping sparrow
Nucifraga columbiana	Clark's nutcracker
Regulus satrapa	Golden-crowned kinglet
Perisoreus canadensis	Gray jay
Dendrocopos villosus	Hairy woodpecker
Hylocichla guttata	Hermit thrush
Sialia currucoides	Mountain bluebird
Parus gambeli	Mountain chickadee
Picoides tridactylus	Northern three-toed woodpecker
Nattallornis borealis	Olive-sided flycatcher
Junco oreganus	Oregon Junco
Pinicola enucleator	Pine grosbeak
Spinus pinus	Pine siskin
Sitta canadensis	Red-breasted nuthatch
Loxia curvrostra	Red crossbill
Turdus migratorius	Robin
Regulus calendula	Ruby-crowned kinglet
Bonasa umbellus	Ruffed grouse
Hylocichla ustulata	Swainson's thrush
Iridoprocne bicolor	Tree swallow
Piranga ludoviciana	Western tanager
Contropus sordidulus	Western wood pewee
Sphyrapicus varius	Yellow-bellied sapsucker

MAMMALS

Ursus americanus	Black bear
Peromyscus maniculatus	Deer mouse
Cervus canadensis	Elk
Eutamius amoenus	Least chipmunk
Sorex cinereus	Masked shrew
Microtus pennsylvanicus	Meadow vole
Alces alces	Moose
Phenacomys intermedius	Mountain phenacomys
Microtus montanus	Mountain vole
Odocoileus hemionus	Mule deer
Glaucomys sabrinus	Northern flying squirrel
Cleithrionomys gapperi	Red-backed vole
Tamiasciurus hudsonicus	Red squirrel
Eutamias umbrinus	Uinta chipmunk
Sorex vagrans	Vagrant shrew
Zapus princeps	Western jumping mouse
Eutamias amoenus	Yellow pine chipmunk

[a] Names are according to Blair, et al. (1957).