29496

National Library of Canada | Bibliothèque nationale du Canada

CANADIAN THESES ON MICROFICHE

THÈSES CANADIENNES SUR MICROFICHE

NAME OF AUTHOR/*NOM DE L'AUTEUR* DENNIS ELROY DUBÉ

TITLE OF THESIS/*TITRE DE LA THÈSE* EARLY PLANT SUCCESSION FOLLOWING A 1968 WILDFIRE IN THE SUBALPINE ZONE OF THE VERMILION PASS, KOOTENAY NATIONAL PARK

UNIVERSITY/*UNIVERSITÉ* UNIVERSITY OF ALBERTA, EDMONTON.

DEGREE FOR WHICH THESIS WAS PRESENTED/*GRADE POUR LEQUEL CETTE THÈSE FUT PRÉSENTÉE* M.Sc.

YEAR THIS DEGREE CONFERRED/*ANNÉE D'OBTENTION DE CE GRADE* 1976

NAME OF SUPERVISOR/*NOM DU DIRECTEUR DE THÈSE* DR. G. H. LAROI

DATED/*DATÉ* April 26/76 SIGNED/*SIGNÉ* Dennis Dube

PERMANENT ADDRESS/*RÉSIDENCE FIXE* 10616 - 64TH AVE.
EDMONTON, ALTA

THE UNIVERSITY OF ALBERTA

EARLY PLANT SUCCESSION FOLLOWING A 1968 WILDFIRE IN THE SUBALPINE ZONE OF THE VERMILION PASS, KOOTENAY NATIONAL PARK

by

DENNIS ELROY DUBÉ ©

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

MASTER OF SCIENCE

DEPARTMENT OF BOTANY

EDMONTON, ALBERTA

SPRING, 1976

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled 'Early plant succession following a 1968 wildfire in the subalpine zone of the Vermilion Pass, Kootenay National Park' submitted by Dennis Elroy Dubé in partial fulfilment of the requirements for the degree of Master of Science.

....
Supervisor

Lawrence C. Bliss

....

Date 13 April 1976

ABSTRACT

The main objectives of this thesis were: (1) to describe and interpret the initial stage of secondary plant succession and tree reproduction after the 1968 wildfire; (2) to determine the structure and species composition of the standing burned trees; (3) to provide a sound foundation for a long-term study of plant succession after fire; (4) to provide a basis for measuring the rate of fuel accumulation on the forest floor resulting from the deterioration of the standing burned trees.

Using 1970 aerial photographs and ground reconnaissance, 12 stands were selected on the NW-facing slope of the Vermilion Pass burn. Six stands were sampled in 1971 and six in 1972. Living post-burn vegetation sampled in 1971 was sampled again in 1972 in the same plots. All plots in the burn were permanently marked. One additional stand was located in the adjoining unburned forest.

The standing dead forest, consisting of Engelmann spruce, subalpine fir and lodgepole pine, was not in an extremely late successional phase of development before the fire. Engelmann spruce dominated, in terms of basal area, followed by lodgepole pine which showed evidence of declining in abundance before the fire. Subalpine fir far outnumbered both spruce and pine but was restricted to the smaller size-classes.

Fire intensity was generally uniformly severe, though stand no. 6 was not as severely burned as the others.

A ten-fold increase of stems fallen since the fire occurred between 1971 and 1972 and most of these, in both years, were in the 2 and 3 in. size-classes.

Lodgepole pine seedlings were most abundant, their density and height growth decreased with increasing elevation and slope steepness. Height growth was also negatively correlated with competition. Pine seedlings more than doubled their height and increased significantly in density between 1971 and 1972.

Species richness increased in the Vermilion Pass burn as a result of the fire. Thirty-five and 20 vascular species were recorded in quadrats in the burned and unburned forest respectively. The six most important subordinate vascular species, based on prominence values, are Epilobium angustifolium (30), Arnica cordifolia (25), Menziesia ferruginea (24), Vaccinium myrtillus/scoparium (12), Linnaea borealis (8), and Cornus canadensis (6).

The major constituents of the post-burn community, with the possible exception of Epilobium angustifolium, were represented in the unburned forest.

Shrubs accounted for 3.6% and herb-dwarf shrubs for 12.6% of the total ground cover. The remaining ground cover was comprised of charred humus (56%), rock, mineral soil, rotten wood, bryophytes, needle litter and fallen logs. Shrub clumps had a very high survival rate (87%). Some species decreased in cover between 1971 and 1972 while others increased.

Three, two-dimensional ordinations of the 12 stands based on basal area and density of the standing dead trees and prominence values of the living subordinate vegetation revealed several distinct patterns with environmental factors.

The fire regime, though important in affecting successional development of the post-burn vegetation, is not fully responsible in determining vegetation pattern.

ACKNOWLEDGEMENTS

I wish to sincerely thank Dr. George H. LaRoi for advice and encouragement during the preparation and writing of this thesis.

Thanks are also due to Mr. J. Carson and the Agricultural Soil and Feed Testing Laboratory, Edmonton, for analysis of soil samples; to personnel of Kootenay and Banff National Parks and Mr. G. Rogers, Parks Canada, Western Regional Office, Calgary; to the Canadian Forestry Service, Northern Forest Research Centre, Edmonton, who provided accommodation and financial assistance during the field portion of this study; to Canadian Forestry Service personnel at the Northern Forest Research Centre, particularly Mr. Y. Kalra, for analysis of soil samples; Mr. M. Walters for drafting many of the figures in the thesis; Mr. D. Morris for capable field assistance; Mr. D. Kiil and Dr. R. Reid for supporting this study; Mr. D. Quintilio, Mr. R. Lieskovsky, Mr. R. Ponto and to other members of the Fire Research group who assisted in the field when required; to fellow graduate students, particularly Dr. G. Douglas, for many helpful suggestions; to Miss M. Dumais for confirmation of vascular species; to Miss L. Atkey for the typing of this thesis.

Special thanks are due to Judy and Charlie for their patience, understanding and encouragement during the course of this thesis.

This study was supported in part by two National Park Scholarships awarded to the author in 1971 and 1972, both of which are gratefully acknowledged.

TABLE OF CONTENTS

TABLE OF CONTENTS CONTINUED

LIST OF TABLES

LIST OF TABLES CONTINUED

LIST OF TABLES CONTINUED

LIST OF FIGURES

LIST OF FIGURES CONTINUED

LIST OF FIGURES CONTINUED

LIST OF PLATES

LIST OF APPENDICES

LIST OF APPENDICES CONTINUED

I OBJECTIVES

This study was initiated to fulfill four major objectives: (1) To describe and interpret the initial stage of secondary plant succession and tree reproduction after the 1968 wildfire in the sub-alpine forest of the Vermilion Pass area, Kootenay National Park; (2) To determine the structure and species composition of the trees in the forest stands before the fire, by quantifying and identifying, where possible, the standing burned trees, and briefly describing and comparing an adjoining unburned stand; (3) To provide a sound foundation for a long-term study of plant succession after fire in the area through the establishment and inventory of permanent plots; (4) To provide a basis for measuring the rate of fuel accumulation on the forest floor resulting from the deterioration of the standing burned trees.

The study is one component of a multi-disciplinary Vermilion Pass burn project sponsored by the Parks Canada Branch of the Department of Indian and Northern Affairs. Other studies in the project will provide detailed accounts of the climate, geology, soils, avifauna and fauna of the immediate area. Preliminary reports by Harris (1971), Noakes and Harris (1971), Olthof (1971), Shank (1971), Edwards (1973), Fitzmartyn (1973), Scott (1973), and Winterbottom (1973) on some of the above studies can be found in the library of the Western Regional Office of Parks Canada located in Calgary, Alberta. In conjunction with the study reported on here, additional data were gathered in three other forest stands of different ages in the Vermilion Pass. The data will provide a quantitative description of the vegetation and fuels in each of these stands. This information will form the basis for determining fuel loadings and sizes, and their vertical and horizontal distribution. Investigations were also carried out to determine the moisture content and distribution of moisture in duff layers in the forest stands at selected intervals since last rain.

II. INTRODUCTION

The importance of fire as a factor influencing forest vegetation pattern in the subalpine zone of the Canadian Rocky Mountains has long been recognized, but not adequately quantified.

A fire of lightning origin burned approximately 2630 hectares (6500 acres) of spruce-fir forest on both sides of the Continental Divide in the Vermilion Pass Valley of Kootenay and Banff National Parks in July 1968. This event afforded an opportunity to initiate a long-term fire ecology investigation. "That a national park be the site of an extended project is justified, because only in a national park is it possible to have the absolute control of land use that will permit completion of the entire research program." (Dennis, 1971).

The subalpine zone of the Northern Rocky Mountains as designated by Daubenmire (1943), has been investigated by Beil (1966). Beil made reference to others who have described this region, including Merriam (1898), Rydberg (1900,1915), Larsen (1930), Daubenmire (1938), Bloomberg (1950), Degrace (1950), Daubenmire (1952), Cormack (1953), Horton (1956) and Patten (1963).

More recent work by Ogilvie (1969), Krajina (1970), Day (1972) and Rowe (1972) has added to our understanding of the subalpine zone.

The area under investigation has been designated by Rowe (1972) as the Interior Subalpine section (SA.2), characterized by; "a forest of western white spruce, Engelmann spruce and their intermediate forms, associated with alpine fir which increases in abundance at higher altitudes and is dominant at treeline. Extensive stands of the pioneer lodgepole pine cover areas of past fires." [sic]. Krajina (1970) has divided British Columbia into four biogeoclimatic formations, seven biogeoclimatic regions and eleven biogeoclimatic zones. The Vermilion Pass area is in the Microthermal Coniferous Forest Formation; the Canadian Cordilleran Subalpine Forest Region; and the Engelmann Spruce-Subalpine Fir Zone. This latter zone is further divided into three latitudinal subzones. The subzone in which the Vermilion Pass is included lies between 49°N. and 53°N. latitude.

Hosie (1969) describes the Subalpine Forest Region as, "A coniferous forest located on mountain uplands of Alberta and British Columbia from the Rocky Mountain range through the Interior of British Columbia to the Pacific Coast inlets. The characteristic species are Engelmann Spruce, Alpine Fir and Lodgepole Pine. There is a close relationship between the Subalpine Forest Region and the Boreal Forest Region, which also shares Black Spruce, White Spruce and Trembling Aspen." [sic]

The role of fire in the environment has been the subject of a great amount of research resulting in numerous publications. Ahlgren and Ahlgren (1960) reviewed the pertinent literature in an effort to bring together the literature concerning the extent of forest fires and their effects on soil and various forms of life. Daubenmire (1968) has provided a comprehensive review of the ecology of fire in grasslands. Recent symposia have used fire as their central theme: "Fire in the Northern Environment" (U.S.F.S., 1972), and "The Ecological Role of Fire in Natural Conifer Forests of Western and Northern North America" (Heinselman and Wright, 1973). Also, proceedings from the Tall Timbers Fire Ecology conferences have been published annually since 1961. A major text, "Fire and Ecosystems" (Kozlowski and Ahlgren, 1974) examining in depth the influence of fire on ecosystems is now available and a bibliography containing 3000 references dealing with fire ecology has been prepared through the auspices of the U.S. IBP program. Despite the profusion of literature, few references are available concerning fire and its effects in the subalpine zone in northern regions.

However, the literature of Canadian explorations and surveys is full of references to forest fires (MacMillan and Gutches, 1910). Those references relating to the general area or of specific importance are included here for the purpose of providing an historical perspective. Capt. John Palliser while in the area of the Kananaskis Valley in 1858 related: "Here, I observed a very satisfactory proof that lightning in the mountains must frequently be the cause of fires, and that all forests are not destroyed by the hand of man, for we saw whole masses of forest, isolated in mountain cliffs, fallen by fire, the mountain trees burnt in places so precipitous that no human hand could ever have reached them." (Palliser, 1863). Sir James Hector, also of the Palliser Expedition, and recognized as the first non-native to traverse the Vermilion Pass, gave this account of the pass in 1858: "The valley at this point [Vermilion Pass summit] is several miles wide, and the mountains on either hand are still wooded a long way up the slope ... We descended the valley of Vermilion river for four hours to the south-west making equal to six miles in a straight line [present location of Vermilion Pass burn] .... The valley is tolerably open and the descent is uniform. The dense woods often compelled us to cross and recross the stream." Approximately one mile southwest of the present burn, Hector stated, "The valley is now quite open on this side [east side of the Vermilion river], but on the other the mountains slope up rather suddenly, but not precipitously, while the woods have all been burnt, giving it a naked bald look. The fire must have run several times, as even the fallen trees had been burnt, which allowed us to pass along freely .... Among the burnt woods the whole surface is covered with a vigorous growth of epilobium angustifolium..." (Palliser, 1863).

G.M. Dawson (1885), while working in the Kicking Horse Pass area and along the Bow Valley, reported that "It may be added here that evidence ... with regard to very old forest fires was noticed in railway cuttings on the Kicking Horse Pass, and also in one place on the Bow River where modern forests, at least a hundred years in age, were growing above the reddened layer, still holding pieces of charcoal, which evidenced the destruction of a former growth." He gives further testimony to fire frequency: "Notwithstanding the evidence previously mentioned of the occasional occurrence of forest fires in ancient times in these mountains, it is only within the historic period for the region (probably not before the beginning of the century) that such fires became common and during the past few years their frequency has increased in a greatly accelerating ratio." W.H. Barneby (1889) indicated that much of the forest in the Bow Valley, from Banff to beyond Field, B.C., was "terribly damaged by fire, whole mountain sides being quite black with charred timber."

R. Bell (1889) discussed forest fires in northern Canada and displayed a modern knowledge of the role of fire in the boreal forest. Macoun (1904) commented on the absence of fires in the Lake Louise – Emerald Lake region, while Dowling (1904) remarked on "large fires in British Columbia, which did incalculable damage to the forest wealth of the country." Edgecombe and Caverhill (1911) indicated that "during the last 60 years likely 60% of the eastern slope has been fire swept," and further that "eighty percent of the territory surveyed has been burned in the last 50 years and 60% of this or 48% of the entire country has been burned over in the last 25 years."

Dwight (1913), in his report on the forest conditions in the Rocky Mountains Forest Reserve, said: "The forest fires of this region are notable for their intensity and the completeness of the destruction wrought by them. Some of the reasons for this are connected with the mountainous topography. The steep slopes aid the flames in gathering headway and the narrow valleys with their high sides create a tremendous draft." Conversely, Allan (1914), in his geological report of the Field, B.C. map area commented that "Fires have not occurred for many years and they are now closely watched as this region[1] is within the park [Yoho National Park] limits."

White (1915) estimated that "Three-fourths of the forest area of the reserve (forested east slopes) has been burned over at various times, mostly within the last 60 years." Dwight (1918), Campbell (1919) and Lewis (1920) provided early statistical summaries of forest fires in the national parks. Munro and McTaggart-Cowan (1944) reported that extensive areas in Kootenay National Park have been burned over in recent times.

Contemporary historical accounts of the mountain park region that include mention of forest fires are found in Spry (1963),

---

1. Allan is apparently referring to the Beaverfoot Valley where he says that trees are mostly small with a few reaching 2 feet in diameter. He has indirectly indicated by his statement a past fire history for this valley.

Nelson (1968), Reeves (1968) and Fraser (1969). Of particular interest is the work of Ogilvie and Scace (1968). In their study of the age-structure of fire-successional lodgepole pine stands on the east slope of the Rocky Mountains it was found that 30% of the stands originated during the early park period (1887-1911), whereas 47% of the stands date from the prospecting and early railway period (1850-1886).

Byrne (1968) provides a comprehensive insight into the fire history of the entire region: He states, "In summary, the admittedly sparse evidence available for the late eighteenth and ninteenth centuries can hardly be used to interpret with any certainty the significance of the prehistoric Indian as a cause of forest fires during what may have been as much as the previous 10,000 years. The lack of more definite historical evidence in itself suggests that, at least during the immediate pre-European period, the Indian had not been important as a cause of forest fires." He further suggests that during the period 1840 to 1911 forest fires greatly increased in frequency and extent, due to the combination of changing climate (Heusser, 1956) and the arrival of the white man.

III. STUDY AREA

A. Location

The study area is located in the Vermilion Pass, in the northeastern part of Kootenay National Park, British Columbia (Fig.1). The Vermilion Pass has a northeast-southwest orientation and was surveyed in 1913 to delimit the boundary between the provinces of Alberta and British Columbia along the Continental Divide (Cautley, Wallace and Wheeler, 1917). At the Continental Divide, the Vermilion Pass is steeply walled on the east side by an outlying shoulder of Storm Mountain and on the west side by a shoulder of Boom Mountain. The slopes are steep and fairly regular.

All sampled stands were located on the northwest-facing slopes of the Vermilion valley, southeast of the Vermilion river and the Banff-Windermere Highway No.93 (Fig.2). The stand locations fall within 116° 00' and 116° 07'W longitude and 51° 11' and 51° 15' N latitude. All stands were within Township 26, Range 15, West of the 5th Meridian. The fire burned an elevational belt from 1530 meters A.S.L. in the southwest to approximately 2280 meters A.S.L. in the northeast, an elevational range of 750 meters (Fig.2).

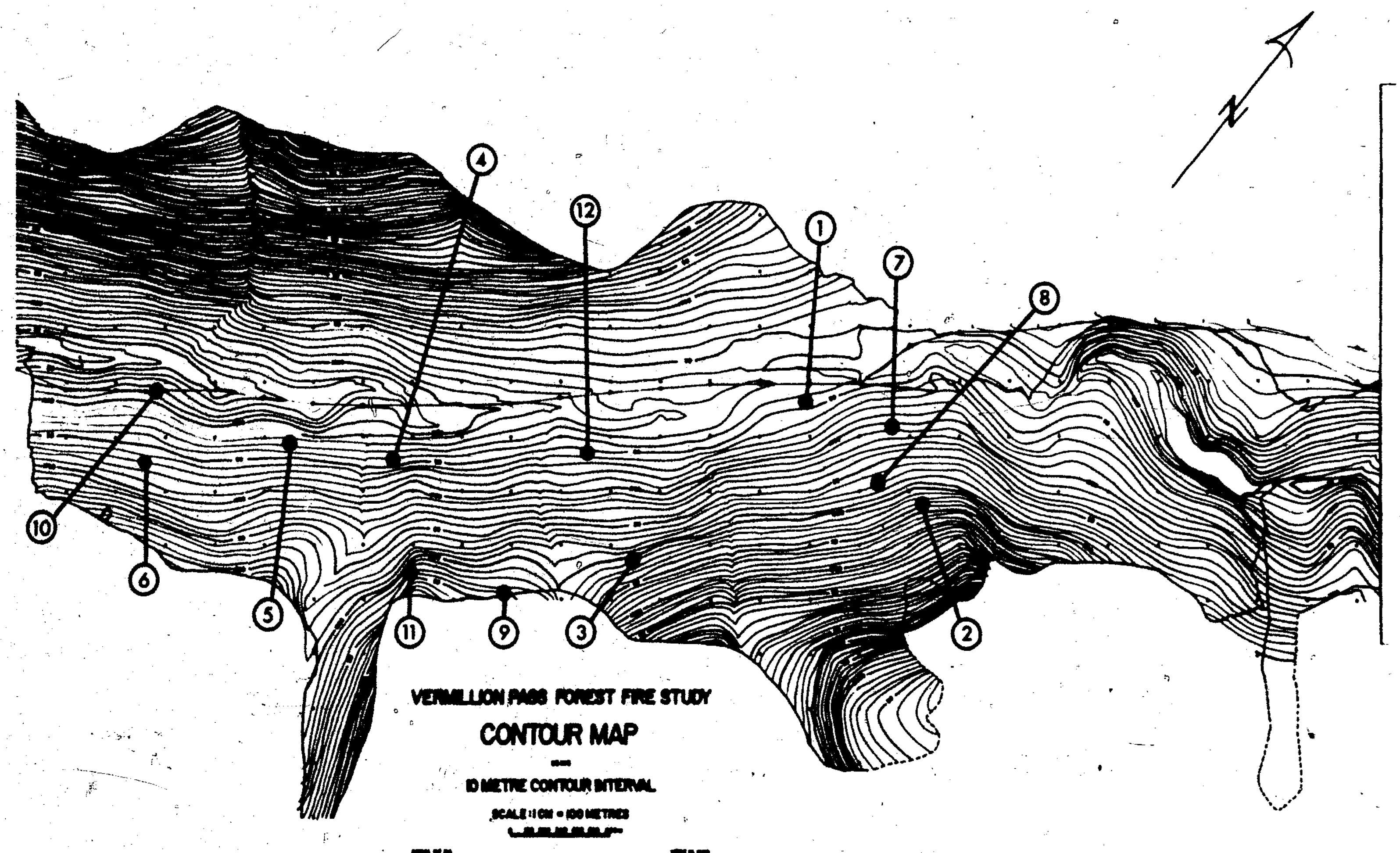
B. Climate

Kootenay National Park is on the eastern edge of the western cordilleran weather system and is occasionally influenced by continental weather patterns (Anon.1972). There is much climatic

Figure 1. Map of Kootenay National Park showing the 1968 Vermilion Pass burn as a blackened area in the northeast. (Canada, Mines and Technical Surveys, Surveys and Mapping Branch, third edition, 1955)


B

Figure 2. Contour map of the Vermilion Pass burn area, showing the location of 12 stands.
(Prepared under contract by the University of Calgary)


N
1
2
3
4
5
6
7
8
9
10
11
12
VERMILLION PASS FOREST FIRE STUDY
CONTOUR MAP
10 METRE CONTOUR INTERVAL
SCALE : 1 CM = 100 METRES

variation in the Park, due to its geographic location, altitudinal range and irregular topography.

From September to June, polar marine air masses move inland from the North Pacific across the mountains, being cooled in the process. By the time the masses reach the parks, they resemble continental air, but are not as cold or dry (Heusser, 1956). During the summer, however, Pacific air moving east mixes with the dry air above and becomes indistinguishable from dry continental air by the time it crosses the Continental Divide. In winter, polar continental air masses developed in the Arctic occasionally straddle the Continental Divide, causing sub-freezing temperatures as far as the west coast. Sub-tropical continental air is occasionally present in the summer or early fall of some years. These air masses are hot and dry and may result in temperatures above 32°C. Such conditions are especially favourable for forest fires. The net effect of these air masses is a fairly evenly distributed monthly precipitation and an extreme seasonal variation of temperature (Rutter, 1965).

Climographs for Kootenay Crossing, 56 km. (35 miles) southwest of the Vermilion Pass, and Lake Louise, approximately the same distance northwest, are presented in Figure 3. Lake Louise is cooler than Kootenay Crossing throughout the year and has more precipitation except in June. Lake Louise is the closest station that provides long-term climatic normals for the area (1941-1970). At this station the mean daily temperature is -0.1°C (31.8°F), the mean daily maximum temperature is 7.3°C (45.2°F) and [illegible] daily minimum temperature is -7.6°C (18.3°F). Total annu[illegible]tion at Lake Louise averages 76.7 cm. (30.2 in.), [illegible].2 in.) falling as

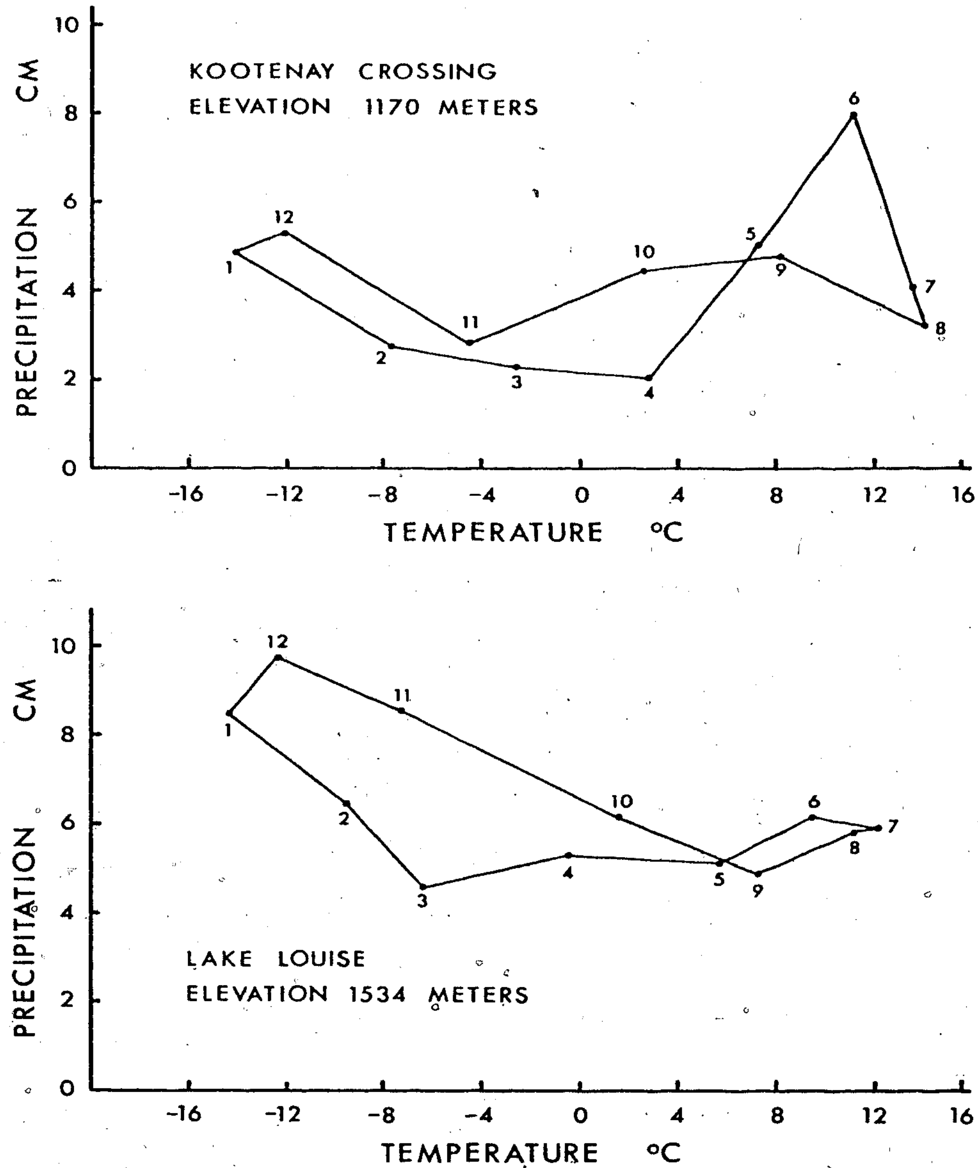


Figure 3. Temperature-precipitation climograph of mean monthly values at Kootenay Crossing and Lake Louise weather stations. Months are indicated by numbers beginning with January. Lake Louise data represents 30-year averages (1941-70), while Kootenay Crossing represents 7-year averages (1965-72). (Environment Canada, 1973).

rain and the remainder as snow (481.8 cm. or 189.7 in.) (Environment Canada, 1973). Monthly mean temperatures are likely lower and precipitation higher in the Vermilion Pass as a consequence of its higher elevation.

C. Geology and Geomorphology

Bostock (1948) has outlined the physiographic units of the Canadian Cordillera. According to his classification, Kootenay National Park occurs in the Rocky Mountains Subdivision of the Rocky Mountain Area in the Eastern System. Holland (1964) separates the Rocky Mountains Subdivision in Canada into four ranges: the Border, Continental, Hart and Muskwa Ranges. The Continental Ranges are further subdivided longitudinally into three structural units: the Front Ranges, the Park (Main) Ranges and the Kootenay (Western) Ranges. The mountain ranges along Kootenay Park's northeast boundary are included in the Park (Main) Ranges. The Park (Main) Ranges are largely underlain by sedimentary and metamorphic rocks of late Precambrian and Lower Palaeozoic age. Thick cliff-forming limestone and quartzite formations of Cambrian age form many of the mountains (Heusser, 1956; Holland, 1964).

The rocks that form Storm and Boom Mountains range from Precambrian at the bottom to middle Cambrian in the peaks (Belyer, 1964). Storm Mountain shows deep bowl-shaped cirques cut into Precambrian and lower Cambrian aged quartzite on its east face (Baird, 1967). The high vertical cliffs of Stanley Peak and Storm Mountain are composed of massive limestone. The upper cliffs of the mountains are Eldon Dolomite and the massive lower gray band is Cathedral Limestone (Gallup, 1954).

Stanley Peak and Mount Whymper are castellate mountains, i.e. cut into more or less flat-lying sedimentary rocks commonly having a profile in which vertical steps alternate with flat or sloping terraces. They are best developed in regions underlain by great thicknesses of rocks in which beds of massive limestone and sandstone or quartzite alternate with less resistant shale or slate beds (Baird, 1964). The softer beds are eroded more rapidly, so that the harder beds are undermined and tend to break off at right angles, forming steep slopes and cliffs.

The mountains of the Vermilion Pass area are rugged, displaying many examples of glacial morphology, including cols, arêtes, horns, cirques, hanging valleys and U-shaped valleys. The basic morphology of the terrain is controlled by bedrock geology, modified principally by glacial erosion (Rutter, 1965). The present physiography is a complex of landforms resulting from the different actions of water, ice, frost and wind. The dominant forms are glacial, although these have been modified by water erosion and deposition (Byrne, 1968), e.g. colluvium over till.

D. Soils

No comprehensive works are available on the soils of Kootenay National Park. The variability of the parent materials and climate combine to produce a very complex association of soils. Brunisolic soils are common in the valley bottoms while variable podzolic soils are found on the upper terraces and slopes (Anon. 1963). Noakes and Harris (1971) indicate that the major soil groups present in the Vermilion Pass are podzols, brunisols, regosols and gleysols. The podzols are characteristic of the better drained north-facing slopes. The brunisols on the north-west-facing slope occur in old drainage channels where internal soil drainage is poor. The regosols are found in small areas on fresh screes and on shallow deposits over rock outcrops. Locally they may occur at low elevations where soil movement prevents horizon development. Gleysols occupy flood plain sites which are extremely limited in area.

IV METHODS

A. Stand Selection

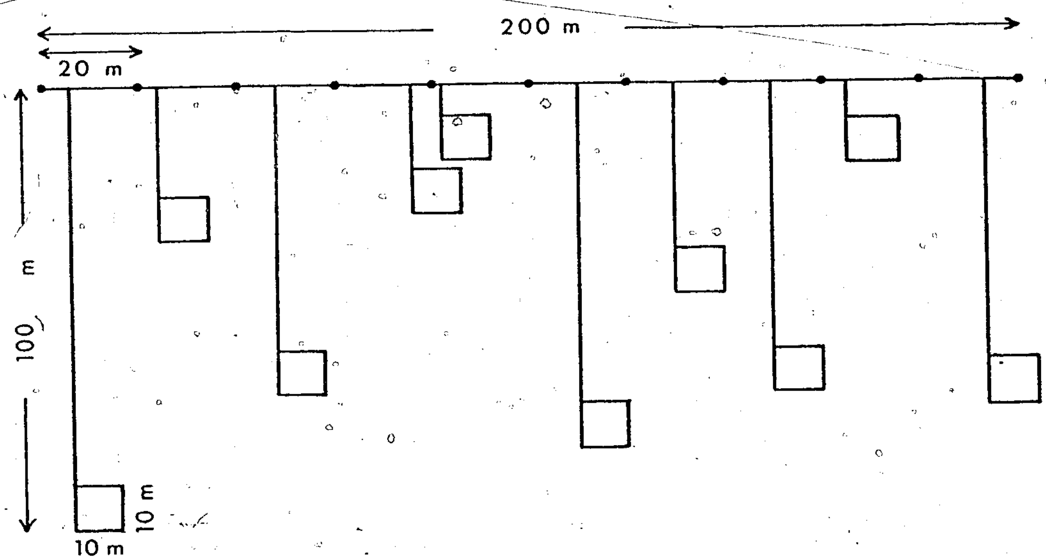
Twelve stands were selected after suitable sites had been located with the use of 1970 aerial photographs (approx. scale 1 cm. = 120 meters) and ground reconnaissance. Aerial photography was done by the Department of Energy, Mines and Resources, Air Photo Division, Government of Canada . The following broad predetermined criteria influenced the process of selecting suitable sites: (1) The study was limited to the northwest-facing slope of the Vermilion Pass valley; (2) Only the area within Kootenay National Park was studied; (3) The perimeter of the burn was avoided so as not to introduce the influence of edge effect (Odum, 1971); (4) Stands were selected in a variety of suspected pre-fire community types based largely on observations noting changes in density of the standing dead forest, elevation and slope angle; (5) Stands were also selected so as to cover areas that seemed to have experienced varying degrees of fire intensity; (6) Each site was relatively uniform in terms of macrotopography, in order to minimize within--stand differences.

B. Sampling Scheme

A 200 meter baseline was established in each stand except stand no.6. The terrain limited the length of the baseline in no. 6 to 100 meters. The baselines were permanently marked with an orange or yellow 76 cm. iron reinforcing rod. Over one-half this length protrudes above the ground. A provincial boundary monument served as the permanent marker for the baseline in stand no.2. Nine of the twelve baselines paralleled topographic contours. In nine stands all plots were located on one side of the baseline (Fig.4a) while in the other three stands plots were located on either side of the baseline (Fig.4b). Ten subsidiary reference lines were located perpendicular to each baseline, using a restricted random sampling method, so that each 20 meter segment of the baseline contained one reference line. This restriction does not bias the essential feature of random sampling (Greig-Smith, 1964) which allows the observed variance of the data to be used as the basis of tests of significance; that is, any point within the area has an equal chance of being represented in the samples. Randomization may be restricted in any way such that this is still true.

A random numbers table was used to locate the exact position of the reference line along the baseline. When the baseline was in the center of the stand, the reference line could be located either to the left or right of it. If the random number selected was odd, the reference line was located to the left of the baseline; if the random number was even, the reference line was located to the right of the baseline. Where the baselines were located in the center of the stands, reference lines were 50 meters in length; where located along the edge of stands reference lines were 100 meters long. All stands measured 200 x 100 meters with the exception of stand no. 6 which was 100 x 100 meters. Six stands (1-6) were sampled in 1971 and six in 1972 (7-12).

(a)



(b)

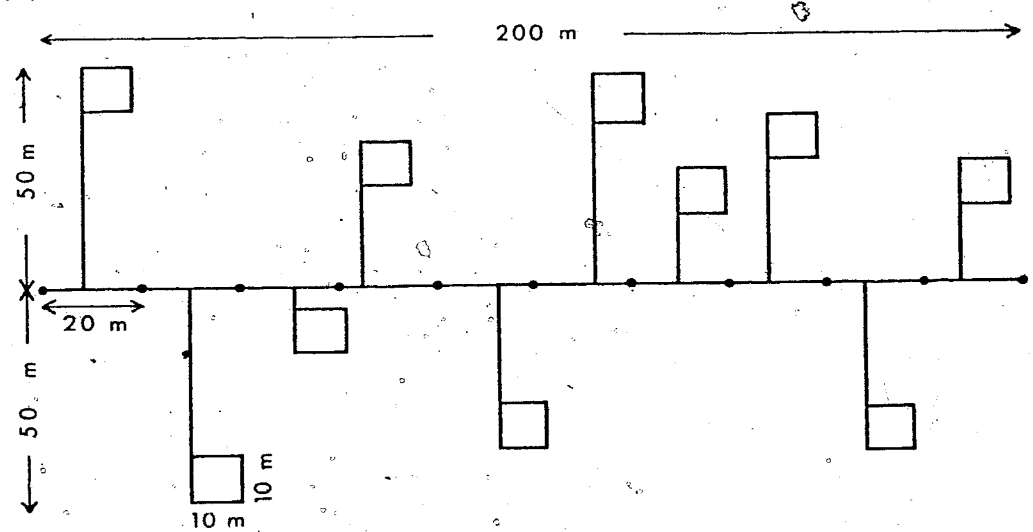


Figure 4. Generalized diagram of plot distribution in a stand with all plots on one side of the baseline (a) and both sides of the baseline (b).

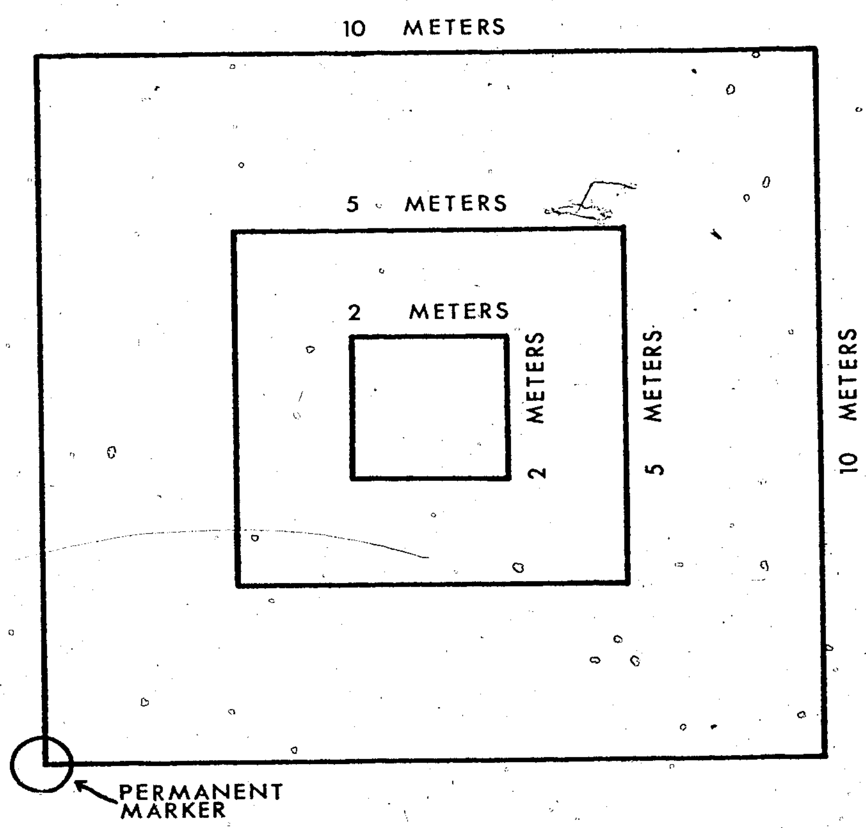
Ten, 10 x 10 meter plots were located in each stand, one along each reference line. They were located using a random numbers table and were permanently marked with an iron reinforcing rod. Appendix A shows all stands and the measured locations of each plot within the stand.

A 5 x 5 meter plot was symmetrically nested at the center of the 10 x 10 meter plot, and in turn a 2 x 2 meter plot was centrally nested within the 5 x 5 meter plot (Fig.5).

Sampling intensity (i.e. area of sample plots expressed as a percentage of stand area) of each stand was 5% except for stand no. 6 which was 10%. The maximum standard error was set at 15% of the mean tree density of standing burned trees. In almost all cases the standard error of the mean was well below the designated 15%, except for stands 7 and 9 which were 16.3% and 17.3% respectively. To further reduce the standard error of the mean of stands 7 and 9, and maintain a uniform sampling intensity, additional sampling and an increase in stand size would be required. Because these standard errors did not greatly exceed 15%, it was felt that the additional information to be obtained by further sampling would not justify the effort expended (Oosting, 1956). Sampling adequacy in each stand was also assessed by use of the species-area curve (Cain, 1938). The minimal area, as determined by the species-area curve, was eclipsed early in the sampling of each stand.

Two additional stands were selected using a slightly different sampling scheme. One stand was in the burned area and one in the adjacent unburned forest. Instead of ten, 10 x 10 meter plots, five 20 x 20 meter plots were located in each stand along a 200

Figure 5. Diagram of sample plot used in community analysis of Vermilion Pass burn.



meter baseline. Three, 2 x 1 meter plots were randomly located within each of the larger plots. These two stands were used to compare the burned and unburned forest.

C. Community Analysis

In the 10 x 10 meter plot, standing trees (living and dead) less than 300 cm tall were assigned to one of four height-classes (0-30 cm ; 31-100 cm ; 101-200 cm ; 201-300 cm). Standing trees (living and dead) over 300 cm tall were assigned to DBH (diameter at breast height, 135 cm) size classes. In addition standing trees were identified to species where possible, and assigned to one of the first 4 categories, and fallen trees to the last 2 categories:

i) Standing dead snags (dead before burn).

ii) Standing dead (by 1968 fire).

iii) Standing dead (held needles for one or two seasons).

iv) Standing with needles (living or dead but less severely burned).

v) Burned on ground, dead before fire (generally barkless with charred exposed roots).

vi) Fallen after fire (i.e. burned standing), counted only if rooted in plot (rootstocks not burned).

Trees in the last category (vi) may have been living or dead before the fire.

Height measurements of approximately six burned trees per plot, representative of the major size-classes and species, were obtained with a Haga altimeter. Diameters of all fallen logs formerly rooted in the 10 x 10 meter plot were recorded.

Identification, density, total height and current year's height growth were determined for all coniferous tree seedlings rooted in the 10 x 10 meter plot.

In the 5 x 5 meter plot, the average height and percent cover, of living shrubs, estimated to the nearest 1% were determined by species. Living and dead density of shrubs were recorded. *Populus tremuloides* Michx. was included in the shrub stratum. *Salix* spp. were, for the most part, difficult to identify at the species level as they were primarily found in a vegetative condition. Thus all *Salix* species were grouped and considered only at the generic level. Several *Salix* species do occur in the immediate area, including *S. vestita*, *S. bebbiana*, *S. discolor*, *S. glauca* and *S. myrtilifolia*.

In the 2 x 2 meter plot, the average height and percent cover of herbs and dwarf shrubs, estimated to the nearest 1%, were determined by species. Living post-burn vegetation sampled in stands 1-6 in 1971 was again sampled in the same plots in 1972.

Vascular species were collected throughout the burned area and unburned forest and a presence list compiled (Appendix D and E). Nomenclature follows Hitchcock *et al.* (1969) for the vascular plants. Non-vascular plants were not collected, except for a few of the more obvious ones. Voucher collections are deposited in herbaria at the University of Alberta and the Northern Forest Research Centre, C.F.S., in Edmonton, Alberta.

Basal area of the standing burned trees was calculated using density and size-class values. Basal area was not calculated for stems occurring in size-classes 0-30 cm., 31-100 cm. and

101-200 cm. For those stems in height class 201-300 cm., an average diameter of 1 inch was assumed for basal area calculations.

Density values and basal area values for the standing trees in quadrats were subjected to analysis of variance to afford a basis of judgement as to whether or not several stands are samples from a single homogeneous population (Snedecor, 1934).

Plot frequency (%) and average cover (%) of each herb and shrub species were calculated for each stand; these values were converted to Prominence Values using the formulae P.V. = % cover x $\sqrt{\%\ \text{frequency}}$, a modification of Beals (1960), LaRoi (1964), Stringer and LaRoi (1970) and used by Douglas and Ballard (1971), Van Der Valk and Bliss (1971) and Douglas (1972).

Ordination techniques (Bray and Curtis, 1957; Beals, 1960) and cluster analysis (Pritchard and Anderson, 1971) were employed to detect and assess differences in the structure of the standing dead tree populations among stands, differences in the structure and composition of the developing plant communities, and to correlate these with environmental variables.

In the two stands used to compare the burned and unburned forest, trees were identified and counted in the 20 x 20 meter plots. Shrubs and herbs were identified in the 2 x 1 meter plots and their percent cover, frequency and height determined.

D. Substrate Analysis

The ground surface substrates of the burn were important constituents of the over-all complex in terms of percent cover.

Seven distinct, observable substrates were recognized: charred humus, rock, mineral soil, rotten wood, bryophytes, needle litter and fallen logs. Percent cover was estimated for each in the 2 x 2 meter plot.

E. Meteorological Analysis

Five climatic stations were established on the northwest-facing slope of Vermilion Pass in 1969 by Parks Canada. Three were located in the burned forest at elevations of 1646, 1707 and 1829 meters A.S.L. and two in the unburned forest at 1677 and 1829 meters A.S.L. Temperature and relative humidity (Lambrecht hygro-thermograph) were recorded on a continuous year-round basis. The hygrothermographs were housed in a Stevenson Screen shelter mounted 135 cm above ground.

F. Soil Analysis

One soil pit was dug in each of the 12 stands and one in the unburned forest. Soil samples were collected from recognizable horizons for subsequent laboratory analyses. The Alberta Soil and Feed Testing Laboratory carried out an analysis on the less than 2 mm fraction which included: available nitrogen (N) (phenoldisulphonic acid method), phosphorus (P) (combined nitric acid vanadate molybdate colorimetric determination), and potassium (K) (flame photometry using the I.L. 143 flame photometer), soil reaction (pH), and conductivity (mmhos) (soil-water extract). When pH was below 5.5 the soil samples were furthur tested for aluminum and manganese (ppm) (atomic absorption spectrophotometer). Semiquantitative estimates of sodium (Na) (flame photometry) and sulfur (S) (modified Johnson Nishita procedure), were also determined. The soils service laboratory at the Northern Forest Research Centre determined particle-size distribution by the modified Bouyoucos hydrometer sedimentation technique (Day, 1965) following H_2O_2 oxidation of organic matter and soluble salt removal. For the B horizon pyrophosphate extractable iron and aluminum were determined according to CSSC methods. Organic carbon was determined by the modified Walkley-Black titrimetric wet oxidation method following recommended procedures of the CSSC (1974). Soil color was described for moist soil using the Munsell soil color charts (1953) in natural light.

G. Physiographic Analysis

Elevation and slope angle were determined at each plot using an aneroid barometer and a hand held Abney level. The depth of the surface organic layer (duff) was measured at each corner of the 10 x 10 meter plots. An average depth of duff for the stand was then calculated.

V RESULTS

A. Standing Dead Trees

The standing fire-killed trees included Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*) and lodgepole pine (*Pinus contorta* var. *latifolia*). Identification of severely burned trees was not always possible, particularly the smaller diameter classes, but generally there were enough distinguishing features of each tree that identification did not prove a difficult task. The standing dead forest also included snags that were dead before the fire passed through. These snags were not numerous and could generally be separated from the 1968 fire-killed trees (Appendix J). Two *Pseudotsuga menziesia* snags were also identified in the burn.

i) Total density and basal area

Total stand density figures include identifiable and unidentifiable standing tree stems (Table 1). The average number of stems for a 10 x 10 meter quadrat in the 12 stands was 33.5 (x 100 = 3350 ha^{-1}). The mean and standard deviation of densities in stands ranged from a high of 48.1 $\pm$ 13.3 in no. 11 to a low of 23.4 $\pm$ 6.7 in no. 5. The standard error of the mean expressed as a % of mean density (i.e. 100 SE/$\bar{x}$) varied from 7.1 % in no. 2 to 17.3% in no. 9; 10 of the 12 stands were less than 15%.

Basal area figures are expressed in square meters per 100 sq. meter quadrat (Table 2). Basal area ranged from 1.9 sq. meters in stand no. 1 to 3.6 sq. meters in stands nos. 3 and 11. Ten of the

Table 1. Density[a] of standing dead trees[b] per quadrat (10x10 m.) for 12 stands in the Vermilion Pass burn.

QUADRAT NUMBER	STAND NUMBER 1	2	3	4	5	6	7	8	9	10	11	12
1	70	32	32	31	30	39	14	40	22	48	58	31
2	63	22	41	34	22	60	45	25	14	43	71	38
3	37	27	41	18	12	31	25	29	16	31	43	17
4	37	32	27	30	33	61	53	21	47	25	33	41
5	56	35	20	16	28	52	25	35	8	28	52	30
6	34	38	59	41	21	26	19	25	34	67	44	23
7	47	38	21	31	26	61	43	37	14	35	60	31
8	24	19	29	18	27	48	24	18	43	53	35	41
9	34	24	41	14	14	26	10	38	49	20	55	31
10	50	36	38	19	21	19	19	34	26	26	30	22
TOTAL	452	303	349	252	234	423	277	302	273	376	481	305
MEAN	45.2	30.3	34.9	25.2	23.4	42.3	27.7	30.2	27.3	37.6	48.1	30.5
STANDARD DEV.	14.6	6.9	11.6	9.2	6.7	16.2	14.4	7.7	15.0	14.8	13.3	8.1
STANDARD ERROR AS % OF MEAN	10.1	7.1	10.5	11.5	9.1	12.1	16.3	8.0	17.3	12.4	8.7	8.3

a - Includes identifiable and unidentifiable trees.

b - Includes all trees assigned to height and DBH classes.

Table 2. Basal area[a] of standing dead trees[b] per quadrat for 12 stands in the Vermilion Pass burn.

QUADRAT NUMBER	STAND NUMBER 1	2	3	4	5	6	7	8	9	10	11	12
1	.242	.350	.132	.275	.404	.319	.151	.231	.422	.289	.328	.450
2	.237	.217	.424	.351	.334	.519	.142	.284	.293	.163	.191	.350
3	.091	.317	.527	.366	.098	.186	.426	.211	.331	.109	.256	.466
4	.396	.301	.275	.079	.245	.189	.345	.293	.384	.270	.787	.338
5	.028	.115	.427	.135	.062	.402	.309	.510	.241	.259	.443	.452
6	.357	.346	.431	.217	.228	.330	.228	.318	.331	.263	.141	.144
7	.210	.241	.274	.147	.112	.434	.252	.396	.183	.294	.190	.230
8	.168	.603	.383	.287	.214	.442	.359	.189	.431	.489	.592	.249
9	.129	.393	.282	.153	.277	.318	.129	.323	.275	.264	.272	.245
10	.040	.393	.478	.215	.193	.285	.340	.369	.142	.363	.433	.286
TOTAL	1.90	3.28	3.63	2.23	2.17	3.42	2.69	3.12	3.03	2.76	3.63	3.21
MEAN	.19	.33	.36	.22	.22	.34	.27	.31	.30	.28	.36	.32
STANDARD DEV.	.12	.13	.12	.10	.11	.11	.10	.10	.10	.10	.20	.11
STANDARD ERROR AS % OF MEAN	21.1	12.1	11.1	13.6	13.6	8.8	11.1	9.7	10.0	10.7	16.7	9.4

a - Basal area expressed in square meters per 100 sq. meter quadrat.

b - Includes identifiable and unidentifiable trees. Trees in ht. classes 0-30 cm., 31-100 cm.; 101-200 cm. not included in B.A. determinations. An average diameter of 1" was assumed for those trees in ht. class 201-300 cm.

12 stands had standard errors of the mean basal area (expressed as a %) of less than 15%.

Analysis of variance was performed to determine if any significant differences existed between total stand densities, as a first approximation of structural variations among the sampled stands. The test was also performed on total stand basal areas. A significant F ratio (F = 4.51) was obtained at the 1% level for stand densities and at the 5% level for stand basal areas (F = 2.35). Duncan's multiple range test was then used to determine which stands (treatments) were significantly different from each other (Table 3).

ii) Density by species

Subalpine fir had the largest number of identifiable dead trees (Table 4). Its proportion of total density averaged 71% and ranged from 59% to 84%. The significant difference in total density appears to be largely a function of differences in subalpine fir density.

In all stands subalpine fir made up the largest percentage of trees. Engelmann spruce ranked second in 11 stands and lodgepole pine ranked second in one (no. 8). Of the unidentified trees 68% were less than 300 cm tall, 7% were larger than 10 in dbh (25.4 cm). and the remaining 30% were less than 10 in dbh (25.4 cm).

iii) Density by size-class and species

In each stand standing trees less than 300 cm in height were assigned to four height-classes and standing trees taller than 300 cm were assigned to 1 " dbh-classes. Trees assigned to height-

Table 3. Duncan's Multiple Range Test[a] for (A) Mean total tree densities, i.e. stems per 100 sq. m., and (B) Mean total tree basal areas, i.e. sq. m. per 100 sq. m., in the Vermilion Pass burn in 1972.

A) MEAN TOTAL TREE DENSITY (F= 4.51, sig. at 1% level)

Stand Number	5	4	9	7	8	2	12	3	10	6	1	11
Mean Density	23.4	25.2	27.3	27.7	30.2	30.3	30.5	34.8	37.6	42.3	45.2	48.1
									—	—	—	—
								—	—	—	—	
					—	—	—	—	—	—		
			—	—	—	—	—	—	—			
	—	—	—	—	—	—	—	—				

B) MEAN TOTAL TREE BASAL AREA (F= 2.35, sig. at 5% level)

Stand Number	1	5	4	7	10	9	8	12	2	6	3	11
Mean Basal Area	.190	.217	.223	.269	.276	.303	.312	.321	.328	.342	.363	.363
				—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—		
		—	—	—	—	—	—	—	—			
	—	—	—	—	—	—						

a - Any two means not underscored by the same line are significantly different at 5% level.

b - Any two means underscored by the same line are not significantly different at 5% level.

Table 4. Density[a] of standing dead trees by species and stand in the Vermilion Pass burn.

STAND NUMBER	SUBALPINE FIR No.	SUBALPINE FIR %	ENGELMANN SPRUCE No.	ENGELMANN SPRUCE %	LODGEPOLE PINE No.	LODGEPOLE PINE %	UNIDENTIFIED STEMS No.	UNIDENTIFIED STEMS %	TOTAL No.
1	327	72.3	49	10.8	2	0.5	74	16.4	452
2	180	59.4	52	17.2	5	1.6	66	21.8	303
3	236	67.5	39	11.2	18	5.2	56	16.1	349
4	162	64.3	31	12.3	4	1.6	55	21.8	252
5	149	64.9	40	17.1	5	2.1	40	17.1	234
6	268	63.4	100	23.6	15	3.5	40	9.5	423
7	217	78.3	14	5.1	11	4.0	35	12.6	277
8	188	62.3	24	7.9	36	11.9	54	17.9	302
9	209	76.6	17	6.2	8	2.9	39	14.3	273
10	317	84.3	22	5.9	4	1.1	33	8.7	376
11	395	82.3	29	5.8	15	3.2	42	8.7	481
12	236	77.4	22	7.2	15	4.9	32	10.5	305
TOTAL	2884	-	439	-	138	-	566	-	4027
MEAN	240	71.0	37	10.8	12	3.5	47	14.1	335

a - Density expressed as number of trees per 1000 sq. meters.

classes seldom exceeded 2 in dbh. All stands exhibit approximately the same distribution of density by height-classes (Table 5). Subalpine fir density is highest in the 31-100 cm height-class in all stands except no. 7, where it peaks in the 101-200 cm height-class. Table 6 summarizes the total densities of each tree species by diameter-class in the 12 stands; the height-classes have been pooled and assigned to the less than 3 in diameter-class.

Both subalpine fir and Engelmann spruce are most abundant in the less than 3 in size-class, and 95% of this size-class were identified as subalpine fir. Subalpine fir dominates the smaller size-classes up to 6in dbh while size classes larger than 6 in dbh are dominated by Engelmann spruce. Lodgepole pine shares a subdominant role with subalpine fir in size-classes 7 and 8 and emerges as the sole subdominant with the rapid decrease of subalpine fir in the larger size-classes. The size-class distribution for each stand is basically similar. The large numbers of subalpine fir occurring in the smaller size-classes indicate that if this forest had not burned it may have advanced to an Abies-Picea successional phase. The scarcity of the pine component in the smaller and larger size-classes suggests that pine was declining in the stand before the fire. The irregular size-class distribution of spruce may in part be an expression of suppression among individuals due to its tolerant nature (Horton, 1959). However, it is more likely indicative of an uneven-aged, late successional species (Day, 1972). The numerical advantage of spruce in the larger size-classes helps to establish it as the dominant species in the pre-fire forest.

Table 5. Density of identified standing trees by height (cm), and dbh (in) classes and by stand[a] in the Vermilion Pass burn.

HEIGHT CLASSES (CM.)	Stand 1 F[b]	Stand 1 S[c]	Stand 1 P[d]	Stand 2 F[b]	Stand 2 S[c]	Stand 2 P[d]	Stand 3 F[b]	Stand 3 S[c]	Stand 3 P[d]	Stand 4 F[b]	Stand 4 S[c]	Stand 4 P[d]	Stand 5 F[b]	Stand 5 S[c]	Stand 5 P[d]	Stand 6 F[b]	Stand 6 S[c]	Stand 6 P[d]
0-30	41	.	.	10	.	.	17	.	.	3	.	.	6	.	.	1	1	.
31-100	194	6	.	53	1	.	125	.	.	113	3	.	102	13	.	160	40	.
101-200	54	11	.	24	.	.	28	.	.	29	3	.	21	4	.	64	18	.
201-300	17	1	.	17	3	.	17	1	.	8	2	.	4	2	.	14	11	.
DIAMETER AT BREAST HEIGHT (IN.)																		
2	3	1	.	17	1	.	12	.	.	1	.	.	.	.	.	2	2	.
3	11	4	.	20	4	.	14	1	.	2	2	.	2	.	.	13	5	.
4	3	6	.	20	3	.	12	3	.	1	3	.	4	1	.	6	.	.
5	1	5	.	9	2	.	6	6	1	3	1	.	5	2	.	.	1	.
6	.	3	.	7	6	1	1	5	1	1	1	.	2	2	.	4	2	.
7	1	2	.	3	8	.	3	9	1	.	2	.	1	3	.	.	1	1
8	1	3	.	.	5	1	.	3	.	.	1	.	2	2	.	2	1	3
9	.	1	.	.	3	1	.	2	4	1	2	1	.	1	1	.	1	3
10	.	1	.	.	3	.	.	2	1	.	4	.	.	2	.	.	2	3
11	1	.	1	.	3	.	1	1	3	.	1	1	.	.	2	.	2	2
12	.	1	1	.	2	.	.	1	4	.	1	1	.	4	.	1	4	.
13	.	.	.	.	2	1	.	2	1	.	.	1	.	1	1	1	2	1
14	.	.	.	.	2	.	.	1	1	.	.	.	.	.	.	.	3	1
15	.	1	.	.	3	.	.	.	1	.	1	.	.	2	.	.	2	1
16	.	2	.	.	.	.	.	1	.	.	1	.	.	.	1	.	1	.
17	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.
18	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	1	.
19	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
20	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.
21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
22	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
23	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 5. continued

HEIGHT CLASSES (CM.)	STAND NUMBER 7 F^b	7 S^c	7 P^d	8 F^b	8 S^c	8 P^d	9 F^b	9 S^c	9 P^d	10 F^b	10 S^c	10 P^d	11 F^b	11 S^c	11 P^d	12 F^b	12 S^c	12 P^d
0-30	.	.	.	2	.	.	5	.	.	16	.	.	25	.	.	17	.	.
31-100	71	.	.	51	.	.	97	.	.	176	.	.	209	.	.	154	.	.
101-200	86	.	.	29	.	.	36	.	.	75	.	.	72	.	.	37	.	.
201-300	28	.	.	24	.	.	26	.	.	33	.	.	37	1	1	13	.	.
DIAMETER AT BREAST HEIGHT (IN.)																		
2	5	.	.	19	.	1	7	.	.	2	.	.	14	.	.	4	.	.
3	13	.	1	26	1	1	14	.	.	7	.	.	16	2	.	7	.	.
4	4	.	.	11	.	6	9	.	.	4	.	.	9	5	3	4	.	1
5	6	.	.	13	1	4	8	.	.	3	.	.	4	2	.	.	2	1
6	3	1	1	9	4	4	2	.	.	1	1	1	5	1	.	.	2	.
7	1	1	1	.	1	6	2	1	.	.	1	.	.	1	2	.	3	.
8	.	.	1	2	6	4	3	2	.	.	2	1	3	2	.	.	1	.
9	.	2	.	2	3	2	.	1	.	.	.	.	1	2	1	.	1	3
10	.	2	2	.	3	1	.	4	.	.	1	1	.	3	2	.	1	1
11	.	1	.	.	1	3	.	2	.	.	2	.	.	1	2	.	2	1
12	.	2	2	.	.	1	.	1	4	.	1	1	.	2	.	.	1	2
13	.	1	1	.	.	2	.	3	2	.	2	.	.	.	1	.	4	5
14	.	.	.	.	1	.	.	.	1	.	4	.	.	1	.	.	2	.
15	.	.	.	.	.	1	.	.	.	.	5	.	.	1	1	.	3	.
16	.	2	1	.	.	.	.	.	1	.	1	.	.	1	1	.	.	.
17	.	.	.	.	.	.	.	1	.	.	.	.	.	3	.	.	.	1
18	.	1	1	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.
19	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
20	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
22	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
23	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.

a - density expressed as number of trees per 1000 sq. meters; X10 = stems per hectare.
b - SUBALPINE FIR; c - ENGELMANN SPRUCE; d - LODGEPOLE PINE

Table 6. Total density[a] of identified standing trees by diameter-class and species in the Vermilion Pass burn.

SPECIES	DIAMETER CLASS (INCHES) <3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	23	TOTAL
SUBALPINE FIR	2527	145	87	58	35	11	13	4	.	2	1	1	.	.	.	.	.	.	.	.	.	2884
ENGELMANN SPRUCE	125	19	21	22	28	33	28	19	28	16	20	17	14	18	10	6	7	2	3	2	1	439
LODGEPOLE PINE	2	2	10	6	8	11	10	16	11	15	16	16	3	4	4	1	2	.	.	1	.	138
TOTAL	2654	166	118	86	71	55	51	39	39	33	37	34	17	22	14	7	9	2	3	3	1	3461

a - Density expressed as number of trees per 12000 sq. meters (12 stands x 1000 sq. meters/stand).

iv) Basal area by species and stand number

Basal area (B.A.) was calculated from the tree diameter data. A diameter of 1 in (2.54 cm) was used to calculate basal area for trees in the 200-300 cm height-class. Smaller height-classes were not included in B.A. determination. Engelmann spruce made up 50% of the total basal area of the standing stems but only 11% of the total density. This attests to the importance of the larger size-classes in contributing to basal area. Subalpine fir and lodgepole pine contributed 11% and 20% respectively and unidentified trees the remaining 18% of the total basal area (Table 7).

Stand no.3 had the largest basal area of any stand with 40% of its basal area in Engelmann spruce. Stand no. 1 had the smallest basal area of the 12 stands, but ranked second in density. In all stands Engelmann spruce made up the largest percent of basal area.

Lodgepole pine had a larger proportion of the basal area than subalpine fir in 10 of the 12 stands. This proportion is probably too high and traceable to the percentage of basal area represented in the unidentified category. Lodgepole pine was more easily recognized than subalpine fir, so that a larger percentage of the unidentified basal area was likely subalpine fir.

v) Basal area by size-class and species

The basal area of identified standing trees by size-class and species is presented in Table 8. The 3, 4 and 5 in diameter-classes comprised 50% of the basal area of subalpine fir, while the 13 and 15 in size-classes accounted for 18% and 12% of the basal area of lodgepole pine and Engelmann spruce respectively. The middle range

Table 7. Basal area[a] of standing dead trees by species and stand in the Vermilion Pass burn.

STAND NUMBER	SUBALPINE FIR		ENGELMANN SPRUCE		LODGEPOLE PINE		UNIDENTIFIED STEMS		TOTAL
	B.A.	%	B.A.	%	B.A.	%	B.A.	%	B.A.
1	2.2	11.6	10.6	55.8	1.3	6.8	4.9	25.8	19.0
2	6.1	18.2	20.2	60.5	3.4	10.2	3.7	11.1	33.4
3	4.2	11.5	14.4	39.5	10.5	28.8	7.4	20.3	36.5
4	1.2	5.1	13.1	58.7	2.6	11.7	5.4	24.2	22.3
5	2.3	10.6	12.1	55.8	3.8	17.5	3.5	16.1	21.7
6	4.2	12.4	16.8	49.7	8.2	24.3	4.6	13.6	33.8
7	2.7	10.0	11.9	44.2	7.1	26.4	5.2	19.3	26.9
8	7.3	21.8	12.7	37.9	11.3	33.7	2.2	6.6	33.5
9	4.5	15.2	14.0	47.3	6.9	23.3	4.2	14.2	29.6
10	1.4	5.1	19.5	70.6	1.7	6.2	5.0	18.1	27.6
11	4.7	13.0	15.9	43.8	9.1	25.1	6.6	18.2	36.3
12	0.8	2.5	13.4	41.5	9.8	30.3	8.3	25.7	32.3
TOTAL	41.6	-	174.6	-	75.7	-	61.0	-	352.9
$\overline{X}$	3.5	11.4	14.5	50.4	6.3	20.4	5.1	17.8	29.4

a - Basal area expressed in sq. meters at breast height per hectare.

Table 8. Total basal area[a] of identified standing dead trees by diameter-class and species in the Vermilion Pass burn.

DIAMETER CLASS (in)	SUBALPINE FIR	ENGELMANN SPRUCE	LODGEPOLE PINE	TOTAL
< 2	0.1	t	t	0.1
2	0.2	t	t	0.2
3	0.7	0.09	t	0.8
4	0.7	0.2	0.08	1.0
5	0.7	0.2	0.08	1.0
6	0.6	0.5	0.2	1.3
7	0.3	0.8	0.3	1.4
8	0.4	1.0	0.3	1.7
9	0.2	0.8	0.7	1.7
10	.	1.4	0.6	2.0
11	0.1	1.0	0.9	2.0
12	0.07	1.5	1.2	2.8
13	0.09	1.5	1.4	3.0
14	.	1.4	0.3	1.7
15	.	2.1	0.5	2.6
16	.	1.3	0.5	1.8
17	.	0.9	0.2	1.1
18	.	1.2	0.3	1.5
19	.	0.4	.	0.4
20	.	0.6	.	0.6
22	.	0.5	0.3	0.8
23	.	0.3	.	0.3
TOTAL	4.2	17.7	7.9	29.8

a – Basal area expressed in sq. meters for all sampled stands (12000 sq. meters).

t – <0.01 sq. meters.

of size-classes, from 9 to 15" dbh, contains over 50% of the total basal area.

vi) Basal area and density comparison

A comparison of the percent density and basal area of the three tree species reveals that although subalpine fir averaged 71% of the stems in each stand it accounts for only 11% of the basal area (Table 9). Conversely, Engelmann spruce averaged 50% of the basal area in each stand but comprised only 11% of the stems in each stand. Similarly, while lodgepole pine exceeded subalpine fir in percent basal area, it only accounted for 4% of the density. The basal area data clearly indicate the quantitative dominance of spruce in the pre-burn forest as compared with subalpine fir and lodgepole pine.

vii) Diameter-height relationships

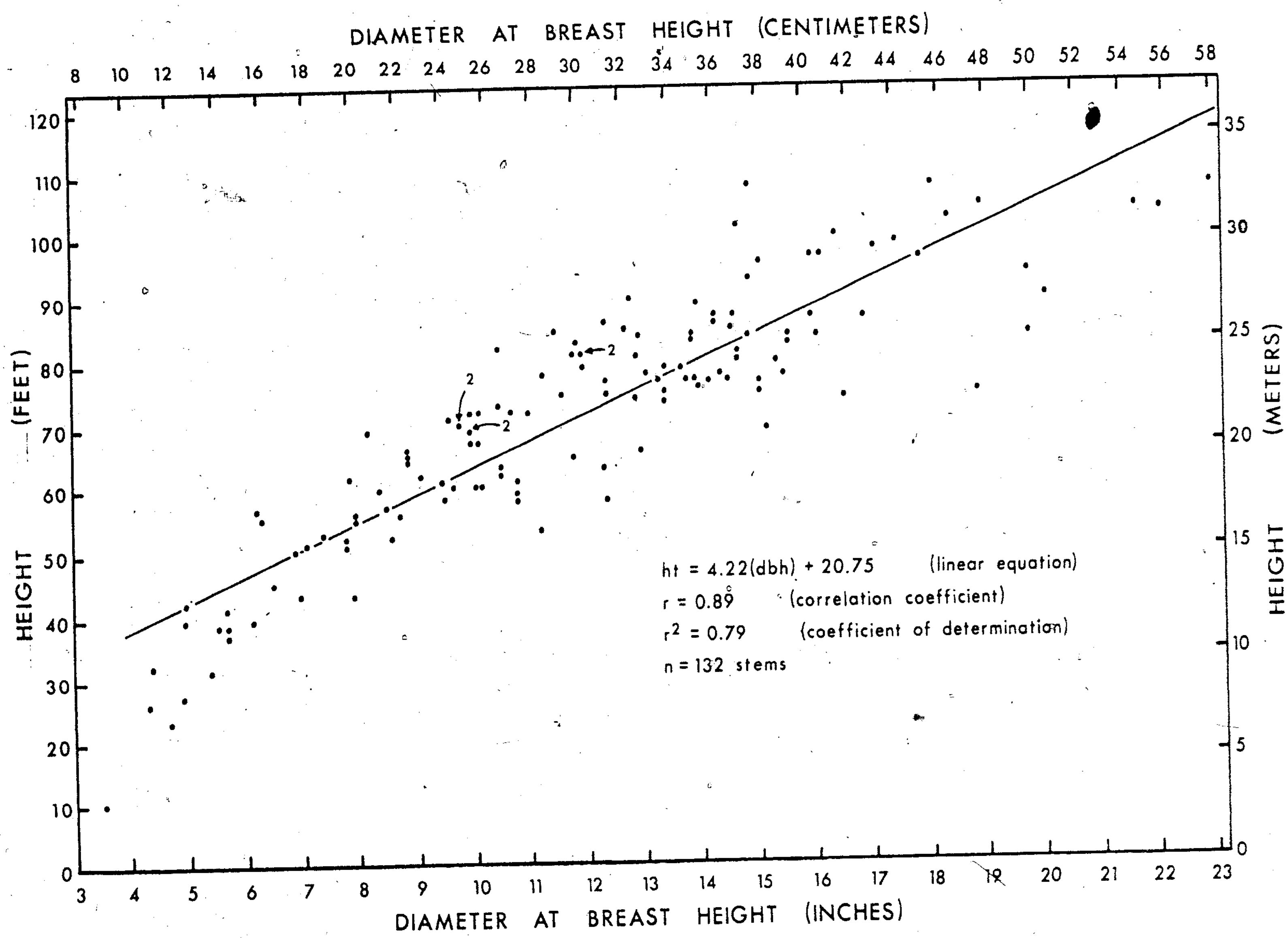
Figures 6, 7 and 8 depict the height and diameter relationships of Engelmann spruce, subalpine fir and lodgepole pine, respectively, in the study area.

Although diameter-height relationships are normally more adequately described by quadratic equations, the straight line obviously fits the points quite well and provides a fairly good empirical statement of the relation between the two variables. For lodgepole pine the relationship is relatively weak (Coefficient of determination = .45). A power curve of the form $Y = ax^b$ provides a slightly better fit ($Y = 21.83x^{.4789}$), with $r = +0.70$ and $r^2 = 0.49$. However, as the main purpose of the equations was

Table 9. Relative basal area and density of standing dead trees by species and stand in the Vermilion Pass burn.

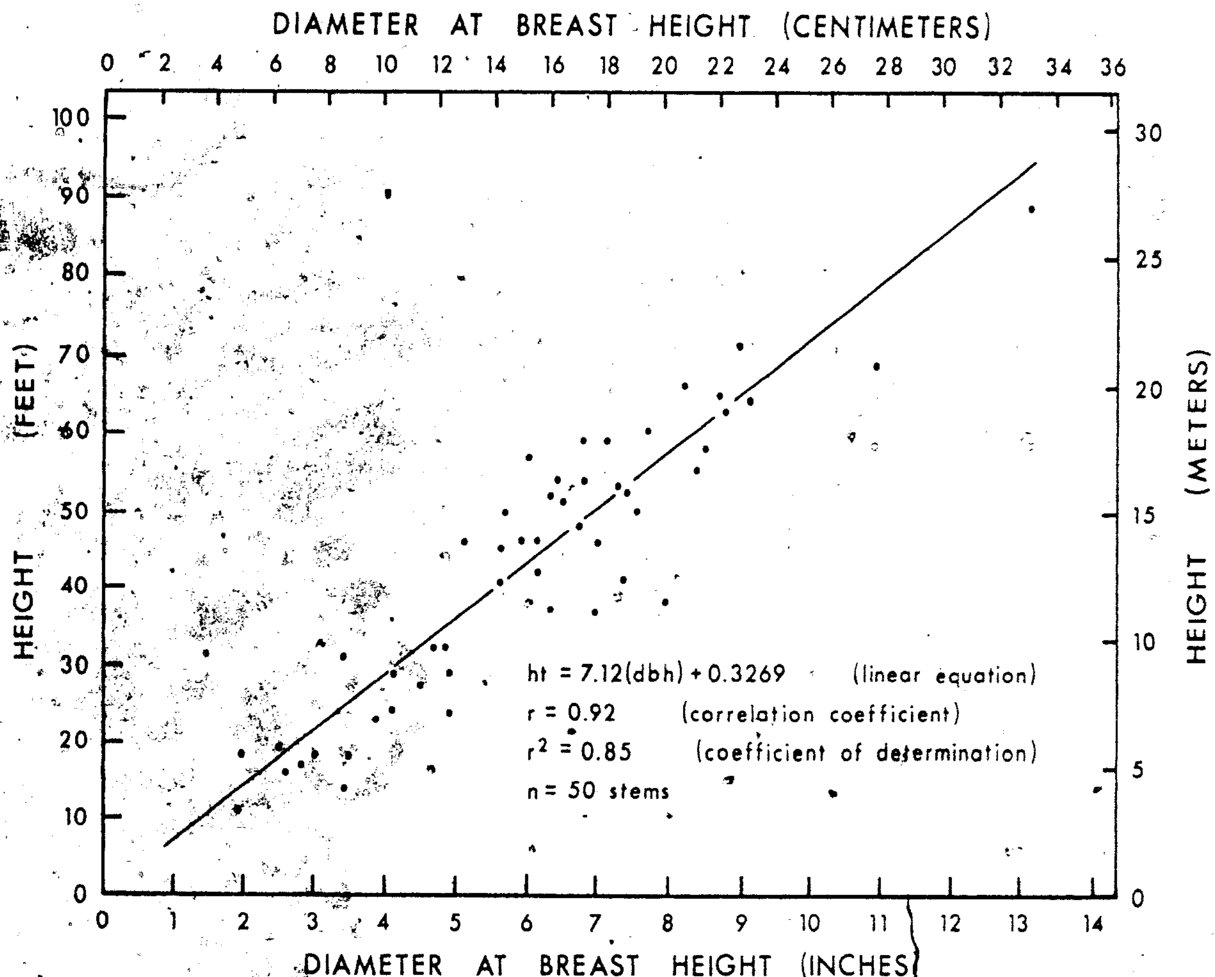
STAND NUMBER	SUBALPINE FIR % DENSITY	SUBALPINE FIR % BASAL AREA	ENGELMANN SPRUCE % DENSITY	ENGELMANN SPRUCE % BASAL AREA	LODGEPOLE PINE % DENSITY	LODGEPOLE PINE % BASAL AREA	UNIDENTIFIED STEMS % DENSITY	UNIDENTIFIED STEMS % BASAL AREA
1	72.3	11.6	10.8	55.8	0.5	6.8	16.4	25.8
2	59.4	18.2	17.2	60.5	1.6	10.2	21.8	11.1
3	67.5	11.5	11.2	39.5	5.2	28.8	16.1	20.3
4	64.3	5.1	12.3	58.7	1.6	11.7	21.8	24.2
5	64.9	10.6	17.1	55.8	2.1	17.5	17.1	16.1
6	63.4	12.4	23.6	49.7	3.5	24.3	9.5	13.6
7	78.3	10.0	5.1	44.2	4.0	26.4	12.6	19.3
8	62.3	21.8	7.9	37.9	11.9	33.7	17.9	6.6
9	76.6	15.2	6.2	47.3	2.9	23.3	14.3	14.2
10	84.3	5.1	5.9	70.6	1.1	6.2	8.7	18.1
11	82.3	13.0	5.8	43.8	3.2	25.1	8.7	18.2
12	77.4	2.5	7.2	41.5	4.9	30.3	10.5	25.7
$\bar{X}$	71.0	11.4	10.8	50.4	3.5	20.4	14.6	17.8

Figure 6. Diameter-height relationship for Engelmann spruce in the study area of the Vermilion Pass burn. English units used in equation.



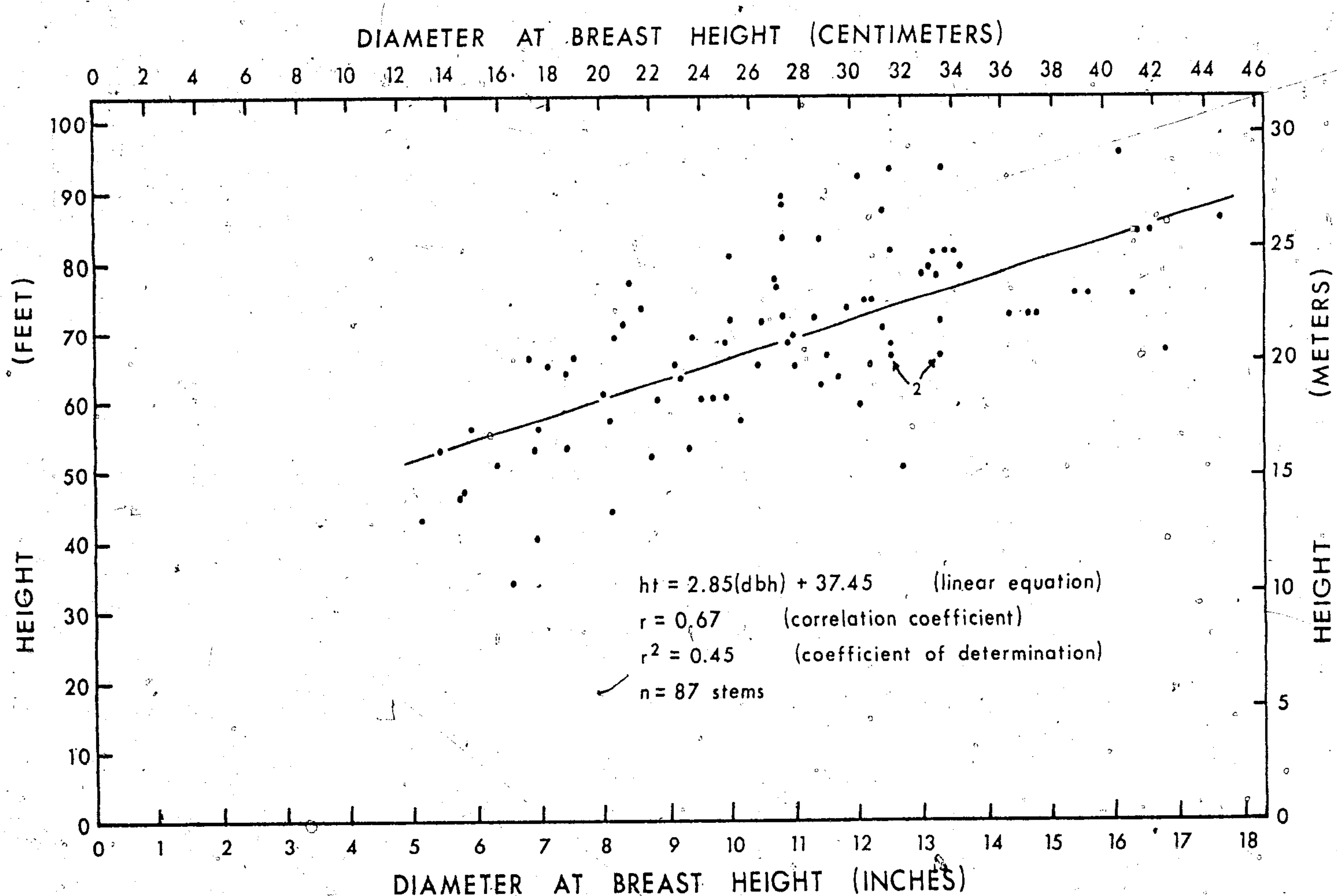
DIAMETER AT BREAST HEIGHT (CENTIMETERS)
8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58
HEIGHT (FEET)
0 10 20 30 40 50 60 70 80 90 100 110 120
HEIGHT (METERS)
0 5 10 15 20 25 30 35
ht = 4.22(dbh) + 20.75 (linear equation)
r = 0.89 (correlation coefficient)
r2 = 0.79 (coefficient of determination)
n = 132 stems
2
2
2
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
DIAMETER AT BREAST HEIGHT (INCHES)

Figure 7. Diameter-height relationship for subalpine fir in the study area of the Vermilion Pass burn. English units used in equation.



DIAMETER AT BREAST HEIGHT (CENTIMETERS)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36
HEIGHT (FEET)
0 10 20 30 40 50 60 70 80 90 100
HEIGHT (METERS)
0 5 10 15 20 25 30
ht = 7.12(dbh) + 0.3269 (linear equation)
r = 0.92 (correlation coefficient)
r² = 0.85 (coefficient of determination)
n = 50 stems
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
DIAMETER AT BREAST HEIGHT (INCHES)

Figure 8. Diameter-height relationship for lodgepole pine in the study area of the Vermilion Pass burn. English units used in equation.



DIAMETER AT BREAST HEIGHT (CENTIMETERS)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46
HEIGHT (FEET)
0 10 20 30 40 50 60 70 80 90 100
HEIGHT (METERS)
0 5 10 15 20 25 30
ht = 2.85(dbh) + 37.45 (linear equation)
r = 0.67 (correlation coefficient)
r2 = 0.45 (coefficient of determination)
n = 87 stems
2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
DIAMETER AT BREAST HEIGHT (INCHES)

descriptive not predictive, the straight line equation was used.

viii) Fire severity index

The intensity of a fire can vary a great deal (Van Wagner, 1965) but depends primarily on fuel weight, fuel arrangement and size, and moisture content, topographic and weather variables (Kilgore, 1973; Rowe and Scotter, 1973). The intensity of a fire should be reflected in post-burn site conditions. Accordingly, an attempt was made to assess the severity of the Vermilion Pass fire in a quantitative manner by classifying trees into three categories: (a) Severely Burned category represents those trees that were killed outright by the 1968 fire, all crown foliage being consumed along with a large percentage of the fine branch material; (b) In the Moderately Burned category stems held their needles for one or two seasons after the fire and were identified primarily by the presence or accumulation of needle litter at their base; (c) Lightly Burned category consists of living trees or those with scorched needles still attached to the branches.

All stands were classed as severely burned and one-third were 100% severely burned. Only one of the stands had more than 10% of its stems moderately burned (no. 6 with 16%). Three of the 12 stands had a lightly burned component, but in no instance did this exceed 8% of the total (Fig.9). Stand no. 6 though classed as"Severely Burned" (76%) was obviously the least severely burned (Plate 1) of the 12 stands; this fact was also evident in the shrub and herb components and will be discussed in a later section. Plate 2 is an example of a very severely burned stand.

Figure 9. Classification of standing burned trees by stand and fire severity index in the Vermilion Pass burn.
(a) Severely burned (b) Moderately burned
(c) Lightly burned.

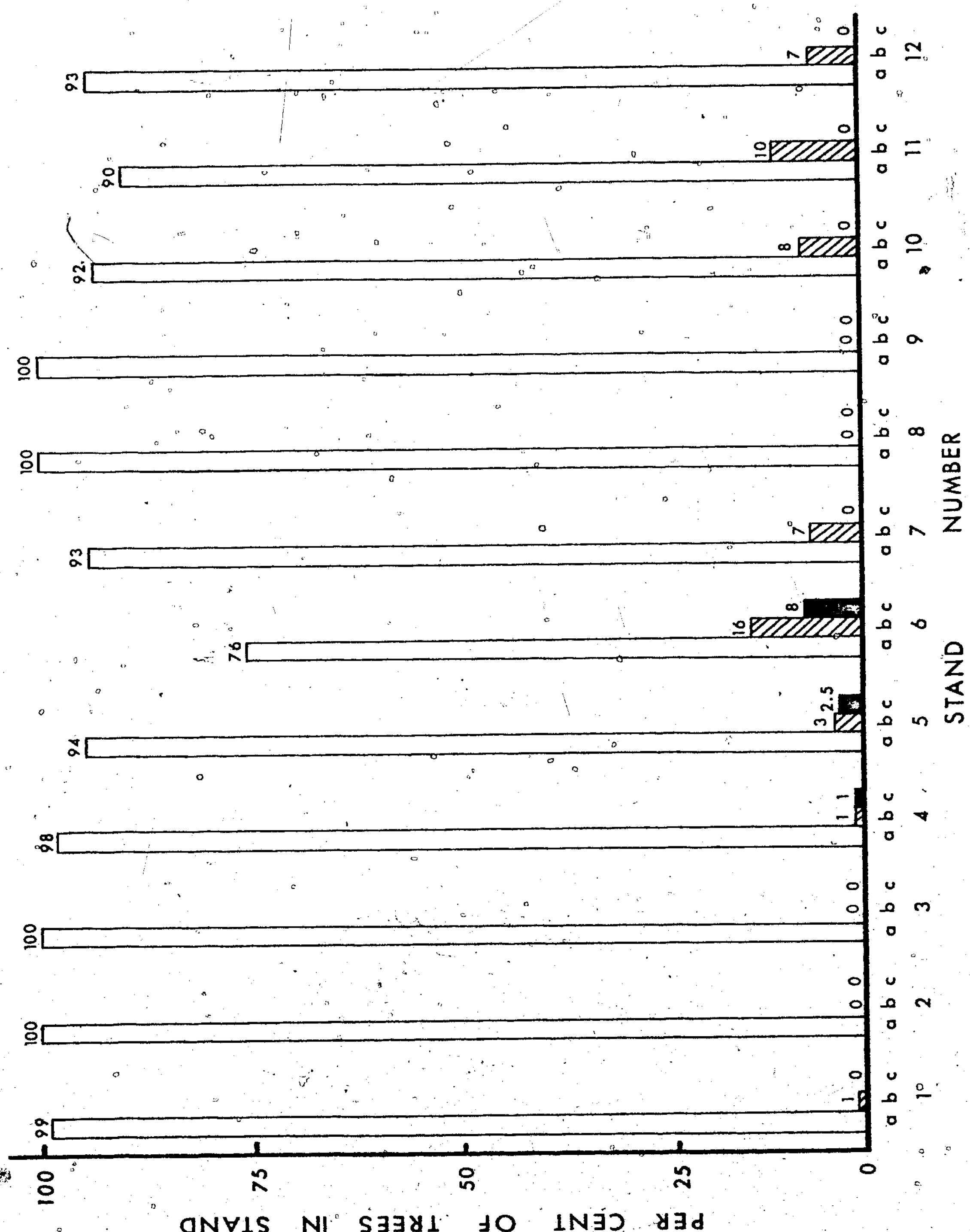

PER CENT OF TREES IN STAND
0
25
50
75
100
STAND NUMBER
1
2
3
4
5
6
7
8
9
10
11
12
a b c
99
1
0
100
0
0
100
0
0
98
1
1
94
3
2.5
76
16
8
93
7
0
100
0
0
100
0
0
92
8
0
90
10
0
93
7
0

Plate 1. Stand 6, the least severely burned stand in the Vermilion Pass fire of 1968. (Photo date, Aug. 1972).

Note, Menziesia ferruginea sprouts in foreground, yellow-flowered Arnica cordifolia, and high "survival" of fine branch material and bark on trees.

Plate 2. A severely burned stand in the Vermilion Pass fire of 1968. (Photo date, Aug. 1972).

Contrast with Plate 1.

B. Trees on the Ground

Stems lying on the ground and previously rooted in the plot were recorded in each stand by one-inch size-classes. An attempt was made to determine if the stem had fallen before or after the fire occurred, primarily by examining the base of the stem. If the main root attachments to the stem were not charred, it was concluded that the tree was standing during the fire. The trees that had fallen after the fire also had loose mineral soil exposed. If the stem was on the ground prior to the fire, the exposed roots were normally severely burned, and the duff immediately surrounding the base was not disturbed other than by the fire. Other observations were also helpful and varied from stem to stem. The status of the smaller stems was more difficult to evaluate.

An average density of 300 stems per hectare was recorded on the ground. Of these approximately 25% had fallen after the fire (Table 10). Discounting the smallest size-classes 2 and 3 (due to possible observational error), only 8% of the stems lying on the ground had fallen since the fire. T-tests comparing stands sampled in 1971 with those sampled in 1972 show no significant difference in the number of stems recorded as fallen <u>before</u> the fire. However, there is a significant difference (1% level) in the number of stems recorded as fallen <u>after</u> the fire. The same results were obtained when the 2 and 3 in. size-classes were excluded from the tests.

Future monitoring of the 12 stands should provide increasingly sound statistical information on the rate of deterioration of the

Table 10. Density of trees lying on the ~~ground~~[a] by stand,[b] year and size-class, in the Vermilion Pass burn.

DIAMETER CLASS (INCHES)	STAND NUMBER 1971 1		2		3		4		5		6		1972 7		8		9		10		11		12		TOTAL	
	B[c]	A[d]	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
2	.	1	.	.	.	1	1	.	1	.	.	1	6	8	11	2	3	6	9	3	3	11	6	18	40	51
3	.	.	1	.	.	.	2	.	4	.	1	.	1	1	4	1	1	1	.	6	4	5	5	6	23	20
4	2	.	1	.	.	.	4	.	5	.	2	.	2	.	4	.	4	2	1	1	2	1	2	.	29	4
5	1	.	1	.	2	.	3	.	3	.	1	.	1	.	2	.	4	.	1	.	1	.	1	1	21	1
6	3	.	1	.	1	1	3	.	3	.	.	.	1	1	1	1	3	.	1	.	2	1	1	.	20	4
7	2	.	.	.	.	.	5	.	3	.	2	.	2	.	1	.	2	1	.	1	1	.	2	.	20	2
8	2	.	1	.	5	.	4	.	2	.	2	.	3	1	.	.	3	.	3	.	2	.	5	.	32	1
9	1	.	.	.	1	.	6	.	4	.	1	.	2	.	2	.	2	.	1	.	.	.	1	.	21	.
10	1	.	1	.	.	.	4	.	6	.	3	.	3	1	.	.	1	.	1	1	1	.	4	.	25	2
11	.	.	.	.	.	.	2	.	1	.	.	.	.	.	.	.	.	.	2	2	1	.	2	.	8	2
12	1	.	.	.	.	.	4	.	2	.	.	.	4	.	2	.	2	.	.	.	1	.	.	.	16	.
13	1	.	.	.	2	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	5	1
14	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	2	1
15	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	2	.	3	.
16	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
17	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
18	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	3	1
21	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
TOTAL	16	1	7	1	11	2	39	.	36	.	13	2	25	12	27	4	26	10	20	14	19	18	32	25	271	89

a. Tabulated only if previously rooted in the plot.
b. Expressed in no. per 1000 sq. meters.
c. Trees fallen before the fire (B).
d. Trees fallen after the fire (A).

burned tree stratum, as well as on the rise of the new one.

C. Conifer Tree Seedlings

Conifer seedlings were counted in the 10 x 10 m. plots of stand nos. 1-6 in 1971 and 1972, and in those of stand nos. 7-12 in 1972 (Fig.10).

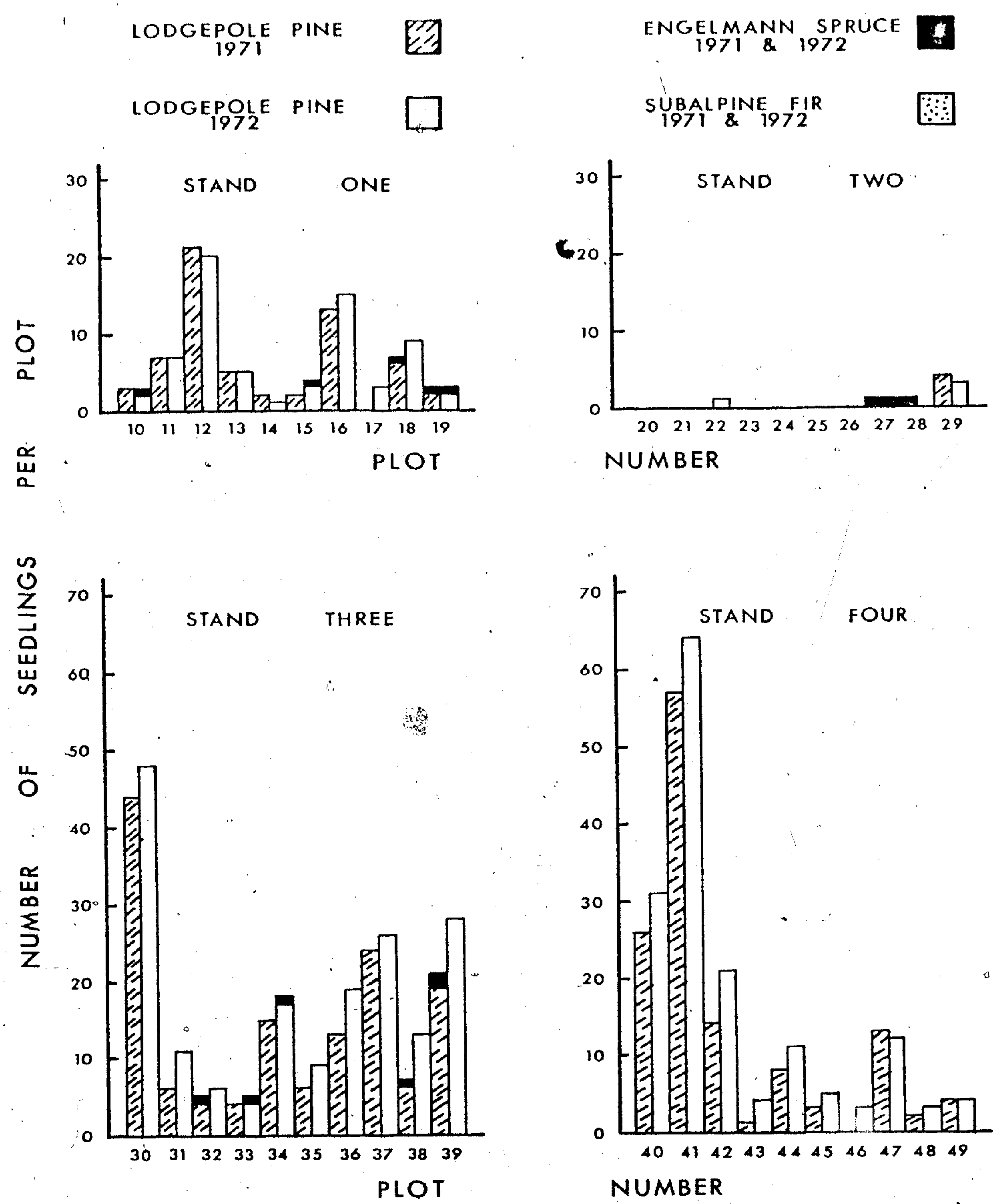
The conifer regeneration consisted almost exclusively of lodgepole pine (98% in 1971 and 1972). Seedlings of lodgepole pine occurred in all 12 stands (100% constance), and had a frequency of 90% in the 120 plots. Spruce seedlings had a constance value of 83% and a frequency value of 25%. Subalpine fir occurred in only 2 of the 12 stands (17% constance) and was the least frequent (2.5%) and least abundant of the three conifers.

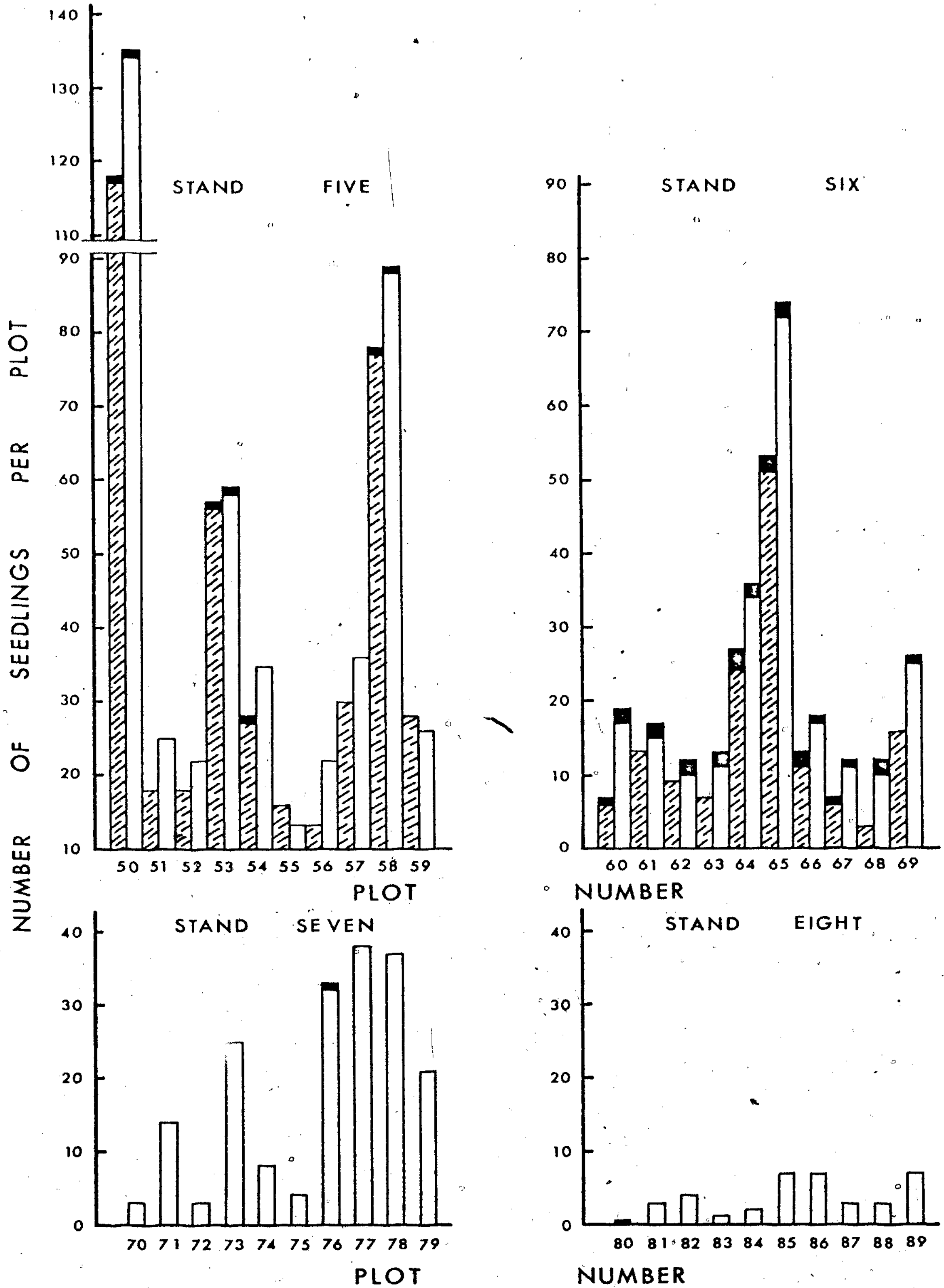
In 1971 and 1972 averages of 147 and 182 lodgepole pine seedlings were recorded per 1000 sq. m. in stand nos. 1-6. This represents a 19% increase from 1971 to 1972. (sig. at 5% level). Table 11 gives the conifer tree seedling density for each stand in 1971 and 1972.

An average of 3.5 spruce seedlings and 0.3 fir seedlings were recorded per stand in 1972. Forty percent of the spruce seedlings occurred in stand no. 6, the least severely burned of the 12 stands. Stand no. 6 occurred closer to the unburned forest than the other stands and was thus closer to an available seed source (Fig.2).

Seedling density of lodgepole pine was extremely variable throughout the burn area even though all stands had an adequate seed source based on the observed density of dead lodgepole pine

Figure 10. Distribution of coniferous tree seedling density by plot in the 12 burn stands, Vermilion Pass.


LODGEPOLE PINE 1971
LODGEPOLE PINE 1972
ENGELMANN SPRUCE 1971 & 1972
SUBALPINE FIR 1971 & 1972
STAND ONE
STAND TWO
STAND THREE
STAND FOUR
NUMBER OF SEEDLINGS PER PLOT
PLOT NUMBER
0
10
20
30
40
50
60
70
10 11 12 13 14 15 16 17 18 19
20 21 22 23 24 25 26 27 28 29
30 31 32 33 34 35 36 37 38 39
40 41 42 43 44 45 46 47 48 49


STAND FIVE
STAND SIX
STAND SEVEN
STAND EIGHT
NUMBER OF SEEDLINGS PER PLOT
PLOT NUMBER
PLOT NUMBER
140
130
120
110
90
80
70
60
50
40
30
20
10
50 51 52 53 54 55 56 57 58 59
90
80
70
60
50
40
30
20
10
0
60 61 62 63 64 65 66 67 68 69
40
30
20
10
0
70 71 72 73 74 75 76 77 78 79
40
30
20
10
0
80 81 82 83 84 85 86 87 88 89

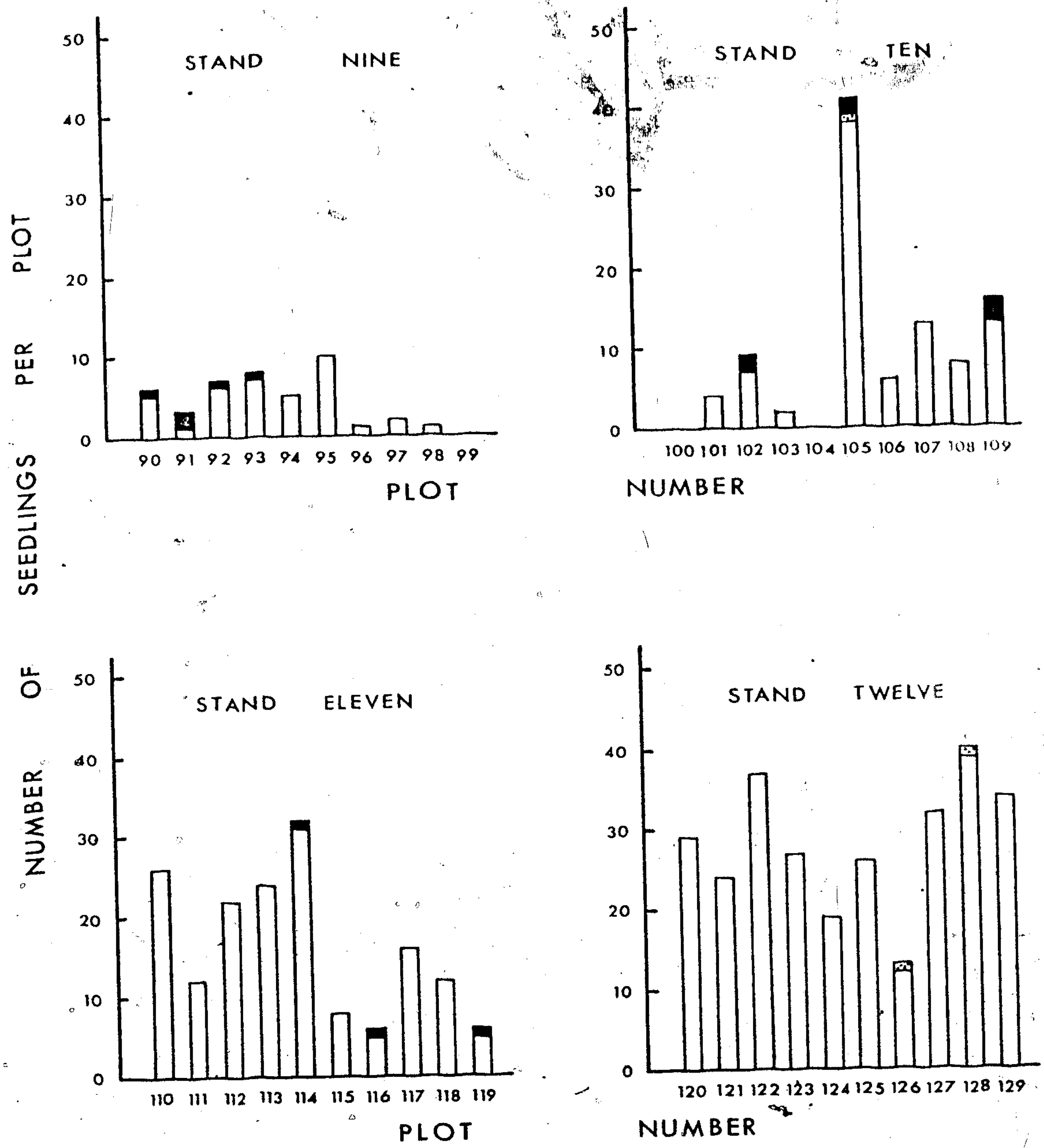

NUMBER OF SEEDLINGS PER PLOT
STAND NINE
0 10 20 30 40 50
90 91 92 93 94 95 96 97 98 99
PLOT
STAND TEN
0 10 20 30 40 50
100 101 102 103 104 105 106 107 108 109
NUMBER
STAND ELEVEN
0 10 20 30 40 50
110 111 112 113 114 115 116 117 118 119
PLOT
STAND TWELVE
0 10 20 30 40 50
120 121 122 123 124 125 126 127 128 129
NUMBER

Table 11. Coniferous tree seedling density per stand (1000 m^2) for 1971 and 1972 in the Vermilion Pass Burn.

STAND NO.	1971			1972		
	S[a]	F[b]	P[c]	S	F	P
1	2	.	61	3	.	67
2	2	.	4	1	.	4
3	4	.	141	2	.	181
4	.	.	128	.	.	158
5	3	.	400	3	.	459
6	9	.	146	17	.	222
7	—[d]	—	—	1	.	185
8	—	—	—	1	.	37
9	—	—	—	5	.	38
10	—	—	—	7	1	91
11	—	—	—	3	.	161
12	—	—	—	.	2	279
TOTAL	20	.	880	43	3	1882
MEAN	3.3	.	146.7	3.5	0.3	156.8

a - Engelmann spruce

b - Subalpine fir

c - Lodgepole pine

d - No 1971 data for stand nos. 7 - 12.

in each stand. The difference in lodgepole pine density between stands may partially reflect differences in physiographic fact of slope and elevation (Table 12) as well as variations in fire intensity. Generally, there is an increase in slope (%) with an increase in elevation (r = +.54) (Fig. 12). Low densities of pine seedlings at higher elevations (r = -0.46) may be a response to less favourable climatic conditions (i.e. cooler and moister) than at lower elevations (Fig. 11).

The height and current year's growth of pine seedlings were recorded in stand nos. 1-6 in 1971 and 1972 and for those of stand nos. 7-12 in 1972. The average height for 1970 in stand nos. 1-6 and for 1971 in stand nos. 7-12 was calculated from the field data (Tables 13 and 14).

Obviously, time of year that the seedlings were measured would have an important bearing on the results. Horton (1958), in the subalpine forests of Alberta, found that leader growth for lodgepole pine saplings consistently started in early May and continued for 12 weeks. Lodgepole pine seedlings in the Hinton area, at an elevation of approximately 5,000 feet had terminated leader growth by the end of June (pers. comm., Dr. H. P. Sims). Seedlings in stand nos. 7-12 were measured between July 12 and July 27, 1972, while those in nos. 1-6 were measured in August of 1971 and 1972. In all likelihood seedling leader growth had terminated before the time of measurement.

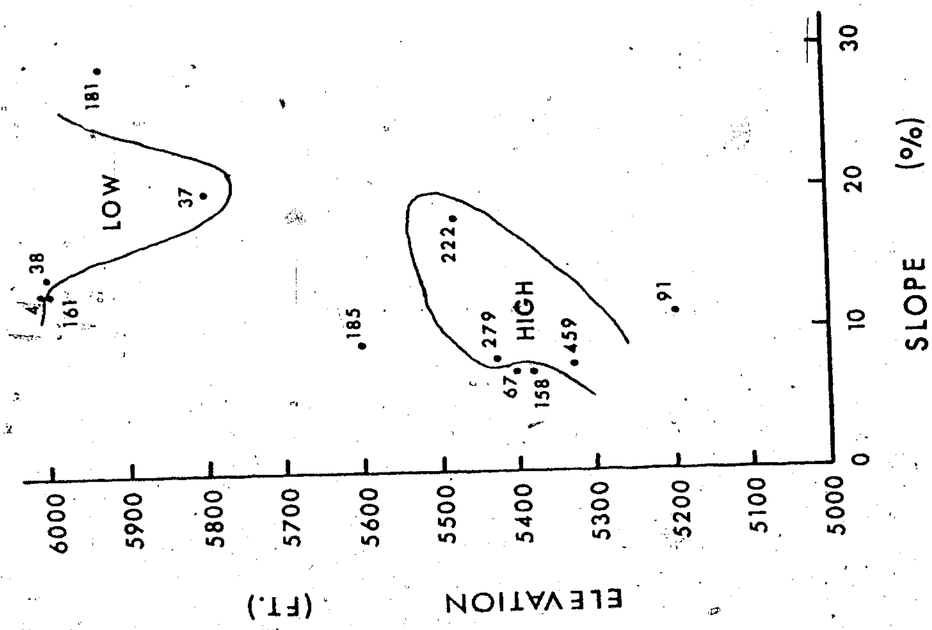
Stand no. 6 had consistently smaller seedlings throughout the three years, with average heights of 0.6 cm., 4.3 cm., and 8.5 cm. in 1970, 1971 and 1972 respectively (Table 13). This stand had a

Table 12. Slope angle and elevation of the 12 burn stands in the Vermilion Pass. All occurred on a NW-facing slope.

STAND NUMBER	SLOPE (%)	ELEVATION (M)	(FT)
1	7	1650	5400
2	13	1830	6010
3	29	1810	5930
4	7	1640	5380
5	8	1630	5330
6	18	1670	5480
7	9	1710	5600
8	20	1770	5800
9	14	1830	6000
10	11	1590	5200
11	13	1830	6000
12	8	1660	5430

Figure 12. Slope (%) and elevation (ft) relationships of 12 stands in the Vermilion Pass burn.

Figure 11. Relationship of pine seedling density (no. per 1000 m^2), in 12 stands to slope (%) and elevation (ft) in the Vermilion Pass burn.


ELEVATION (FT.)
6000
5900
5800
5700
5600
5500
5400
5300
5200
5100
5000
SLOPE (%)
0
10
20
30
LOW
HIGH
181
37
38
161
222
185
279
67
158
459
91

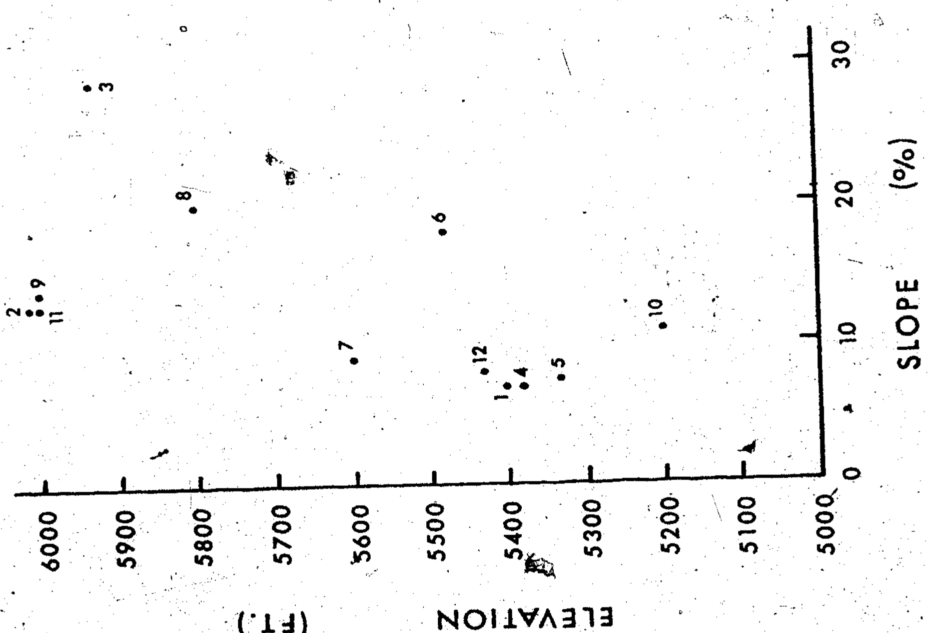

ELEVATION (FT.)
6000
5900
5800
5700
5600
5500
5400
5300
5200
5100
5000
SLOPE (%)
0
10
20
30
3
8
6
2
9
11
10
7
12
1
4
5

Table 13. Average heights (cm.) and average new growth (cm.) for lodgepole pine seedlings for 3 years in stands 1-6 in the Vermilion Pass burn.

STAND NUMBER	AVERAGE HEIGHT[a] 1970	AVERAGE NEW GROWTH 1971	AVERAGE HEIGHT 1971 (1971)[b]	AVERAGE NEW GROWTH 1972	AVERAGE HEIGHT 1972
1	2.01	9.09	11.10 (9.23)	12.85	22.08
2	2.39	9.68	12.07 (5.70)	9.50	15.20
3	1.36	5.25	6.61 (5.08)	7.33	12.41
4	2.38	7.48	9.86 (8.45)	11.76	20.21
5	2.46	8.47	10.93 (9.20)	11.94	21.14
6	0.63	3.70	4.33 (3.23)	5.31	8.54
MEAN	1.87	7.28	9.15 (6.82)	9.78	16.60
STD. DEV.	0.73	2.34	3.02	2.97	5.44

a - Calculated values - Average height in 1971 minus average new growth in 1971.

b - Calculated values - Average height in 1972 minus average new growth in 1972.

Table 14. Average heights (cm.) and average new growth (cm.) for lodgepole pine seedlings for 2 years in stands 7-12 in the Vermilion Pass burn.

STAND NUMBER	AVERAGE HEIGHT 1970	AVERAGE NEW GROWTH 1971	AVERAGE HEIGHT[a] 1971	AVERAGE NEW GROWTH 1972	AVERAGE HEIGHT 1972
7	.	.	6.46	10.19	16.65
8	.	.	8.06	10.51	18.57
9	.	.	7.21	9.47	16.68
10	.	.	6.82	11.52	18.34
11	.	.	5.04	9.86	14.90
12	.	.	9.08	14.12	23.20
MEAN	.	.	7.11	10.95	18.06
STD. DEV.	.	.	1.38	1.70	2.85

a - Calculated values - Average height in 1972 minus average new growth in 1972.

greater ground cover of herbs and shrubs than the other stands so that these smaller seedling heights may reflect competition with other plants such as Vaccinium spp. for light and soil moisture. The height of seedlings in the 12 stands may also be related to slope and elevation. Generally, height of seedlings decreases with an increase in slope (r = -0.7) and elevation (r = -0.5) (Fig.13).

In stand nos. 1-6 the average measured height in 1971 plus the average new growth of 1972 always exceeds the average height in 1972. This is to be expected due to seedling mortality, new seedlings and browsing of seedlings by rodents. The average height in 1972 represents an 80% ht. increment over 1971 in stand nos. 1-6. If only calculated values are considered, rather than measured values, then the increment is 145%. Similarly, in stands 7-12 where values are calculated for 1971 the increment is 150% (Table 14).

The rapid growth of young lodgepole pine trees reported here will enable them to attain early dominance in competition with species that are more shade tolerant.

D. Vegetation of the Vermilion Pass Burn

i) Systematic considerations of the vascular flora

A total of 63 vascular species were identified in the study area of the burn, representing 50 genera and 26 families. A complete species list is given in Appendix D. A total of 35 vascular species in 31 genera and 17 families were recorded within quadrats of the 12 stands sampled. Of these, 3 were tree regeneration, 14 were shrubs and 18 were classed as herbs and dwarf shrubs. The two most important

Figure 13. Relationship of pine seedling height (cm.) to slope (%) and elevation (ft.) in 12 burned stands, Vermilion Pass.

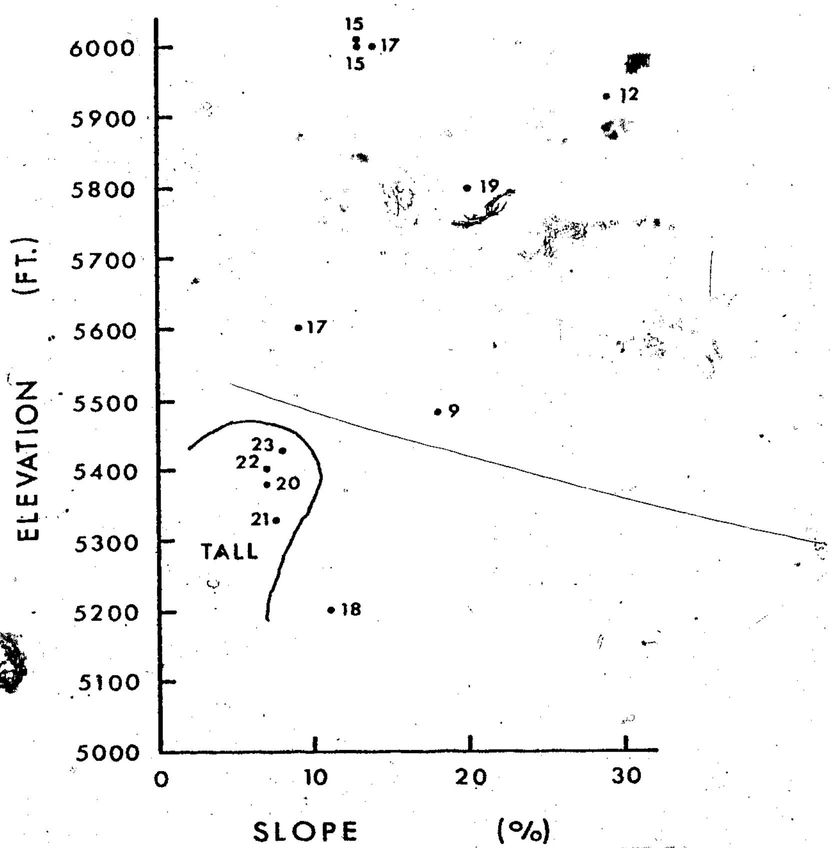
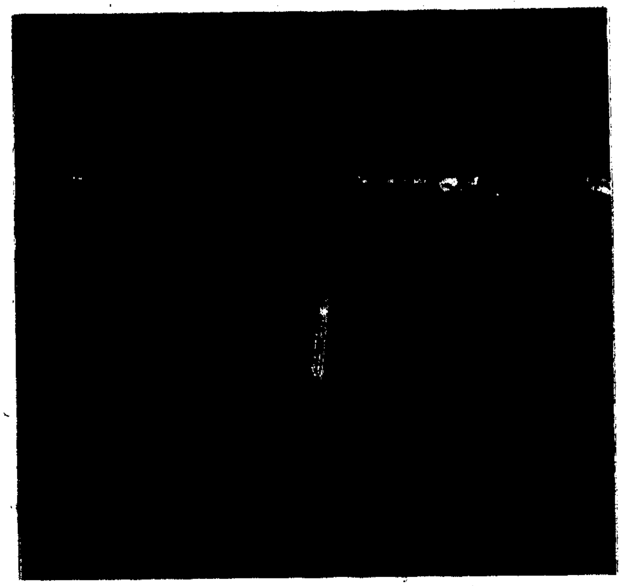
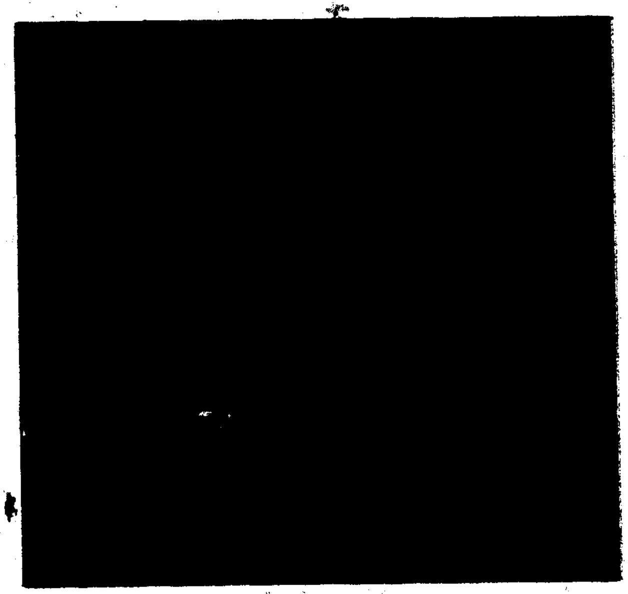


Plate 3. A healthy lodgepole pine seedling in the Vermilion Pass burn area. (Photo date, July, 1972).

Plate 4. A severely browsed lodgepole pine seedling in the Vermilion Pass burn area. (Photo date, July, 1972).





families, in terms of number of genera, were Ericaceae and Rosaceae with 4 genera each. Caprifoliaceae, Compositae and Pinaceae each had 3 genera. Cyperaceae was represented by 1 genus, Carex, and 4 species.

a. Constancy

Constance values (occurrence in equal-area samples from different stands) were obtained for each species by expressing the number of stands of occurrence as a percentage of the total number of stands. Sampling areas were of equal size among stands, but varied between major plant strata as follows: 1,000 sq. meters for coniferous tree regeneration, 250 sq. meters for shrub species and 40 sq. meters for herb and dwarf shrub species.

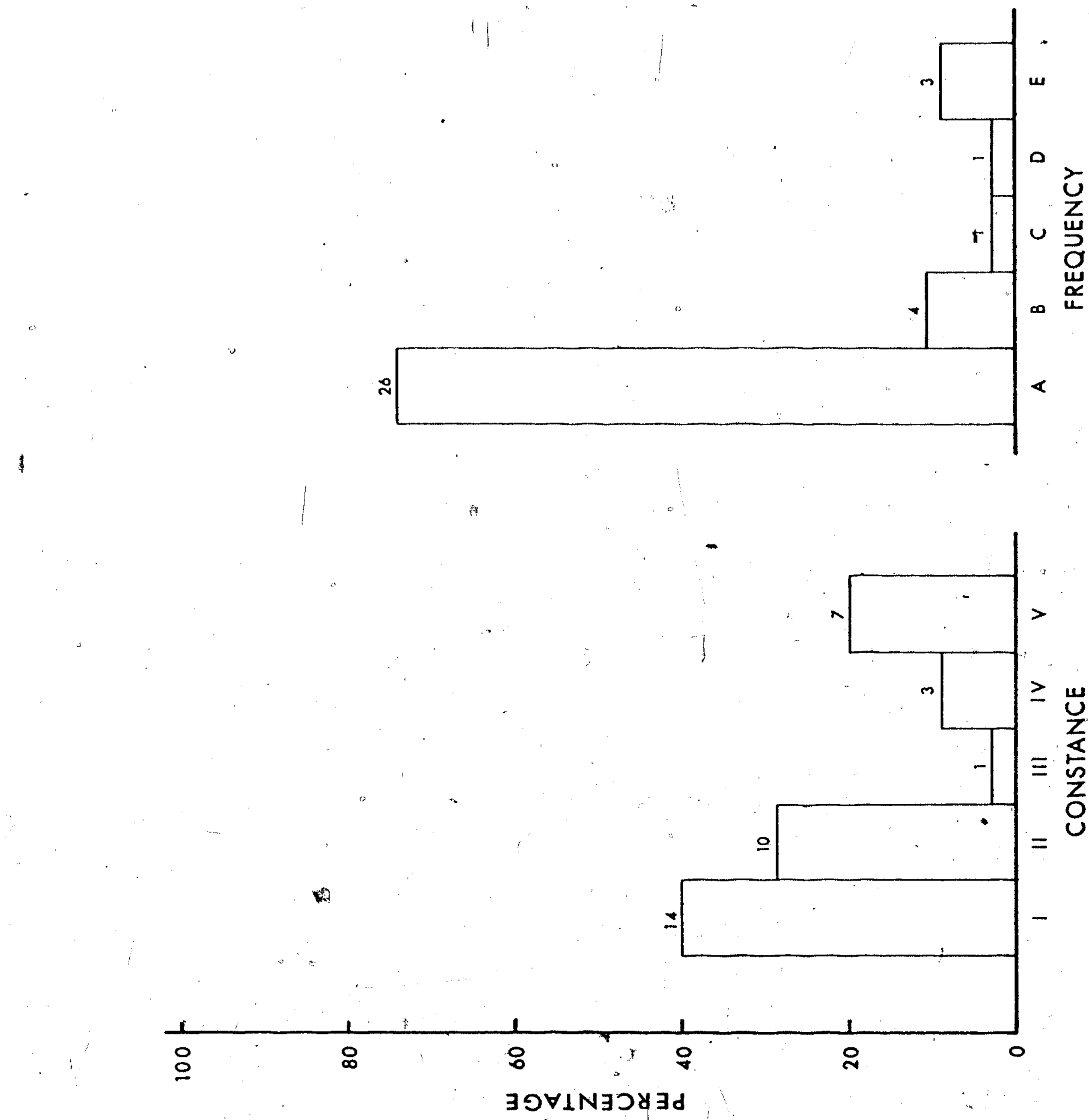
The distribution of the flora in the 5 constance classes indicates that 29% of the vascular species occur in more than 60% of the stands, while 40% occurred in less than 20% of the stands sampled (Fig.14).

b. Frequency

Frequency values were obtained for each species by expressing the number of quadrats of occurrence as a percentage of the total number of quadrats (120) in the 12 stands. About 75% of the species had a frequency of less than 20% (Fig.14), indicating the simple floristic nature of the post-burn vegetation. Six species occurred in all stands and 3 species had a frequency of greater than 80%. It is evident that (1) the burned site is in a very early stage of successional development and presents a fairly severe environmental test for potential colonizing species, and (2) a small number of species occurs throughout the burn and seem to be very well adapted to the changed environment.

Figure 14. Distribution of vascular species by constancy and frequency classes in 12 sampled stands in the Vermilion Pass burn.

In each diagram the bars represent progressively higher percentage classes from left to right (1-20; 21-40; 41-60; 61-80; 81-100). The height of each bar represents the percentage of species which occurred in [illegible] class and the number of species is given at the top of each bar.


PERCENTAGE
100
80
60
40
20
0
14
10
1
3
7
I
II
III
IV
V
CONSTANCE
26
4
1
1
3
A
B
C
D
E
FREQUENCY

ii) Constancy and frequency classification of the vascular strata

a. Tree stratum

The tree stratum per se consisted only of dead individuals. Seedlings of two tree species, Pinus contorta var. latifolia and Picea engelmannii occurred throughout the stands (100% and 83% constance respectively). However pine had a frequency of 90% while spruce frequency was only 26%. This suggests that although Picea engelmannii may be regularly dispersed in the burn it is by no means abundant. It further indicates that the first forest to develop and mature in the burn area will consist mainly of lodgepole pine.

b. Shrub stratum

Only one shrub, Menziesia ferruginea var. glabella occurred constantly (100%) and frequently (83%) throughout the burn. No other shrubs were of importance in terms of frequency but Salix spp. and Sambucus racemosa var. melanocarpa were relatively constant occupants of the stands (75% constancy for each).

c. Herb-dwarf shrub stratum

Of the 18 species of herbs and dwarf shrubs recorded, only one had both high constancy and frequency values: Epilobium angustifolium (100%, 81%). Three other species, Vaccinium myrtillus/scoparium, Cornus canadensis and Arnica cordifolia, had constancy values of 100%, and one other, Linnaea borealis var. longiflora had a relatively high constancy value (75%). Aside from fireweed, Vaccinium myrtillus/scoparium had relatively high frequence in the stands (73%) (Tables 15 and 16).

The most immediately obvious feature of the post-burn

Table 15. Constancy class distribution of vascular species by strata within the 12 stands in the Vermilion Pass burn.

CLASS	PERCENTAGE	NUMBER OF SPECIES TREES	SHRUBS	HERBS	TOTAL
I	0-20	1	3	10	14
II	21-40	0	7	3	10
III	41-60	0	1	0	1
IV	61-80	0	2	1	3
V	81-100	2	1	4	7
TOTAL		3	14	18	35

Table 16. Frequency class distribution of vascular species by strata within the 12 stands in the Vermilion Pass burn.

CLASS	PERCENTAGE	NUMBER OF SPECIES TREES	SHRUBS	HERBS	TOTAL
A	0-20	1	12	13	26
B	21-40	1	1	2	4
C	41-60	.	.	1	1
D	61-80	.	.	1	1
E	81-100	1	1	1	3
TOTAL		3	14	18	35

vegetation is its low local species richness, even though more species were recorded throughout the burn (63 species) and within the sampled plots (35 species) than in the unburned forest stand (38 species present and 20 species within plots).

However, the spruce-fir zone is recognized as floristically simple (Oosting and Reed, 1952), so that the low species richness of the post-burn may be normal. If not, it may be the result of a limited seed source as well as fire intensity, time elapsed since burn and other historical and environmental characteristics.

iii) Cover of vascular species

Percent cover of all shrubs, herbs and dwarf shrubs found in plots located in the burn are given in Table 17.

a. Shrub stratum

Fourteen "shrubs" were found in the burn, including suckers of Populus tremuloides (see Methods). Together they had a cover of 3.6% and ranged from 0.3% in stand no. 1 to 9.4% in stand no. 6 (Table 18). Menziesia ferruginea, with a mean cover of 2.6%, was the most important shrub and accounted for 74% of the total shrub cover. The abilities of this species to survive the fire and to reproduce vegetatively accounts in part for its relative importance in the burn. All other shrubs had mean cover values of less than 1%. Listed in order of decreasing cover values, the other major species were; Ledum glandulosum (0.25%), Sambucus racemosa (0.12%), Spiraea betulifolia (0.12%) and Lonicera involucrata (0.10%) (Table 19).

Table 17. Mean cover[a] and mean prominence values[b] of shrubs, herbs and dwarf shrubs found in 12 stands in the Vermilion Pass burn in 1972.

SPECIES	STAND NUMBER 1	2	3	4	5	6	7	8	9	10	11	12
Alnus sinuata	.	.	.	T (*)	.	.	.	.	.	.	.	.
Aquilegia flavescens	.	.	.	T (*)	.	.	.	.	.	.	.	.
Arnica cordifolia	T (0.5)	2.1 (13)	4.7 (30)	6.5 (36)	9.2 (71)	8.5 (76)	2.2 (12)	T (0.6)	T (1)	7.2 (46)	4.2 (35)	3.5 (19)
Aster conspicuus	.	.	.	T (4)	.	2.7 (*)	.	.	.	1.4 (8)	.	T (2)
Calamagrostis canadensis	.	.	.	1 (3)	.	.	.	.	.	3.3 (25)	.	.
Carex pachystachya	.	.	.	.	T (2)	.	.	.	.	T (2)	.	.
Carex phaeocephala	3.5 (29)	.	.	.	.	.	.	.	.	.	.	.
Carex rossii	.	.	.	.	.	.	T (2)	1.0 (4)	.	.	.	.
Carex spp.	T (7)	T (*)	T (0.5)	.	.	.	.	.	.	.	.	.
Cornus canadensis	T (5)	T (*)	T (2)	T (7)	1.6 (15)	3.4 (32)	T (1)	T (0.5)	T (0.7)	T (8)	1.1 (8)	1.3 (12)
Elymus innovatus	.	.	.	.	.	1.1 (5)	.	.	.	1.0 (3)	.	.
Epilobium angustifolium	11.5 (115)	1.6 (15)	2.2 (21)	2.2 (19)	2.1 (18)	T (0.7)	4.2 (39)	3.6 (32)	1.4 (12)	5.2 (52)	1.9 (14)	4.4 (44)

Table 17 cont'd

SPECIES	STAND NUMBER 1	2	3	4	5	6	7	8	9	10	11	12
Epilobium platyphyllum	T (0.5)	.	.	.	.	.	.	.	.	.	.	T (*)
Equisetum scirpoides	T (0.5)	.	.	.	.	.	.	.	.	T (*)	.	.
Ledum glandulosum	.	.	.	T (4)	T (3)	1.5 (13)	.	.	T (*)	T (2)	T (0.7)	T (*)
Linnaea borealis	1.2 (8)	.	1.2 (7)	2.6 (14)	3.3 (21)	T (5)	.	T (2)	T (*)	5.0 (46)	T	2.6 (20)
Lonicera involucrata	.	.	.	.	1.0 (*)	T (*)	.	.	.	T (0.7)	.	.
Menziesia ferruginea	T (0.8)	1.0 (8)	5.4 (54)	T (6)	2.0 (18)	7.1 (67)	3.2 (30)	2.5 (23)	3.2 (29)	1.2 (10)	3.4 (30)	1.9 (19)
Populus tremuloides	T (*)	.	.	.	T (3)	.	.	T (0.5)	.	.	.	.
Pyrola secunda	.	.	.	.	.	.	T (*)	.	.	.	.	.
Rhododendron albiflorum	.	.	T (3)	.	T (*)	.	.	.	T (0.5)	.	T (2)	.
Ribes lacustre	.	.	.	T (*)	.	T (*)	.	.	.	T (*)	.	.
Rosa acicularis	.	.	.	T (*)	.	.	.	.	.	.	.	.
Rubus idaeus	.	.	.	.	.	.	T (*)	T (*)	.	.	.	.
Salix spp.	T (0.5)	T (0.5)	T (*)	T (*)	T (0.8)	.	T (2)	T (0.8)	T (*)	.	.	T (1)

Table 17 cont'd

SPECIES	STAND NUMBER 1	2	3	4	5	6	7	8	9	10	11	12
Sambucus racemosa	.	T (0.6)	.	T (1)	T (*)	T (*)	T (*)	T (5)	T (2)	T (*)	T (0.7)	.
Shepherdia canadensis	.	.	.	T (*)	T (*)	T (0.7)	.	.	.	T (*)	.	.
Sorbus sitchensis	.	.	.	.	T (0.5)	T (0.8)	.	T (*)	.	.	T (*)	.
Spiraea betulifolia	.	.	.	.	1.0 (3)	T (1)	.	T (*)	.	.	.	.
Stenanthium occidentale	.	.	.	.	.	T (*)	.	.	.	.	.	.
Taraxacum spp.	T (*)	.	.	.	.	.	T (0.5)	.	.	T (*)	.	.
Vaccinium myrtillus/scoparium	T (2)	T (4)	1.1 (10)	T (2)	T (5)	4.9 (43)	T (5)	1.2 (12)	1.1 (11)	T (4)	5.6 (56)	T (0.5)

a - number not in parenthesis

b - number in parenthesis

T - (Trace) mean cover < 1%

* - mean P.V. < 0.5

Table 18. Total cover (%) of the shrub stratum and herb-dwarf shrub stratum in 12 stands in the Vermilion Pass burn in 1972.

VASCULAR STRATA	STAND NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	MEAN COVER
HERB--DWARF SHRUB STRATUM	17.35	5.10	9.50	14.35	17.10	21.35	7.65	6.65	2.95	24.7	12.70	12.35	12.65
SHRUB STRATUM	0.30	1.25	5.85	1.70	5.30	9.40	3.55	3.60	3.75	1.8	4.05	2.10	3.55
TOTAL	17.65	6.35	15.35	16.05	22.40	30.75	11.20	10.75	6.70	26.5	16.75	14.45	16.20

b. Herb-dwarf shrub stratum

Eighteen species of herbs and dwarf shrubs were recorded in the 120 2 x 2 meter plots. Both Vaccinium myrtillus and V. scoparium occurred in the burn, with the latter species much less common. As they were not always readily distinquishable from each other, they are considered together in the cover estimates. The herb-dwarf shrub stratum had a mean cover of 12.6% and ranged from 2.9% in no. 9 to 24.7% in no. 10 (Table 18). Two species, Arnica cordifolia and Epilobium angustifolium, accounted for 58% of the herb and dwarf shrub cover (Table 20). Other species listed in order of decreasing cover are Linnaea borealis, Vaccinium myrtillus/scoparium and Cornus canadensis.

c. Total cover of shrubs, herbs and dwarf shrubs

Total cover of the 32 species of shrubs, herbs and dwarf shrubs accounted for 16.2% of the ground cover of the burn in 1972. Although 44% of the species identified in the burn were shrubs, this stratum accounted for only 22% of the vascular cover. Five species, 1 shrub and 4 herbs and dwarf shrubs, accounted for approximately 80% of the total subordinate vascular cover.

iv) Prominence values of vascular species

Frequency % (F) and average % cover (C) for each herb and dwarf shrub species were converted to Prominence Values (P.V.), where P.V. = $C \times \sqrt{F}$. The P.V.'s for all vascular species are given in Table 17. The P.V.'s are synthetic expressions reflecting the relative importance of each species in the burn. For instance Epilobium angustifolium has an average P.V. of 30, the highest P.V. of any species, but ranks second

Table 19. Percentage cover[a] of the major shrub species in the Vermilion Pass burn in 1972.

SPECIES	% COVER
Menziesia ferruginea	2.61 ± 2.02
Ledum glandulosum	0.25
Sambucus racemosa	0.12
Spiraea betulifolia	0.12
Lonicera involucrata	0.10
Others ([illegible] species)	0.35
TOTAL	3.55 ± 2.47

a - Average cover in 12 stands, based on 120, 5 x 5 meter plots.

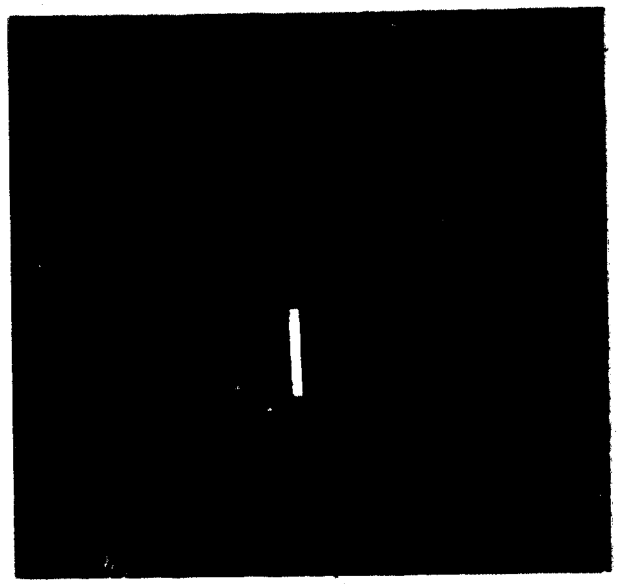
Table 20. Percentage cover[a] of the major herb and dwarf shrub species in the Vermilion Pass burn in 1972.

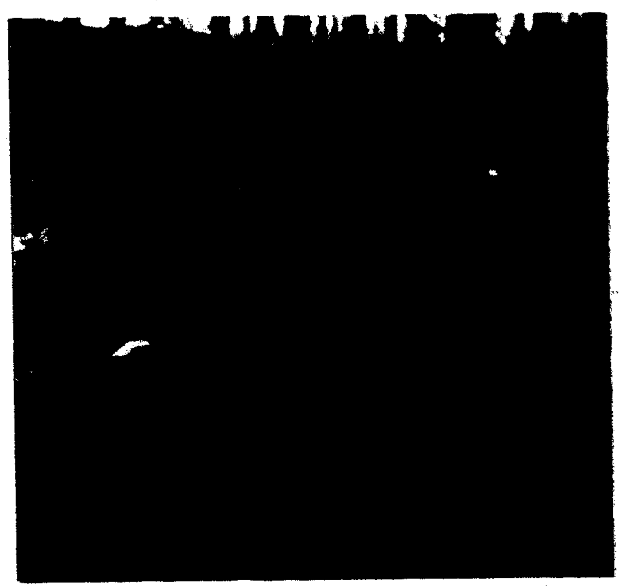
SPECIES	% COVER
Arnica cordifolia	4.05 ± 3.24
Epilobium angustifolium	3.34 ± 2.95
Linnaea borealis	1.43 ± 1.61
Vaccinium myrtillus/scoparium	1.39 ± 1.82
Cornus canadensis	0.86 ± 0.93
Others (13 species)	1.58
TOTAL	12.65 ± 6.66

a - Average cover in 12 stands based on 120, 2 x 2 meter plots.

Plate 5. Linnaea borealis growing on exposed mineral soil in the Vermilion Pass burn. (Photo date, Aug. 1972).

Plate 6. Epilobium angustifolium, the dominant plant species in the Vermilion Pass burn. (Photo date, Aug. 1972).





in average percent cover behind Arnica cordifolia and second in frequency behind Menziesia ferruginea (Table 21). Epilobium angustifolium P.V.'s ranged from 115 (the highest of any species) in stand no. 1 to 0.7 in no. 6, the least severely burned stand. This further shows the sparse state of the vascular plant communities as the upper limit of the P.V. scale is 1,000.

v) Height of major vascular species in 1972

The mean heights of those vascular species other than tree regeneration having a constancy value of ≥ 75% are given in Table 22. Two shrubs were the tallest species in the burn area in 1972: Sambucus racemosa (51 cm.) and Menziesia ferruginea (32 cm.) The height of the latter shrub was approximately 122 cm. in the unburned forest stand so that growth in the burn appears quite rapid in terms of time since burn. Cornus canadensis is a slightly suffruticose (diminutively shrubby) perennial herb with a creeping rootstock, and according to Moss (1959), ranges from 8-18 cm. in height. In no instance throughout the burn did Cornus canadensis reach 8 cm. in height. This suggests that this species may be experiencing some stress in the post-burn environment.

Generally the height of vascular plants in the burn is low. Continued monitoring of height growth in other years will provide interesting and valuable information on developing post-burn plant communities.

Height of all vascular species for 1972 is given in Appendix F.

Table 21. Cover[a], Frequency[b] and Prominence Values[c] of six major vascular species in the Vermilion Pass burn in 1972.

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	MEAN ± ST. DEV.
	STAND NUMBER												
EPILOBIUM ANGUSTIFOLIUM	11.5[a]	1.55	2.2	2.15	2.05	0.15	4.15	3.6	1.35	5.2	1.85	4.35	3.34 ± 2.95
	100[b]	90	90	80	80	20	90	80	80	100	60	100	81
	115[c]	15	21	19	18	0.7	39	32	12	52	14	44	30
ARNICA CORDIFOLIA	0.1	2.1	4.7	6.5	9.2	8.5	2.15	0.20	0.25	7.2	4.2	3.5	4.05 ± 3.24
	20	40	40	30	60	80	30	10	20	40	70	30	39
	0.45	13	30	36	71	76	12	0.63	1	46	35	19	25
MENZIESIA FERRUGINEA	0.15	0.95	5.4	0.60	2.0	7.05	3.20	2.45	3.2	1.15	3.35	1.85	2.61 ± 2.02
	30	80	100	90	80	90	90	90	80	80	80	100	83
	0.8	8	54	6	18	67	30	23	29	10	30	19	24
VACCINIUM MYRTILLUS/SCOPARIUM	0.3	0.45	1.1	0.30	0.70	4.85	0.60	1.2	1.1	0.40	5.55	0.10	1.30 ± 1.82
	50	70	90	60	50	80	80	100	100	80	100	20	73
	2	4	10	2	5	43	5	12	11	4	56	0.45	12
LINNAEA BOREALIS	1.2	-	1.2	2.6	3.3	0.65	-	0.55	0.10	5.0	-	2.6	1.43 ± 1.61
	50	-	30	30	40	60	-	20	10	90	-	60	33
	8	-	7	14	21	5	-	2	0.32	46	-	20	8
CORNUS CANADENSIS	0.7	0.05	0.25	0.80	1.55	3.35	0.20	0.10	0.15	0.85	1.10	1.25	0.86 ± 0.93
	60	10	40	70	90	90	30	20	20	90	50	90	55
	5	0.16	2	7	15	32	1	0.45	0.67	8	8	12	6

a. Cover in per cent
b. Frequency based on 10 plots per stand
c. Prominence value = cover x $\sqrt{frequency}$

Table 22. Average height[a] of the major vascular species[b] in the Vermilion Pass burn in 1972.

SPECIES	MEAN HEIGHT (cm.)
Sambucus racemosa	51.3
Menziesia ferruginea	32.0
Arnica cordifolia	28.1
Epilobium angustifolium	22.9
Vaccinium myrtillus/scoparium	7.6
Cornus canadensis	6.0
Linnaea borealis	3.0

a - Height in cm., based on approximately 360 measurements for each species ; measurements made in late summer; Arnica and Epilobium values are for flowering specimens.

b - Species having $\geq$ 75% constancy.

vi) Height and cover of major vascular species in 1971 and 1972

Cover and height of the six major species in the burn area were recorded in 1971 and 1972, to determine if any appreciable changes had occurred over a one year period. Measurement was done in the first part of August for both years, in the same plots.

Two of the six species showed statistically significant differences when analysed with Student's t test. Cornus canadensis had an average increase in height from 4.6 cm. in 1971 to 5.5 cm. in 1972, (significant at the 5% level) but a decrease in % cover from 3% in 1971 to 1.4% in 1972 (significant at the 5% level). Similarly, Menziesia ferruginea increased significantly in height (1% level) from 24 cm. in 1971 to 34 cm. in 1972 while decreasing significantly (5% level) in cover from 6% to approximately 3% in 1972 (Table 23). Epilobium angustifolium and Arnica cordifolia increased in cover in 1972 though not significantly.

The height data represents real measured values as opposed to subjective ocular estimates of cover. The increase in height, then, is a real difference and of ecological significance, whereas, the decrease in cover could reflect a more conservative estimate on the part of the observer in 1972, particularly when the differences are so slight. However, because Epilobium angustifolium and Arnica cordifolia increased in cover, though not significantly, it is more likely that the reported decreases in cover for Cornus canadensis and Menziesia ferruginea may reflect increased competition from the former 2 species. It may also reflect an adjustment by the latter species to changing nutrient regimes since the burn and possibly a depletion of pre-burn root reserves in the two species. Continued

Table 23. Height (cm) and cover(%) of six major species in the Vermilion Pass burn in 1971 and 1972.

STAND NO.		Epilobium angustifolium 1971	Epilobium angustifolium 1972	Vaccinium myrtillus/ scoparium 1971	Vaccinium myrtillus/ scoparium 1972	Linnaea borealis 1971	Linnaea borealis 1972	Cornus canadensis 1971	Cornus canadensis 1972	Arnica cordifolia 1971	Arnica cordifolia 1972	Menziesia ferruginea 1971	Menziesia ferruginea 1972
1	H[a]	19.8	31.8	7.5	6.2	2.5	3.2	3.7	5.3	3.3	5.0	17.2	25.0
	C[b]	5.7	11.5	0.7	0.3	2.3	1.2	1.3	0.7	1.1	0.1	0.6	0.2
2	H	20.4	28.7	8.2	9.3	.	.	.	4.0	30.0	27.0	17.0	29.5
	C	0.7	1.6	1.3	0.5	.	.	.	.	1.8	2.1	3.2	1.0
3	H	9.3	23.4	5.8	8.8	2.3	2.7	3.8	5.0	35.8	38.5	22.1	34.8
	C	0.7	2.2	4.8	1.1	1.3	1.2	0.6	0.3	2.5	4.7	13.1	5.4
4	H	23.8	22.1	6.6	8.8	3.0	2.7	4.7	4.7	37.0	34.0	26.2	30.2
	C	0.9	2.2	0.5	0.3	2.0	2.6	2.5	0.8	5.5	6.5	2.5	0.6
5	H	33.7	23.3	6.3	8.6	3.4	3.3	5.3	7.0	34.6	36.8	30.1	42.8
	C	1.7	2.1	0.9	0.7	2.8	3.3	3.9	1.6	8.9	9.2	3.8	2.0
6	H	43.0	23.5	5.8	6.6	2.9	4.0	5.3	7.1	38.8	37.8	30.6	43.7
	C	0.1	0.2	3.6	4.9	1.1	0.7	6.7	3.4	8.6	8.5	11.5	7.1
MEAN	H	25.0	25.5	6.7	8.1	2.8	3.2	4.6	5.5	29.9	29.9	23.9	34.3
	C	1.6	3.3	2.0	1.3	1.9	1.8	3.0	1.4	4.7	5.2	5.8	2.7

a. Height (cm)
b. Cover (%)

monitoring of post-burn vegetation and environmental factors at intervals in the future will assist in elucidating post-burn development of plant communities.

It is also of interest to note that while Epilobium angustifolium increased in height from 1971 to 1972 in stand nos. 1-3, it decreased in stand nos. 4-6. The former stands, located at the northeast end of the burn, were more severely burned than the latter stands which were located toward the southwest end of the burn. This suggests that, not only is fireweed adapted to burn sites, but is even better adapted to the more severely burned sites.

Vaccinium myrtillus/scoparium decreased in cover from 1971 to 1972 in stands 1-5 but increased in no. 6 where Epilobium angustifolium cover was only 0.2% and thus may be reacting to decreased competition from the latter species.

Generally, it can be stated that very little change occurred in the two years in terms of post-fire succession, but significant trends may be developing.

vii) Density of the shrub stratum

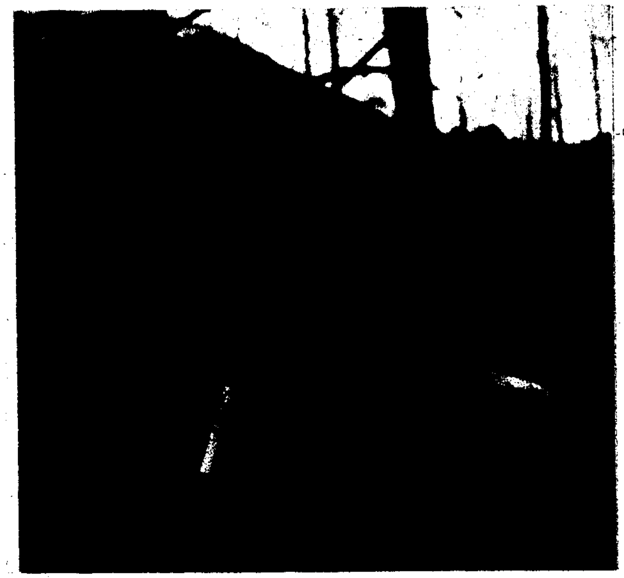
Density of living and dead members of the shrub stratum was recorded in the 5 x 5 meter plots in each stand. The remains of dead shrubs usually consisted of a basal cluster of charred stems and it was impossible to routinely identify these in the field (Plates 7 & 8).

Shrub density averaged 3567 ha^{-1} of which 3148 ha^{-1} or 87% were living per stand. Only in stand no. 2 was the percentage of living shrubs less than 60% (Table 24).

Menziesia ferruginea accounted for 74% of the living shrubs

Plate 7. Living <u>Menziesia ferruginea</u> growing vegetatively from basal remains of the pre-burn plant. (Photo date, Aug. 1972).

Plate 8. Basal cluster of charred dead shrub in Vermilion Pass burn. (Photo date, Aug. 1972).



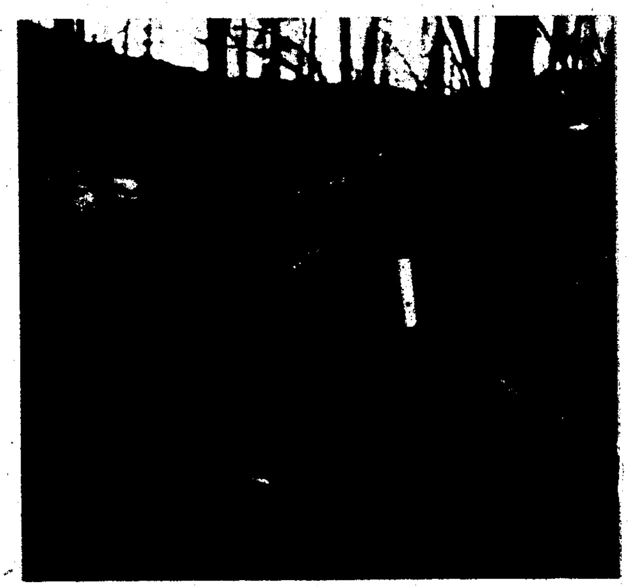


Table 24. Density[a] per hectare of the shrub stratum in the Vermilion Pass burn in 1972.

STAND NO.	TOTAL SHRUB DENSITY	LIVING SHRUB NO.	LIVING DENSITY (%)	MENZIESIA FERRUGINEA NO.	MENZIESIA FERRUGINEA (% OF LIVING)
1	480	360	(75)	241	(67)
2	2600	1508	(58)	1312	(87)
3	6800	6120	(90)	5630	(92)
4	2360	2242	(95)	919	(41)
5	3920	3842	(98)	2190	(57)
6	5880	5880	(100)	3998	(68)
7	2960	2338	(79)	1964	(84)
8	4280	3295	(77)	2307	(70)
9	4480	3763	(84)	3349	(89)
10	2280	2280	(100)	1436	(63)
11	4200	3822	(91)	3210	(84)
12	2560	2330	(91)	2120	(91)
MEAN	3567	3148	86.5%	2390	74%

a - Density values estimated from the number of individual shrubs in 10, 5 x 5 meter plots per stand (250 sq. meters).

throughout the stands. Invariably, living <u>Menziesia</u> was represented by new shoots protruding from amongst the charred basal cluster of the pre-burn plant. This attests to the ability of <u>Menziesia</u> to regenerate vegetatively from surviving below-ground parts in a post-burn situation. Only in stand no. 6 was this not entirely true; here, the fire had burned the finer top branchlets of <u>Menziesia</u> but much of the original plant shoot system was still living.

E. Substrates of the Vermilion Pass Burn

The average total subordinate vascular plant cover in the burn was only 16.2%. The remaining ground cover was a composite of 7 major substrates (Table 25). The most important substrate in terms of percent cover was charred duff with 56%. The other major substrates listed in order of decreasing percent cover were: exposed rotten wood (6.7%), moss complex (6.5%), fallen logs (5.9%), needle litter (4.5%), rock (3.5%) and mineral soil (1.7%). In total the substrate cover was 84.6% and ranged from 97% in stand no. 9 to 72% in no. 10.

Needle litter was recorded in 7 of the 12 stands. It did not occur where the fire was hot enough to consume it. In stand no. 6, with 24.2% needle litter cover, the fire was hot enough to scorch the needles on the trees but not hot enough to consume them. Subsequent to the fire, the needles have accumulated on the ground. Stand no. 6 also had the greatest cover of mosses (10.8%) and the least cover of charred duff (29%) and exposed mineral soil (0.5%), all indicative of a less intense fire than in other stands.

Table 25. Cover (%) of substrate types in the 12 stands of the Vermilion Pass burn in 1972.

SUBSTRATE TYPE	STAND NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	MEAN COVER	ST. DEV.
CHARRED DUFF	46.5	79.0	58.2	53.5	54.0	29.0	56.3	59.0	72.5	49.0	53.5	58.5	55.8 ±	12.5
ROCK	2.1	1.0	14.8	0.3	0.8	4.2	3.4	12.0	0.8	0.1	0.1	2.6	3.5 ±	4.9
MINERAL SOIL	4.9	0.5	4.6	1.5	1.6	0.5	0.5	0.6	1.7	1.8	2.2	0.8	1.7 ±	1.5
ROTTEN WOOD	14.5	2.6	1.9	11.3	7.3	2.3	5.0	5.8	9.0	9.7	3.9	7.3	6.7 ±	3.9
MOSS COMPLEX	3.7	6.0	4.6	6.0	7.2	10.8	10.0	6.9	7.1	1.7	8.4	5.8	6.5 ±	2.5
FALLEN LOGS	9.2	0.8	1.2	12.6	5.8	6.2	7.7	3.2	6.4	5.0	4.6	8.4	5.9 ±	3.4
NEEDLE LITTER	-	-	-	1.0	1.0	24.2	4.6	-	-	4.5	13.7	4.6	4.5 ±	7.4
TOTAL % COVER	80.9	89.8	85.2	86.1	77.7	77.2	87.4	87.4	97.4	71.7	86.3	87.9	84.6 ±	6.8

F. Depth of Duff in the Vermilion Pass Burn

The overall average depth of the charred duff to mineral soil was 2.84 cm., with a range from 1.7 cm. in no. 8 to 6.3 cm. in no. 6 (Table 26). Duff depth in stand no. 6 indicates that the fire there was less severe.

The depth of duff in the unburned forest stand averaged 11 cm. compared to 2 cm. in a comparative burned stand indicating that approximately 80% of the forest floor was consumed during the fire.

G. Soils of the Vermilion Pass Burn

Soils were described in the field by researchers from the University of Calgary (Noakes and Harris, 1972) who were conducting a preliminary soil survey of the Vermilion Pass burn. The main soil groups present in the study area are podzols, brunisols, regosols and gleysols. The podzols are characteristic of the better-drained north-facing slopes. The brunisols generally occur in old drainage channels where internal soil drainage is poor (Noakes and Harris, 1972). Regosols, in mountainous regions, occur in areas where soil development is limited, where erosion is rapid, and in areas of rapid downslope movement and frequent deposition of fresh parent material. Gleysols are typical of poorly drained locations at any altitude (Landals and Knapik, 1972).

The chemical and physical soil properties of the samples collected in the burned and unburned forest are given in Table 27. Soils are light to medium textured and nutrient poor. Soils in 11 stands and

Table 26. Average depth[a] of duff (cm.) in 12 stands in the Vermilion Pass burn.

STAND NO.	DUFF DEPTH	STAND NO.	DUFF DEPTH
1	2.1	7	2.1
2	3.7	8	1.7
3	2.1	9	2.4
4	4.2	10	2.0
5	2.9	11	2.8
6	6.3	12	1.8

a - Depth of duff was measured at each corner of the 10 x 10 meter plots, giving 40 measurements per stand.

Table 27. Physical and chemical soil properties from the N.W.-facing slope, Vermilion Pass burn, and one unburned stand.

STAND	HORIZON TYPE	HORIZON DEPTH (cm.)	TEXTURE (%) SAND	TEXTURE (%) SILT	TEXTURE (%) CLAY	TYPE	PYROPHOSPHATE EXTRACTABLE (%) Al	PYROPHOSPHATE EXTRACTABLE (%) Fe	ORG. CAR. %	pH	Kg. per Ha. N	Kg. per Ha. P	Kg. per Ha. K	PPM Al	PPM Mn	Na	S	COND. MMHOS.
1	Ae	3	32	54	14	SiL	.	.	.	4.7	0	0	62	21.8	3.0	L	L	0.2
	Bf	17	53	37	10	SL	0.37	0.08	1.33	6.0	0	0	67	.	.	L	M	0.2
	C	-	66	22	12	SL	.	.	.	7.1	0	0	34	.	.	L	.	0.2
2	Bf	5	50	42	8	L	0.65	0.25	3.50	5.4	0	0	112	2.4	3.2	L	M	0.2
	C	-	72	19	9	SL	.	.	.	5.2	0	0	45	4.6	9.2	L	.	0.2
3	Ae	3	35	53	12	SiL	.	.	.	4.5	0	31	95	30.6	22.8	L	L	0.2
	Bf	7	54	36	10	SL	0.60	0.19	3.01	5.2	0	0	67	5.0	2.0	L	.	0.2
	C	-	56	23	21	SCL	.	.	.	6.0	0	0	45	.	.	L	.	0.2
4	Ae	4	17	62	21	SiL	.	.	.	4.3	0	0	84	54.8	0.9	L	L	0.2
	Bf	6	38	48	14	L	0.46	0.18	1.70	5.6	0	0	56	.	.	L	L	0.2
	C	-	16	54	30	SiCL	.	.	.	8.0	0	0	62	.	.	L	.	0.3
5	Ae	4	22	64	14	SiL	.	.	.	4.9	0	8	118	17.2	3.6	L	L	0.2
	Bf	13	26	64	10	SiL	0.57	0.16	2.33	5.7	0	0	78	.	.	L	M	0.2
	C	-	28	45	27	L	.	.	.	6.9	0	0	90	.	.	L	.	0.2
6	Ae	6	30	56	14	SiL	.	.	.	4.3	0	0	84	30.4	1.0	L	L	0.2
	Bf	9	30	52	10	SiL	0.65	0.21	3.03	6.2	0	0	28	.	.	L	L	0.2
	C	-	51	38	11	L	.	.	.	7.9	3	0	17	.	.	L	.	0.3
7	Ah	-	.	.	.	.	.	.	.	4.1	0	10	162	17.2	9.6	L	L	0.2
	Ae	6	31	59	10	SiL	.	.	.	4.2	0	9	95	46.6	1.0	L	L	0.2
	Bf	12	53	41	6	SL	0.33	0.30	1.12	4.8	0	0	28	10.8	2.6	L	L	0.2
	C	-	.	.	.	.	.	.	.	5.5	0	0	34	0.8	17.0	L	.	0.2

Table 27. cont'd.

STAND	HORIZON TYPE	HORIZON DEPTH (cm.)	TEXTURE (%) SAND	TEXTURE (%) SILT	TEXTURE (%) CLAY	TYPE	PYROPHOSPHATE EXTRACTABLE (%) Al	PYROPHOSPHATE EXTRACTABLE (%) Fe	ORG. CAR. %	pH	Kg. per Ha. N	Kg. per Ha. P	Kg. per Ha. K	PPM Al	PPM Mn	Na	S	COND. MMHOS.
8	Bm	10	54	27	19	SL	0.31	0.29	1.06	4.6	0	0	56	37.0	3.1	L	L	0.2
	G	-	60	23	17	SL	.	.	.	5.6	0	0	45	.	.	L	.	0.2
9	Bf	21	27	53	20	SiL	0.57	0.36	1.73	5.6	1	0	50	.	.	L	L	0.2
	C	-	43	35	22	L	.	.	.	7.5	1	0	50	.	.	L	.	0.3
	Ae	1	.	.	.	.	.	.	.	4.4	67	39	45	7.4	9.2	L	M	0.3
10	Bf	5	28	58	14	SiL	0.67	0.32	2.19	6.1	11	0	123	.	.	L	L	0.2
	C	-	26	54	20	SiL	.	.	.	7.1	3	0	62	.	.	L	.	0.2
	Ae	4	.	.	.	.	.	.	.	4.4	0	2	106	17.6	46.4	L	L	0.2
11	Bf	5	36	46	18	L	0.66	0.28	2.63	6.2	2	0	73	.	.	L	L	0.2
	C	-	50	35	15	L	.	.	.	7.7	1	0	39	.	.	L	.	0.3
	Ae	3	29	57	14	SiL	.	.	.	4.6	0	8	101	32.4	12.6	L	L	0.2
12	Bf	15	40	50	10	SiL	0.41	0.08	1.30	6.2	0	0	73	.	.	L	M	0.2
	C	-	75	17	8	SL	.	.	.	7.9	1	0	22	.	.	L	.	0.2
UN-	Ae	-	16	64	20	SiL	.	.	.	4.9	1	0	39	12.6	0.7	L	L	0.2
BURNED	Bf	-	24	58	18	SiL	0.25	1.13	1.80	4.9	6	0	39	13.0	0.9	L	L	0.2
STAND	C	-	20	64	16	SiL	.	.	.	5.4	3	4	11	1.8	6.6	L	.	0.2

L for sodium (Na); 0-235 kg. per ha.
L for sulfur (S) ; 0.0-3.0 ppm in soil.
M for sulfur (S) ; 3.1-12.0 ppm in soil.

in the unburned forest are humo-ferric podzols (Plate 10). In stand no. 8, the ratio of pyrophosphate-extractable Al and Fe to clay (<2 mm.) in the Bm horizon was less than 0.05, therefore this soil was classed as a dystric brunisol.

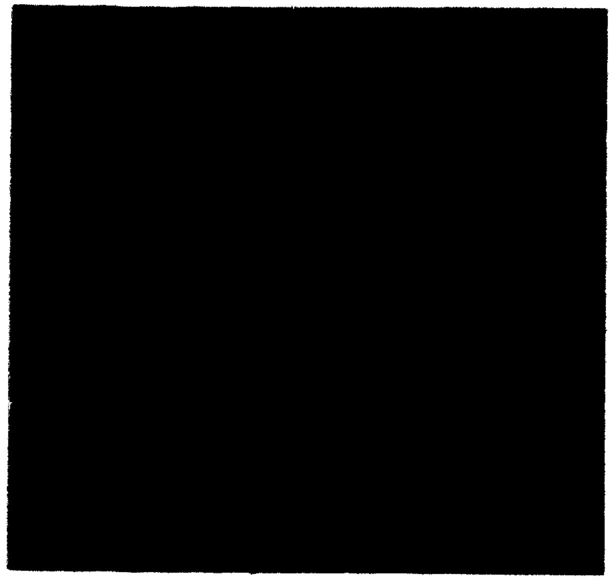
Fire normally increases pH due to the ashing of the organic layer, which is relatively rich in calcium (Lutz, 1956; Rowe and Scotter, 1973). The soils of the Vermilion Pass are quite acid. Austin and Baisinger (1955) indicate that the initial decrease in acidity resulting from the fire is relatively short-lived and that pH values return to near pre-fire levels within two years. The pH values for the Vermilion Pass are from samples taken 3 years after the fire so that the effects of the fire on soil acidity may be diminished or no longer evident. The pH of the Ae horizons are similar to that found in the unburned forest stand but generally higher in the Bf horizon suggesting that these soils may not have returned to pre-fire levels.

H. Climate of the Vermilion Pass Burn

Five weather stations were established on the NW-facing slope of the Vermilion Pass in 1969. Three of the stations are located in the burned forest at elevations of 1646, 1707 and 1829 m. A.S.L. and two in unburned forest at 1677 and 1829 m. A.S.L. Mean maximum, minimum and daily temperatures (°C) for May through September of 1972 are presented in Table 28. Students t-tests were performed to determine if ambient mean daily air temperature varies significantly between stations on an elevational gradient and in burned and unburned

Plate 9. The moss complex substrate in the Vermilion Pass burn. (Photo date, Aug. 1972).

Plate 10. A typical Humo-ferric Podzol from the Vermilion Pass burn. (Photo date, Aug. 1972).



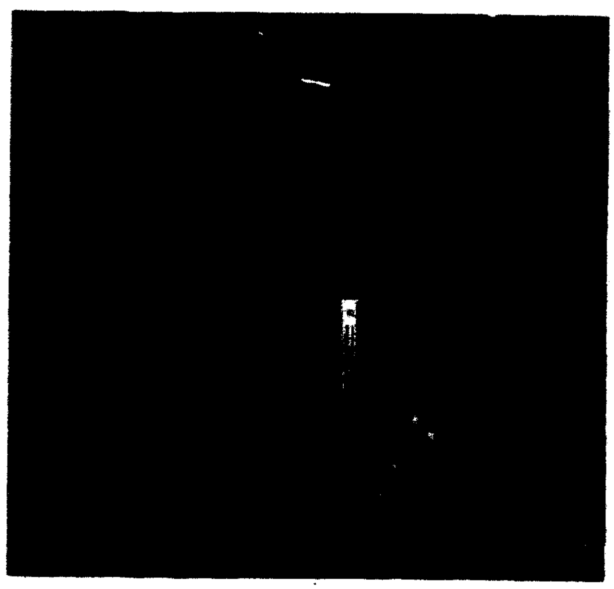


Table 28. Mean maximum, minimum and daily temperatures (°C) for five months in 1972 at five weather stations located on the NW-facing slope of Vermilion Pass.

AREA	RECORDING STATION	ELEV. (M.)	MONTH (1972) MAY	JUNE	JULY	AUG.	SEPT.
1968 Burn Area	A	1646	10.1[a]	13.1	15.7	20.3	6.4
			-2.7[b]	1.3	1.6	2.3	-3.0
			3.7[c]	7.2	8.6	11.3	1.7
	M	1707	10.2	13.7	15.1	20.7	7.7
			0.0	3.6	4.0	7.0	-0.4
			5.1	8.7	9.6	13.8	3.6
	B	1829	6.6	8.7	11.9	16.5	3.1
			-1.7	1.5	2.8	6.5	-3.0
			2.4	5.1	7.3	11.5	0.0
Unburned (control) Area	C	1829	5.7	9.2	13.1	17.5	3.4
			-0.7	2.4	3.9	7.7	-2.3
			2.5	5.8	8.5	12.6	0.6
	D	1677	11.8	14.7	17.1	21.7	7.6
			0.7	4.8	5.0	7.4	-0.3
			6.2	9.8	11.1	14.6	3.6

a - Mean maximum temperature.

b - Mean minimum temperature.

c - Mean daily temperature.

locations. All t-tests showed significant difference at the 5% level (see Table 29).

Station M, the mid-elevation burn station, had the highest mean minimum and mean daily temperatures of the three stations in the burned forest, and also the highest mean maximum temperatures, with the exception of July when Station A, a low elevation station was 0.6°C warmer. The higher temperatures at mid-elevation reflect the thermal belt as described by Geiger (1957) and Schroeder and Buck (1970) where cold air drainage produces nocturnal inversion and thus higher temperatures at mid-slope.

Forest communities are known to exert modifying effects on local climate factors including solar radiation, air and soil temperatures, wind, atmospheric humidity, precipitation, evaporation and transpiration (Geiger, 1957; Johnson et al., 1971). Among these effects are a reduction of maximum temperatures and an increase of minimum temperatures (Pavari, 1962), resulting in lower mean temperatures in the forest than in openings (Raynor, 1971). Kittredge (1962) observed that mean daily temperatures tend to obscure forest influences and suggested that maximum and minimum temperatures are sounder guides to the influence of the forest on air temperatures. In the Vermilion Pass, mean daily, maximum and minimum temperatures in the unburned forest are mostly warmer than in the burned forest at similar elevations. The open nature of the burned forest allowing greater air circulation may produce a cooling effect. Similarly removal of a portion of the forest canopy to establish the weather station in the unburned forest may have partially offset the modifying effect of the forest stand resulting in warmer temperatures here

Table 29. Results of Student t-tests on mean daily temperatures for five weather stations in the Vermilion Pass (see Table 28).

STATIONS TESTED		SIGNIFICANT DIFFERENCE	
1 (ELEV. M)	2 (ELEV. M)	5%	1%
A (1646)	M (1707)	Yes	Yes
A	B (1829)	Yes	No
A	D*(1677)	Yes	Yes
M	B	Yes	Yes
M	D*	Yes	No
B	C*(1829)	Yes	No
C*	D*	Yes	Yes

* - Unburned forest

than in the unburned forest.

Figure 15 shows the average diurnal temperature march for the five stations during the growing season (May/September). All diurnal regimes are quite similar with minima occurring at approximately 6:00 A.M. and maxima occurring between 3-6:00 P.M. The daily temperature range is greatest at Station A (low elevation). This agrees with Baumgartners' (1960) more intensive work on a mountain slope in the Bavarian Forest, Germany.

Figure 16 shows the average diurnal march of relative humidity for the five stations during the growing season (May/September). Relative humidities are highest in the early morning hours (6-9:00 A.M.) and lowest between 3 and 6:00 P.M. for all stations. Station D in the unburned forest has consistently higher relative humidities than other stations. In the afternoon both stations in the unburned forest (C & D) maintain higher relative humidities than those stations in the burned forest. Schroeder and Buck (1970) indicate that small openings normally do not have daytime relative humidities much different from those under the canopy, which in turn are higher than those in large openings. Generally, relative humidities are lower at night under a closed canopy, however small openings in the forest serve as chimneys for convective airflow, and surface air is drawn into them from the surrounding forest. At night in these small openings, the stagnation coupled with strong radiational cooling can cause locally high humidities as noted at Station D.

Figure 15. Average diurnal air temperature march during May - September, 1972 at the five Vermilion Pass weather stations.

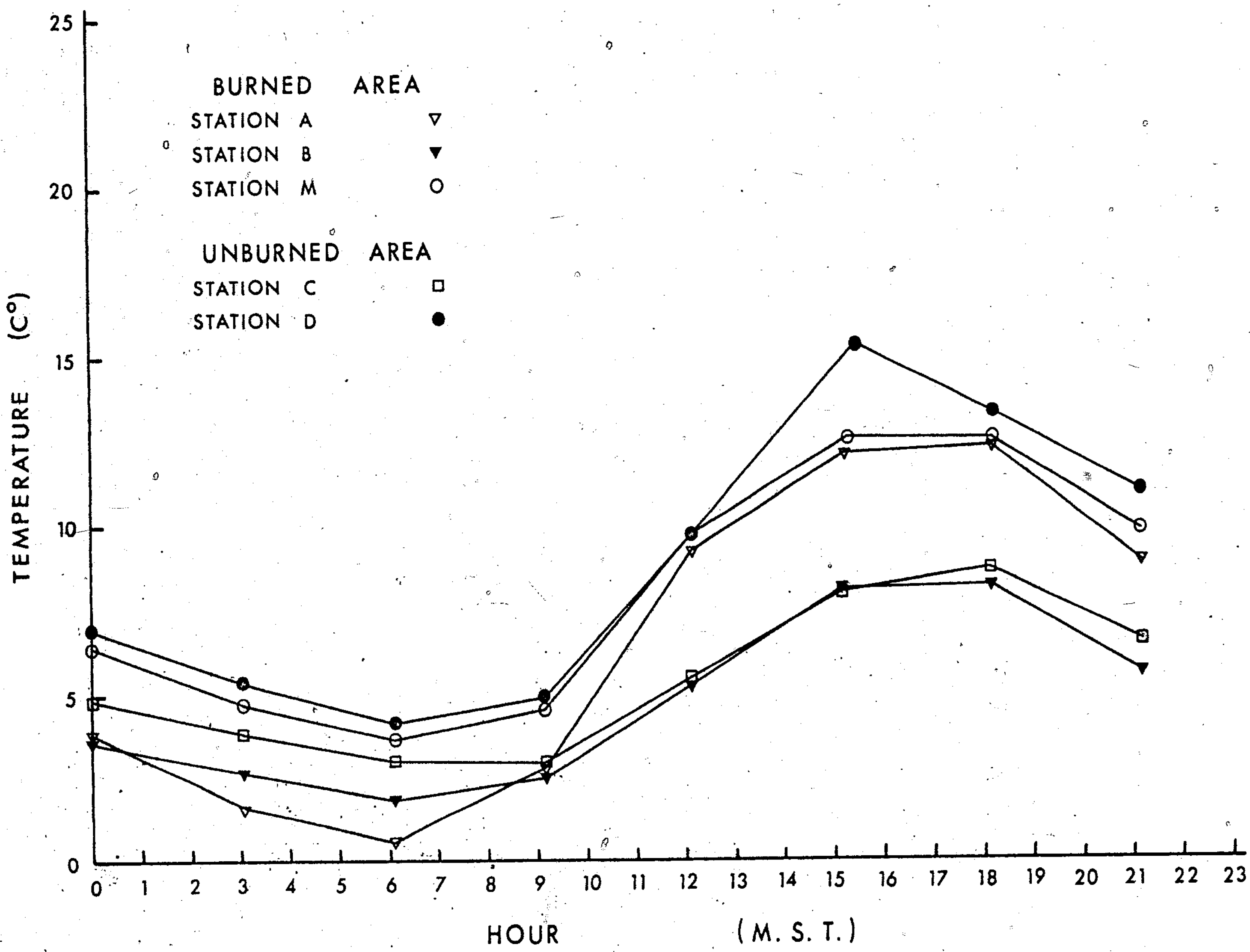
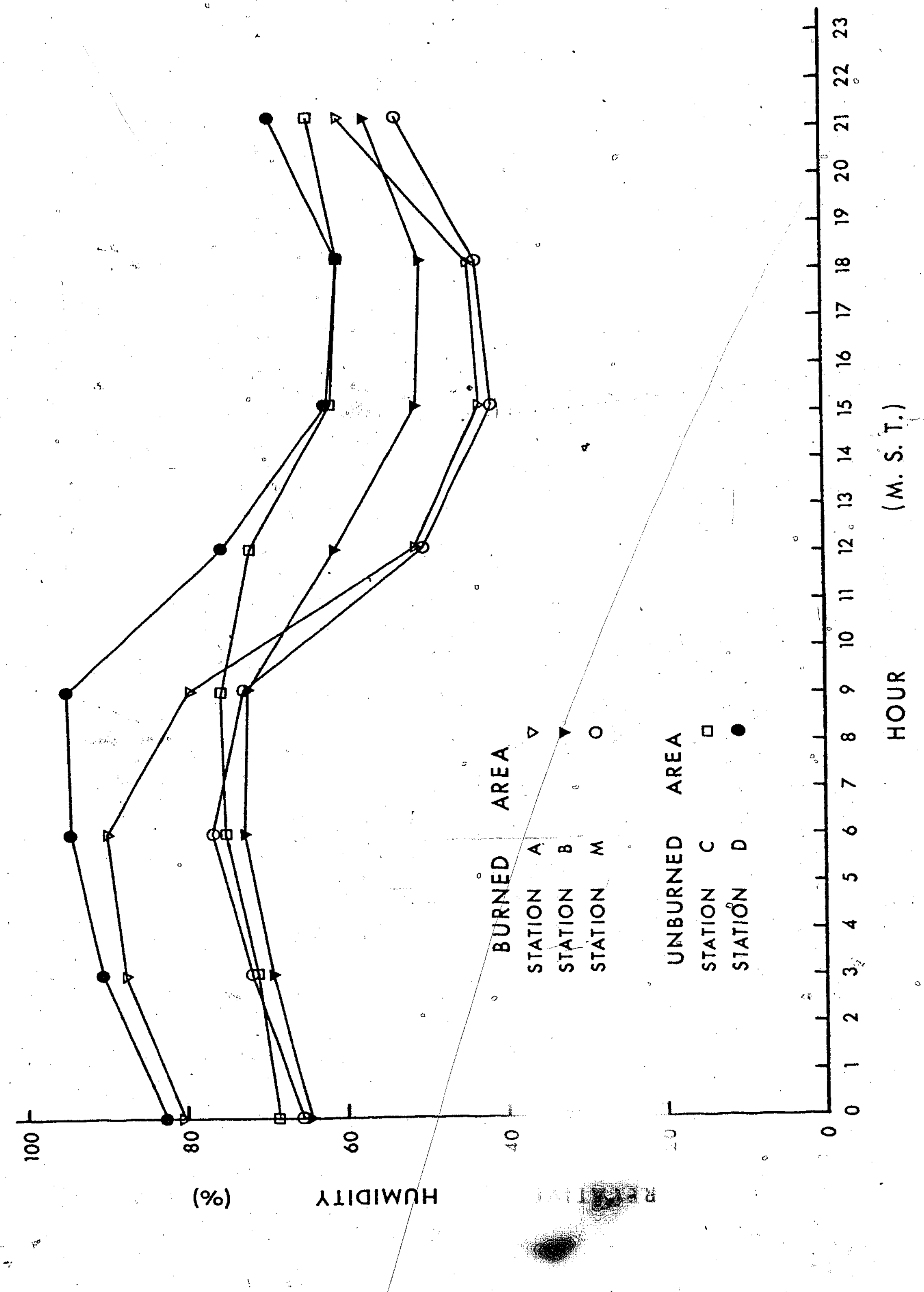

BURNED AREA
STATION A
STATION B
STATION M
UNBURNED AREA
STATION C
STATION D
TEMPERATURE (C°)
0
5
10
15
20
25
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HOUR (M. S. T.)

Figure 16. Average diurnal relative humidity march during May - September, 1972 at the five Vermilion Pass weather stations.


BURNED AREA
STATION A
STATION B
STATION M
UNBURNED AREA
STATION C
STATION D
100
80
60
40
20
0
HUMIDITY (%)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HOUR
(M. S. T.)

I. Vegetation of the Adjoining Unburned Forest

One stand was sampled in the adjoining unburned forest to document the pre-burn vegetation and to provide a basis from which to compare the rates and changes of plant succession in the burned forest.

Figure 17 shows the living and dead stem densities of major tree species in the unburned and burned forests. A students' t-test shows no significant difference (P = 0.01) between them and thus indicates that both sites are from the same original population. Thirty-eight vascular species were included in a presence list of the unburned forest (Appendix E) while 63 vascular species were recorded in the burned forest (Appendix D). Eighteen vascular species were common to the burn and the unburned forest, and 14 of these were woody (Table 30).

The major moss species occurring in the unburned forest were *Pleurozium schreberi* and *Hylocomium splendens*. In the burn, *Polytrichum juniperinum* occurred regularly and *Pohlia nutans* was also present but not as common as the former species.

Twenty vascular species were recorded within the plots located in the unburned forest including 2 trees, 6 shrubs and 12 herbs and dwarf shrubs. *Menziesia ferruginea* was the dominant shrub with a mean cover of 12% and occurring with 100% frequency (Table 31). The dominant herbs and dwarf shrubs listed in order of decreasing % cover were *Cornus canadensis* (4.1), *Vaccinium myrtillus* (3.0), *Rubus pedatus* (3.0), *Linnaea borealis* (1.4) and *Arnica cordifolia* (1.4) (Table 32). Of the six species listed above only *Rubus pedatus*

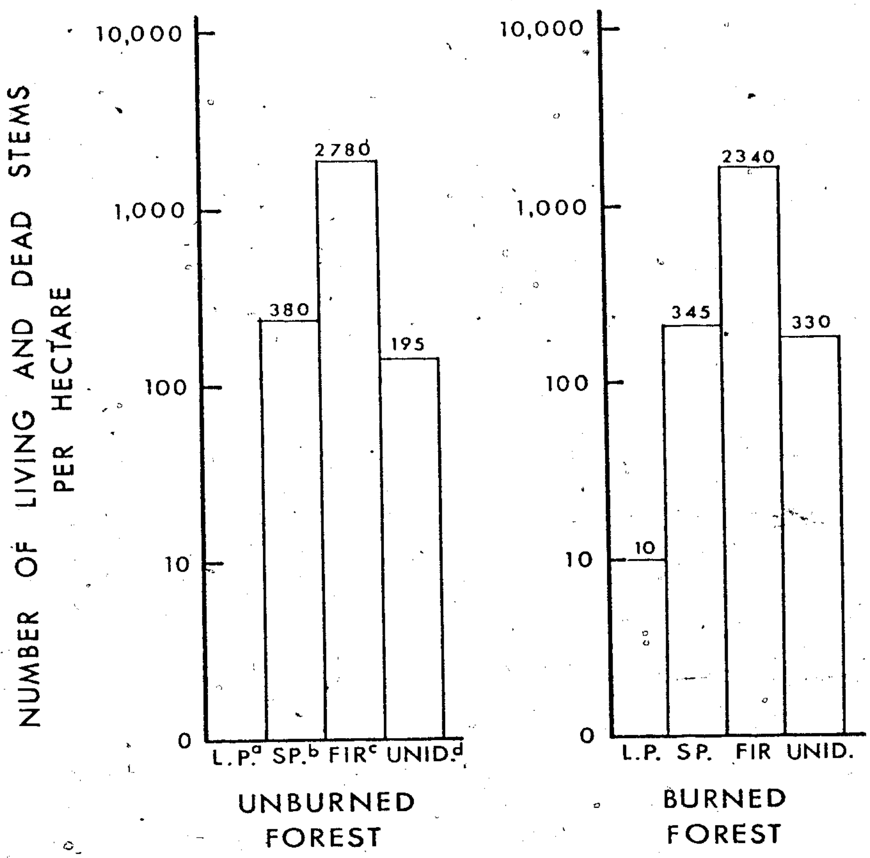


Figure 17. Living and dead stem densities of major tree species in the unburned and burned forest, Vermilion Pass.

a. Lodgepole pine.
b. Engelmann spruce.
c. Subalpine fir.
d. Unidentified stems.

Plate 11. The unburned (control) spruce-fir forest stand in the Vermilion Pass. (Photo date, Aug. 1972).

Table 30. Vascular species[a] occurring in both the burned and unburned forest, Vermilion Pass.

SPECIES	HERBACEOUS	WOODY
Abies lasiocarpa		X
Arnica cordifolia	X	
Calamagrostis canadensis	X	
Cornus canadensis		X
Empetrum nigrum		X
Equisetum pratense	X	
Linnaea borealis		X (Semi-woody)
Lonicera involucrata		X
Menziesia ferruginea		X
Picea engelmanii		X
Pinus contorta		X
Ribes lacustre		X
Rosa acicularis		
Salix spp.		X
Sorbus sitchensis		X
Stenanthium occidentale	X	
Vaccinium myrtillus		X
Vaccinium scoparium		X

a - Nomenclature follows Hitchcock et al (1969).

Table 31. Height (cm.), cover (%) and frequency (%) of shrubs in the unburned forest stand, Vermilion Pass.

SPECIES	MEAN HEIGHT (cm)	MEAN COVER (%)	FREQUENCY (%)
Ribes lacustre	37	< 1	60
Menziesia ferruginea	122	12.4	100
Sorbus sitchensis	76	< 1	20
Lonicera involucrata	30	< 1	40
Ledum groenlandicum	58	3.0	60
Rosa acicularis	25	≤ 1	40

Table 32. Height (cm.), cover (%) and frequency (%) of herbs and dwarf shrubs in the unburned forest stand, Vermilion Pass.

SPECIES	MEAN HEIGHT (cm.)	MEAN COVER (%)	FREQUENCY (%)
Arnica cordifolia	11	1.4	80
Aster spp.	13	< 1	20
Cornus canadensis	8	4.1	100
Equisetum pratense	28	2.2	40
Vaccinium myrtillus	16	3.0	100
Petasites palmatus	13	< 1	40
Rubus pedatus	5	3.0	80
Linnaea borealis	5	1.4	100
Listera cordata	6	< 1	20
Fragaria virginiana	12	< 1	40
Osmorhiza depauperata	9	< 1	20
Pyrola asarifolia	5	< 1	20

did not contribute to the vascular flora of the burn. The other five, along with Epilobium angustifolium were the major species found in the Vermilion Pass burn.

J. Ordination and Cluster Analysis

i) Ordination

Ordination, as introduced by Goodall (1954), includes a series of techniques which graphically represent similarity among stands, species and environmental variables, which are used in constructing the ordination and/or plotted on and related to it (Risser and Rice, 1971). Many authors have observed that the most important function of ordination is to detect possible or actual vegetation-environmental relationships (Greig-Smith, 1964; Gittins, 1965a, 1965b, 1965c; Beals, 1973).

Several ordination techniques exist and their relative advantages and disadvantages have been extensively reviewed in the literature (Lambert and Dale, 1964; Orloci, 1966; Austin and Orloci, 1966; Whittaker, 1967; Austin, 1968; Austin and Greig-Smith, 1968; Bannister, 1968; Anderson, 1971; Gauch and Whittaker, 1972; Beals, 1973). Ordination procedures following Bray and Curtis (1957) and Beals (1960) have been employed here to elucidate relationships among stands in the Vermilion Pass burn. Although other mathematically sophisticated ordinations are available (e.g., Principal Components Analysis), computational time is excessive (Orloci, 1966) and the Bray and Curtis ordination (1957) has given results that are equally satisfactory ecologically (Gauch and Whittaker, 1972; Bannister, 1968; Beals, 1973).

Three separate 2-dimensional ordinations were constructed. Density and basal area values of the standing dead forest were used as a basis for two, while Prominence Values [P.V. = % cover x $\sqrt{\text{Frequency (\%)}}$] of the lesser vegetation were used for the third ordination. In each ordination, similarity coefficients [$\underline{C} = 2\underline{W}/(\underline{A}+\underline{B}) \times 100$] between stands were first determined, where $\underline{C}$ is the similarity coefficient, $\underline{W}$ is the sum of the lowest common values of the two stands, $\underline{A}$ is the sum of the values in one stand and $\underline{B}$ is the sum of the corresponding values for a second stand. In the third ordination P.V.'s of species were not expressed as a percentage of their maximum values as in Bray and Curtis (1957). Matrixes of dissimilarity values (D = 100-C) were calculated and used for the construction of the two-dimensional ordinations.

a. Stand ordination based on dead tree density values

Sixty vegetation and environment factors were separately plotted on the density-based ordination, and only five of these suggested strong relationships. Figure 18 shows the location of each stand on the ordination. The major factor that accounts for the configuration of the ordination is the density of subalpine fir (Fig.18a). This species shows a marked increase in density towards the upper right of the ordination. The total density of the standing dead forest shows a similar patern (Fig.18b) though not as pronounced as in subalpine fir.

The only measured edaphic factor showing a relatively strong relationship to density of the standing dead trees is the pH of the B horizon (Fig.19). The pH's less than 6.0 occur in the lower left and those greater than 6.0 in the right centre of the ordination.

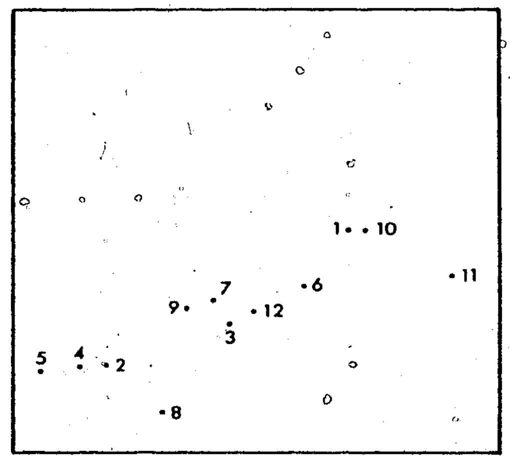


Figure 18. Location of the 12 burn stands on the ordination using density values of the standing burned trees.

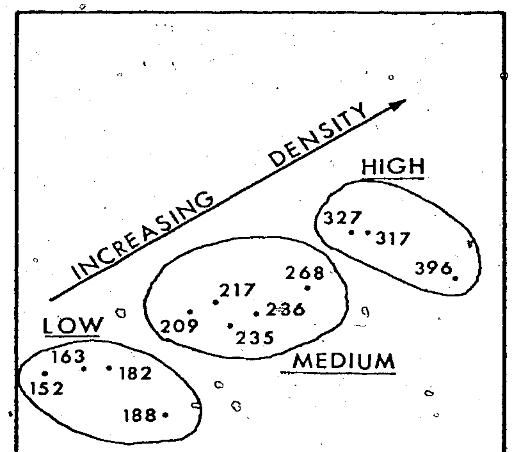


Figure 18a. Density distribution of burned Subalpine Fir on the tree density-based ordination.

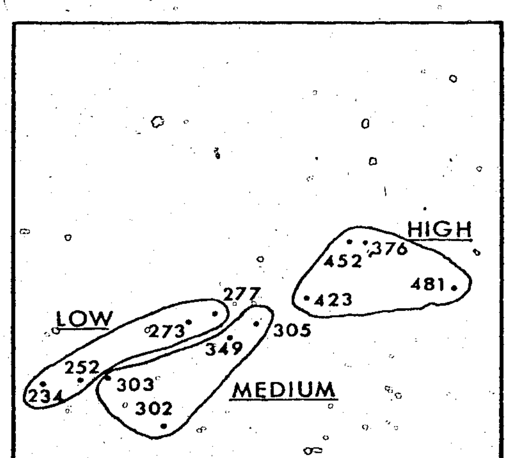


Figure 18b. Density distribution of the standing dead forest on the tree density-based ordination.

Although all pH's in the B horizon were acidic, it appears that subalpine fir of the pre-burn forest preferred weakly acidic soils to strongly acidic soils, assuming that pH's have returned to near pre-fire levels.

Percent cover of needle litter increases from the lower left to the upper right on the ordination, and is postively correlated with the stem density of subalpine fir and pH of the B horizon (Fig.19a). Stands with less needle cover may have had greater fire intensity in the crown space. However, fire intensity would, in the absence of other stand difference, likely be greater in dense stands. Thus, the direct relationship of needle litter to subalpine fir density is likely a function of simple proportion (i.e. more trees, more needle cover). Site quality may be higher in the upper right of the ordination.

The only post-fire species that showed a relationship to the pre-fire tree density was *Vaccinium myrtillus/scoparium*. Its mean height decreases from left to right on the ordination, indicating a negative relationship with the density of dead subalpine fir and pH of the B horizon (Fig.19b). The vigorous height growth of *Vaccinium myrtillus/scoparium* on the lower left of the ordination suggests a preference of this species for strongly acidic soils, as noted by Szczawinski (1962). The greater height growth may also be due to a more favourable light regime as a result of decreased density of the standing dead subalpine fir.

b. Stand ordination based on dead tree basal area values

The basal area ordination proved to be much more informative than the density ordination, particularly in terms of physiographic

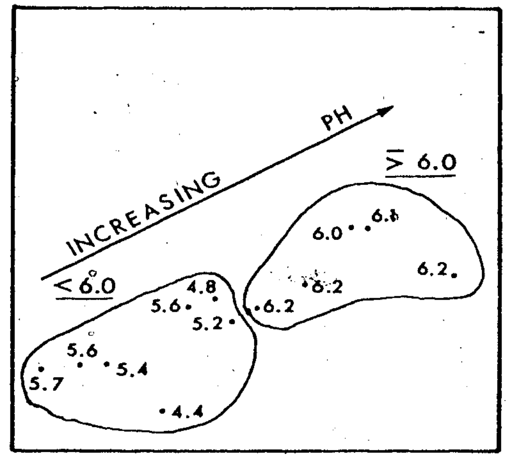


Figure 19. Acidity of the B f horizon on the tree density-based ordination.

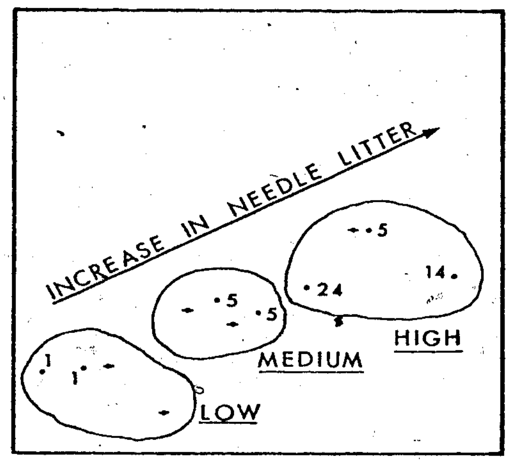


Figure 19a. Distribution of needle litter cover (%) on the tree density-based ordination.

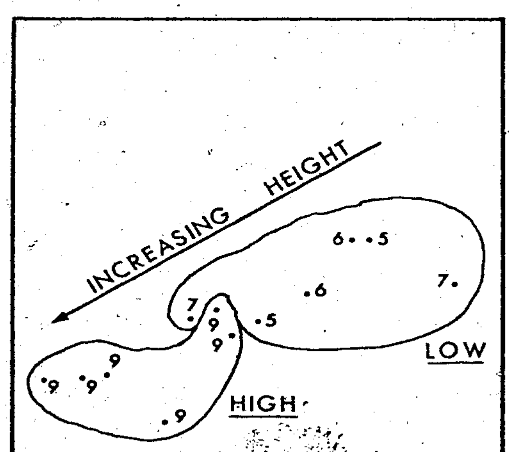


Figure 19b. Distribution by mean height (cm.) of <u>Vaccinium myrt/scop</u>. on the tree density-based ordination.

variables. Figure 20 shows the location of the stands on the ordination using basal area values of the standing dead trees. Figure 20a shows total basal area increasing from the lower right to the upper left on the ordination. The basal areas of Engelmann spruce, lodgepole pine and subalpine fir (Figs. 20b, 21 and 21a) also show distinct patterns. Both elevation and slope angle increase from the bottom to the top on the ordination (Figs. 21b and 22). Generally, all three dead tree species had greater basal areas at elevations above 5400' with a slope angle of greater than 10%. Both subalpine fir and lodgepole pine appear more sensitive to elevation change than does Engelmann spruce, at least in terms of basal area.

The density of lodgepole pine varies directly with its basal area (Fig.22a) which suggests a uniform size-class of this species.

Prominence values of Vaccinium myrtillus/scoparium and Menziesia ferruginea increase towards the upper left of the ordination (Fig.22b and 23) and thus vary directly with elevation. Percent cover of the shrub stratum also increases with an increase in elevation (Fig.23a).

c. Stand ordination based on prominence values of living plant species

The ordination based on P.V.'s of species proved to be the most informative of the three ordinations. Figure 24 shows the locations of the stands on the ordination based on Prominence Values. Twenty of the 60 variables exhibited definite patterns on the ordination.

Elevation shows a definite increase from the top of the ordination to the bottom (Fig.24a). Stands on the upper left of the

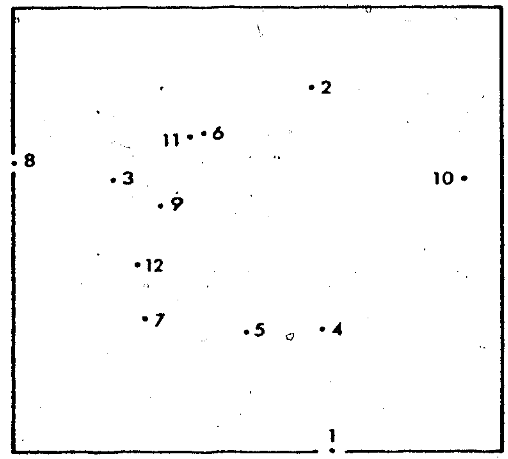


Figure 20. Location of stands on the ordination using basal area values of the standing dead trees.

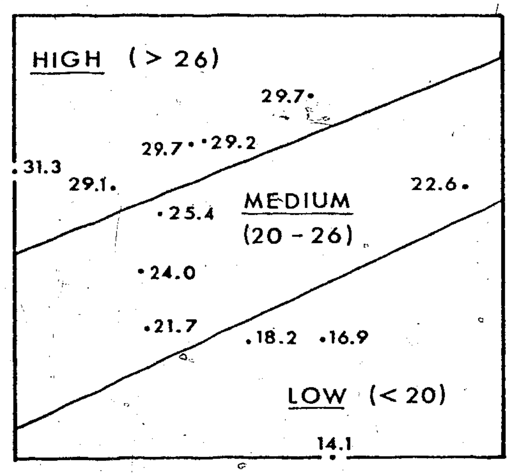


Figure 20a. Basal area distribution of the standing dead forest (in m^2 ha^{-1}). on the basal area-based ordination.

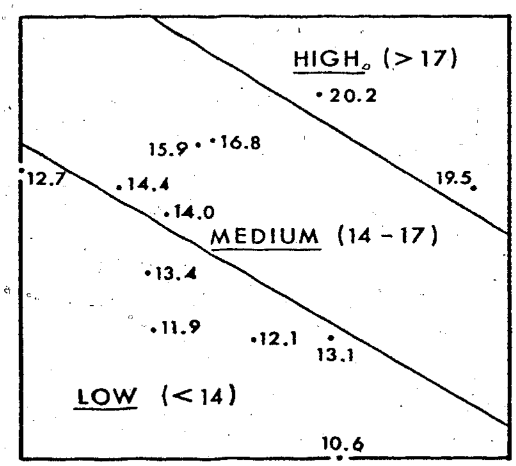


Figure 20b. Basal area distribution of Engelmann Spruce (in m^2 ha^{-1}). on the basal area-based ordination.

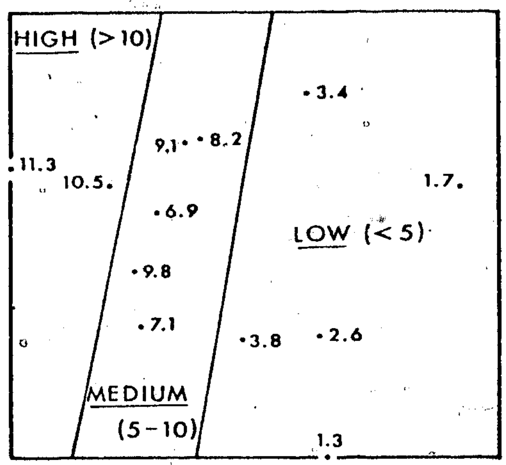


Figure 21. Basal area distribution of Lodgepole Pine (m^2 ha^{-1}). on the basal area-based ordination.

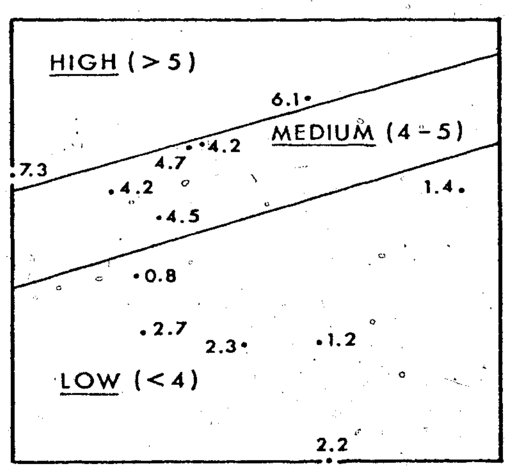


Figure 21a. Basal area distribution of Subalpine Fir (m^2 ha^{-1}). on the basal area-based ordination.

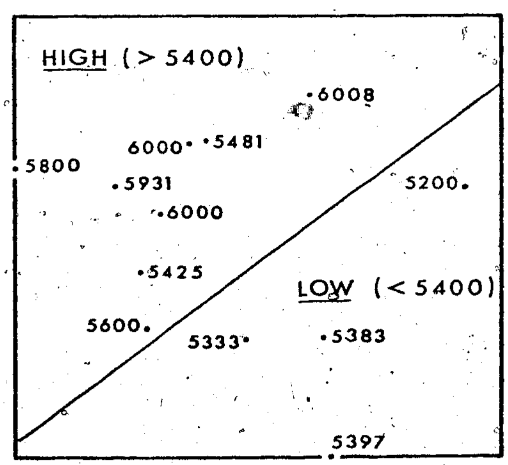


Figure 21b. Elevational distribution of stands on the basal area-based ordination. (elev. in ft.)

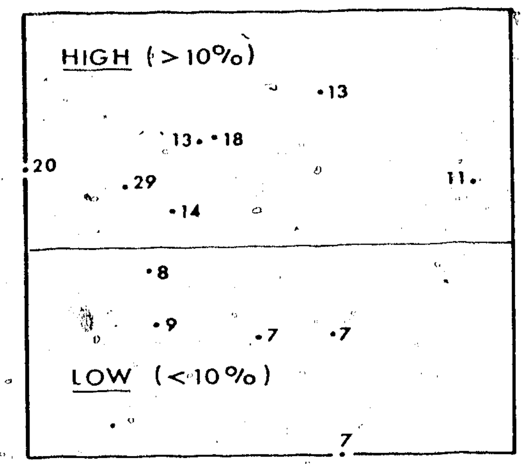


Figure 22. Slope angle (%) on the basal area-based ordination.

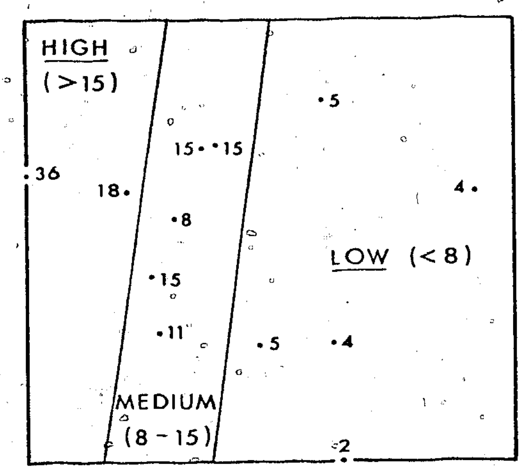


Figure 22a. Density distribution of dead Lodgepole Pine (no. of stems per 1000 sq. meters), on the basal area-based ordination.

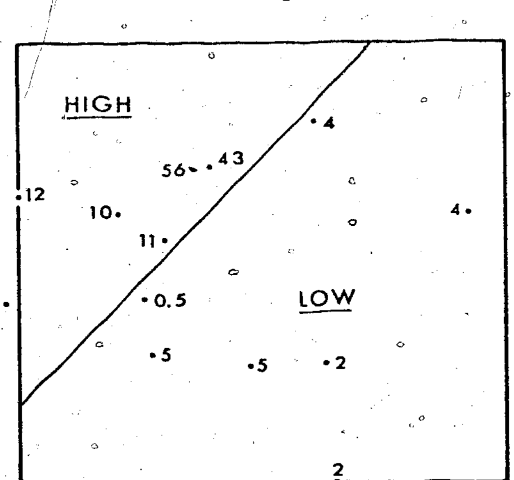


Figure 22b. Distribution of <u>Vaccinium myrtillus/scoparium</u> prominence values on the basal area-based ordination.

Figure 23. Distribution of <u>Menziesia ferruginea</u> prominence values on the basal area-based ordination.

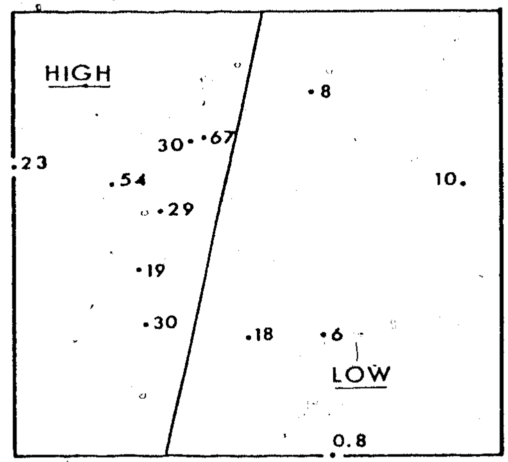


Figure 23a. Distribution of shrub stratum cover (%) on the basal area-based ordination.

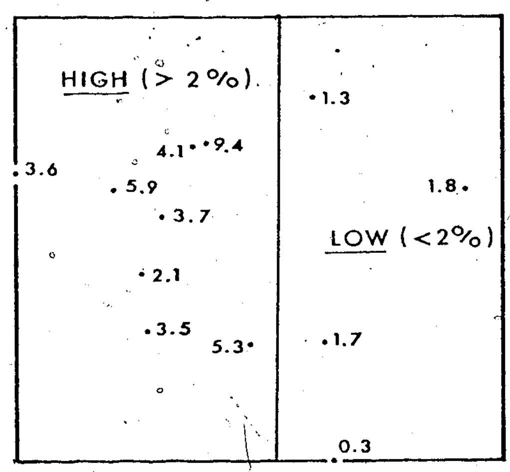
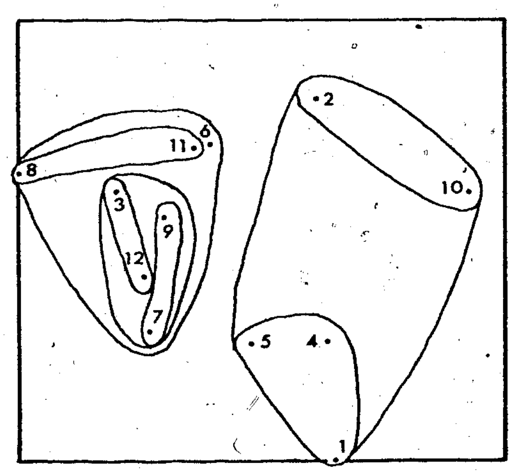


Figure 23b. Relationship of basal area derived clusters to basal area derived ordination.
(see also Fig. 32a)



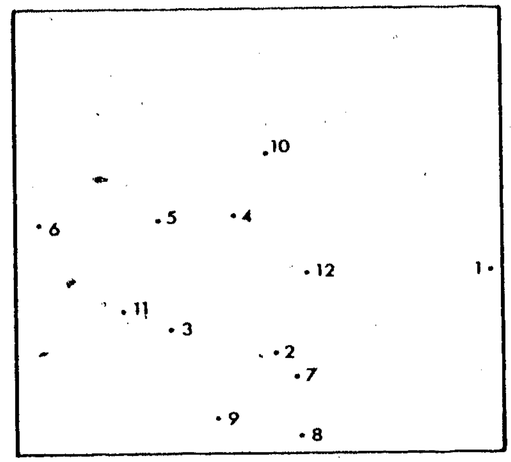


Figure 24. Locations of stands on the ordination based on prominence values of living species.

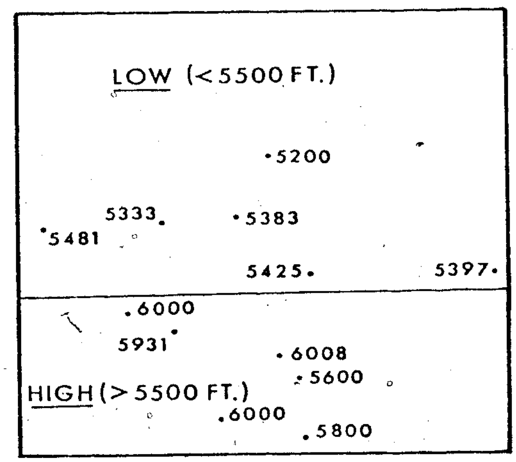


Figure 24a. Elevations of the twelve stands on the PV-based ordination.

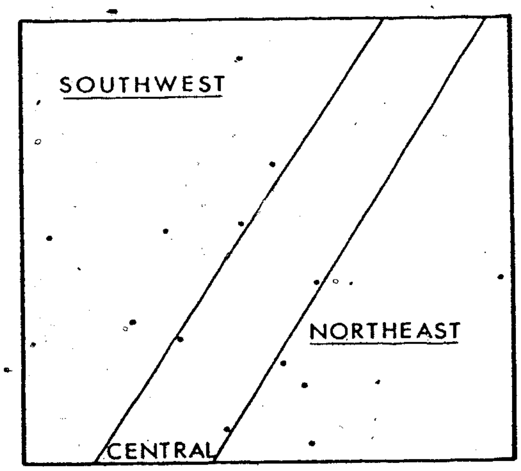


Figure 24b. Geographical locations of the twelve stands on the PV-based ordination.

ordination are located in the SW part of the burn, while those on the lower right occur in the NE part of the burn (Fig.24b). Generally, slope angle increases from the upper right to the lower left on the ordination (Fig.25).

The ordination suggests an increase in acidity of the B and C horizons with an increase in elevation (Fig.25a and 25b). Greater precipitation at higher elevations would favour eluviation of fine soil particles which in turn would enhance the development of acidic upper horizons. The ordination also shows that soils located in the NE portion of the burn are more acidic, have a greater sand content in the B horizon and less silt in the B and C horizons (Fig.26, 26a, 26b) than those soils found towards the SW.

The percent cover of rock is generally greater towards the NE of the burn (Fig.27) which supports observations made during field sampling. The mean heights of Menziesia ferruginea and Arnica cordifolia increase from right to left on the ordination (Figs.27a and 27b). The greater heights in the southwest region of the burn may be related to the edaphic factors mentioned previously. Living shrub density and cover of shrubs appears to be related to slope angle, i.e. shrub density increases with slope angle (Figs.28 and 28a). The cover of the herb and dwarf shrub stratum appears to be jointly related to elevation and pH (Fig.28b). Stands at high elevations (lower on the ordination) had less cover, which may be due to the more acidic nature of the soils as well as climatic differences.

Although lodgepole pine seedling density does not correlate with slope angle, the average seedling height decreases with an increase in slope angle (Fig.29). Runoff is likely more pronounced

Figure 25. Slope angle (%) on the PV-based stand ordination.

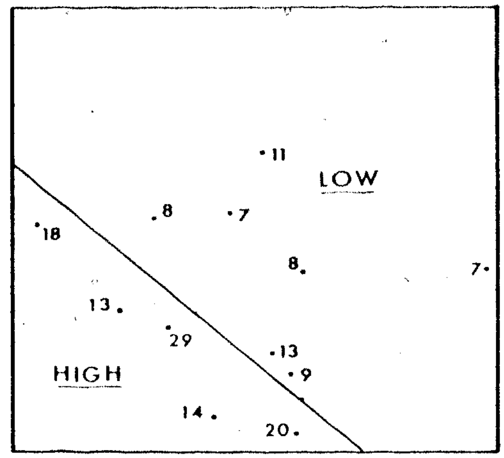


Figure 25a. The pH in the B horizon on the PV-based stand ordination.

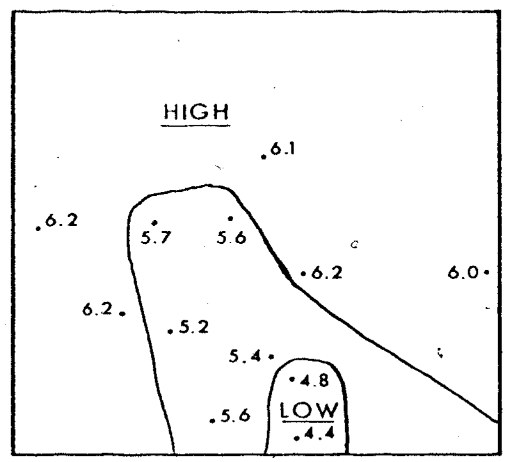


Figure 25b. The pH in the C horizon on the PV-based stand ordination.

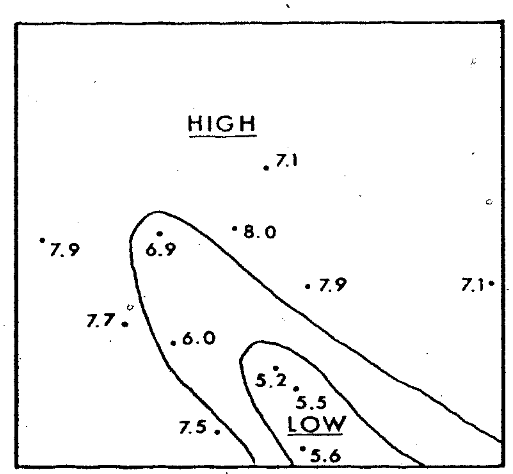


Figure 26. Percent sand in the B horizon on the PV-based ordination.

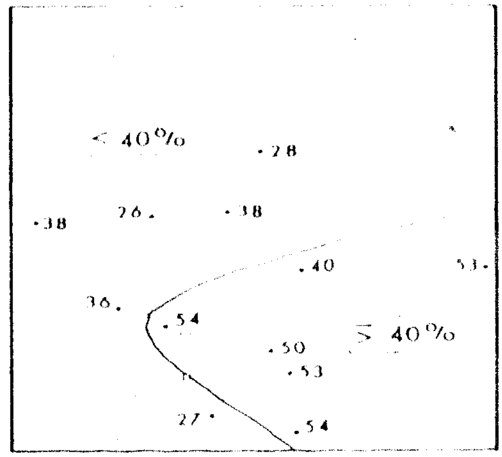


Figure 26a. Percent silt in the B horizon on the PV-based ordination.

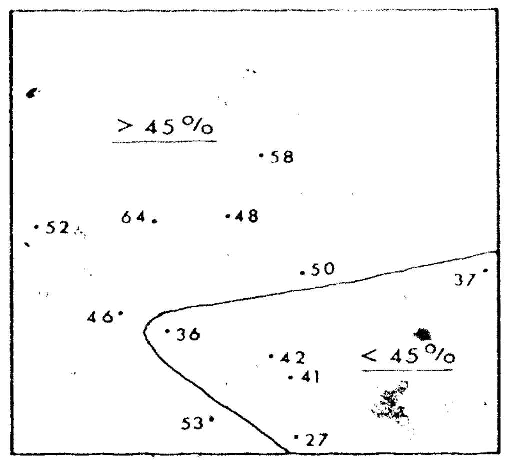
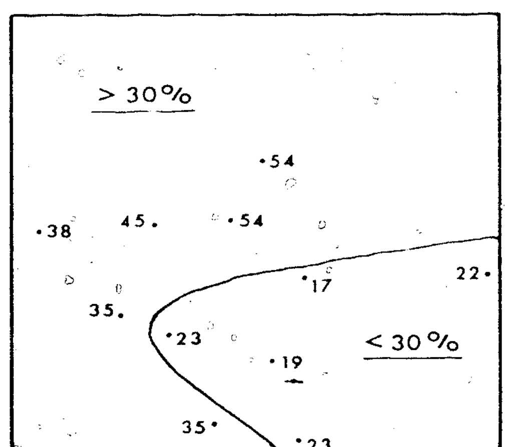


Figure 26b. Percent silt in the C horizon on the PV-based ordination.



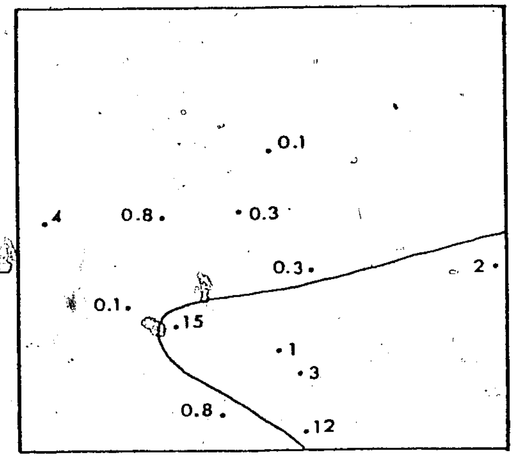


Figure 27. Distribution of rock cover (%) on the PV-based ordination.

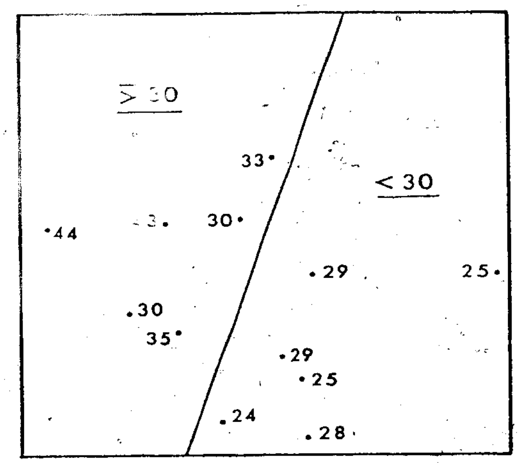


Figure 27a. Mean height (cm.) of *Menziesia ferruginea* on the PV-based ordination.

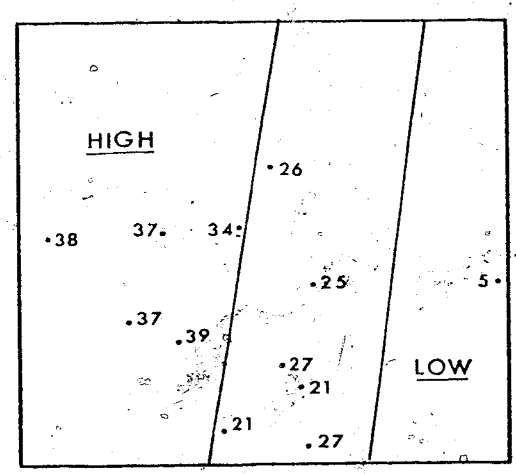


Figure 27b. Mean height (cm.) of *Arnica cordifolia* on the PV-based ordination.

Figure 28. The distribution of living shrub density on the PV-based ordination.

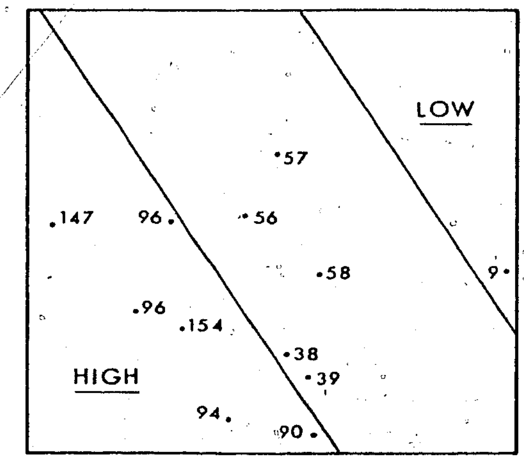


Figure 28a. Percent cover of the shrub stratum of the PV-based ordination.

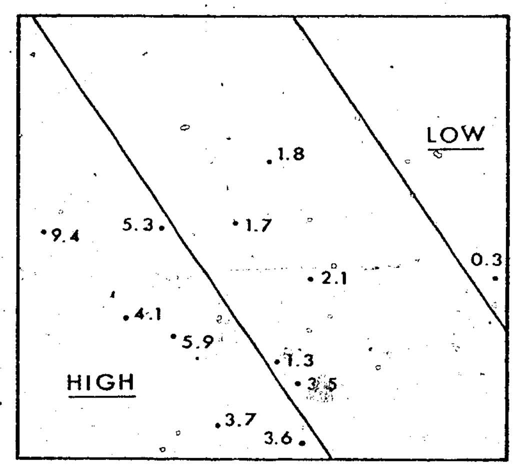
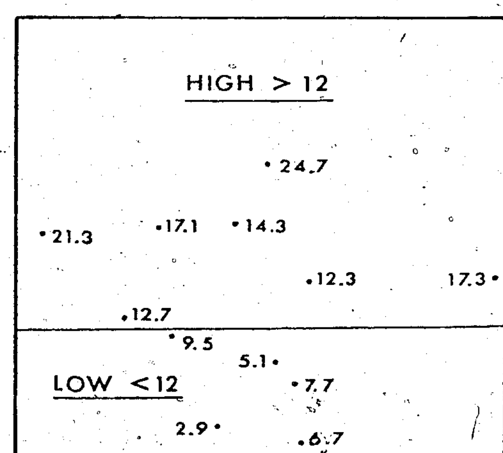


Figure 28b. Percent cover of the herb-dwarf shrub stratum on the PV-based ordination.



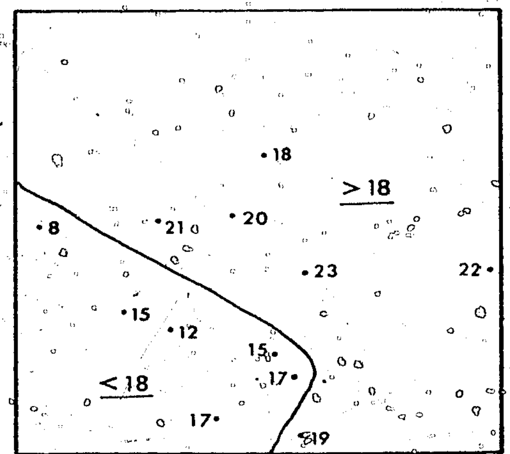


Figure 29. Average height (cm.) of Lodgepole Pine seedlings on the PV-based ordination.

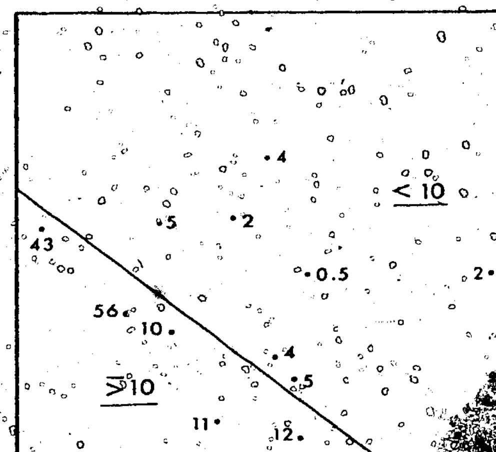


Figure 29a. PV of Vaccinium myrtillus/ scoparium on the PV-based ordination.

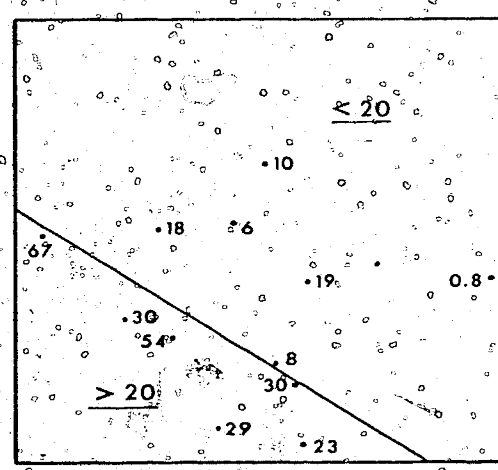


Figure 29b. PV of Menziesia ferruginea on the PV-based ordination.

on steep slopes so that seedling growth would be adversely affected on steep slopes unable to provide optimum moisture conditions. Prominence Values of *Vaccinium myrtillus/scoparium*, *Menziesia ferruginea* and *Linnaea borealis* are all related to slope angle (Fig. 29a, 29b and 30). The prominence of *L. borealis* decreases with an increase in slope angle while those of the other two species increase with an increase in slope angle. Prominence Values of *Epilobium angustifolium* and *Arnica cordifolia* are negatively correlated to each other (Fig. 30a and 30b). Both patterns may reflect edaphic relationships. It was noted earlier that where fire intensity was low (stand 6), cover of *A. cordifolia* was relatively high and of *E. angustifolium* relatively low. Although the fire intensity index used was not critical enough to further quantify fire intensity on a stand by stand basis, the relative prominence of *E. angustifolium* and *A. cordifolia* may well be indicative of fire intensity. If this hypothesis is valid, then fire intensity would have increased from the SW (low *E. angustifolium*; high *A. cordifolia*) towards the NE (high *E. angustifolium*; low *A. cordifolia*), the actual direction in which the fire did move. Although other physical parameters measured (depth of duff, cover of exposed mineral soil and rotten wood) do not show a corresponding relationship, the potential for post-burn species to indicate fire intensity is an area that requires further research. Prominence values of *Cornus canadensis* suggest a pattern similar to *A. cordifolia* but may reflect acidic soil conditions (Fig. 31).

Species richness (Fig. 31a) was highest at low elevations towards the SW end of the burn, and in areas where soils contained greater than 45% silt and less than 40% sand in the B horizon.

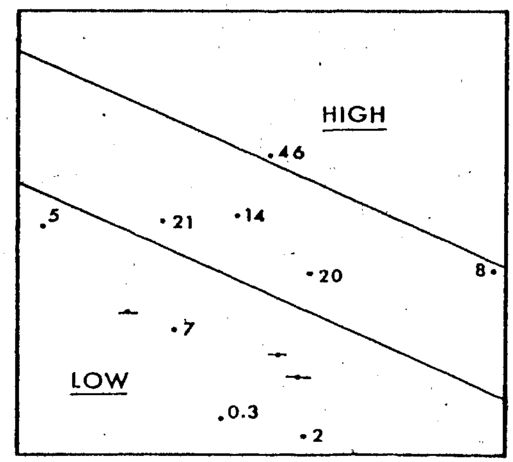


Figure 30. PV of <u>Linnaea borealis</u> on the PV-based ordination.

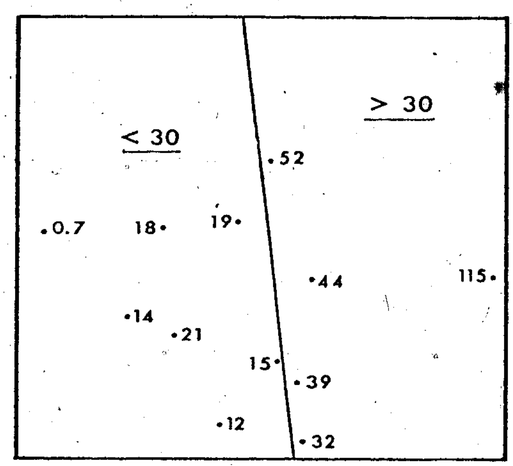


Figure 30a. PV of <u>Epilobium angustifolium</u> on the PV-based ordination.

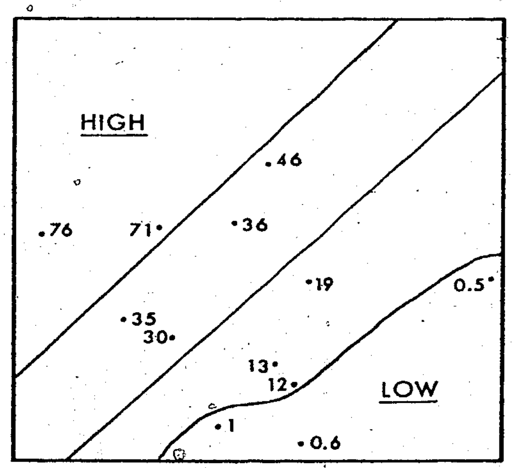


Figure 30b. PV of <u>Arnica cordifolia</u> on the PV-based ordination.

Figure 31. PV of <u>Cornus canadensis</u> on the PV-based ordination.

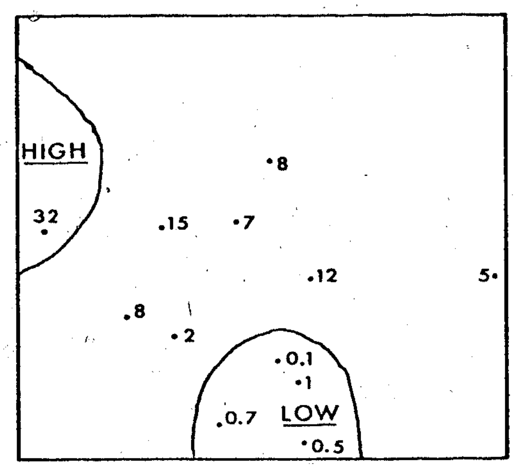


Figure 31a. Vascular species richness in stands on the PV-based ordination.

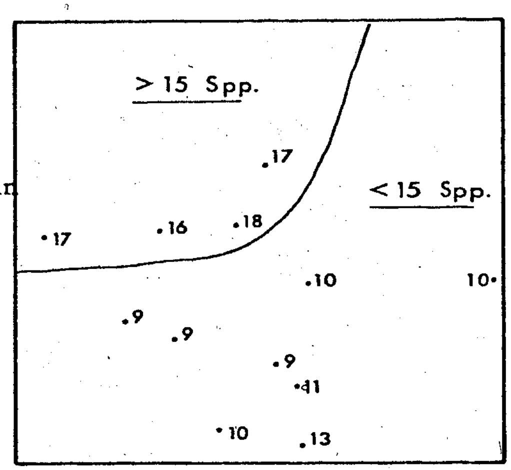


Figure 32 supports the hypothesis that fire severity increased from the SW towards the NE. The relationships of the PV derived clusters to the PV derived ordination is presented in figure 32a. (See also fig. 23b).

Figure 32. Fire severity in 12 stands on the PV-based ordination. (Fire severity ranked from low (1) to high (8). See fig. 9).

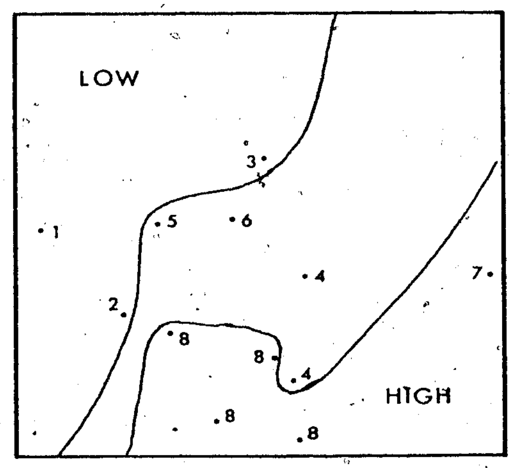
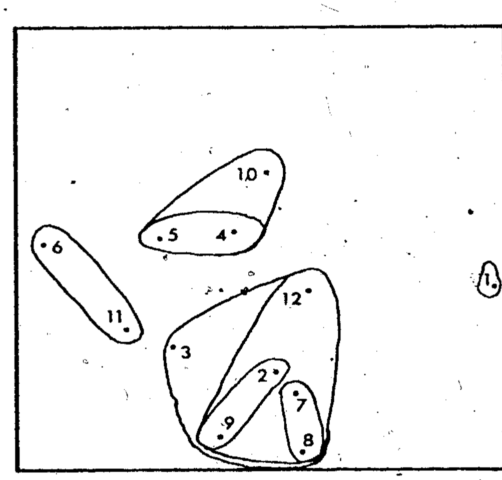


Figure 32a. Relationship of PV derived clusters to PV derived ordination. (See also fig. 23b).



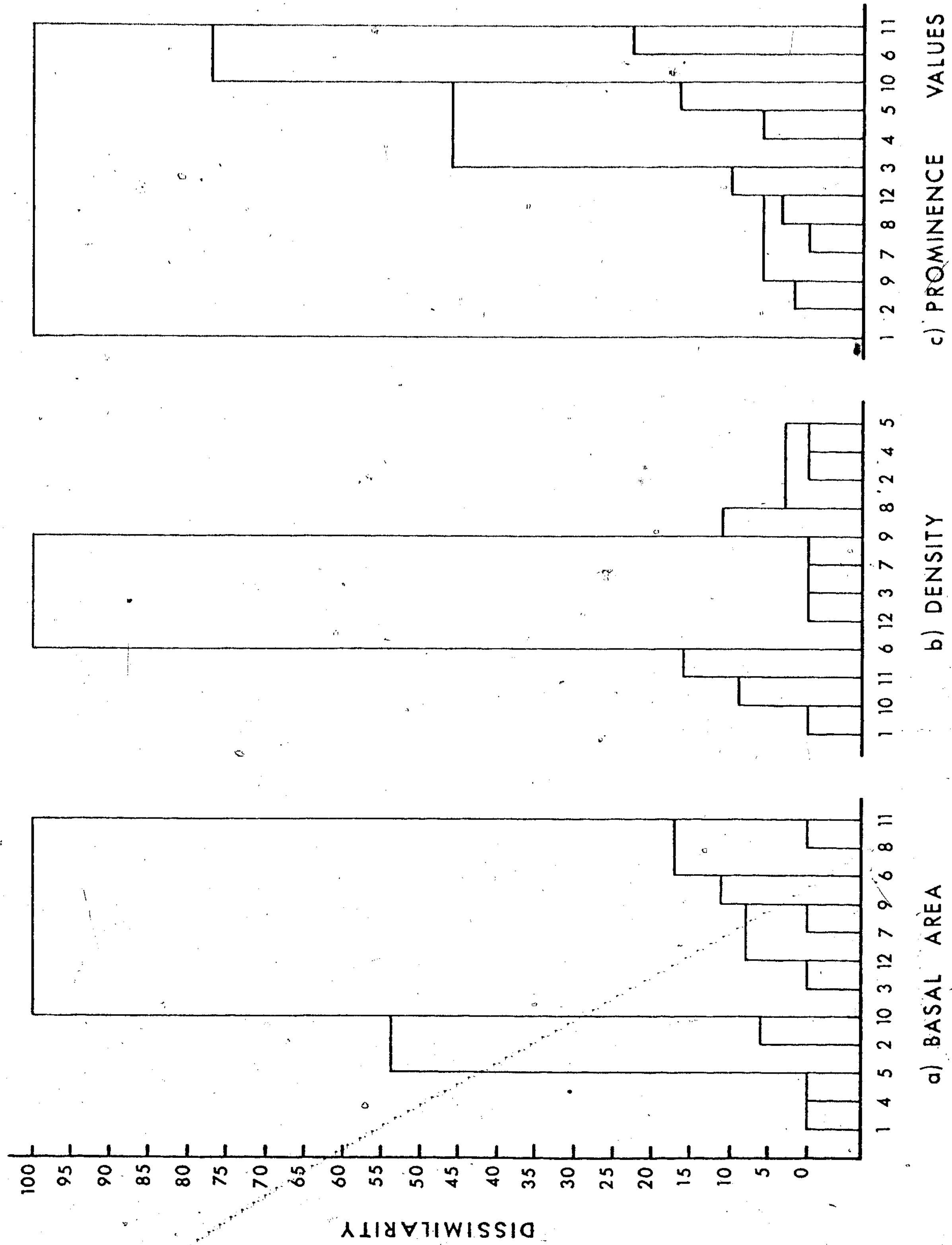
ii) Cluster Analysis

The data used for constructing the ordinations was also used in the construction of dendrograms. The dendrograms are graphic displays of a computer-derived, agglomerative clustering technique (Pritchard and Anderson, 1971). Minimum variance cluster analysis was used primarily to clarify and verify the stand relationships on the ordinations.

The dead tree density-based dendrogram (Fig.33) shows three clusters of high similarity involving nine stands (i.e. nos. 1 and 10 form one cluster; 12, 3, 7 and 9 form a second cluster; and 2, 4 and 5 form the third cluster). The other three stands (11, 6 and 8) link into the original clusters at lower levels of similarity, and show greater interstand distances on the ordination (Fig.18). Stand 6 is more similar to the first cluster than to the second cluster, but in the ordination (Fig.18a) it is included with the latter cluster. Placement of stand 6 in either cluster does not seriously affect the relationship depicted in the ordination. The density-based dendrogram makes it clear that stands of cluster 2 are more closely allied to stands of cluster 3 than to those of cluster 1. This relationship is not as readily apparent on the ordination diagram of Fig. 18.

The basal area-based dendrogram (Fig.33) serves to clarify the stand groupings on the basal area ordination (Fig.23b), particularly the rather congested groupings of stands located towards the upper left of the ordination. Conversely, where stands are fairly well distributed on the ordination as in Fig. 24, the dendrogram based on Prominence Values (Fig.33) provides some assistance in determining the inter-stand relationships. (Fig. 32a).

Figure 33. Dendograms of minimum variance cluster analysis of stands using values of (a) basal area, (b) density of the standing dead trees and (c) prominence values of the living subordinate vegetation.


DISSIMILARITY
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1 4 5 2 10 3 12 7 9 6 8 11
a) BASAL AREA
1 10 11 6 12 3 7 9 8 2 4 5
b) DENSITY
1 2 9 7 8 12 3 4 5 10 6 11
c) PROMINENCE VALUES

VI DISCUSSION AND CONCLUSIONS

Standing Dead Forest

One objective of this study was to determine the structure and species composition of the tree stratum in the forest stands before the 1968 Vermilion Pass fire. The dead standing trees consisted almost entirely of Engelmann spruce, subalpine fir, and lodgepole pine. Whitebark pine was very rare in the upper part of the burn area, and one Douglas fir snag was seen. Engelmann spruce was the dominant tree in terms of basal area, followed by lodgepole pine. Numerically, however, subalpine fir far outnumbered both spruce and pine, but was primarily restricted to the smaller size-classes. Many authors have reported the same basic structure and species composition for subalpine spruce-fir-pine forests in the Rock[illegible]

In Colorado, Ho[illegible] and Foster (1910) found Engelmann spruce and subalpine fir in densities of 148 and 55 trees per hectare respectively, where "tree" $\geqq$38 cm dbh. Spruce density was more than twice as high in the Vermilion Pass (375 ha^{-1}), but no subalpine fir achieved tree size there. Alexander (1974) reported that in the Central Rocky Mountains spruce commonly makes up 70% or more of the overstory basal area, but he did not specify the size-class limits of overstory and understory. Considering trees $\geqq$ 38 cm dbh as the overstory component, Engelmann spruce accounts for 80% and lodgepole pine for 20% of the basal area in the Vermilion Pass.

In a study of virgin climax spruce-fir forests in the Medicine Bow Mountains of Wyoming, Oosting and Reed (1952) found considerably higher densities of both spruce and fir than those in Vermilion Pass, but the relative densities of spruce and fir in the two areas were quite similar (ca. 46% spruce and 54% fir).

In a high-elevation spruce-fir forest in the Madison Range Mountains of SW Montana, Patten (1963) reported 672 trees ha^{-1}, where "tree" $\geq$ 10 cm dbh. This compares with 436 trees ha^{-1} in the Vermilion Pass. Patten's relative tree densities were 6%, 43% and 48% for pine, spruce and fir, respectively, compared with 24%, 52%, 24% in the Vermilion Pass.

In Alberta, Horton (1959) reported a total basal area of 54.9 m^2 ha^{-1} in Engelmann spruce dominated subalpine forest. In the Vermilion Pass total basal area was only 29.4 m^2 ha^{-1}. Of the total basal area reported by Horton, 90% was Engelmann spruce compared with 50% in the Vermilion Pass. Horton's total density was 1785 trees ha^{-1}, where "tree" $\geq$ 2.5 cm dbh compared to 1160 ha^{-1} in the Vermilion Pass. The relative densities of spruce and fir were about 50:50% in both studies.

Beil (1966) has studied the virgin, climax spruce-fir forests of Banff and Jasper National Parks. He found mean relative tree densities of 47%, 50% and 1% for Engelmann spruce, subalpine fir and lodgepole pine, where "tree" $\geq$ 7.5 cm dbh. In the Vermilion Pass, comparable mean densities of the three species were 53%, 29% and 18%, respectively. Fir far outnumbered spruce in the smaller size-classes in both studies, but detailed comparisons are not possible since so many of the small stems in the Vermilion Pass were charred by the fire.

Many other qualitative and quantitative descriptions of the subalpine spruce-fir forests of the Rocky Mountains are available, but only those especially pertinent to this study, have been discussed here.

The major differences between the pre-fire forest at Vermilion

Pass and those of the other study areas discussed above are (1) the lack of subalpine fir in the overstory, and (2) the relative abundance of lodgepole pine in the overstory. Because pine was absent in the understory of the pre-fire forest, I conclude that pine was declining in abundance before the fire. The standing dead forest was not in a late successional phase of development before the fire, but in an earlier phase similar to that described by Day (1972): "Pinus is decadent or dying and Picea dominates .... Abies is about four times as numerous as Picea in the understory ....". Had the Vermilion Pass burn of 1968 not occurred, the forest would probably have advanced to an Abies-Picea late successional phase by the middle of the next century.

Fire Intensity

Fire intensity is an important factor affecting post-fire plant succession (Stahelin 1943; Lutz 1956; Ahlgren and Ahlgren 1960; Rowe and Scotter 1973). It is normally quite variable (Van Wagner 1965; Kilgore 1973), especially in mountainous terrain. However, fire intensity in the Vermilion Pass was generally uniformly severe in all stands. Weather conditions at the time of the burn preceded by a lengthy drought enabled this intense crown fire to move rapidly from the lightning strike at the SW end to the Continental Divide at the NE end of the valley. Although the fire was very intense in every respect, several small pockets (unsampled) of vegetation partially or wholly escaped incineration (Appendix B), and stand No. 6 was not as severely burned as the others. The unburned pockets are seed sources inside the burn perimeter and are no doubt contributing to revegetation of the area.

In an intense crown fire, temperatures can be lethal to seeds in unburned as well as burned serotinous cones (Muraro 1971). The abundance of lodgepole pine seedlings in the post-burn vegetation indicates that either (1) temperatures and/or heat duration were not sufficient to destroy all viable seed in the burn area, or (2) seed has uniformly dispersed into the burn area from pine populations in the surrounding unburned vegetation. The first explanation seems much more plausible since there were no strong gradients of decreasing seedling density from the fire margins into the burn center and pine seed is not generally disseminated far from the forest margin (Armit 1966). The extent to which the fire reduced quantities of viable seed is unknown, but survival seems adequate to insure dominance of pine in the regenerating forest.

On the forest floor, the fire was severe enough to consume most of the litter and much of the deadfall, and in some places to expose mineral soil. But it did not completely destroy the below-ground living portions of several shrub and other subordinate species.

Trees Fallen Since Fire

The standing dead forest trees represent a portion of the total nutrient capital present in the burn and thus the rate at which the standing stems fall to the ground and decay is important in understanding nutrient cycling and secondary succession in burned ecosystems. They also provide a favourable habitat for many invertebrates which in turn attract a variety of birds, thus contributing to species diversity.

The protection from solar radiation and wind afforded by the standing stems tends to ameliorate ground surface temperatures which may assist seedling and root sprout establishment and growth of many species. Martin and Brackebusch (1974) generalize that over a period of years standing fire-killed trees shed a succession of needles, small twigs, large twigs, branches and bark, until the tree topples. In the Vermil[illegible]s a ten-fold increase of stems fallen since the fire occurred between 1971 and 1972. Most of the new-fallen stems in both years were in the 2 and 3 inch size-class. It is expected that future annual "fall" rates will be extremely variable because of space-time variations in windstorms, stand structure and fire intensity.

When trees uproot and fall to the ground they alter the local site conditions and provide microsites themselves (Graham 1925; McCullough 1948), and expose mineral soil seedbeds favoured by some conifers. Some trees snap off rather than uproot, leaving vertical snags. Once on the ground, the rates of decay and humification of wood and bark is a function of texture, nitrogen content, presence of decay-inhibiting compounds, moisture content and aeration (Bollen 1974).

Future monitoring of the 12 stands should provide statistically sound information on the rate of decay and re-cycling of the burned tree stratum.

Conifer Seedlings

Lodgepole pine, represented by seedlings, was the dominant conifer species on the Vermilion Pass burn. This species has long been recognized as a fire species (Clements 1910; Mason 1915; Bates 1930; Horton 1956), with best germination occurring in full sunlight on mineral soil or disturbed duff free of competition from other species. Its ability to regenerate readily after fire can often be attributed to its serotinous (i.e. late-opening) cone habit (Lotan 1973), which is particularly widespread in the Rocky Mountains (Fowells 1965), ensuring a large quantity of available seed for release following fire.

Cones in the crowns of the fire-killed lodgepole pine likely provided most of the viable seed for regeneration in the study area. The distribution of the pine seedlings was very uneven but not related to the proximity or density of either living or dead seed trees. However, the turbulent, pulsating nature of the wildfire could have caused wide spatial variations in the amount of viable seed subsequently released, resulting in irregular distribution patterns (Brown 1973). Local site conditions obviously influence germination and survival as well (Armit 1966).

The results of this study show that the density of pine seedlings decreased with increasing elevation and slope steepness. Seedling density was highest below 1700 m (ca. 5500 ft) ASL and lowest above 1800 m (ca. 5800 ft) ASL. Horton (1953) also found the steepest slopes least stocked with pine seedlings. The decrease in seedling density with increase in elevation and slope angle may be due to elevationally correlated temperature and moisture gradients that are unfavourable to pine. Higher-elevation stands in the Vermilion Pass burn area will doubtless be more open-structured than those at lower elevations for many years into the future. Hettinger (1975) reported that lodgepole pine forests were usually more open-structured at higher than at lower elevations in the Vine Creek basin of Jasper National Park. Older burn areas in the study area show the same trend.

There was no indication that pine seedling density was affected by competition from other plants at the time of the study. Clements (1910) thought that Vaccinium species provided strong competition with pine seedlings in the Central Rockies, while Stahelin (1943) found coniferous reproduction better on plots with Vaccinium cover than on plots with grass cover. The relative amount of interspecific competition may be more important than the kinds of competing species.

The results of this study show that pine seedling height growth is negatively correlated with increasing elevation, slope angle and competition (both inter- and intra-specific). Clements (1910) also reported pronounced differences in the growth rate of lodgepole pine seedlings with elevation. Horton (1958), however, did not report evidence for such a correlation in his Alberta work. Competition did not seem to affect initial seedling density in the Vermilion Pass, but in stand No. 6 it appears to have intensified after the seedlings became fairly well established, resulting in growth retardation.

Pine seedling density increased significantly in the study plots from 1971 to 1972 (1470 ha^{-1} to 1820 ha^{-1}). Clements (1910) reported that effective seeding took place only during the first year after fire, but Horton (1953) and Corns and La Roi (1976) have shown that in Alberta most establishment occurs over the first three years and continues even longer on some sites. Since the fire occurred in 1968, it seems certain that successful pine seedling establishment continued for at least five years in the study area.

Pine seedlings more than doubled their height between 1971 and 1972 (from 7 cm to 17 cm). Rapid growth in young pine trees is common (Pfister and Daubenmire 1973), enabling them to attain early dominance, even in circumstances where other more shade-tolerant species establish simultaneously with pine. Arnit (1966) reported normal height increments of 20-40 cm per year on average sites for at least the first 30 years.

Browse damage to pine seedlings was observed in the study area, but it was not regarded as significant. Baranyay and Stevenson (1964), working in the Hinton area of Alberta, found 14% of the young lodgepole pine browsed by ungulates. Other animals may affect the density and vigor of pine seedlings in the study area, but to what extent is not known. Seedling mortality is doubtless occurring due to climatic and competitive factors as well as to birds, mammals and other organisms. However, the increased seedling density between 1971 and 1972 indicates that pine establishment and survival more than compensated for mortality induced by physical and biotic factors.

Both Engelmann spruce and subalpine fir depend on a "residual seed source" (i.e. surviving trees and/or unburned seedbeds) for regeneration following fire (Hodson and Foster 1910). Lack of seed is the main reason why few spruce and fewer fir were found in the Vermilion Pass burn. Abundant spruce regeneration was observed on the bulldozed fireline adjacent to the unburned forest, an available seed source. Spruce seedlings found within the burn perimeter were concentrated in a less severely burned area where some mature spruce survived. Here seedling survival was likely aided by relatively lower light intensities (Alexander 1958a; Le Barron and Jemison 1953) and cool, moist micro-environments (Day 1963). Small pockets or refugia of unburned forest within the burn also provide a seed source for the dispersal of spruce and fir into the adjoining burned area.

Subalpine fir is less exacting in its seedbed requirements than Engelmann spruce (Alexander 1958b), but lack of a seed source and relatively rigorous light, temperature and moisture regimes are preventing establishment and survival of subalpine fir.

Succession of Tree Species After Fire

Forest succession initiated by fire in the subalpine zone has been discussed by many investigators (Stahelin 1943; Bloomberg 1950; Cormack 1953; Horton 1955, 1956, 1959; Moss 1955; Ogilvie 1969; Day 1972). They have all recognized a general trend from lodgepole pine to a spruce-fir climax, but detailed quantitative studies of rates and patterns of succession have not been enunciated.

Competition from spruce and fir is a major factor in the later decline of pine (Cormack 1953; Horton 1956). The very low density of spruce and fir seedlings in the early successional stage will likely result in an extended pine stage, and the progression to spruce-fir climax will be relatively slow in the study area. The developing pine stand will provide more favourable conditions for the successful invasion of spruce and fir, which were hampered in the earliest post-fire stage by low seed supply, dispersal and establishment problems on the burn area. Pine regeneration should soon decline or cease in much of the study area because of the inability of the pine to establish beneath its own canopy (Day 1972). Fir recovery will also be extremely slow because of (1) its almost complete destruction in the fire, and (2) its relative immaturity and low seed production in the surrounding vegetation. Day (1972) stated that sporadic survivors of fir must develop a seed-producing population before recovery is possible. When this eventually takes place, fir will increase in abundance with stand age because of its tolerant nature (Bloomberg 1950). It seems reasonable to predict that the new forest developing on the burn will, at maturity, resemble the one that preceded it, i.e. with pine and spruce the major species in largest size-classes, and fir a minor species in smaller size-classes.

Continued and regular monitoring of permanent plots in the Vermilion Pass burn area will document the rates and patterns of succession, and the factors regulating them.

Vegetation

A major objective of this study was to describe and interpret the initial stage of secondary plant succession after the 1968 wildfire in the Vermilion Pass. In 1972, four years after the burn, nearly twice as many species were present in the burned forest as in the surrounding unburned forest. Most of these, however, were of very minor importance in the burned forest stands.

Of the 63 species present in the burn, 35 were herbaceous and 28 were woody. "Invader species", i.e. those found only in the burned forest (Vogl 1964), accounted for 90% of the herbs and 48% of the woody plants. "Residual species", i.e. those occurring in the burned and unburned forest, made up the remainder. The invasion of a large number of herbaceous species, coupled with a large percent of resprouting woody residuals has resulted in a substantial increase in species richness in the Vermilion Pass, as a result of the fire.

Barth (1970), working in northern Colorado one year after a subalpine wildfire, found only half as many species as recorded in the Vermilion Pass and 87% of them were in[illegible]

Of the 35 vascular species recorded in quadrats, 29% of them occurred in more than 60% of the stands, indicating that some species are distributed throughout the burn. However, fully 75% of the vascular flora occurred in less than 20% of the 120 quadrats and were thus either rare or scattered irregularly over the area. Ahlgren (1974) has suggested that the distribution of many species in a recently burned area is often a key to their means of dissemination. Evenly distributed species are of vegetative or seed origin which survived the fire and are the first to appear abundantly over the area. Wind-borne seeds from distant sources germinate later and are also fairly evenly distributed. Plants scattered irregularly over the area may be brought in by animals and birds in the first few years after the fire. Corns (1972) found similar percentages of regular and scattered species patterns in a study of clear-cut pine forests in Alberta.

Only six species occurred in all stands: *Pinus contorta*, *Menziesia ferruginea*, *Epilobium angustifolium*, *Vaccinium myrtillus/scoparium*, *Cornus canadensis* and *Arnica cordifolia*. Together with *Linnaea borealis* they were also the major cover components of the post-burn vegetation.

The large number of invader species and their scattered distribution indicates that the duration of the invading phase is quite long here and presents a fairly severe environmental test for potential colonizing species. Only a small number of species, the evenly distributed residual species, seem to be very well adapted to the changed environment.

Menziesia ferruginea was the only quantitatively important shrub in the burn and accounted for 75% of the shrub cover. Many authors report excellent recovery of shrub species after fire (Ahlgren 1974; Habeck 1970; Lutz 1956; Barth 1970). Shrubs, because of their low stature and small stems, are easily killed by fire (Lutz 1956) but the underground stems and roots are not usually damaged (Rowe and Scotter 1973). Their ability to regenerate vegetatively after fire from basal or underground parts, and to respond favourably to increases in light intensity (Lutz 1953; Ahlgren 1974) partially accounts for successful shrub regeneration after fire. Wright (1973) reported that seeds of certain shrubs can survive relatively high temperatures and thus aid in successful regeneration of burned areas.

Results of this study indicate a very high survival rate of shrub clumps (87%). In every instance *Menziesia ferruginea* was seen to be growing from a charred basal stem indicating no successful reproduction by seed. Shrubs such as *Menziesia* that sprout after fire have an advantage over those that reproduce only from seed because they have well developed roots and grow much faster than seedlings (Biswell 1974). Although the recovery of the dominant shrub in the burn was excellent, the shrub stratum as a whole was relatively poorly developed in 1971 and 1972, with a cover of only 3.6%.

Total herb and dwarf shrub cover in the burn was only 12.6%, but four times that of the shrub stratum. The herbs *Arnica cordifolia* and *Epilobium augustifolium* accounted for over half of the cover while the dwarf shrubs *Linnaea borealis* and *Vaccinium myrtillus/scoparium* made up much of the rest. The only other species of relative importance in the burn was the dwarf shrub *Cornus canadensis*. Fires are favourable to some herb species because they temporarily reduce competition from shrubs, destroy allelopathic materials produced by shrubs, and prepare a good seedbed high in nutrients (Biswell 1974). Generalizations regarding the influence of fire on residual herbaceous plants are difficult (Rowe and Scotter 1973) because of the number of species, their different ecological requirements, and our limited knowledge of their autecologies. *Cornus canadensis* generally develops abundantly from underground rhizomes after fire, while *Linnaea borealis* is completely destroyed by fire except in unburned spots which serve as centers from which it spreads (Lutz 1956). *Arnica cordifolia* can develop vegetatively after fire (Lyon 1966) or reproduce from wind disseminated seed (Hayes 1970).

Epilobium angustifolium is probably the most widely recognized herbaceous perennial fire species. Heavy wind-borne seed crops facilitate the rapid invasion of burned areas by both residual and invading fireweed and once established this species has an exceptional capacity for vegetative reproduction (Moss 1936; Lutz 1956; Habeck 1970). These factors, along with the dependence by fireweed on nitrates released during a fire (Ahlgren and Ahlgren 1960), are probably the main reasons why *Epilobium augustifolium* was the dominant plant in the Vermilion Pass burn.

Vaccinium myrtillus/scoparium can reproduce from subterranean parts, and very few seedlings were found. Other minor components of the Vermilion Pass fire such as *Corydalis sempervirens* and *Anaphalis margaritacea* are of seed orgin and wind disseminated (Ahlgren 1960), while *Calamagrostis canadensis* and *Carex* spp. are fast-growing species, adept at rapid invasion by seed or vegetative means, and develop best in full sunlight (Rowe and Scotter 1973).

The pattern of early plant succession on recently burned areas is complex and correlated with the variability and limitations imposed by the site (Viereck 1973) and the ability of the species to colonize an area (Lutz 1956). Generally, herbaceous annual invader species are the first to colonize a burned area along with herbaceous and shrubby species which survived the fire (Larsen 1929; Martin 1955; Dyrness 1973). Shafi and Yarranton (1973) divide early post-fire succession into 2 phases: (1) Initial, lasting for approximately 1 year, and quite heterogeneous attributable to spatial variations in the intensity of burning and in the prefire vegetation, and (2) Early, which is more homogeneous and dominated by species which survive the fire in various ways. Results from the Vermilion Pass indicate that successional development was in the early phase because of the dominance of residual species.

Lyon (1966) found natural vegetation recovered rapidly following fire in south-central Idaho and had reached 69% of ground cover in the second year. Dyrness (1973) also recorded rapid increases after a slash fire in the Western Cascades of Oregon by the fifth year. Wein and Bliss (1973) showed that annual plant production had almost recovered in a tundra community two growing seasons after fire. It is concluded from results in the Vermilion Pass that successional development of the major species, at least between 1971 and 1972 was relatively slow. Lyon (1969) found similar results in the Sleeping Child fire of Montana.

Three species, Cornus canadensis, Menziesia ferruginea and Vaccinium myrtillus actually decreased in cover between 1971 and 1972. Though it is possible that this may be a function of sampling technique, two species, Epilobium angustifolium and Arnica cordifolia, showed corresponding increases in cover. It is suggested that the former, i.e. decreasing species may be reacting to increased competition or experiencing a depletion of pre-burn root reserves.

Four years after the fire the mean height of the important vascular species in the burn had not yet attained pre-burn height levels, with the exception of Arnica cordifolia which appears particularly well adapted to the burn site. By 1972 Menziesia ferruginea had reached approximately 25% its pre-burn cover and height despite its rather slow growth between 1971 and 1972.

Several authors have reported that the majority of the significant species appearing after fire are those which were present in the pre-burn forest (Ahlgren 1974; Lyon 1971). Wein and Bliss (1973) report that no new species invaded the area they studied but was rapidly revegetated by the original pre-burn species. In the Vermilion Pass, invader species did appear following the fire, particularly in the herbaceous category. However, the major constituents of the post-burn community, with the possible exception of Epilobium angustifolium, were represented in the unburned forest stand. The only major herb-dwarf shrub species in the unburned forest not present in the burn area was Rubus pedatus. Some minor species of the unburned forest were also absent. Several factors may be related to their absence in the burn. They may be shallow-rooted and therefore unable to survive the fire, or they may simply be unable to grow and/or compete with more light-tolerant species in openings created by fire. If their seeds were present in the soil on the burned-over area or dispersed into the area after fire, apparently they were unable to survive and grow (Ahlgren 1960).

Substrates and Soils

The charred, blackened surface of the Vermilion Pass fire accounted for 56% of the ground cover. Lutz (1956) indicated that this kind of a surface is less favourable than mineral soil as a seedbed because the latter has a more stable moisture supply, more readily available plant nutrients, and lower surface temperatures. Wein and Bliss (1973) pointed out that because the blackened surface absorbs more short wave energy a warmer soil mass results which may be conducive to better growing conditions in Arctic tundra. The effect of this surface is not known in the Vermilion Pass, but it no doubt plays a role in effecting initial plant succession.

No significant changes were noted between soils in the burned and unburned forest. Results of physical and chemical analyses of the soils show that they are light to medium-textured, nutrient-poor and acid. All soils were identified as humo-ferric podzols except one which was identified as a dystric brunisol.

Climate

Analysis of available meteorological data show that summer air temperatures were warmest at mid-slope elevation. The effects of temperature regime on the vegetation are difficult to evaluate because the temperatures are recorded above the height of the developing plant cover and only one year's data was available. Long-term monitoring of the climatic regime may ultimately provide information relevant to the rate of plant succession on the Vermilion Pass burn.

Ordination of Stands

The stand ordinations proved useful in relating the post-burn vegetation and the standing dead forest to edaphic and physiographic variables as well as to each other. The more important relationships are: (1) An increase in basal area of the standing dead forest and the post-burn shrub cover with elevation; (2) a decrease in cover of herbs and dwarf shrubs with elevation; (3) greater vascular species richness at lower elevations; (4) Arnica cordifolia and Epilobium augustifolium are negatively associated with each other and may reflect differential response patterns of the two species to the fire regimes; (5) soil acidity increases with an increase in elevation; (6) fire severity increased from the SW towards the NE.

Concluding Remarks

It is concluded that the fire regime, though important in affecting successional development of the post-fire vegetation, is not fully responsible for determining vegetation pattern. Rather, it must be viewed as one of many important variables affecting post-fire succession in the subalpine zone.

Dyrness (1973) observed that most investigators have studied vegetation on a number of burned areas ranging in age from recently burned to much older, rather than following vegetation changes on the same site over a period of years. They have then attempted to reconstruct successional sequences from data obtained from a wide range of sites. Only broad successional stages may be discerned by this approach since the properties of vegetation on disturbed sites are not only a function of the time interval since disturbance.

The results of this study, and the establishment of permanent plots, have provided the basis for a long-term study of plant succession after fire in the subalpine on a single site. With the increased awareness and acceptance of fire's role as a naturally recurring phenomenon, profoundly affecting and maintaining vegetated landscapes, it is particularly appropriate and relevant that monitoring of this site should continue.

VII SUMMARY

A. The objectives of this study were:

1. To describe and interpret the initial stage of secondary plant succession and tree reproduction after the 1968 wildfire in the subalpine forest of the Vermilion Pass area, Kootenay National Park.
2. To determine the structure and species composition of the trees in the forest stands before the fire, by quantifying and identifying, where possible, the standing burned trees, and briefly describing and com--paring an adjoining unburned stand.
3. To provide a sound foundation for a long-term study of plant succession after fire in the area through the establishment and inventory of permanent plots.
4. To provide a basis for measuring the rate of fuel accumulation on the forest floor resulting from the deterioration of the standing burned trees.

B. Using 1970 aerial photographs and ground reconnaissance, 12 stands were selected. The stands were selected based on the following predetermined criteria.

1. The study was limited to the northwest-facing slope of the Vermilion Pass valley.
2. Only the area within Kootenay National Park was studied.
3. The perimeter of the burn was avoided so as not to introduce the influence of edge effect.
4. Stands were selected in a variety of suspected pre-fire community types based largely on observations

noting changes in density of the standing dead forest, elevation and slope angle.

5. Stands were also selected so as to cover areas that seemed to have experienced varying degrees of fire intensity.
6. Each site was relatively uniform in terms of macro-topography, in order to minimize within-stand differences.

C. Restricted random sampling was done within a stand area of 100 X 200 meters (except stand no. 6 which was 100 X 100 meters). Ten subsidiary reference lines, 50 or 100 meters in length, were located perpendicular to a 200 meter baseline (100 meter baseline in stand no. 6). At 1 random location, along each subsidiary reference line, a 10 X 10 meter square quadrat was located and permanently marked with an iron reinforcing rod. A 5 X 5 meter plot was symmetrically nested at the center of the 10 X 10 meter plot, and a 2 X 2 meter plot was centrally nested within the 5 X 5 meter plot. One stand consisting of 5 20 X 20 meter plots was located in the unburned forest.

D. In the 10 X 10 meter plots, standing trees from the pre-burn forest were identified, tallied by height class or diameter class and assigned to a fire severity index. Fallen stems were assigned to one of two categories; fallen before the fire or fallen after the fire.

Identification, density, total height and current years height growth for conifer seedlings were determined.

In the 5 X 5 meter plot the average height and percent cover of living shrubs was determined by species. Living and dead density of shrubs were recorded. In the 2 X 2 meter plot the average height and percent cover of herbs and dwarf shrubs were determined by species. Percent cover was estimated for seven ground surface substrates. Six stands (1-6) were sampled in 1971 and six (7-12) in 1972. Living post-burn vegetation sampled in 1971 was sampled again in 1972 in the same plots. Vascular species were collected throughout the burned area and unburned forest and a presence list compiled.

E. Observations in quadrats were made of slope angle, elevation and depth of the surface organic layer (duff). Five climatic stations, 3 in the burned and 2 in the unburned forest were established by Parks Canada at different elevations in the Vermilion Pass. Temperature and relative humidity were analyzed from May to Sept. in 1972. Soil horizon samples from each stand were analyzed for physical and chemical properties.

F. The standing dead forest consisted almost entirely of Engel-mann spruce, subalpine fir and lodgepole pine. Engelmann spruce was the dominant tree in terms of basal area, followed by lodgepole pine. Numerically, however, subalpine fir far outnumbered both spruce and pine, but was primarily restricted to the smaller size-classes. Pine was absent in the under-story of the pre-fire forest and was thus declining in abund-ance before the fire. The standing dead forest was not in a late successional phase of development before the fire.

G. Fire intensity in the Vermilion Pass was generally uniformly severe in all stands. Although the fire was very intense in every respect, several small pockets of vegetation partially or wholly escaped incineration and stand no. 6 was not as severely burned as the others.

H. In the Vermilion Pass a ten-fold increase of stems fallen since the fire occurred between 1971 and 1972. Most of the new-fallen stems, in both years, were in the 2 and 3 in. size-classes. It is expected that annual "fall" rates will be extremely variable because of space-time variations in windstorms, stand structure and fire intensity.

I. Lodgepole pine, represented by seedlings, was the dominant conifer species on the Vermilion Pass burn. The distribution of the pine seedlings was very uneven but not related to the proximity or density of either living or dead seed trees. The density of pine seedlings decreased with increasing elevation and slope steepness. Seedling density was highest below 1700 m. ASL and lowest above 1800 m. ASL. Pine seedling height growth is negatively correlated with increasing elev--ation, slope angle and competition. Pine seedling density increased significantly in the study plots from 1971 to 1972. It seems certain that successful pine seedling establishment continued for at least five years in the study area. Pine seedlings more than doubled their height between 1971 and 1972. Browse damage to pine seedlings was observed in the study area but it was not regarded as significant. Few spruce and fewer subalpine fir seedlings were found in the Vermilion Pass burn.

J. Large numbers of pine seedlings and low densities of spruce and fir seedlings will likely result in an extended pine stage and the progression to spruce-fir climax will be relatively slow in the study area. It seems reasonable to predict that the new forest developing on the burn will, at maturity, resemble the one that preceded it; i.e. with pine and spruce the major species in largest size-classes, and fir a minor species in smaller size-classes.

K. Sixty-three species were present in the burn; 35 species were herbaceous and 28 were woody. "Invader species" accounted for 90% of the h[illegible] and [illegible]% of the woody plants. "Residual species" made up the r[illegible]er. The invasion of a large number of herbaceous species, coupled with a large percent of resprouting woody residuals has resulted in a substantial increase in species richness in the Vermilion Pass, as a result of the fire.

L. Thirty-five vascular species were recorded in quadrats. 29% of them were distributed throughout the burn. 75% of the vascular flora occurred in less than 20% of the 120 quadrats and were thus either rare or scattered irregularly over the area.

M. The six most important subordinate vascular species, based on prominence values, are Epilobium angustifolium (30), Arnica cordifolia (25), Menziesia ferruginea (24), Vaccinium myrtillus/scoparium (12), Linnaea borealis (8), and Cornus canadensis (6).

N. The large number of invader species and their scattered distri--bution indicates that the duration of the invading phase is quite long here and presents a fairly severe environmental test for potential colonizing species. Only a small number of species, the evenly distributed residual species, seem to be very well adapted to the changed environment.

O. Results of this study indicate a very high survival rate of shrub clumps (87%). In every instance Menziesia ferruginea was seen to be growing from a charred basal stem, indicating no successful reproduction by seed. The shrub stratum, as a whole, was relatively poorly developed with a cover of only 3.6%. Mean total herb-dwarf shrub cover in the burn was only 12.6%. Mean total vascular ground cover was 16.2%

P. Three species, Cornus canadensis, Menziesia ferruginea and Vaccinium myrtillus/scoparium decreased in cover between 1971 and 1972, while Epilobium angustifolium and Arnica cordifolia increased in cover. The former species may be reacting to increased competition or experiencing a deplet--ion of pre-burn root reserves.

Q. The major constituents of the post-burn community, with the possible exception of Epilobium angustifolium, were represented in the unburned forest stand.

R. Substrates accounted for [illegible]% of the ground cover. [illegible] accounted for 56% of the ground cover. Soils, identified as humo-ferric podzols, were light to medium-textured, nutrient poor and acid.

S. Summer air temperatures were warmest at mid-slope.

T. Stand ordinations indicated the following environment-plant relationships; (1) An increase in basal area of the standing dead forest and the post-burn shrub cover with elevation;

(2) A decrease in cover of herbs and dwarf shrubs with elevation; (3) Greater vascular species richness at lower elevations; (4) *Arnica cordifolia* and *Epilobium angustifolium* are negatively associated with each other and may reflect differential response patterns of the two species to the fire regime; (5) Soil acidity increases with an increase in elevation; (6) Fire severity increased from the SW towards the NE.

U. The fire regime, though important in affecting successional development of the post-burn vegetation, is not fully responsible for determining vegetation pattern. Rather, it must be viewed as one of many important variables affecting post-fire succ--ession in the subalpine zone.

VIII LITERATURE CITED

Ahlgren, C.E. 1960. Some effects of fire on reproduction and growth of vegetation on northwestern Minnesota. Ecology 41:431-445.

Ahlgren, C.E. 1974. Effects of fires on Temperate forests: North Central United States. In Fire and Ecosystems. Edit. by Kozlowski, T.T. and C.E. Ahlgren. Academic Press, Inc. p. 195-223.

Ahlgren, I.F. and C.E. Ahlgren. 1960. Ecological effects of forest fires. Bot. Rev. 26:483-533.

Alexander, R.R. 1958a. Silvical characteristics of Engelmann spruce. U.S., Forest Serv., Rocky Mt. For. Range Exp. Sta., Pap. 31.

Alexander, R.R. 1958b. Silvical characteristics of subalpine fir. U.S., Forest Serv., Rocky Mt. For. Range Exp. Sta., Pap. 32.

Alexander, R.R. 1974. Silviculture of subalpine forests in the Central and Southern Rocky Mountains: The Status of our knowledge. U.S., Forest Serv., Rocky Mt. For. Range Exp. Sta., Res. Pap. RM-121.

Anderson, A.J.B. 1971. Ordination methods in ecology. J. Ecol. 59:713-726.

Anonymous. 1963. Canadian Society of Soil Science. Banff to Columbia Icefield. Soil tour, 1963. Publ. by Northwest Nitro-Chemicals Ltd.

Anonymous. 1972. Kootenay National Park Provisional Master Plan. p. 15. National and Historic Parks Branch.

Allan, J.A. 1914. Geology of the Field map area, B. C. and Alberta. Geol. Surv. Can., Memo 55. 312 p.

Armit, D. 1966. Silvics and silviculture of lodgepole pine in the North Central Interior of British Columbia: A Problem Analysis.

Research Notes No. 40. British Columbia Forest Service. Dept. of Lands, Forests and Water Resources.

Austin, M.P. 1968. An ordination study of a chalk grassland community. J. Ecol. 56:739-757.

Austin, M.P. and L. Orloci. 1966. Geometric models in Ecology. II. An evaluation of some ordination techniques. J. Ecol, 54:217-227.

Austin, M.P. and P. Greig-Smith. 1968. The application of quantitative methods to vegetation survey. II. Some methodological problems of data from Rain forest. J. Ecol. 56:827-843.

Austin, R.C. and D.H. Baisinger. 1955. Some effects of burning on forest soils of western Oregon and Washington. J. Forest. 53(4):275-280.

Baird, D.M. 1964. Kootenay National Park, wild mountains and great valleys. Geol. Surv. Can., Misc. Rept. 9.

Baird, D.M. 1967. Banff National Park. Geol. Surv. Can., Misc. Rept. 13.

Bannister, P. 1968. An evaluation of some procedures in simple ordinations. J. Ecol. 56:27-34.

Baranyay, J.R. and G.R. Stevenson. 1964. Mortality caused by Armillaria root rot, peridermium rusts and other destructive agents in lodgepole pine regeneration. Forest. Chron. 40(3).

Barneby, W.H. 1889. The New Far West and the Old Far East. London: Edward Stanford. 316 p.

Barth, R.C. 1970. Revegetation after a subalpine wildfire. Unpubl. M. Sc. Thesis. University of Colorado, Colorado.

Bates, C.G. 1930. The production, extraction and germination of lodgepole pine seed. U.S.D.A., Tech. Bull. 191.

Baumgartner, A. 1960. The temperature of the air as a locality-factor at the mountain, Gr. Falkenstein. Translated from Forstwissenchaftliches Centralblatt. 79:362-373.

Beals, E.W. 1960. Forest bird communities in the Apostle Islands of Wisconsin. Wilson Bull. 72:156-181.

Beals, E.W. 1973. Ordination: Mathematical elegance ecological naivete. J. Ecol. 61:23-34.

Beil, C.E. 1966. An ecological study of the primary producer level of the subalpine spruce-fir ecosystem of Banff and Jasper National Parks, Alberta. Unpubl. M. of Sc. Thesis. Univ. of Alta., Edmonton. 233 p.

Bell, R. 1889. Forest fires in northern Canada. Proc. Amer. Forest. Congr. 7:50-55.

Belyea, H.R. 1964. The story of the mountains in Banff National Park. Geol. Su[illegible], Ottawa, Queens Printer.

Benjey, W.G. 1974. Seasonal energy balance trends in the subarctic: The microclimate of a broken spruce forest and clearing, Kluane Lake, Yukon, 1970-1971. Ph. D. Unpubl., Univ of Michigan.

Biswell, H.H. 1974. Effects of fire on chaparral. In Fire and Ecosystems. Edit. by Kozlowski, T.T. and C.E. Ahlgren. Academic Press, Inc. p. 321-364.

Bloomberg, W.J. 1950. Fire and Spruce. Forest. Chron. 26(2):137-161.

Bollen, W.B. 1974. Soil Microbes. In Environmental Effects of Forest Residues Management in the Pacific Northwest. A state of knowledge compendium. U.S., Forest Serv., Pac. Northwest For. Range Exp. Sta., Rept. PNW-24.

Bostock, H.S. 1948. Physiography of the Canadian cordillera, with special reference to the area north of the fifty-fifth parallel. Can. Geol. Surv. Mem. 247: 101 p.

Bray, J.R. and J.T. Curtis. 1957. An ordination of upland forest communities of southern Wisconsin. Ecol. Monogr. 27:325-349.

Brown, J.K. 1973. Fire cycles and community dynamics in lodgepole pine forests. pp 428-456. In Management of lodgepole pine ecosystems. Symposium proceedings, D.M. Baumgartner (ed.), Washington State Univ. Co-op. Ext. Service. Vol. 1, 495 p.

Byrne, A.R. 1968. Man and landscape change in the Banff Park area before 1911. Studies in land use history and landscape change. Nat. Parks Service, No. 1, Calgary. Univ. of Calgary. 173 p.

Cain, S.A. 1938. The species - area curve. Amer. Midl. Natur., 17:725-740.

Campbell, R.H. 1919. Forest fires in Canada, 1917. Dept. of the Interior, Canada. Forest. Br., Bull. 68.

Canada Dept. of Agriculture. 1970. The system of soil classification for Canada. Queens Printer for Canada. Ottawa.

Canadian Soil Survey Committee. 1974. Tentative Manual on soil sampling and methods of analysis. Ottawa.

Cautley, R.W., J.N. Wallace, and A.O. Wheeler. 1917. Report of the Commission Appointed to delineate the boundary between the Provinces of Alberta and British Columbia. Part I. From 1913 to 1916. Office of the Surveyor General, Ottawa.

Clements, F.E. 1910. The life history of lodgepole burn forests. U.S., Forest Serv., Bull. 79.

Cormack, R.G.H. 1953. A survey of coniferous forest succession in the

Eastern Rockies. Forest. Chron. 29(3):218-232.

Corns, I. 1972. Plant succession after clearcutting lodgepole pine. Unpubl. M. of Sc. Thesis, University of Alta., Edm. Alta.

Corns, I. and G.H. LaRoi. 1976. A comparison of mature with recently clearcut and scarified lodgepole pine forests in the lower foothills of Alberta. C.J. For. Res., In [illegible]

Crossley, D.I. 1956. Fruiting habits of lodgepole pine. Can. Dept. North. Aff. and Nat. Resour., Forest. Br., For. Res. Div., Tech. Note 35.

Daubenmire, R.F. 1938. Merriams life zones of North America. Quart. Rev. Biol. 13:327-332.

Daubenmire, R.F. 1943. Vegetational zonation in the Rocky Mountains. Bot. Rev. 9:326-393.

Daubenmire, R.F. 1952. Forest vegetation of northern Idaho and adjacent Washington and its bearing on concepts of vegetation classification. Ecol. Monogr. 22:301-330.

Daubenmire, R.F. 1968. Ecology of fire in grasslands. Advan. Ecol. Res. 5.

Dawson, G.M. 1885. Preliminary report on the physical and geological features of that portion of the Rocky Mountains between latitudes 49° and 50° 30'. Geol. Surv. Can. Vol. 1, Rept. B. (1886). p. 7B-167B.

Day, P.R. 1965. Particle fractionation and particle-size analysis. pp. 545-567. <u>In</u> C.A. Black <u>et al</u> (eds.) Methods of Soil Analysis. Soc. Agron. Monog., No. 9. Madison, Wisconsin, U.S.A.

Day, R.J. 1964. The microenvironments occupied by spruce and fir regeneration in the Rocky Mountains. Dept. of Forest., For.

Res. Br., Publ. 1037.

Day, R.J. 1972. Stand structure, succession and use of southern Alberta's Rocky Mountains forest. Ecology 53(3):472-478.

DeGrace, L.A. 1950. Selective logging of spruce in subalpine Alberta. Can. Dept. Resour. Develop., Forest. Br., For. Res. Div., Silvicult. Res. Note 96.

Dennis, J.G. 1971. Ecology of the Vermilion Pass Fire: Review of past work and proposal for further studies. Unpubl. manuscript prepared for National and Historic Parks Branch, Dept. of Indian Affairs and Northern Development. Contract No. WR.226-70.

Douglas, G.W. 1972. Subalpine plant communities of the western North Cascades, Washington. Arctic and Alpine Research 4:147-166.

Douglas, G.W., and T.M. Ballard. 1971. Effects of fire on alpine plant communities in the North Cascades, Washington. Ecology 52:1058-1064.

Dowling, D.B. 1904. The Cascade coal basins and their continuation northward. In Summary report on the operations of the geological survey for the year 1904 by R. Bell p. 107A. Geol. Surv. Can., Annu. Rept., Vol. XVI.

Dwight, T.W. 1913. Forestry conditions in the Rocky Mountains forest reserve. Dept. of the Interior, Can., Forest. Br., Bull. 33.

Dwight, T.W. 1918. Forest fires in Canada, 1914-15-16. Dept. of the Interior, Can., Forest. Br., Bull. 64.

Dyrness, C.T. 1973. Early stages of plant succession following logging and burning in the Western Cascades of Oregon. Ecology 54(1).

Edgecombe, G.H. and P.Z. Caverhill, 1911. Rocky Mtns. Forest Reserve. Report of boundary survey parties. Dept. of the Interior, Canada.

Forest. Br., Bull. 18.

Edwards, B. 1973. Avi-fauna of the Vermilion Pass burn area. Unpubl. report. Parks Canada. Western Regional Office, Calgary, Alberta.

Environment Canada, Atmospheric Service. 1965-1972. Monthly record of meteorological observations in Canada (12 vols. per year).

Environment Canada. 1973. Canadian Normals, Precipitation, Vol. 2, 1941-1970. Atmospheric Environment Service, Downsview, Ontario.

Environment Canada. 1973. Canadian Normals, Temperature, Vol. 1, 1941-1970. Atmospheric Environment Service, Downsview, Ontario.

Fitzmartyn, G. 1973. Report on the small mammals of the Vermilion Pass burn. Final report. Unpubl. report. Parks Canada, Western Regional Office, Calgary, Alberta.

Fowells, H.A. 1965. Silvics of forest trees of the United States. U.S., Forest. Serv., Ag. Handbook 271.

Fraser, E. 1969. The Canadian Rockies: early travels and explorations. M.G. Hurtig Ltd., Edm. 252 p.

Gauch, H.G., Jr., and R.H. Whittaker. 1972. Comparison of ordination techniques. Ecology 53:868-875.

Geiger, R. 1957. The climate near the ground. (2nd Edition, revised by M.N. Stewart). Harvard Univ. Press, Cambridge, Mass.

Gittins, R. 1965a. Multivariate approaches to a limestone grassland community. I. A stand ordination. J. Ecol. 53:385-401.

Gittins, R. 1965b. Multivariate approaches to a limestone grassland community. II. A direct species ordination. J. Ecol. 53.

Gittins, R. 1965c. Multivariate approaches to a limestone grassland community. III. A comparative study of ordination and association analysis. J. Ecol. 53.

Goodall, D.W. 1954. Objective methods for the classification of vegetation. III. An essay in the use of factor analysis. Aust. J. Bot. 2(3):304-324.

Graham, S.A. 1925. The felled tree trunk as an ecological unit. Ecology 6:397-411.

Greig-Smith, P. 1964. Quantitative plant ecology. Butterworth and Co. (Canada) Ltd. Toronto. 2nd. Ed. 256 p.

Habeck, J.R. 1970. Fire ecology investigations in Glacier National Park. Historical considerations and current observations. Dept. of Botany, Univ. of Montana.

Harris, S.A. 1971. Preliminary results of soil movement studies at Vermilion Pass. Unpubl. report, University of Calgary, Dept. of Geography and Environmental Sciences Centre.

Hayes, G.L. 1970. Impacts of fire use on forest ecosystems. In The Role of Fire in the Intermountain West. Symposium. Intermountain Fire Research Council. Missoula, Montana.

Heinselman, M.L. and H.E. Wright, Jr. Edts. 1973. The ecological role of fire in natural conifer forests of western and northern North America. J. Quat. Res. 3(3).

Hettinger, L.R. 1975. Vegetation of the Vine Creek Drainage basin, Jasper National Park. Unpubl. Ph. D. Thesis, Univ. of Alta. 276 p.

Heusser, C.J. 1956. Postglacial environments in the Canadian Rocky Mountains. Ecol.Monogr. 26:263-302.

Hitchcock, C.L., A. Cronquist, M. Ownbey, and J.W. Thompson. 1969. Vascular plants of the Pacific Northwest. 5 Vols. University of Washington Press. (Lib. of Cong. Cat. Card No. A55-9302).

Hodson, E.R. and J.H. Foster. 1910. Engelmann spruce in the Rocky Mountains. U.S., Forest Serv., Cir. 170.

Holland, S.S. 1964. Landforms of British Columbia. A physiographic outline. British Columbia Dept. of Mines and Petroleum Resources. Bull. 48.

Horton, K.W. 1953. Causes of variation in the stocking of lodgepole pine regeneration following fire. Project K-71. Can. Dept. North. Devel. and Nat. Resouc. Forest. Br., Silvicult. Leafl. 95.

Horton, K.W. 1955. Early developments in a subalpine lodgepole pine stand of fire origin. Can. Dept. North. Aff. and Nat. Resour. Forest. Br., For. Res. Div., Tech. Note 16.

Horton, K.W. 1956. The ecology of lodgepole pine in Alberta and its role in forest succession. Can. Dept. North. Aff. and Nat. Resour. Forest. Br., For. Res. Div., Tech. Note 45.

Horton, K.W. 1958. Seasonal leader growth of lodgepole pine in the subalpine forest of Alberta. Forest. Chron. 34(4):382-386.

Horton, K.W. 1959. Characteristics of subalpine spruce in Alberta. Can. Dept. North. Aff. and Nat. Resour. Forest. Br., For. Res. Div., Tech. Note 76.

Hosie, R.C. 1969. Native trees of Canada. Dept. of Fish. and Forest., Canad. Forest. Serv., Queens Printer, Ottawa.

Johnson, H.J., H.F. Cerezke, F. Endean, G.R. Hillman, A.D. Kill, J.C. Lees, A.R. Loman, and J.M. Powell. 1971. Some implications of large-scale clear-cutting in Alberta. A literature review. Canad. Forest. Serv., North. For. Res. Cent. Inf. Rep. NOR-X-6.

Kilgore, B.M. 1973. The ecological role of fire in Sierran conifer forests. Its application to National Park Management.

J. Quat. Res. 3(3):496-513.

Kittredge, J. 1962. The influence of the forest on the weather and other environmental factors. p. 81-137. In Forest Influences, FAO. Forestry and Forest Products Studies, No. 15. FAO Rome. 307 p.

Kozlowski, T.T. and C.E. Ahlgren, Editors. 1974. Fire and Ecosystems. Academic Press. 542 pages.

Krajina, V.H. and R.C. Brooke, eds. 1970. The subalpine mountain hemlock zone. Subalpine vegetation in southwestern British Columbia, its climatic characteristics, soils, ecosystems and environmental relationships. by Brooke, R.C., E.B. Peterson and V.J. Krajina. Vol. 2 No. 2, University of British Columbia.

Lambert, J.M., and M.B. Dale. 1964. The use of statistics in phytosociology. Advan. Ecol. Res. 2:55-99.

Landals, A.G. and L.J. Knapik. 1972. Great divide trail. An ecological study of the proposed route. Jasper National Park and vicinity. Can. Wildl. Serv., Dept. Environ. Canada. 251 p.

La Roi, G.H. 1964. An ecological study of the boreal spruce-fir forests of the North American Taiga. Ph. D. dissertation, Duke Univ., North Carolina.

Larsen, J.A. 1929. Fires and forest succession in the Bitterroot Mtns. of Northern Idaho. Ecology 10:67-76.

Larsen, J.A. 1930. Forest types of the Northern Rocky Mountains and their climatic controls. Ecology 11:631-672.

Le Barron, R.K. and G.M. Jemison. 1953. Ecology and silviculture of the Engelmann spruce - Alpine fir type. J. Forest. 51.

Lewis, R.G. 1920. Forest fires in Canada, 1918. Dept. of the Interior, Canad. Forest. Br., Bull. 70.

Lindsey, G.D. 1973. The influence of animals on lodgepole pine regeneration. In Management of lodgepole pine ecosystems. Vol. 1 Symposium Proceedings. Edit. by D.M. Baumgartner, Washington State University Co-operative Extension Service.

Lotan, J.E. 1973. The role of cone serotiny in lodgepole pine forests. In Management of lodgepole pine ecosystems, Vol. 1, Proceedings. Edit. by D.M. Baumgartner, Washington State Univ. Co-operative Extension Service.

Lutz, H.J. 1953. The effects of forest fires on the vegetation of Interior Alaska. U.S., Forest Serv., Alaska For. Res. Centre. Sta. Pap. 1.

Lutz, H.J. 1956. Ecological effects of forest fires in the interior of Alaska. U.S.D.A. Tech. Bull. 1133.

Lyon, L.J. 1966. Initial vegetal development following prescribed burning of Douglas-Fir in South-Central Idaho. U.S., Forest Serv. Intermountain For. Range Exp. Sta., Res. Pap. INT. 29.

Lyon, L.J. 1969. Wildlife habitat and fire in the Northern Rockies. Proc. 9th. Annu. Tall Timbers Fire Ecol. Conf.

Lyon, L.J. 1971. Vegetal development following prescribed burning of Douglas-Fir in South-Central Idaho. U.S., Forest Serv., Intermountain For. Range Exp. Sta., Res. Pap. INT. 105.

MacMillan, H.R. and G.R. Gutches. 1910. Forest fires in Canada. Dept. of the Interior., Canada. Forest. Br., Bull. 9.

Macoun, J. 1904. Natural history of the National Park. In Summary report on the operations of the geological survey for the year 1904 by R. Bell. p. 100A-105A. Geol. Surv. Can., Annu. Rept. Vol. XVI.

Martin, J.L. 1955. Observations on the origin and early development of plant community following a forest fire. Forest. Chron. 31(2)154-161.

Martin, R.E. and A.P. Brackebusch. 1974. Fire hazard and conflagration prevention. In Environmental Effects of Forest Residues Management in the Pacific Northwest. U.S., Forest Serv., Pac. Northwest For. Range Exp. Sta., Gen. Tech. Rept. PNW-24.

Mason, D.T. 1915. The life history of lodgepole pine in the Rocky Mountains. U.S.D.A., Bull. 154.

McCullough, H.A. 1948. Plant succession on fallen logs in a virgin spruce-fir forest. Ecology 29:508-513.

Merriam, C.H. 1898. Results of a biological survey of the San Francisco Mountain region. North Amer. Fauna 3. 136 p.

Moss, E.H. 1936. The ecology of Epilobium angustifolium with particular reference to rings of periderm in the wood. Am. J. Bot. 23:114-120.

Moss, E.H. 1955. The vegetation of Alberta. Bot. Review. 21(9):493-567.

Moss, E.H. 1959. The flora of Alberta. University of Toronto Press., Toronto. 546 p.

Munro, J.A. and I. McTaggart-Cowan. 1944. Preliminary report on the birds and mammals of Kootenay National Park, British Columbia. Canad. Field Natur. 58:34-51.

Munsell Soil Color Charts. 1954. Munsell Color Co. Inc., Baltimore, Maryland.

Muraro, S.J. 1971. The lodgepole pine fuel complex. Dept. of Fish. and Forest., Canad. Forest. Serv., Inf. Rep. BC-X-53, 35 p.

Nelson, J.G. 1968. Man and landscape change in Banff National Park:

A National Park problem in perspective. 111-150. In The Canadian National Parks: Today and Tomorrow. Vol. 1 eds. J.G, Nelson and R.C. Scace - Studies in land use history and landscape change. Nat. Park Series No. 3.

Nakes, A. and S.A. Harris. 1971 Preliminary report of the soil survey, Vermilion Pass burn, Banff and Kootenay National Park. Unpubl. report submitted to National and Historic Parks Branch, Western Region, Calgary.

Odum, E.P. 1971. Fundamentals of Ecology. 3rd. Edition. Philadelphia. W.B. Saunders, Co., Lib. of Cong. catalog card No. 76-81826.

Ogilvie, R.T. 1969. The mountain forest and alpine zones of Alberta. In Vegetation, Soils and Wildlife; Process and Method in Canadian Geography. J.G. Nelson and M.J. Chambers, Eds., Toronto, Metheun Publ.

Ogilvie, R.T. and R.C. Scace. 1968. Guide for field trip to Banff National Park, Oct. 12 and 13, 1968: 989-1015. In The Canadian National Parks; Today and Tomorrow, J.G. Nelson and R.C. Scace eds. Calgary, Univ. of Calgary.

Olthof, P. 1971. Vermilion Pass fire study, vegetative study. Unpubl. report. Parks Canada Western Regional Office, Calgary, Alberta.

Oosting, H.J. 1956. The study of plant communities. W.H. Freeman & Co. San Francisco. 440 p.

Oosting, H.J. and J.F. Reed. 1952. Virgin spruce-fir forests in the Medicine Bow Mountains, Wyoming. Ecol. Monogr. 22:69-91.

Orloci, L. 1966. Geometric models in ecology. I. The theory and application of some ordination methods. J. Ecol. 54:193-215.

Palliser, J. 1863. The Journals, detailed reports and observations relative to the exploration by Capt. Palliser of that portion of

British North America which, in latitude, lies between the British Boundary line and the height of land or watershed of the Northern or frozen ocean respectively and in longitude, between the western shore of Lake Superior and the Pacific Ocean, during the years 1857, 1858, 1859, and 1860. London, Printed by George Edward Eyre and William Spottiswoode, Printers to the Queens most Excellent Majesty.

Patten, D.T. 1963. Vegetational pattern in relation to environments in the Madison Range, Montana. Ecol. Monogr. 33(4).

Pavari, A. 1962. Introductory Remarks. In Forest Influences. FAO, Forestry and Forest Products Studies No. 15. FAO Rome. 307 p.

Pfister, R.D. and R. Daubenmire. 1973. Ecology of lodgepole pine. In Management of lodgepole pine ecosystems. Vol. 1, Symposium Proceedings. Edit. by O.M. Baumgartner. Washington State University Co-operative Extension Service. p. 27-46.

Pritchard, N.M. and A.J.B. Anderson. 1971. Observations on the use of cluster analysis in botany with an ecological example. J. Ecol. 59:727-747.

Raynor, G.S. 1971. Wind and temperature structure in a coniferous forest and a contiguous field. Forest Sci. 17(3):351-363.

Reeves, B. 1968. Man and his environment, the past 10,000 years: An approach to park interpretation. p. 243-261. In The Canadian National Parks: Today and Tomorrow. Vol. 1, edited by J.G. Nelson and R.C. Scace: Studies in land use history and landscape change. National Parks Series. No. 3.

Risser, P.G. and E.L. Rice. 1971. Phytosociological analysis of Oklahoma upland forest species. Ecology 52:940-945.

Rowe, J.S. 1972. Forest Regions of Canada. Dept. of the Enviro. Canad. Forest. Serv., Publ. 1300: 172 p.

Rowe, J.S. and G.W. Scotter. 1973. Fire in the Boreal Forest. J. Quat. Res. 3(3):444-464.

Rutter, N.W. 1965. Surficial geology of the Banff area, Alberta. Unpubl. Ph. D. dissertation, Univ. of Alberta., Edmonton, Alberta.

Rydberg, P.A. 1900. Phytogeography of Montana. Bull. Torrey Bot. Club 27:292-294.

Rydberg, P.A. 1915. Phytogeographical notes on the Rocky Mountain Region. IV. Forests of the subalpine and montane zones. Bull. Torrey Bot. Club 42:11.25.

Schroeder, M.J. and C.C. Buck. 1970. Fire Weather, A Guide for Application of Meterological Information to Forest Fire Control Operation. U.S., Forest Serv., Ag. Handbook 360.

Scott, G. 1973. Avifauna of the Vermilion Pass burn. Final report. Unpubl. reports, Parks Canada, Western Regional Office, Calgary, Alberta.

Shafi, M.I. and G.A. Yarranton. 1973. Vegetational heterogeneity during a secondary (post-fire) succession. Can. J. Bot. 51(1).

Shank, C.C. 1971. Report on the small mammals of the Vermilion Pass burn. Unpubl. report. Parks Canada, Western Regional Office, Calgary, Alberta.

Slaughter, C.W., R.J. Barney, and G.M. Hansen, (Eds.) 1971. Proceedings, Fire in the northern environment, a symposium. U.S. Forest Serv., Northwest For. Range Exp. Sta., Portland, Oregon.

Snedecor, G.W. 1934. Calculation and interpretation of analysis of variance and covariance. Collegiate Press, Inc., Ames, Iowa. 96 p.

Spry, I.M. 1963. The Palliser Expedition - An account of John Palliser's British North America Exploring Expedition, 1857-1860. Publ., The MacMillan Co. of Canada Ltd.

Stringer, P.W. and G.H. LaRoi. 1970. The Douglas-fir forests of Banff and Jasper National Parks, Canada. Can. J. Bot. 48:1703-1726.

Stahelin, R. 1943. Factors influencing the natural restocking of high altitude burns by coniferous trees in the Central Rocky Mountains. Ecology 24.

Szczawinski, A.F. 1962. The Heather Family of British Columbia. British Columbia Provincial Museum. Handbook No. 19.

U.S. Forest Service. 1972. Fire in the environment, Symposium proceedings., U.S.F.S., FS-276. Denver, Colorado.

Van der Valk, A.G., and L.C. Bliss. 1971. Hydrarch succession and net primary production of Oxbow Lakes in central Alberta. Can. J. Bot. 49:1177-1200.

Van Wagner, C.E. 1965. Describing forest fires - old ways and new. Forest. Chron. 41(3):301-305.

Viereck, L.A. 1973. Wildfire in the Taiga of Alaska. J. Quat. Res. 3(3).

Vogl, R.J. 1964. The effects of fire on a muskeg in northern Wisconsin. J. of Widl. Manage. H, 317-327.

Wein, R.W. and L.C. Bliss. 1973. Changes in Arctic Eriophorum tussock communities following fires. Ecology 54(4).

White, J.H. 1915. Forestry on Dominion Lands, Part VI. In Forest Protection in Canada, 1913-1914. Commission of Conservation, Canada.

Whittaker, R.H. 1967. Gradient analysis of vegetation. Biol. Rev. 42:207-264.

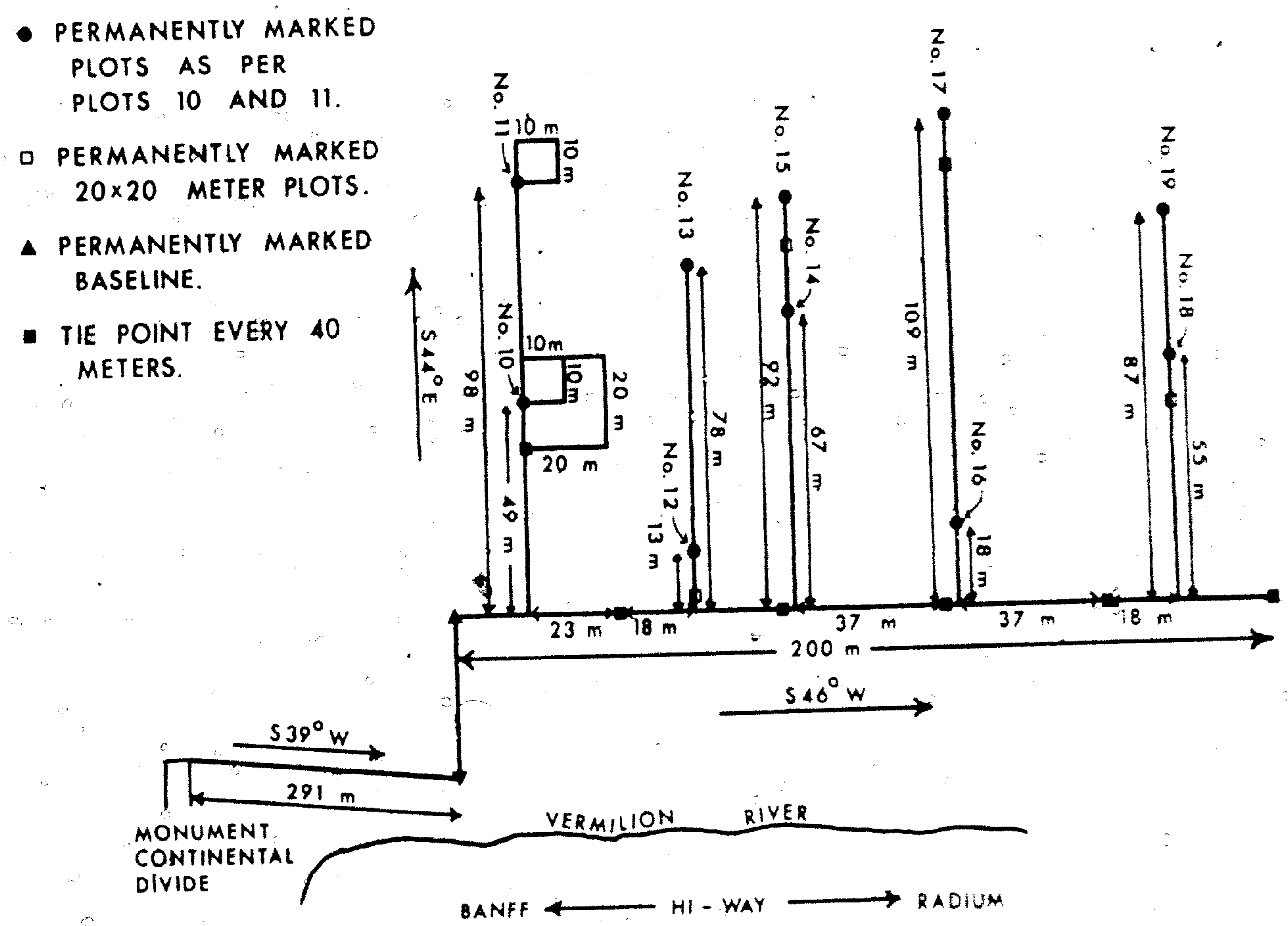
Winterbottom, K.M. 1973. Avalanche slope vegetation, Vermilion Pass burn. Final report. Unpubl., Parks Canada, Western Regional Office, Calgary, Alberta.

Wright, E. 1931. The effect of high temperature on seed germination. J. Forest. 29:679-687.

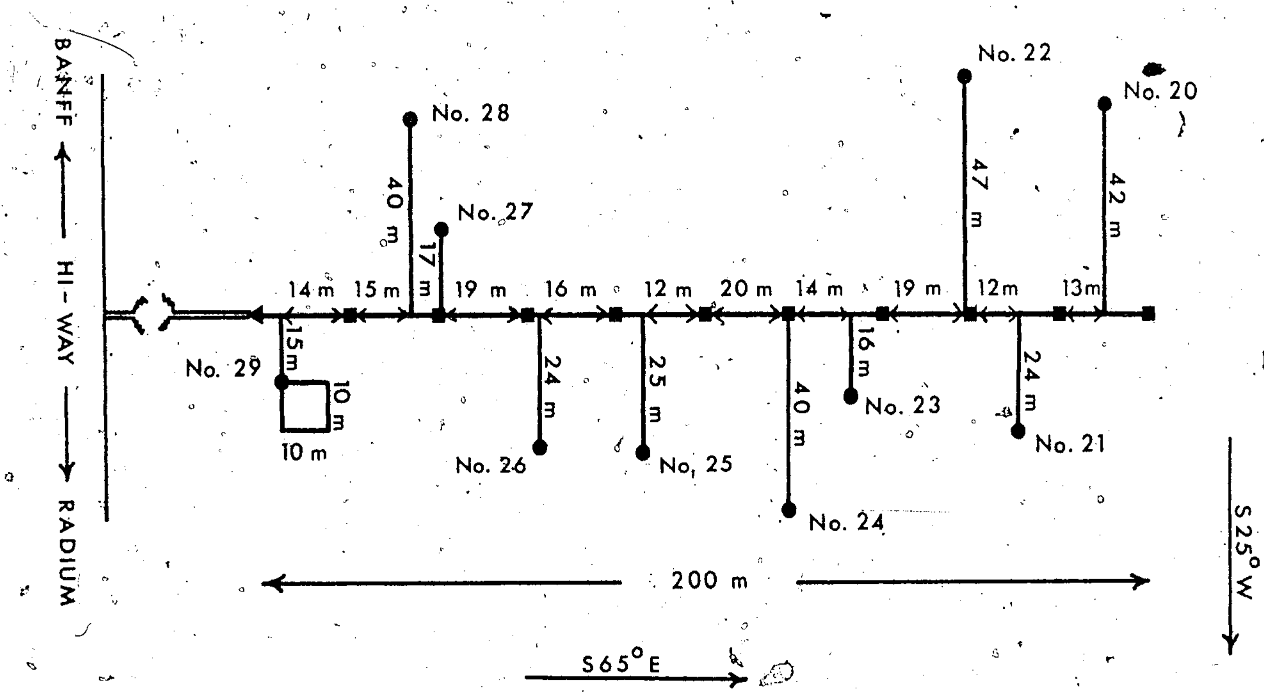
IX APPENDICES

Appendix A. Location of stands and plots in the Vermilion Pass burn.

STAND 1 - BURN


● PERMANENTLY MARKED PLOTS AS PER PLOTS 10 AND 11.
□ PERMANENTLY MARKED 20×20 METER PLOTS.
▲ PERMANENTLY MARKED BASELINE.
■ TIE POINT EVERY 40 METERS.
No. 10
No. 11
No. 12
No. 13
No. 14
No. 15
No. 16
No. 17
No. 18
No. 19
10 m
20 m
98 m
49 m
13 m
78 m
92 m
67 m
109 m
18 m
87 m
55 m
23 m
37 m
200 m
S 44° E
S 46° W
S 39° W
291 m
MONUMENT CONTINENTAL DIVIDE
VERMILION RIVER
BANFF
HI - WAY
RADIUM

STAND 2 - BURN



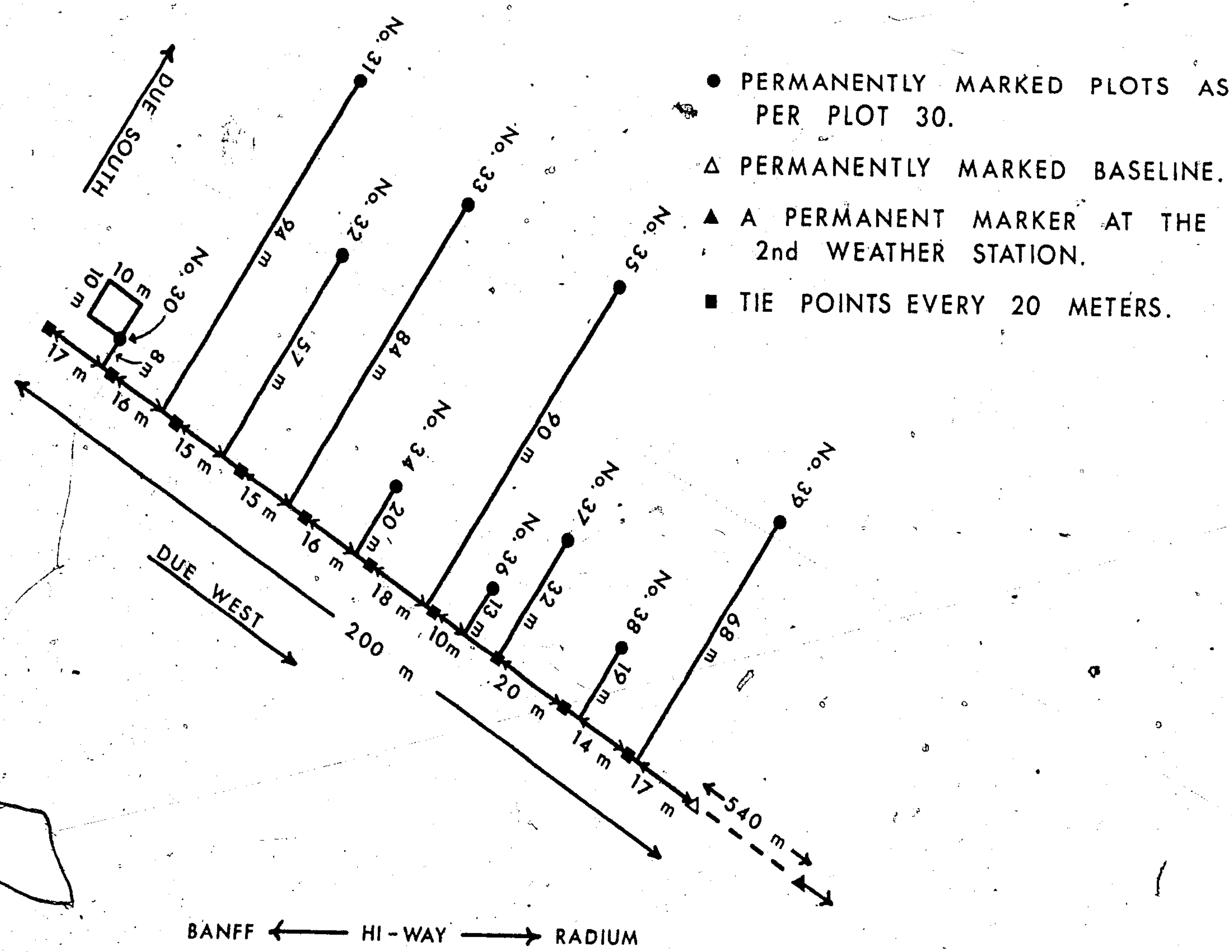
● PERMANENTLY MARKED PLOTS AS PER PLOT 29.

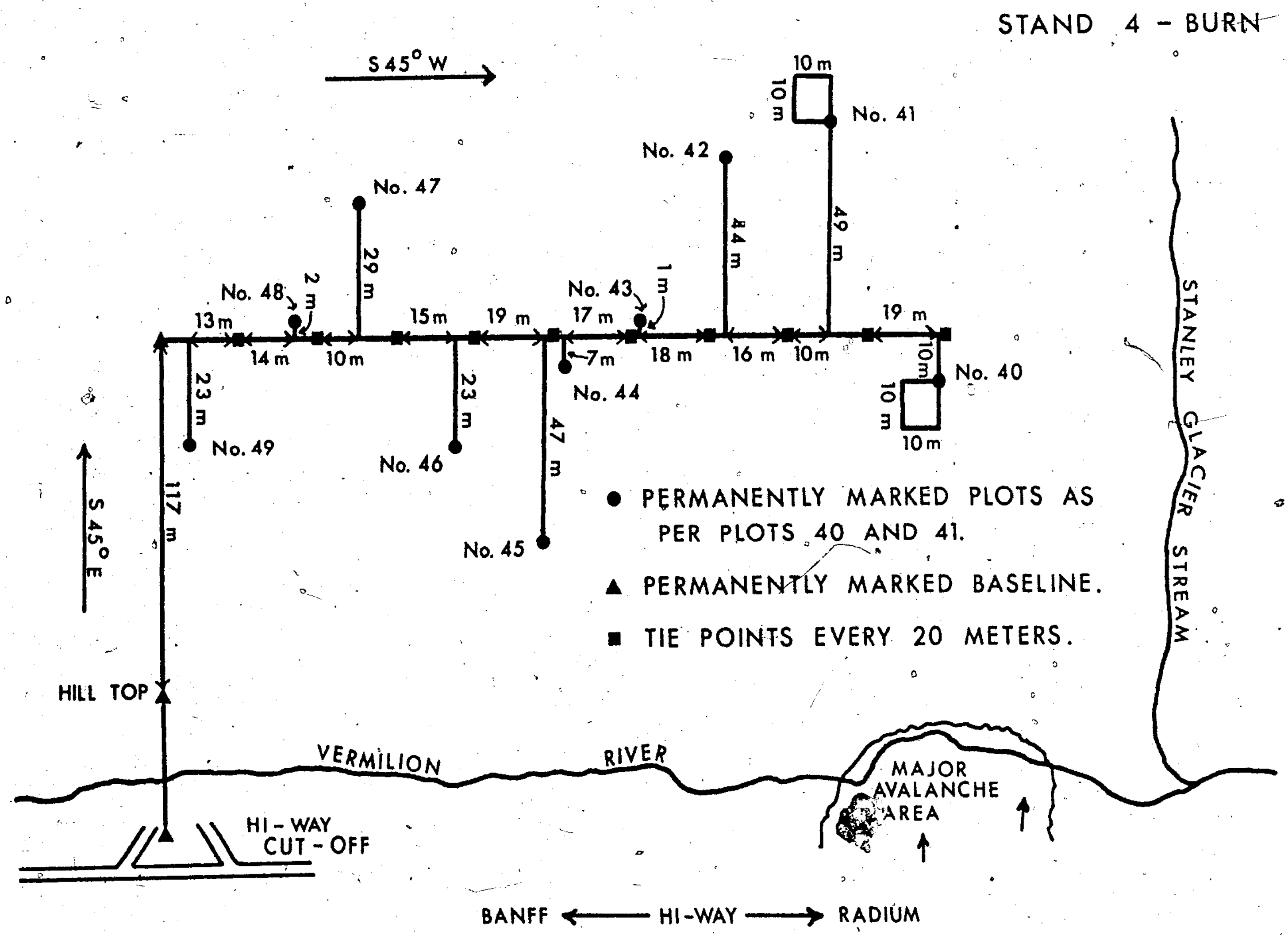
▶ MONUMENT ON CONTINENTAL DIVIDE AT 5945′ ELEVATION.

■ TIE POINTS EVERY 20 METERS.

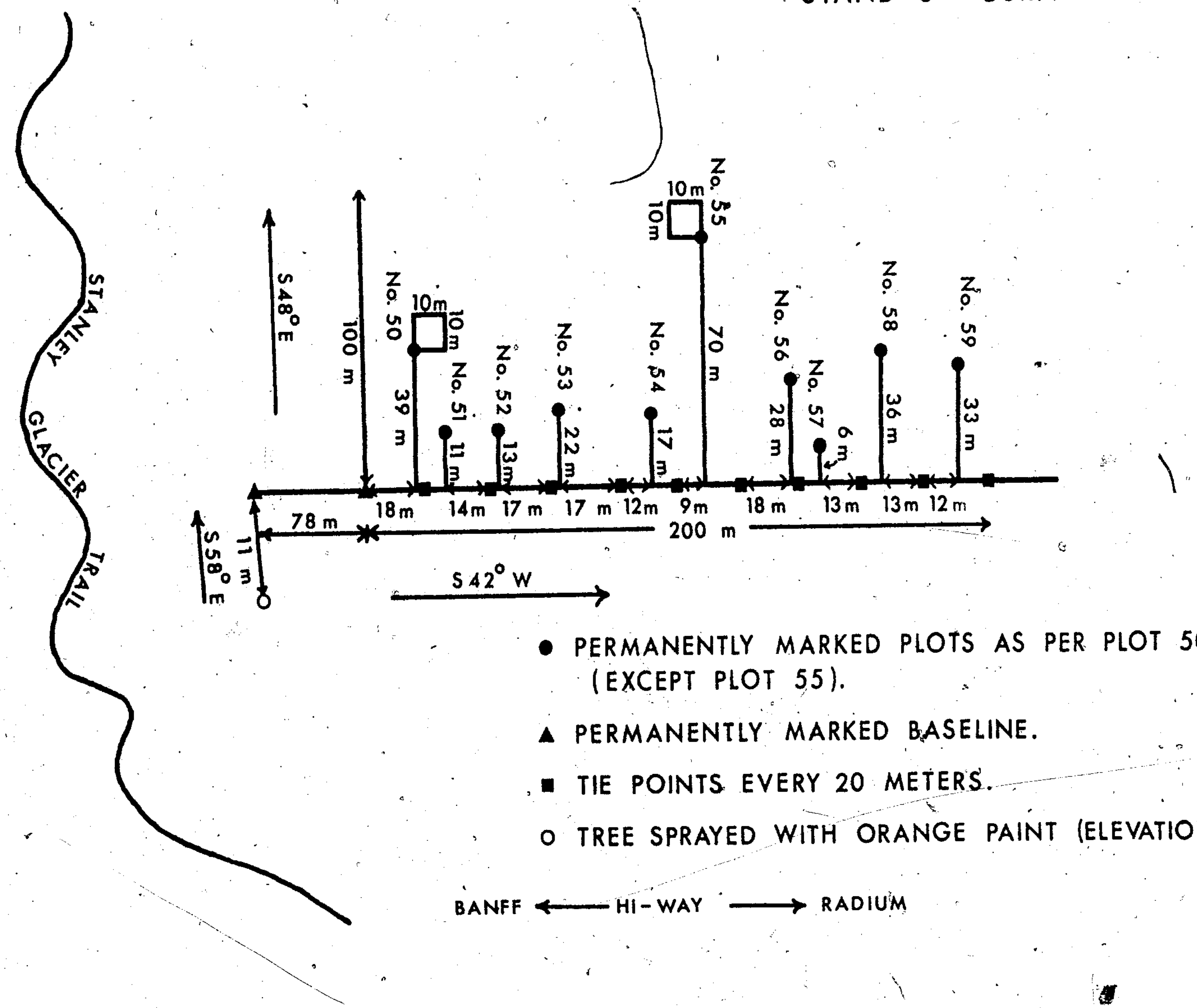
NOTE: BASELINE IS CUTLINE REPRESENTING THE PROVINCIAL BORDER.

STAND 3 - BURN


DUE SOUTH
No. 30
No. 31
No. 32
No. 33
No. 34
No. 35
No. 36
No. 37
No. 38
No. 39
10 m
10 m
8 m
94 m
57 m
84 m
20 m
90 m
13 m
32 m
19 m
68 m
17 m
16 m
15 m
15 m
16 m
18 m
10m
20 m
14 m
17 m
540 m
DUE WEST
200 m
BANFF ← HI-WAY → RADIUM
● PERMANENTLY MARKED PLOTS AS PER PLOT 30.
△ PERMANENTLY MARKED BASELINE.
▲ A PERMANENT MARKER AT THE 2nd WEATHER STATION.
■ TIE POINTS EVERY 20 METERS.


STAND 4 - BURN
S 45° W
S 45° E
No. 40
No. 41
No. 42
No. 43
No. 44
No. 45
No. 46
No. 47
No. 48
No. 49
10 m
49 m
44 m
29 m
23 m
47 m
117 m
13 m
14 m
10 m
15 m
19 m
17 m
18 m
16 m
1 m
2 m
7 m
HILL TOP
● PERMANENTLY MARKED PLOTS AS PER PLOTS 40 AND 41.
▲ PERMANENTLY MARKED BASELINE.
■ TIE POINTS EVERY 20 METERS.
STANLEY GLACIER STREAM
VERMILION RIVER
MAJOR AVALANCHE AREA
HI-WAY CUT-OFF
BANFF ← HI-WAY → RADIUM

STAND 5 - BURN



● PERMANENTLY MARKED PLOTS AS PER PLOT 50, (EXCEPT PLOT 55).

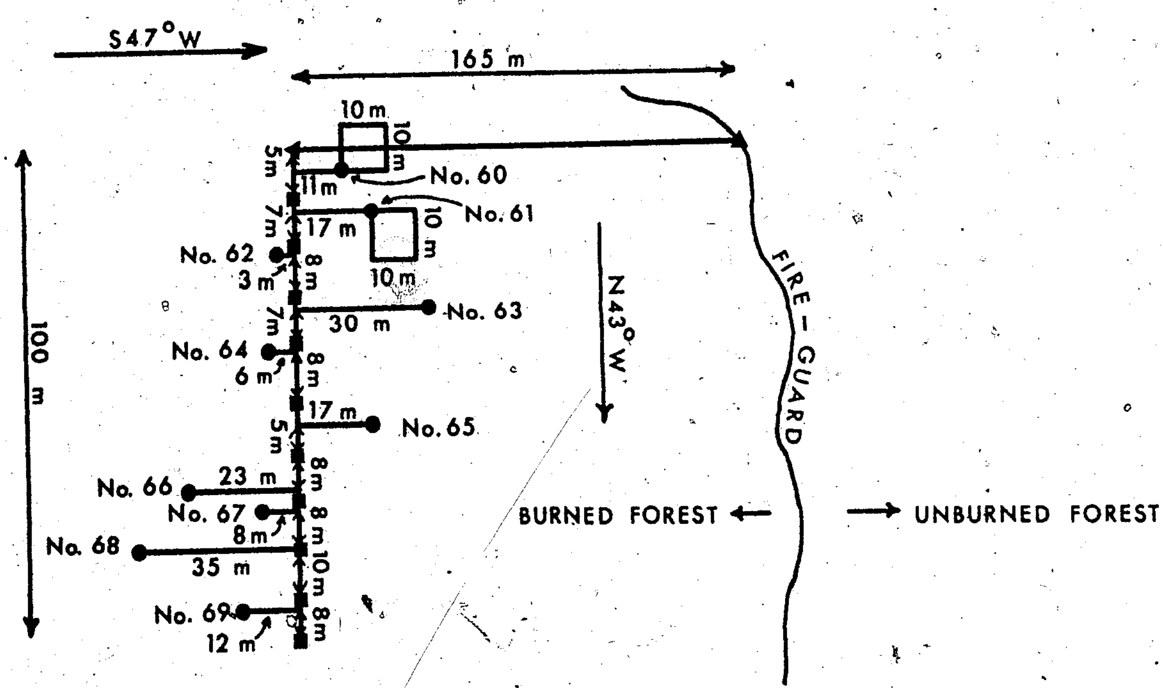
▲ PERMANENTLY MARKED BASELINE.

■ TIE POINTS EVERY 20 METERS.

○ TREE SPRAYED WITH ORANGE PAINT (ELEVATION 5320').

BANFF ← HI-WAY → RADIUM

STAND 6 – BURN

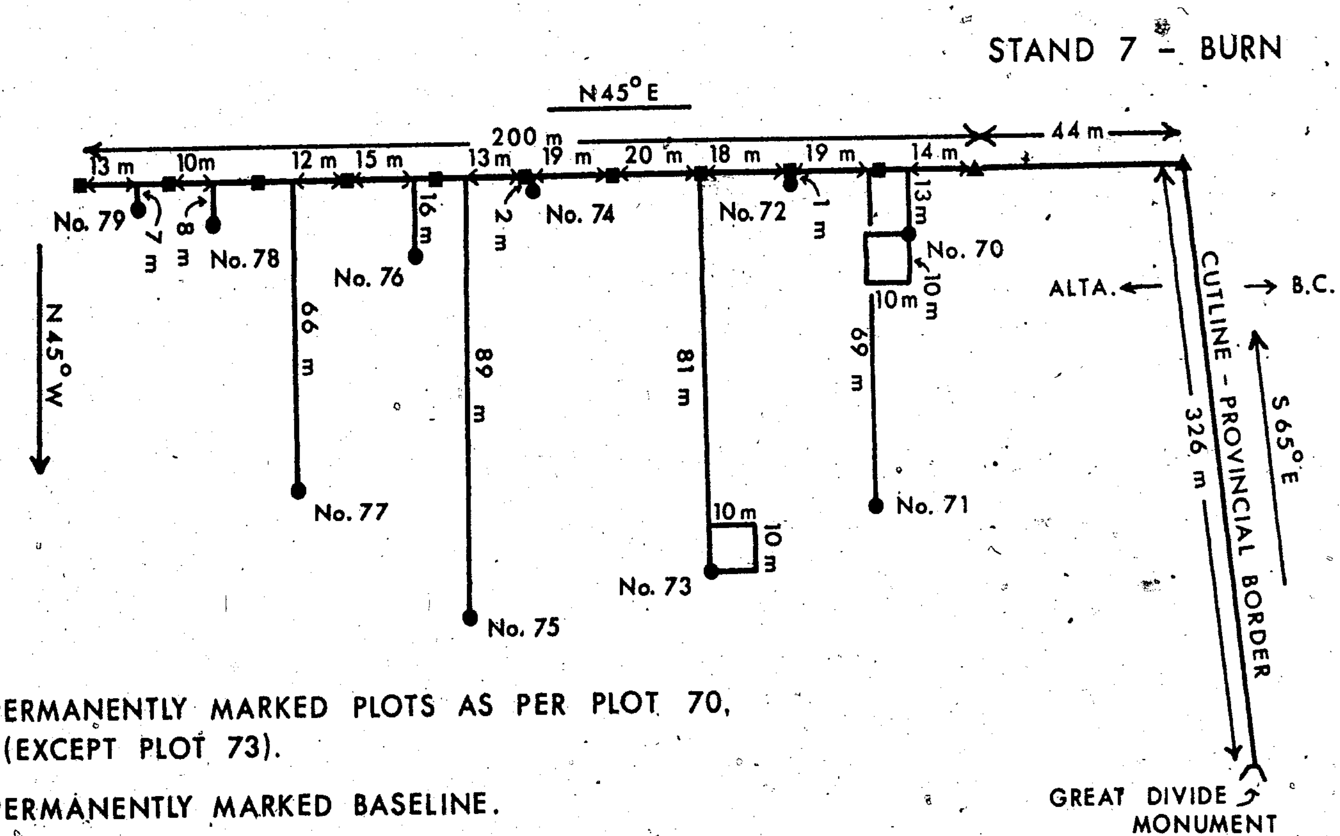


● PERMANENTLY MARKED PLOTS 62, 64, 66 AS PER PLOT 60; AND PLOTS 63, 65, 67, 68, 69 AS PER PLOT 61.

▲ PERMANENTLY MARKED BASELINE.

■ TIE POINT EVERY 10 METERS.

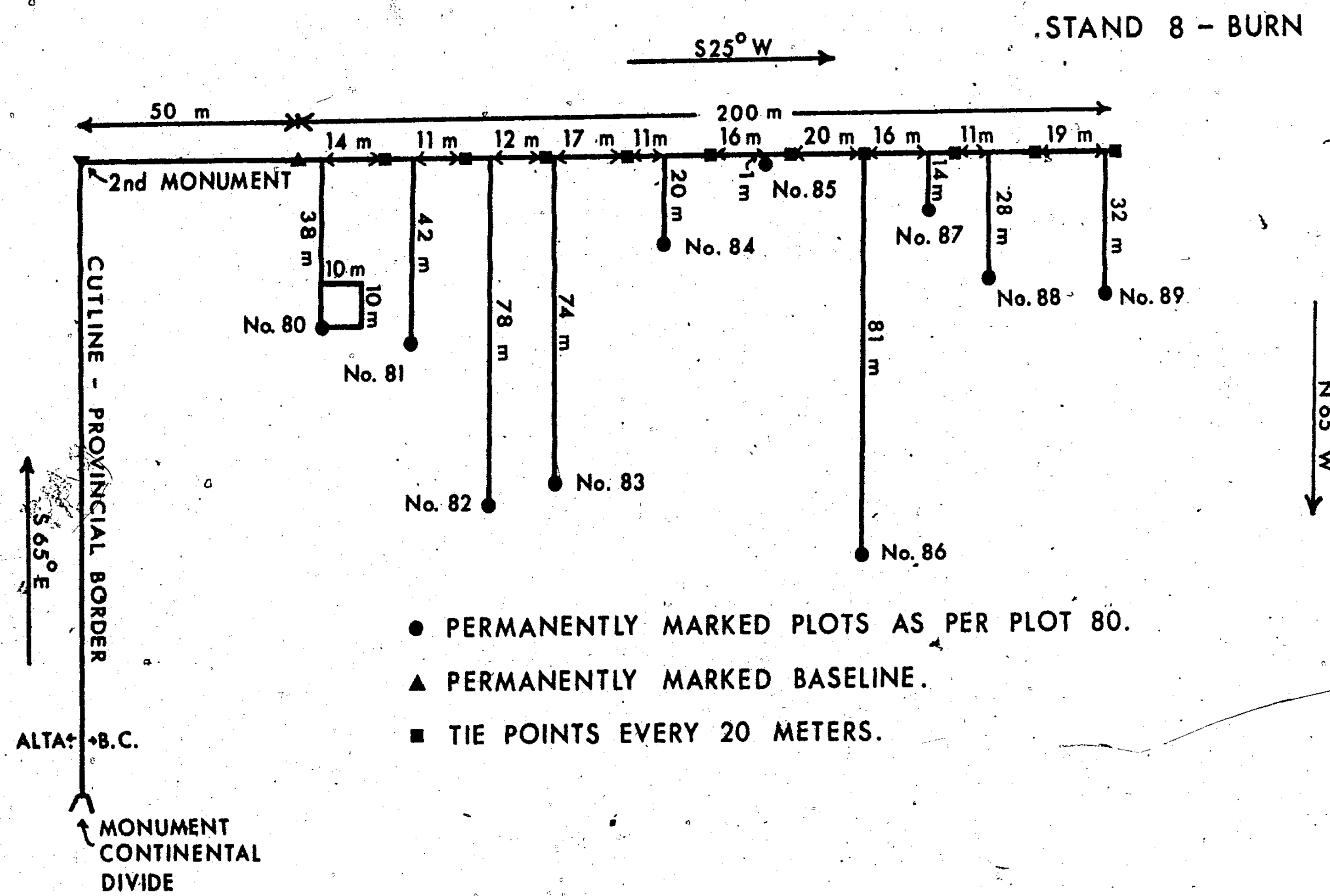
BANFF ⟵ HI – WAY ⟶ RADIUM



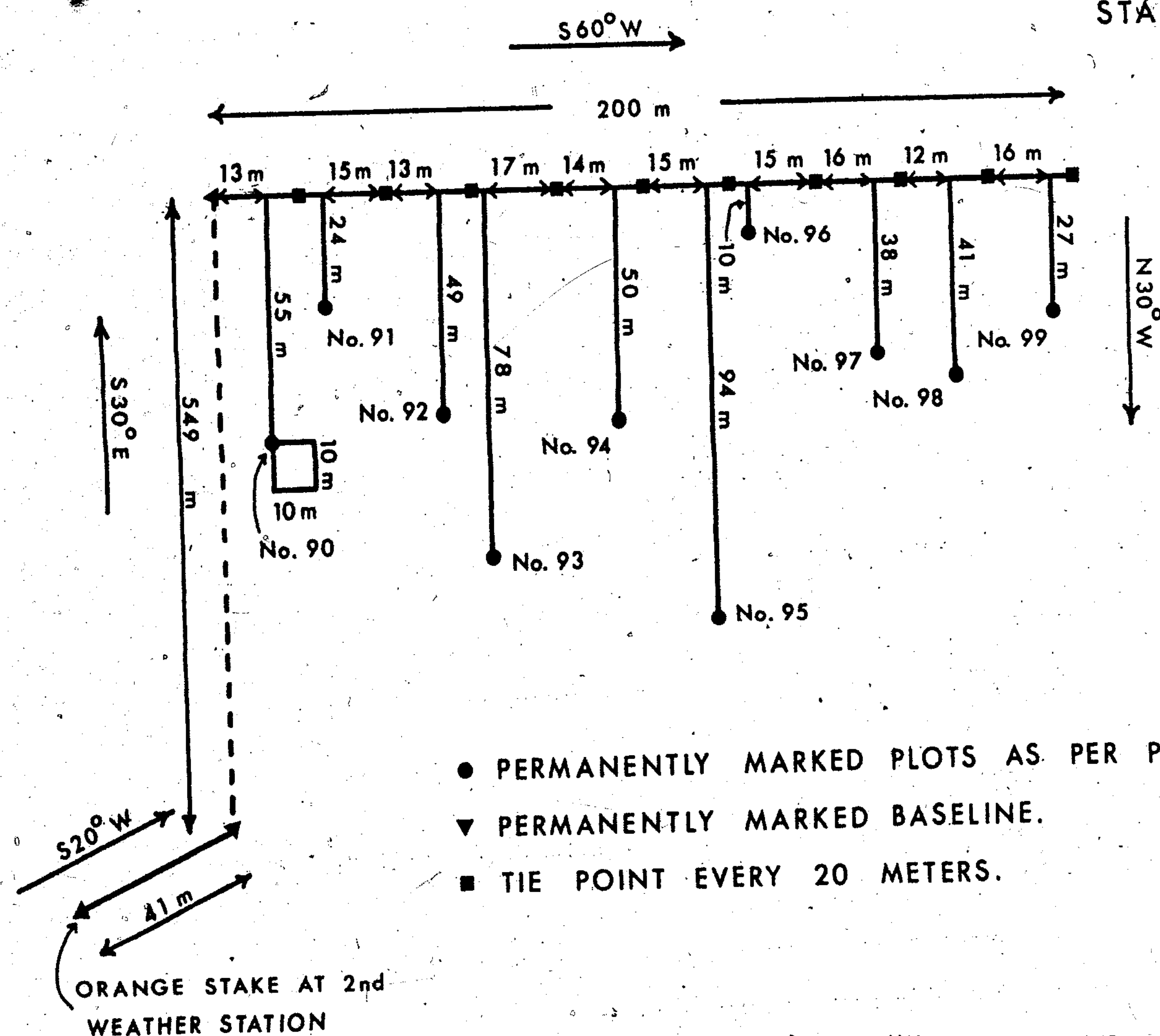
● PERMANENTLY MARKED PLOTS AS PER PLOT 70, (EXCEPT PLOT 73).

▲ PERMANENTLY MARKED BASELINE.

■ TIE POINTS EVERY 20 METERS.


STAND 8 - BURN
S25° W
N 65° W
S 65° E
50 m
200 m
14 m
11 m
12 m
17 m
11m
16 m
20 m
16 m
11m
19 m
2nd MONUMENT
38 m
10 m
10 m
42 m
78 m
74 m
20 m
1 m
81 m
14m
28 m
32 m
No. 80
No. 81
No. 82
No. 83
No. 84
No. 85
No. 86
No. 87
No. 88
No. 89
CUTLINE - PROVINCIAL BORDER
ALTA. B.C.
MONUMENT CONTINENTAL DIVIDE
● PERMANENTLY MARKED PLOTS AS PER PLOT 80.
▲ PERMANENTLY MARKED BASELINE.
■ TIE POINTS EVERY 20 METERS.
BANFF ← HI-WAY → RADIUM

STAND 9 – BURN

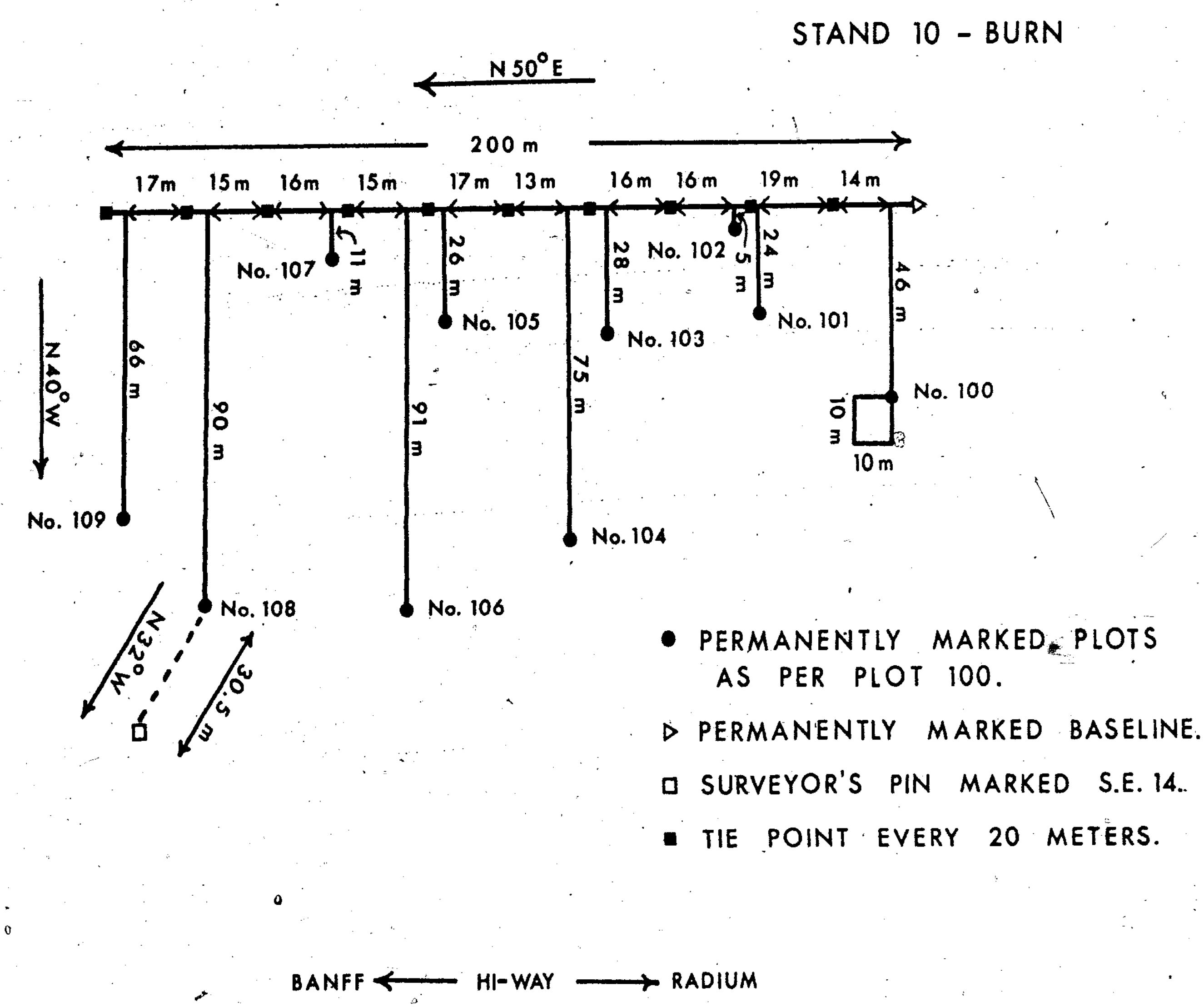


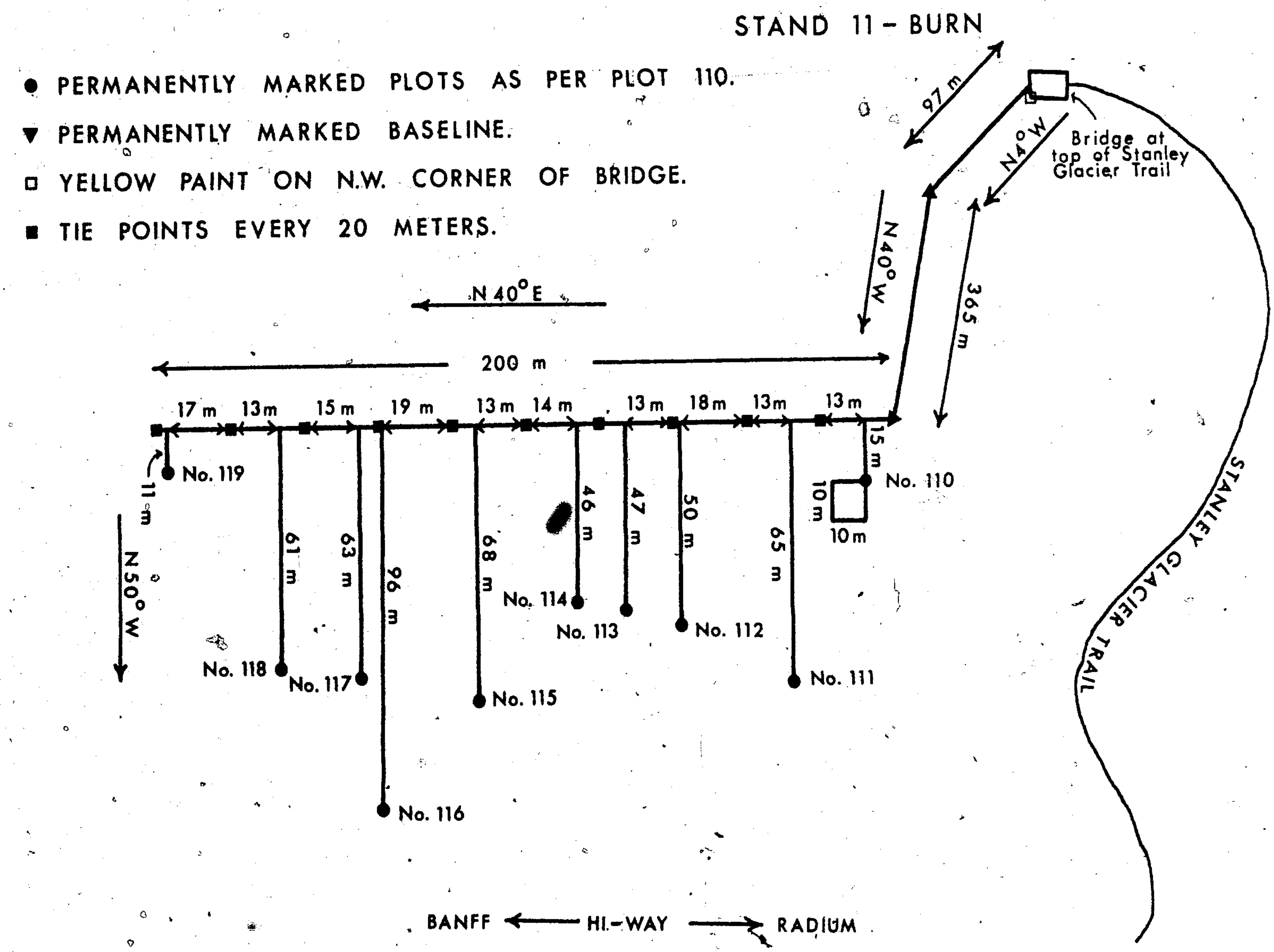
● PERMANENTLY MARKED PLOTS AS PER PLOT 90.

▼ PERMANENTLY MARKED BASELINE.

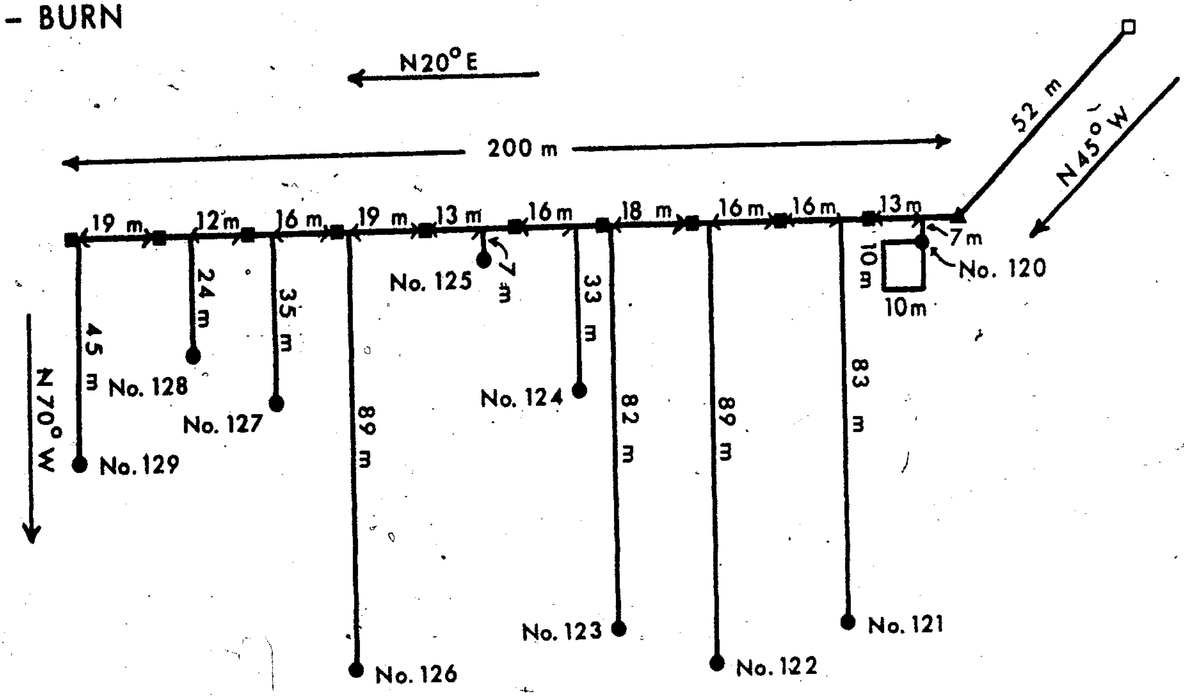
■ TIE POINT EVERY 20 METERS.

BANFF ⟵ HI-WAY ⟶ RADIUM


STAND 10 - BURN
N 50°E
200 m
17m
15m
16m
15m
17m
13m
16m
16m
19m
14m
46 m
No. 100
10 m
10 m
24 m
No. 101
5 m
No. 102
28 m
No. 103
75 m
No. 104
26 m
No. 105
91 m
No. 106
11 m
No. 107
90 m
No. 108
30.5 m
N32°W
66 m
No. 109
N40°W
PERMANENTLY MARKED PLOTS AS PER PLOT 100.
PERMANENTLY MARKED BASELINE.
SURVEYOR'S PIN MARKED S.E. 14.
TIE POINT EVERY 20 METERS.
BANFF
HI-WAY
RADIUM


STAND 11 - BURN
● PERMANENTLY MARKED PLOTS AS PER PLOT 110.
▼ PERMANENTLY MARKED BASELINE.
□ YELLOW PAINT ON N.W. CORNER OF BRIDGE.
■ TIE POINTS EVERY 20 METERS.
STANLEY GLACIER TRAIL
Bridge at top of Stanley Glacier Trail
97 m
N40°W
N40°W
365 m
N 40° E
200 m
17 m
13m
15 m
19 m
13 m
14 m
13 m
18m
13m
13 m
15 m
10 m
10 m
11 m
N50°W
No. 110
No. 111
No. 112
No. 113
No. 114
No. 115
No. 116
No. 117
No. 118
No. 119
65 m
50 m
47 m
46 m
68 m
96 m
63 m
61 m
BANFF
HI.-WAY
RADIUM

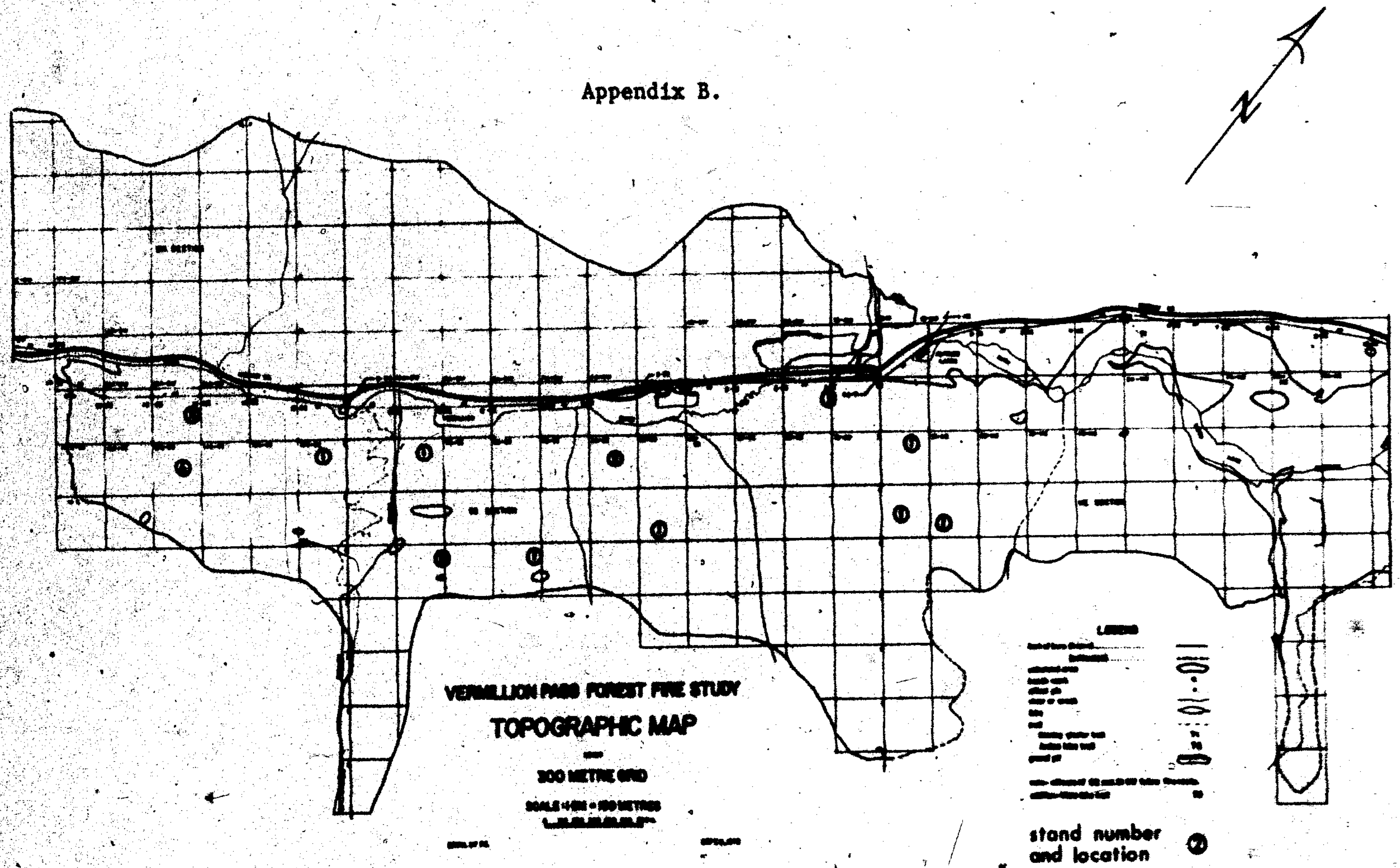
STAND 12 – BURN



- ● PERMANENTLY MARKED PLOTS AS PER PLOT 120.
- ▲ PERMANENTLY MARKED BASELINE.
- □ ORANGE STAKE AT 2nd WEATHER STATION.
- ■ TIE POINTS EVERY 20 METERS.

BANFF ← HI-WAY → RADIUM

Appendix B.


VERMILLION PASS FOREST FIRE STUDY
TOPOGRAPHIC MAP
300 METRE GRID
stand number and location

APPENDIX C. Basal area[a] of identified and unidentified standing stems by size-class and stand in the Vermilion Pass burn.

DIAMETER AT BREAST HEIGHT (INCHES)	STAND NUMBER 1				2				3				4			
	F[b]	S[c]	P[d]	U[e]	F	S	P	U	F	S	P	U	F	S	P	U
<2	.9	0.1	.	0.2	.9	.2	.	.4	.9	.1	.	.1	.4	.1	.	.4
2	.6	.2	.	.	3.4	.2	.	.2	2.5	.	.	.4	.2	.	.	.
3	5.0	1.8	.	0.9	9.1	1.8	.	.	6.3	.5	.	2.7	.9	.9	.	.5
4	2.5	4.8	.	0.8	16.2	2.5	.	1.6	9.7	2.5	.	4.1	.8	2.5	.	.
5	1.3	6.3	.	2.5	11.4	2.5	.	1.3	7.6	7.6	1.3	5.1	3.8	1.3	.	1.3
6	.	5.5	.	.	12.8	11.0	1.8	.	1.8	9.1	1.8	7.3	1.8	1.8	.	7.3
7	2.5	5.0	.	7.5	7.4	19.9	.	5.0	7.5	22.4	2.5	7.5	.	5.0	.	2.5
8	3.2	9.7	.	.	.	16.2	3.2	16.2	.	9.7	.	.	.	3.2	.	3.2
9	.	4.1	.	8.2	.	12.3	4.1	12.3	.	8.2	16.5	16.5	4.1	8.2	4.1	4.1
10	.	5.1	.	.	.	15.2	.	.	.	10.1	5.1	5.1	.	20.3	.	15.2
11	6.1	.	6.1	.	.	18.4	.	.	6.1	6.1	18.4	.	.	6.1	6.1	12.3
12	.	7.3	7.3	.	.	14.6	.	.	.	7.3	29.2	.	.	7.3	7.3	7.3
13	.	.	.	8.6	.	17.2	8.6	.	.	17.2	8.6	8.6	.	.	8.6	.
14	.	.	.	.	.	19.9	.	.	.	9.9	9.9	.	.	.	.	.
15	.	11.4	.	.	.	34.2	.	.	.	.	11.4	.	.	11.4	.	.
16	.	25.9	.	.	.	.	.	.	.	13.0	.	.	.	13.0	.	.
17	.	.	.	.	.	.	.	.	.	.	.	.	14.7	14.7	.	.
18	.	.	.	.	.	16.5	16.5	.	.	.	.	16.5	.	.	.	.
19	.	18.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
20	.	.	.	20.3	.	.	.	.	.	20.3	.	.	.	20.3	.	.
21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
22	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
23	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

APPENDIX C. cont'd

DIAMETER AT BREAST HEIGHT (INCHES)	STAND NUMBER 5				6				7				8			
	F	S	P	U	F	S	P	U	F	S	P	U	F	S	P	U
2	0.2	.1	.	.1	.7	.6	.	.1	1.4	.	.	.2	1.2	.	.	.4
2	.	.	.	.	.4	.4	.	.	1.0	.	.	.	3.9	.	.2	.2
3	.9	.	.	.5	5.9	2.3	.	1.4	5.9	.	.5	.	11.9	.5	.5	.5
4	3.2	.8	.	.8	4.8	.	.	.8	3.2	.	.	.8	8.9	.	4.8	3.2
5	6.3	2.5	.	3.8	.	1.3	.	5.1	7.6	.	.	.	16.5	1.3	5.1	.
6	3.7	3.7	.	3.7	7.3	3.7	.	.	5.5	1.8	1.8	.	16.5	7.3	7.3	1.8
7	2.5	7.5	.	2.5	.	2.5	2.5	.	2.5	2.5	2.5	2.5	.	2.5	14.9	7.5
8	6.5	6.5	.	6.5	6.5	3.2	9.7	3.2	.	.	3.2	3.2	6.5	25.9	13.0	3.2
9	.	4.1	4.1	12.3	.	4.1	12.3	16.5	.	8.2	.	.	8.2	12.3	8.2	.
10	.	10.1	.	5.1	.	10.1	15.2	5.1	.	10.1	10.1	10.1	.	15.2	5.1	5.1
11	.	.	12.3	.	.	12.3	12.3	6.1	.	6.1	.	.	.	6.1	18.3	.
12	.	29.2	.	.	7.3	29.2	.	7.3	.	14.6	14.6	7.3	.	.	7.3	.
13	.	8.6	8.6	.	8.6	17.2	8.6	.	.	8.6	8.6	.	.	.	17.2	.
14	.	.	.	.	.	29.8	9.9	.	.	.	.	.	.	9.9	.	.
15	.	22.8	.	.	.	22.8	11.4	.	.	.	.	.	.	.	11.4	.
16	.	.	13.0	.	.	13.0	.	.	.	25.9	13.0	13.0	.	13.0	.	.
17	.	.	.	.	.	.	.	.	.	.	.	14.7	.	.	.	.
18	.	.	.	.	.	16.5	.	.	.	16.5	16.5	.	.	32.8	.	.
19	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
22	.	24.5	.	.	.	.	.	.	.	24.5	.	.	.	.	.	.
23	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

APPENDIX C. cont'd

DIAMETER AT BREAST HEIGHT (INCHES)	STAND NUMBER 9 F	S	P	U	10 F	S	P	U	11 F	S	P	U	12 F	S	P	U
2	1.3	.	.	.5	1.7	.	.	.1	1.9	.1	.1	.4	.7	.	.	.2
2	1.4	.	.	.	.4	.	.	.	2.8	.	.	.	.8	.	.	.
3	6.4	.	.	.	3.2	.	.	.	7.3	.9	.	1.8	3.2	.	.	.
4	7.3	.	.	.8	3.2	.	.	2.5	5.1	4.1	2.5	2.5	3.2	.	.8	.8
5	10.1	.	.	1.3	3.8	.	.	2.5	9.1	2.5	.	5.1	.	2.5	1.3	2.5
6	3.7	.	.	12.8	1.8	1.8	1.8	1.8	.	1.8	.	7.3	.	3.7	.	3.7
7	5.0	2.5	.	9.9	.	2.5	.	7.5	9.7	2.5	5.0	2.5	.	7.5	.	5.0
8	9.7	6.5	.	.	.	6.5	3.2	13.0	4.1	6.5	.	.	.	3.2	.	9.7
9	.	4.1	.	4.1	.	.	.	.	.	8.2	4.1	12.3	.	4.1	12.3	4.1
10	.	20.3	.	5.1	.	5.1	5.1	15.2	.	15.2	10.1	.	.	5.1	5.1	.
11	.	12.3	.	.	.	12.3	.	.	.	6.1	12.3	.	.	12.3	6.1	12.3
12	.	7.3	29.2	7.3	.	7.3	7.3	7.3	.	14.6	.	.	.	7.3	14.6	.
13	.	25.7	17.2	.	.	17.2	.	.	.	.	8.6	.	.	34.3	42.8	8.6
14	.	.	9.9	.	.	39.7	.	.	.	9.9	.	9.9	.	19.9	.	.
15	.	.	.	.	.	57.0	.	.	.	11.4	11.4	11.4	.	34.2	.	22.8
16	.	.	13.0	.	.	13.0	.	.	.	13.0	13.0	13.0	.	.	.	13.0
17	.	14.7	.	.	.	.	.	.	.	43.9	.	.	.	.	14.7	.
18	.	.	.	.	.	32.8	.	.	.	.	.	.	.	.	.	.
19	.	.	.	.	.	.	.	.	.	18.3	.	.	.	.	.	.
20	.	20.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.
21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
22	.	.	.	.	.	.	.	.	.	.	24.5	.	.	.	.	.
23	.	26.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.

a. Basal area expressed in square decimeters per 1,000 square meters.
b. Subalpine fir
c. Engelmann spruce
d. Lodgepole pine
e. Unidentified stem

APPENDIX D

Presence list of vascular species recorded on the NW-facing slope in the burned forest area, Vermilion Pass. Taxonomic authority for vascular plants is Hitchcock and Cronquist (1973), except for Salix discolor (Moss, 1959) and Draba lonchocarpa (Mulligan, 1976). Plants are listed alphabetically by families, genera and species.

VASCULAR PLANTS

Betulaceae

Alnus sinuata (Regel) Rydb.

Caprifoliaceae

Linnaea borealis L. var. longiflora Torr.

Lonicera involucrata (Rich.) Banks ex Spreng.

Sambucus racemosa L. var. melanocarpa (Gray) McMinn.

Viburnum edule (Michx.) Raf.

Compositae

Achillea spp.

Anaphalis margaritacea (L.) B & H.

Antennaria spp.

Arnica cordifolia Hook.

Aster conspicuus Lindl.

Aster sibiricus L. var. meritus (A. Nels.) Raup.

Erigeron peregrinus (Pursh) greene spp. callianthemus (Greene) Cronq. var. callianthemus

Senecio pseudaureus Rydb.

Taraxacum spp.

APPENDIX D (CONT'D)

Cornaceae

Cornus canadensis L.

Cruciferae

Draba lonchocarpa Rydb. var. lonchocarpa

Cupressaceae

Juniperus communis L.

Cyperaceae

Carex pachystachya Cham. ex. Steud.

Carex phaeocephala Piper

Carex rossii Boott.

Carex spp.

Elaeagnaceae

Shepherdia canadensis (L.) Nutt.

Empetraceae

Empetrum nigrum L.

Equisetaceae

Equisetum pratense Ehrh.

Equisetum scirpoides Michx.

Ericaceae

Ledum glandulosum Nutt. var. glandulosum.

Menziesia ferruginea Smith, var. glabella (Gray) Peck.

Pyrola secunda L. var. secunda.

Rhododendron albiflorum Hook.

Vaccinium myrtillus L.

Vaccinium scoparium Leiberg

APPENDIX D (CONT'D)

Fumariaceae

Corydalis sempervirens (L.) Pers.

Gramineae

Elymus innovatus Beal.

Calamagrostis canadensis (Michx.) Beauv. var. acuminata Vasey.

Grossulariaceae

Ribes lacustre (Pers.) Poir.

Juncaceae

Juncus drummondii E. Meyer var. drummondii.

Labiatae

Moldavica parviflora (Nutt.) Britt.

Liliaceae

Stenanthium occidentale Gray.

Onagraceae

Epilobium alpinum L. var. lactiflorum (Hausskn.) C.L. Hitchc.

Epilobium angustifolium L.

Epilobium platyphyllum Rydb.

Pinaceae

Abies lasiocarpa (Hook.) Nutt.

Picea engelmannii Parry ex. Engelm.

Pinus albicaulis Engelm.

Pinus contorta Dougl. ex Loud. var. latifolia Engelm.

Polypodiaceae

Polystichum lonchitis (L.) Roth.

Portulacaceae

Claytonia lanceolata Pursh.

APPENDIX D (CONT'D)

Ranunculaceae

Anemone parviflora Michx.

Aquilegia flavescens Wats.

Thalictrum occidentale Gray.

Thalictrum venulosum Trel.

Rosaceae

Rosa acicularis Lindl.

Rubus idaeus L.

Sorbus sitchensis Roemer var. sitchensis

Spiraea betulifolia Pall. var. lucida (Dougl.) C.L. Hitchc.

Salicaceae

Populus tremuloides Michx.

Salix discolor Muhl.

Salix myrtillifolia Anderss.

Salix spp.

Salix vestita Pursh.

Scrophulariaceae

Castilleja miniata Dougl. ex Hook.

Pedicularis bracteosa Benth.

Valerianaceae

Valeriana sitchensis Bong.

APPENDIX E

Presence list of vascular species recorded in the unburned forest, Vermilion Pass. Taxonomic authority for vascular plants is Hitchcock and Cronquist (1973). Plants are listed alphabetically by families, genera and species.

VASCULAR PLANTS

<u>Betulaceae</u>

Alnus sinuata (Regel) Rydb.

<u>Caprifoliaceae</u>

Linnaea borealis L. var. longiflora Torr.

Lonicera involucrata (Rich.) Banks ex Spreng.

<u>Compositae</u>

Arnica cordifolia Hook.

Aster spp.

Erigeron acris L. var. asteroides (Andrz.) Bess.

Petasites frigidus (L.) Fries, var. palmatus (Ait.) Cronq.

Solidago multiradiata Ait. var. scopulorum Gray.

<u>Cornaceae</u>

Cornus canadensis L.

<u>Empetraceae</u>

Empetrum nigrum L.

<u>Equisetaceae</u>

Equisetum pratense Ehrh.

<u>Ericaceae</u>

Arctostaphylos uva-ursi (L.) Spreng.

Ledum groenlandicum Oeder.

APPENDIX E (CONT'D)

Ericaceae (cont'd)

Menziesia ferruginea Smith, var. glabella (Gray) Peck.

Pyrola asarifolia Michx. var. asarifolia.

Pyrola minor L.

Vaccinium myrtillus L.

Vaccinium scoparium Leiberg

Gramineae

Calamagrostis canadensis (Michx.) Beauv. var. acuminata Vasey.

Grossulariaceae

Ribes lacustre (Pers.) Poir.

Liliaceae

Stenanthium occidentale Gray.

Lycopodiaceae

Lycopodium annotium L.

Lycopodium complanatum L.

Orchidaceae

Listera cordata (L.) R. Br.

Pinaceae

Abies lasiocarpa (Hook.) Nutt.

Picea engelmannii Parry ex Engelm.

Pinus contorta Dougl. ex Loud. var. latifolia Engelm.

Pinus albicaulis Engelm.

Polypodiaceae

Dryopteris austriaca (Jacq.) Woynar ex Schinz & Thell.

Ranunculaceae

Ranunculus acris L.

APPENDIX E (CONT'D)

Rosaceae

Fragaria virginiana Duchesne, var. glauca Wats.

Rosa acicularis Lindl.

Rubus pedatus J.E. Smith

Rubus pubescens Raf.

Sorbus sitchensis Roemer var. sitchensis

Salicaceae

Salix spp.

Saxifragaceae

Tiarella unifoliata Hook.

Umbelliferae

Osmorhiza depauperata Phil.

APPENDIX F. Mean height (cm) of species found in twelve stands on the NW - facing slope in the Vermilion Pass burn

SPECIES	STAND NUMBER											
	1	2	3	4	5	6	7	8	9	10	11	12
Alnus sinuata	.	.	.	39	.	.	.	.	.	.	.	.
Aquilegia flavescens	.	.	39	37	.	.	.	.	.	.	.	.
Arnica cordifolia	5	27	39	34	37	38	21	27	22	26	37	25
Aster conspicuus	.	.	.	37	.	42	.	.	.	40	.	47
Calamagrostis canadensis	.	.	.	86	.	.	.	.	.	59	.	.
Carex pachystachya	.	.	.	.	35	.	.	.	.	22	.	.
Carex phaeocephala	23	.	.	.	.	.	.	.	.	.	.	.
Carex rossii	.	.	.	.	.	.	22	22	.	.	.	.
Carex spp.	25	18	9	.	.	.	.	.	.	.	.	.
Cornus canadensis	5	4	5	5	8	8	5	6	3	7	8	6
Elymus innovatus	.	.	.	.	.	52	.	.	.	65	.	.
Epilobium angustifolium	32	29	23	22	23	24	17	17	17	26	20	25
Epilobium platyphyllum	31	.	.	.	.	.	.	.	.	.	.	33
Equisetum scirpoides	.	.	.	5	.	.	.	.	.	6	.	.
Ledum glandulosum	.	.	.	37	89	29	.	.	15	34	34	30
Linnaea borealis	3	.	3	3	3	4	.	2	2	4	.	4
Lonicera involucrata	.	.	.	.	40	33	.	.	.	50	.	.
Menziesia ferruginea	25	30	35	30	43	44	25	28	25	33	30	29
Populus tremuloides	77	.	.	.	31	.	.	24	.	.	.	.
Pyrola secunda	.	.	.	.	.	.	3	.	.	.	.	.
Rhododendron albiflorum	.	.	43	.	25	.	.	.	26	.	27	.
Ribes lacustre	.	.	.	12	.	30	.	.	.	15	.	.
Rosa acicularis	.	.	.	15	.	.	.	.	.	.	.	.
Rubus idaeus	.	.	.	.	.	.	17	12	.	.	.	.
Salix spp.	36	49	24	25	36	.	24	29	17	.	.	27
Sambucus racemosa	.	95	.	59	40	50	50	39	49	45	35	.
Shepherdia canadensis	.	.	.	21	35	50	.	.	.	42	.	.
Sorbus sitchensis	.	.	.	.	50	61	.	20	.	.	30	.
Spiraea betulifolia	.	.	.	.	40	42	.	32	.	.	.	.
Stenanthium occidentale	.	.	.	.	.	45	.	.	.	.	.	.
Taraxacum spp.	7	.	.	.	.	.	38	.	.	46	.	.
Vaccinium myrtillus/scoparium	6	9	9	9	9	6	9	9	7	6	8	6

Appendix G. Coefficient of similarity values, based on dead tree density, expressed as percentage, for 12 stands in the Vermilion Pass burn.

STAND NO.	1	2	3	4	5	6	7	8	9	10	11	12
1	100											
2	75.1	100										
3	82.6	84.5	100									
4	67.8	90.8	80.4	100								
5	66.8	90.0	79.3	94.1	100							
6	83.8	76.5	85.5	67.9	67.2	100						
7	75.2	83.1	90.5	82.0	77.1	77.4	100					
8	68.4	86.2	85.0	85.4	80.5	71.9	86.9	100				
9	74.5	85.7	88.8	84.9	79.9	75.9	97.1	88.4	100			
10	94.6	71.0	82.4	69.6	65.2	81.0	80.3	72.4	79.7	100		
11	87.6	63.3	76.5	61.3	57.8	75.9	71.1	66.1	69.5	87.7	100	
12	79.9	81.2	96.5	80.0	75.4	83.2	94.0	86.4	92.3	85.1	76.7	100
TOTAL	956	987	1032	964	933	947	1015	978	1017	969	894	1031

Appendix H. Coefficients of Similarity values, based on basal area, expressed as percentages, for 12 stands in the Vermilion Pass burn

STAND NO.	1	2	3	4	5	6	7	8	9	10	11	12
1	100											
2	63.1	100										
3	64.0	74.8	100									
4	83.0	72.5	73.5	100								
5	85.9	74.3	76.9	90.6	100							
6	63.9	82.8	91.9	73.3	76.8	100						
7	77.4	70.0	85.4	81.4	90.2	85.3	100					
8	60.9	72.8	90.7	68.5	73.5	83.0	81.9	100				
9	70.1	79.5	92.1	79.9	83.5	91.9	91.3	85.0	100			
10	71.1	86.4	67.7	81.0	74.5	76.8	67.7	58.6	71.3	100		
11	63.1	80.8	94.2	72.5	76.0	96.1	84.4	86.9	92.2	76.9	100	
12	65.3	65.6	90.4	80.7	79.2	84.2	86.7	84.3	85.4	68.2	86.8	100
TOTAL	868	923	1001	957	981	1006	1001	946	1022	900	1010	977

Appendix I. Coefficient of similarity values, based on prominence values of the lesser vegetation, expressed as percentages, for 12 stands in the Vermilion Pass burn.

STAND NO.	1	2	3	4	5	6	7	8	9	10	11	12
1	100											
2	18.9	100										
3	23.5	45.2	100									
4	24.5	53.9	58.7	100								
5	22.5	39.4	56.1	63.5	100							
6	7.0	16.4	51.8	32.4	55.5	100						
7	35.4	56.3	63.0	42.6	44.0	27.3	100					
8	32.8	45.5	55.5	35.8	39.2	22.9	74.7	100				
9	15.5	48.6	58.7	29.7	34.4	26.5	64.4	71.9	100			
10	37.4	31.1	44.3	57.7	60.8	36.7	44.1	34.6	21.2	100		
11	14.9	40.6	64.2	49.6	53.1	57.0	51.9	45.4	54.9	40.7	100	
12	43.6	45.2	56.3	58.4	64.5	30.6	69.5	57.0	38.9	64.0	46.0	100
TOTAL	376	541	677	607	633	464	673	615	565	573	618	674

Appendix J. Diagnostic features used in identifving the pre-fire forest trees.

A. Standing stems - alive before the fire.

1. General tree form.
2. Bark present and type.
3. Cones (form and whether present or absent on tree).
4. Needles on tree or at it's base.
5. Resin ducts on wood.

B. Standing stems - dead before the fire.

1. Bark free.
2. No branches (or few) present.
3. Very severely charred.

C. Stems on the ground - fallen before the fire.

1. Generally, no bark.
2. Charred exposed roots.
3. No exposed mineral soil at it's base.

D. Stems on the ground - fallen after the fire.

1. Generally, bark present on tree.
2. Roots not burned.
3. Mineral soil exposed from post-burn uprooting.