Forests, Fuels and Fire in the Selway-Bitterroot Wilderness, Idaho

JAMES R. HABECK
Department of Botany, University of Montana, Missoula

INTRODUCTION

THE Selway-Bitterroot Wilderness (SBW) is a 1.2 million-acre (486,000 ha) forested tract located in northern Idaho and portions of adjacent western Montana (46°00′ N, 115° W, Fig. 1). This wilderness represents the largest roadless area in conterminous United States classified under the Wilderness Act of 1964. It lies within portions of the Nez Perce, Bitterroot, Clearwater and Lolo National Forests (Northern Region, USDA Forest Service) which collectively provide control and management for this wilderness.

Two of the current wilderness management objectives in the Selway-Bitterroot Wilderness are (1) the determination of the natural role of wildfires within the varied forest communities composing the wilderness, and (2) the determination of suitable means of returning to wildfire at least some of these natural functions (Habeck and Mutch, 1973). The successful pursuit of these management objectives requires the development of a detailed description of forest compositions and distributions as well as an assessment of organic fuel production and accumulations within different forest types.

Wildfire is believed to have played a critical ecological role as a decomposer of organic matter in many of the northern Rocky Mountain coniferous forests (Habeck, 1972, 1973; Habeck and Mutch,

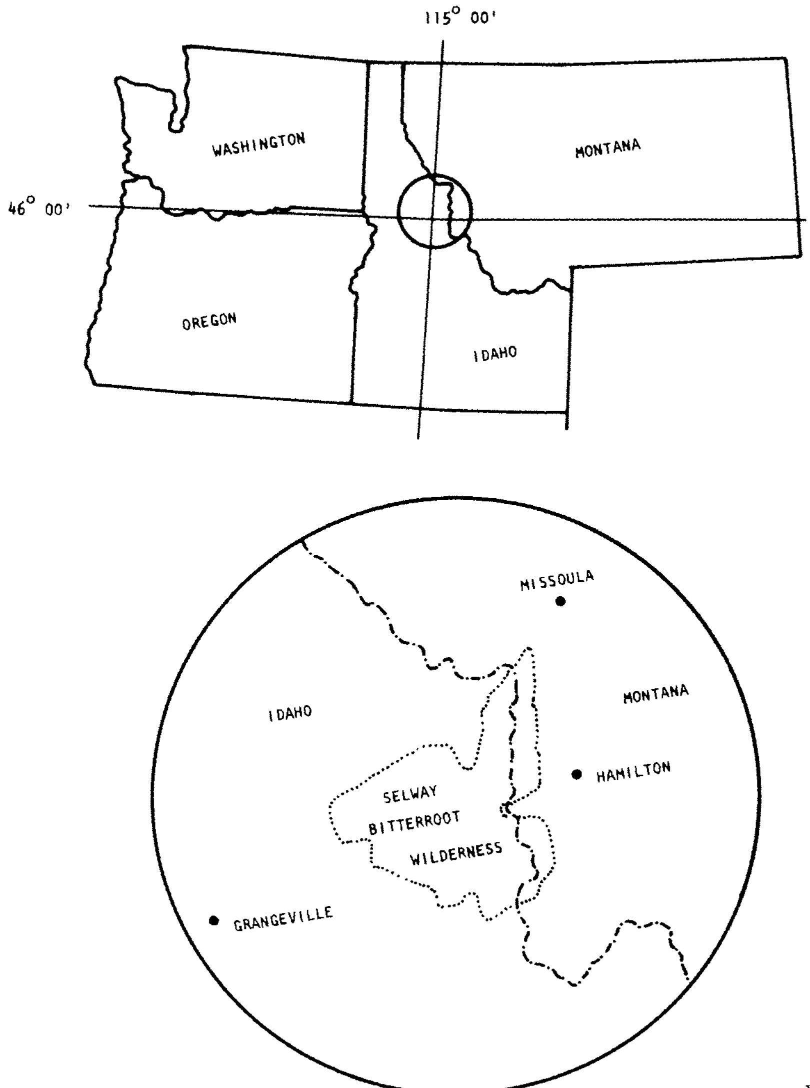

Fig. 1. Map of the Pacific Northwest and location of the Selway-Bitterroot Wilderness in northern Idaho and adjacent western Montana.

1973), and consequently an integral and natural process in these ecosystems. Modern fire suppression activities, implemented with ever-increasing effectiveness, even in remote wilderness areas, may well have induced major changes in ecosystems that evolved in the presence of periodic fire (Lunan and Habeck, 1973)

NATURE OF THE PROBLEM

Within the SBW a wide range of environmental conditions exists. The area's topography is mountainous, and steep moisture and elevational gradients are exhibited. The environmental mosaic supports a wide variety of forest community types (Habeck, 1972, 1973).

Fig. 2. South slope system on the lower White Cap Creek drainage, SBW. Much of area in view was covered by a wildfire in 1973. Grasslands, ponderosa pine savannah and Douglas fir forests form the vegetation mosaic. Photo taken 1974.

Grasslands and ponderosa pine *(Pinus ponderosa)* savannah represent the community types found on the warmest and driest habitats at lower elevations (Fig. 2). Douglas-fir (*Pseudotsuga menziesii*) and mixtures of Douglas-fir and grand fir (*Abies grandis*) occupy mid and lower slope positions between 2600 and 5000 ft (800 to 1500 m), and compose a major portion of the total forest cover in the SBW. Western redcedar *(Thuja plicata)*, occurring in various combinations with grand fir and/or Engelmann spruce *(Picea engelmannii)*, is found in most streamside and ravine habitats throughout the northern two-thirds of the SBW. At elevations above 5600 ft (1700 m) subalpine fir *(Abies lasiocarpa)* becomes a conspicuous dominant (Fig. 3), but is generally found in mixtures that include lodgepole

Fig. 3. Subalpine fir forest zone at Bear Creek Pass, SBW. Elevation 6500 feet. Englemann spruce, lodgepole pine and whitebark pine are common associates. Area in view has not burned in last century; mosaic pattern seen is the result of topographic factors such as rock outcrops and talus slides.

pine *(Pinus contorta)*, whitebark pine *(Pinus albicaulis)*, alpine larch *(Larix lyallii)* and Engelmann spruce.

Fire has affected all of the SBW forests examined during the past 4 years; it is generally not difficult to detect the varied patterns of forest development induced by the multiplicity of past fires. The influence of past fires has been imposed differentially, however, on this wilderness landscape. The oldest forest communities (over 400 years old), those burned least often, are those dominated by redcedar on the moist streamsides and in ravines. The ponderosa pine forests and grasslands appear to have experienced fires at about 20-year intervals prior to modern fire control. The forests at high elevations are a mixture of young pioneer stands on well-drained slopes, dominated by subalpine fir and Engelmann spruce.

This vegetational mosaic has been the subject of detailed study since 1971 and is under continued investigation at this time. Efforts have been directed towards understanding forest successional processes and ground fuel accumulations among the various forest community types found in the SBW. Fire exclusion policies during the past ½ century have evidently limited the number and assortment of pioneer and early seral stages of forest development (0-50 years old) that can be located in each of the forest zones. It also appears true that many of the mature forest communities, those 200 years or older, are often found in habitats that are cooler and more moist compared with open slope sites. The greater age of moist-site stands may be the result of a reduced fire frequency or lower fire intensities experienced in such habitats.

The major emphasis of this report will be placed on a description and discussion of forest community compositions and distributions along elevational and moisture gradients, with a concomitant presentation and interpretation of the organic fuel accumulations (loadings) in the wilderness stands studied.

Even though stands representative of the widest range of developmental stages, within each forest zone, are not as yet included in the data presented in this report, some significant relationships between forest community age and fuel accumulations have emerged, and these can be expected to be improved as additional field data are gathered.

DESCRIPTION OF THE AREA

The terrain encompassed within the boundaries of the SBW is notably characterized by topographic contrasts; the area is extremely rugged throughout, with elevational relief between valley bottoms and ridgetops not uncommonly exceeding 5000 to 6600 ft (1500 to 2000 m). Bounding the wilderness on its eastern edge are the Bitterroot Mountains, a fault-formed system attaining elevations up to 10,000 ft (3000 m). A large portion of the total drainage within the SBW is encompassed within the Selway River system, which ultimately drains into the Columbia River.

The Bitterroot Mountains and much of the mountain terrain within the SBW consists of granitic rock (quartz-monzonite) representing the northern extension of the great Idaho batholith (Lindgren, 1904). Lindgren concludes that the geological history of this region began with the deposition of pre-Cambrian sediments on the base of gneiss. At a much later date, probably during early Mesozoic, additional sediments and lavas covered the area; these were uplifted and then eroded prior to the beginning of the Cenozoic. A second uplifting occurred, raising this eroded surface to the present level of the Clearwater Plateau. The deep canyons dissecting the SBW area were mostly excavated before the eruption of the Columbia River basalt.

Pleistocene glaciation also left its imprint on the SBW landscape. Mountain glaciation occurred in the Bitterroot Mountains and several other places in the wilderness; evidence indicates that the mountain glaciers extended downward to elevations of about 4000 ft (1200 m). Thus a portion of the SBW displays many of the classical features of glaciation—cirque lakes, U-shaped valleys and moraines.

The meteorological features within the SBW are well correlated with an east-west gradient across the wilderness. This is due to the fact that much of the SBW occupies the west slope of the Bitterroot Mountains, where elevations shift from 1980 ft (600 m) at stream level on the western boundary to 10,000 ft (3000 m) on the Bitterroot Mountain divide to the east. Most of the air masses that influence the SBW region originate from westernly directions. Mean annual precipitation ranges from about 36 in. (90 cm) in the western portions of the SBW to over 60 in. (150 cm) in the upper reaches of the Bitterroot Mountains.

Summer and winter temperatures show similar gradational differences. At the higher elevations within the Bitterroot Mountains, July temperatures average 60°F (16°C), and January readings average 18°F (−8°C). On the lower, western wilderness boundary the summer and winter temperature averages are 72°F (22°C) and 28°F (−2°C) respectively.

These generalized averages for precipitation and temperature are locally modified by topography. The high mountain sites accumulate over 100 in. (250 cm) of snow during winter and early spring; the narrow valley canyons are cooler and more moist during the summer than are the open mountain slopes. The area encompassed by the SBW generally experiences a mid-summer reduction of precipitation as a consequence of the coastal storm tracks moving further northward during the July-August period. This reduction in summer rainfall, combined with higher summer temperatures reduces fuel moisture content, and thus increases forest flammability. Summer electrical storms, accompanied by little or no rainfall, are known to be of primary importance in fire ignitions in the SBW. A single storm in August, for example, is capable of initiating several dozen fires in this region.

PHYTOGEOGRAPHICAL FEATURES

Prior to the uplift of the Cascade Mountains, approximately during the Miocene, much greater amounts of coastal moisture penetrated eastward into the northern Rocky Mountains than occurs at the present time. Following the development of the Cascades, the total amount of moisture reaching northern Idaho was reduced. The reduced moisture, particularly at lower elevations, led to an increase in the amount of drier vegetation types (desert and grassland) in northern Idaho and eastern Washington, although sufficient moisture persisted to support coniferous forest vegetation on the mountain slopes. Species with high moisture requirements such as western redcedar and western hemlock *(Tsuga heterophylla)* appear to occupy a much smaller area within northern Idaho and western Montana than in former times. Disjunct, relict forest communities composed of coastal trees, shrubs and herbs can be found in both Idaho and Montana that support the contention that many of these species enjoyed a broader distribution in the past.

The SBW lies within a particularly interesting geographical area where range limits of many Pacific coastal species are reached. Both western hemlock and mountain hemlock *(Tsuga mertensiana)* reach their southern range limits at or just north of the wilderness boundary. Western larch *(Larix occidentalis)* and western white pine *(Pinus monticola)* occur within the northern portion of the wilderness as small isolated populations or individuals. Western redcedar is well represented in the region north of the Selway River, but reaches its southern range limits in the central portion of the SBW. Of the major coastal tree species, only grand fir is well distributed throughout the SBW, and extends itself well into central Idaho, and eastward to the Continental Divide in western Montana.

Other major tree species, such as Douglas-fir and ponderosa pine, are widely distributed throughout the low and mid-elevations of the SBW, Douglas-fir has been noted to occur at elevations between 2000 and 9000 ft (600 and 2700 m) in the SBW, although it is uncommon above 5600 ft (1700 m). Ponderosa pine has been noted to occur at elevations up to 6000 ft (1800 m), but is primarily found on the lower, southern and western aspects. Ponderosa pine is not uncommon on streamside sites dominated by redcedar and/or grand fir; it is a minor seral species in such situations, made possible perhaps by the absence of other post-fire seral species in the area such as western larch and western white pine.

Although subalpine fir, Engelmann spruce and lodgepole pine form the major forest cover at elevations above 6000 ft (1800 m), all of these species are found in varying, but smaller amounts in streamside and ravine sites dominated by redcedar and/or grand fir. This is similar to the occurrence of these species in the cedar-hemlock forests in Glacier National Park, Montana (Habeck, 1968). The spruce mentioned in this report does not generally display the same amount of hybridization with white spruce *(Picea glauca)* as observed in western Montana (Habeck and Weaver, 1969), and thus the epithet employed in this report will be *Picea engelmannii.*

FIRE HISTORY

Fire scars, charred wood and charcoal in soil profiles are continual reminders that the forest communities in the SBW have been subject to a long history of fire. Exact fire chronologies have not been investigated in much of the wilderness. Destructive harvest techniques, that would provide the best and most detailed record of past fires have not been employed in this wilderness study. Increment boring of trees displaying external fire scars has been attempted in some cases, but the low degree of precision attained by this technique has not encouraged its wide application.

The written record does provide a good insight of past fire occurrences however. One of the best early efforts was made by J. B. Leiberg in a report published in 1900. Within his report Leiberg provides a detailed map of burned areas encompassing a time period of about 180 years (1719 to 1898). The map, which includes an area far greater than the present SBW, reveals only a few portions that were unaffected by fire during this nearly 2-century period. The data provided by Leiberg reveals that about 35 percent of the Selway River drainage was burned over in the 35-40 years prior to his 1898 field studies. Leiberg primarily faults Indians and white men (hunters, miners, etc.) for this fire disturbance. Nowhere in his lengthy report does Leiberg mention the role of lightning in fire ignitions.

Modern fire records, compiled and maintained by the U.S. Forest Service provide an excellent insight into the remarkable record of fire control during the past century. Between the years 1880 and 1919 large portions of the SBW were affected by numerous fires. For a comparable length of time, between 1920 and 1968, the number of fires exceeding 100 acres (40 ha) was drastically reduced. The fire records reveal that fire ignitions are still common in the SBW, but a majority have been kept to 1 acre (.5 ha) or less in size.

An aerial or an on-the-ground examination of the SBW forest communities reveals several interesting things about fires in this area. The large redcedar groves, occurring along the major rivers and streams are composed of individuals up to 12 ft (4 m) dbh, and of an estimated age of over 4 centuries. Extensive examination of these groves reveals that about one in fifty of the large, old cedars has been damaged and/or extensively burned as a result of lightning strikes in past times. In spite of these ignitions, fire has failed to spread elsewhere within the groves.

An examination of the present-day forest communities in the subalpine fir zone reveals that the mosaic pattern of young, intermediate, old and unforested areas, caused by fires before 1900 can still be easily observed. Forest establishment has not occurred in some areas where charred stumps reveal that an earlier forest once existed. In contrast, other areas burned just a few decades ago are currently supporting dense stands of lodgepole pine. Although moist ravines and wet depressions have not been completely exempt from burning in the past, most of the oldest-aged subalpine fir-Engelmann spruce stands have been observed in such habitats.

Among the drier ponderosa pine communities, trees with multiple numbers of fire scars are not uncommon. The grass and forb understories, together with pine needle litter, appear to be capable of carrying a ground fire annually. Most of the grasses, forbs and shrub species associated with the ponderosa pine communities exhibit rapid post-fire recovery, and it is likely that many past fires in these drier community types were too low in intensity to record their occurrence via fire scars. Some of the stands presently dominated by ponderosa pine appear to occupy sites that Douglas-fir could successfully occupy; data will be presented in this report that indicate that the recent decades of fire exclusion have led to successful invasion of Douglas-fir reproduction within some ponderosa pine stands. Furthermore, the data will show that stands dominated by ponderosa pine seedlings and saplings are becoming increasingly scarce.

The last source of useful historical information are aerial photos. Photos dated 1939 and 1970 have been examined for a variety of points within the wilderness (Fig. 4). The earlier photo coverage reveals that the wilderness landscape supported a high degree of life-form diversity at both the lower and upper elevations up to 1939. Fires prior to 1920 were extensive in many parts of the SBW, and the 1939 photos reflected the multiplicity of successional stages supported on this landscape. The 1970 coverage for the same areas shows that in the 31 year interval a large amount of the life form

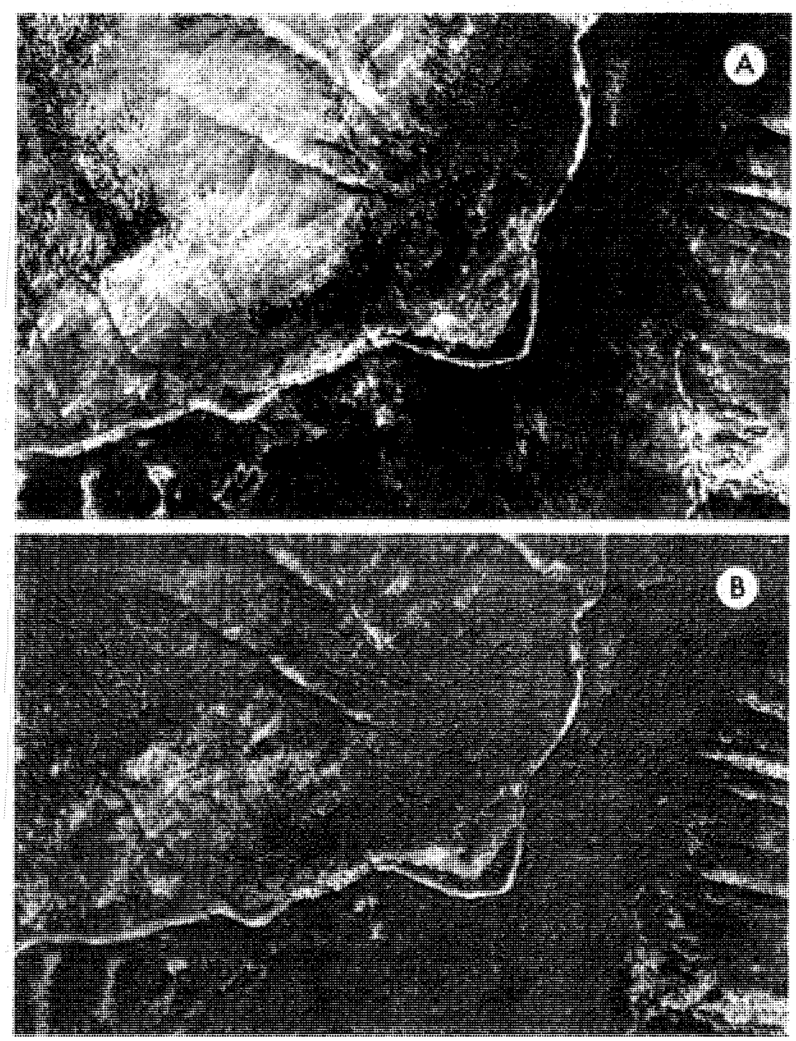

Fig. 4. Paired aerial photos of the Elbow Bend area of the East Fork of Moose Creek, SBW. Photo A was taken in 1939, photo B in 1970. The earlier photo illustrates the extensive brushfields that developed after early fires in 1910. Forest invasion on the upland slopes is well advanced in the 1970 photo. The dense streamside forests in both photos are western redcedar groves, 500 or more years of age.

diversity has been lost. The brush fields and young forests at low and intermediate elevations, that stood out on the 1939 photos, now reveal a markedly reduced contrast to the nearby forests. Recent aerial and ground reconnaissance supports the view that the forest cover in the SBW is taking on a more homogenous character, on greater and greater numbers of contiguous acres.

METHODS

Vegetational Analysis:—During the summer of 1971 a rather extensive examination was made of the forest vegetation throughout much of the SBW. During this period both floristic features and general vegetation distributional patterns were studied in all forest zones. During this extensive reconnaissance an insight was gained (Habeck, 1972) of the influence of past wildfire on these vegetation types, and a preliminary understanding was obtained of the impact of modern fire exclusion. During the summers of 1972 and 1973 a series of 115 stands was selected for detailed analysis of stand composition and structure. Seventy-two of these, up to this time, have also been quantitatively sampled for organic fuel loading.

General stand features were tabulated using a single, circular 375m^2 plot established in each stand. The location of this plot was subjectively determined after the entire stand was examined. The plot site selected was one judged to be representative of the conditions seen in the general stand area. Within the plot all trees over 4.5 ft (1.3 m) in height were tallied by 2-inch (½-decimeter) dbh size classes. Tree seedlings less than 4.5 ft (1.3 m) in height were counted within a centralized 50m^2 circular subplot.

An estimate was made of the canopy coverage contributed by each tree species within each of three diameter size classes: over 12" 4-12" (1-3 dm), and less than 4" (1 dm). Seven coverage classes were employed: T=0-1 percent, 1=1-5 percent, 2=5-25 percent, 3=25-50 percent, 4=50-75 percent, 5=75-95 percent, and 6=95-100 percent. The vascular understory species within the 375m^2 plot were treated in the same way employing the same coverage class scale. A special designation was given to any vascular species noted as occurring within the stand, but not occurring within the sample plot; thus a total species listing was compiled for each stand studied.

The 115 stands from which detailed information has been tallied represent a wide variety of forest types and ages found at all elevations between 2300 and 6600 ft (700 and 2000 m) and on numerous slopes and aspects.

Fuel Analysis:—Fuel data were collected by a specially trained fuel appraisal team employed by the USDA Forest Service (Northern Forest Fire Laboratory). Fuel data collection and laboratory analysis followed procedures developed by Dr. James K. Brown (Brown, 1970, 1971a, 1971b). The details of the fuel sampling methods will not be repeated here; however, it is of importance to list the kinds of fuel information determined by these techniques.

The following fuel categories or fuel characteristics were determined: (1) branchwood fuels, partitioned into three diameter size classes—0-0.5 cm, 0.5-1.6cm, and 1.6-10.0 cm; (2) dead ground fuels (limbs and stems) greater than 10.0 cm in diameter, and designated as either in sound or rotten condition; (3) weight and depth of the litter layer; (4) weights of living and dead brush fuels; (5) weights of living and dead grass-forb fuels; (6) weight and depth of duff layer.

The fuel analysis also includes subtotals of several of the categories listed above: (7) fine fuels, a summation of 0-0.5 and 0.5-1.6 cm branchwood fuels, plus litter weights and dead grass-forb weights; (8) total 0-10.0 cm fuels, a summation of 1.6-10.0 cm branchwood fuels, dead shrub weights and total fine fuels; (9) total organic fuel loading, summation of all fuel categories, of all sizes. All of the fuel loading values are expressed in metric tons per hectare.

Forest Stand Ordination:—The 115 forest communities were ordinated utilizing the Index of Similarity method as described by Bray and Curtis (1957) and Beals (1960). The results of this ordination are shown in Figures 5 and 6.

Direct Gradient Analysis:—In an effort to attain further understanding of the possible relationships between stand development

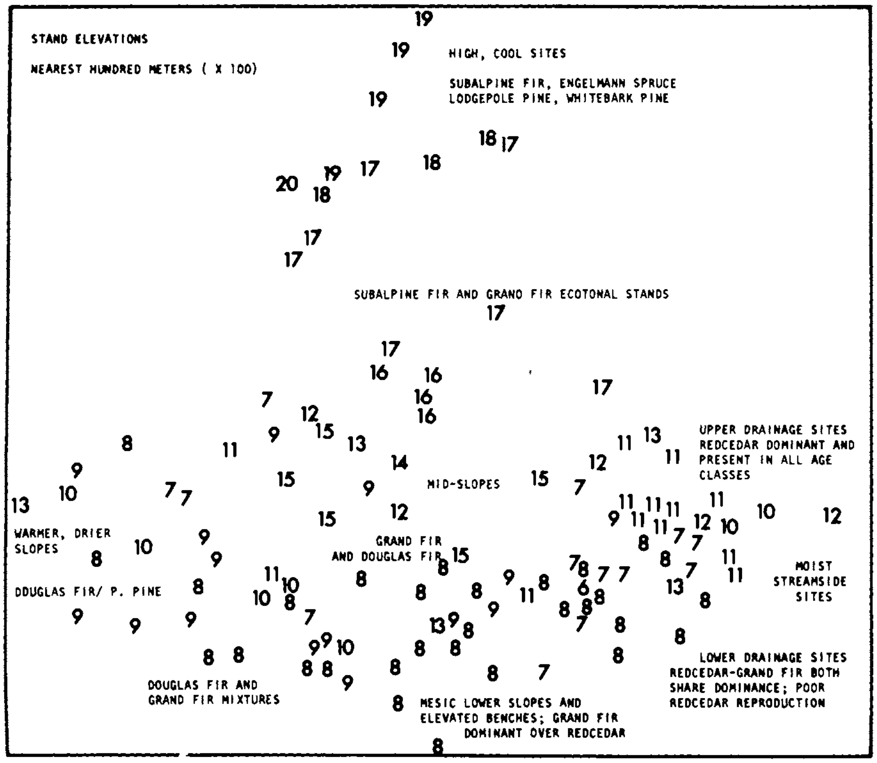

Fig. 5. Forest ordination illustrating stand distributions and site elevations. Each elevation value represents the location of a single stand within the ordination. Descriptive notes are included that describe the general character of the stands.

and organic fuel accumulations, the stand samples taken from each forest community type were arranged on the basis of actual or estimated age. At this stage of the wilderness fire investigations, it became recognized that arriving at an exact figure representative of a stand's age is often a tenuous procedure. The least difficulty and the greatest accuracy is enjoyed in stands that were mostly or entirely re-established following a high intensity fire. Low and moderate intensity fires leave many trees intact—often the largest trees, but occasionally trees in smaller diameter classes too. New tree repro-

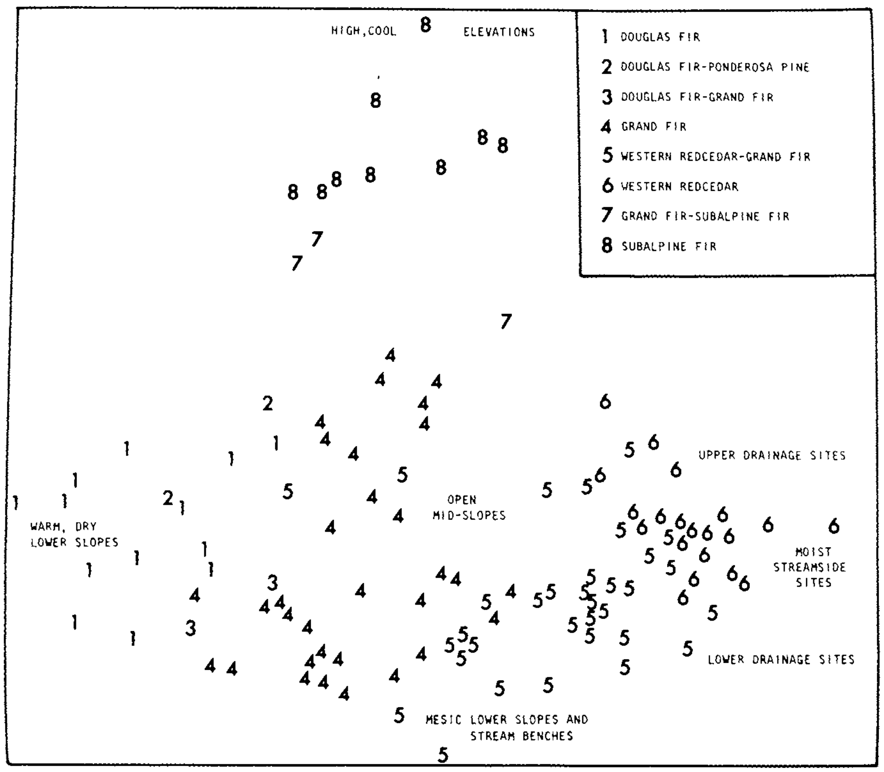

Fig. 6. Distribution of major forest community types within the stand ordination. Each individual stand is number-keyed to one of the eight types delineated.

duction joining these survivors creates stands composed of trees of various numbers, sizes, and ages.

Internal stem decay in both redcedar and grand fir often present problems in stand aging where these trees are dominants. Estimates of stand ages were arrived at by extrapolating growth rates exhibited in the outer, sound wood to the entire diameter of the trees.

RESULTS

General Organization of Vegetation:—Stand ordinations of the sort depicted in Figures 5 and 6 have been demonstrated to be very useful in detecting and describing vegetation patternizations and provide an avenue to understanding the relationships between environmental factors and plants, and plant communities. Within Figure 6 eight forest community types have been delineated using a number symbol system. The driest, warmest aspects, on low and midslopes, are currently dominated by mixtures of ponderosa pine and Douglas-fir (Types 1 and 2). These forest types grade into communities dominated by Douglas-fir and grand fir (Types 3 and 4) which occur on generally well-drained slopes between 2600 and 5600 feet (800 to 1700 m). Grand fir is the most widespread tree species in this wilderness area; although it reaches its best development in the stands located in the central portion of the ordination, its presence has been noted in many other communities too.

With increasing site moisture redcedar becomes more common, but in most instances it is found in close association with grand fir (Type 5). Grand fir is rarely absent from stands dominated by redcedar. The few cases where this comes close to occurring involve old-aged, streamside cedar groves. Cedar is longer-lived than grand fir, and in groves that have remained intact for more than 400 years, grand fir is a very minor associate.

The community distribution pattern shown in Figure 6 reveals that several of the stands (Type 7) represent mixtures of both subalpine fir and grand fir. These transitional mixtures occur at elevations between 5600 and 5800 ft (1700 to 1750 m). At elevations above 5800 ft (1750 m) subalpine fir becomes distinctly more dominant, although even at elevations up to 6600 ft (2000 m) some amount of grand fir has been encountered.

The vegetational organization of the SBW forest communities, as illustrated by this ordination, is a continuum; compositional discontinuities do not exist. The elevation and moisture factors that exert a major influence on stand composition and distribution appear to be very well related to the vegetation patterns seen within the ordination.

The question arises as to what influence does successional development have on stand compositions and stand positions within the ordination. Although fire has been markedly reduced in the last

½ century, within the life-span of these community types this fire exclusion has influenced mostly the production of younger developmental forest communities (0-50 years old). Thus much of the forest vegetation in all parts of the SBW has been gradually developing towards more mature stages. How does this affect a stand's position within the ordination? An examination of the individual stands within each community type reveals that the younger, developing stands within each major grouping are often located slightly to the left (towards the dry end of the ordination) of the stands of mature or nearly mature status of the same community type. This juxtaposition is the result of compositional changes occurring between developing and mature stages, and involves primarily changes in the cover values for sets of species that both younger and older stands share in common.

Individual Tree Species:—Further elaboration of the current ecological status of several of the major tree species in the SBW can be attained from an examination of Figures 7-10. In Figure 7 canopy coverage data for both mature and sapling-sized ponderosa pine are represented. Lines are drawn that enclose the stands that exhibit similar levels of cover for trees over 12″ dbh (mature) and saplings below 4″ dbh. This figure indicates that the larger, older-aged ponderosa pine occur in a greater number of stands, particularly those in the central portion of the ordination. It is not uncommon to encounter old-growth ponderosa pine in stands presently dominated by grand fir and redcedar. In contrast, present-day pine reproduction is more confined to stands on the left-hand side of the ordination, and it is noteworthy that only a few stands display sapling cover values over 3 percent. The reduction in the general abundance of ponderosa pine in the smaller, younger classes in the SBW may be illustrative of the impact of fire exclusion in this area over the past 50 years.

A similar set of data are provided for Douglas-fir in Figure 8. Here, we see a rather distinct shift to the left of the cover values for Douglas-fir. This species is considered a major seral species in the grand fir/cedar stands located in the central and right-hand portion of the ordination. There are many stands located just left of the ordination

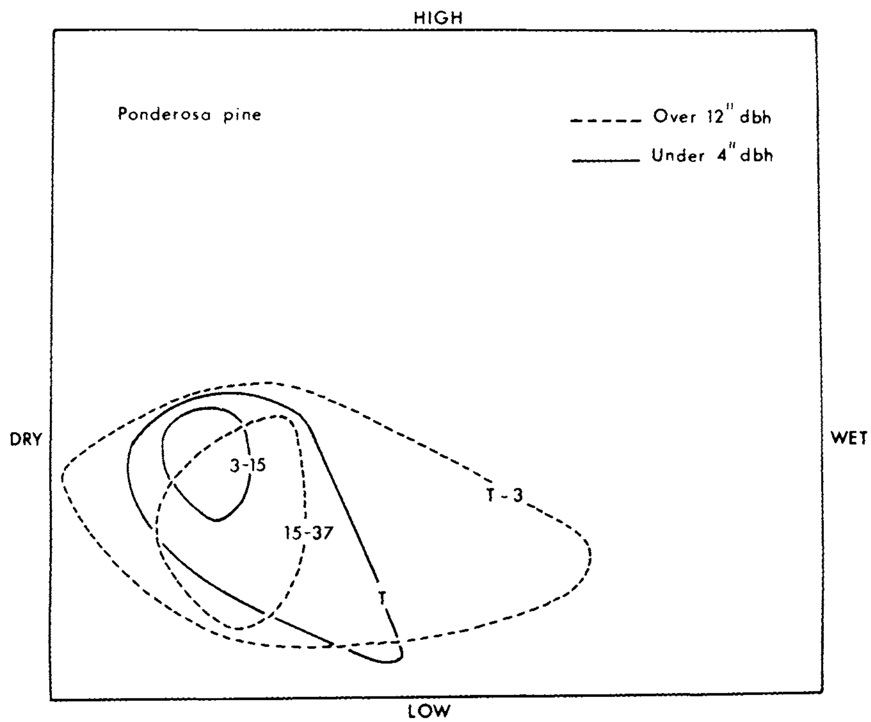

Fig. 7. Graphical analysis of the distribution patterns of larger, older ponderosa pine and smaller, younger pines within the forest stand ordination. Lines enclose stands that display either high or low cover percentages for the two size/age classes of pine. T=less than 1 percent cover. See text for further explanations.

mid-region where Douglas-fir is present in all size and age classes. In these stands Douglas fir functions as a co-dominant with grand fir. A comparison of the data for ponderosa pine (Fig. 7) and Douglas fir indicates that many of the stands currently dominated by ponderosa pine are being invaded by Douglas-fir reproduction. Periodic ground fires in the past no doubt maintained some areas as ponderosa pine savannah, and the near absence of recent fire has encouraged the successful entrance of Douglas-fir. With continued fire suppression it is likely that a greater number of stands in the SBW will achieve high cover values for Douglas-fir.

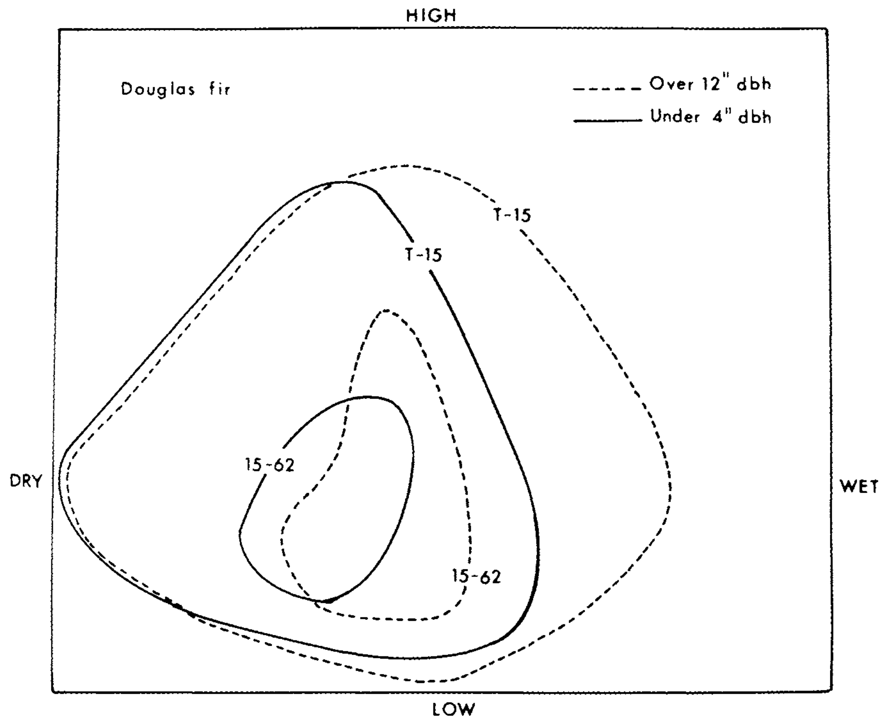

Fig. 8. Ordinational analysis of Douglas-fir populations. See Figure 7 and text for explanations.

Grand fir (Fig. 9) achieves its highest cover values in the stands located in the lower, central portion of the ordination. It appears that grand fir reproduction is best displayed in these mesic site stands and even extends into many of the wetter, cedar-dominated stands. It is clear that both grand fir and Douglas-fir co-exist on a large portion of the SBW landscape. A close comparison of each tree's reproduction data reveals that the best performance of Douglas-fir (15-62% cover) is restricted in scope and located left of center, whereas abundant grand fir reproduction (15-62% cover) is distributed throughout a large number of stands within the ordination. The information in Figure 9 also indicates that grand fir reproduc-

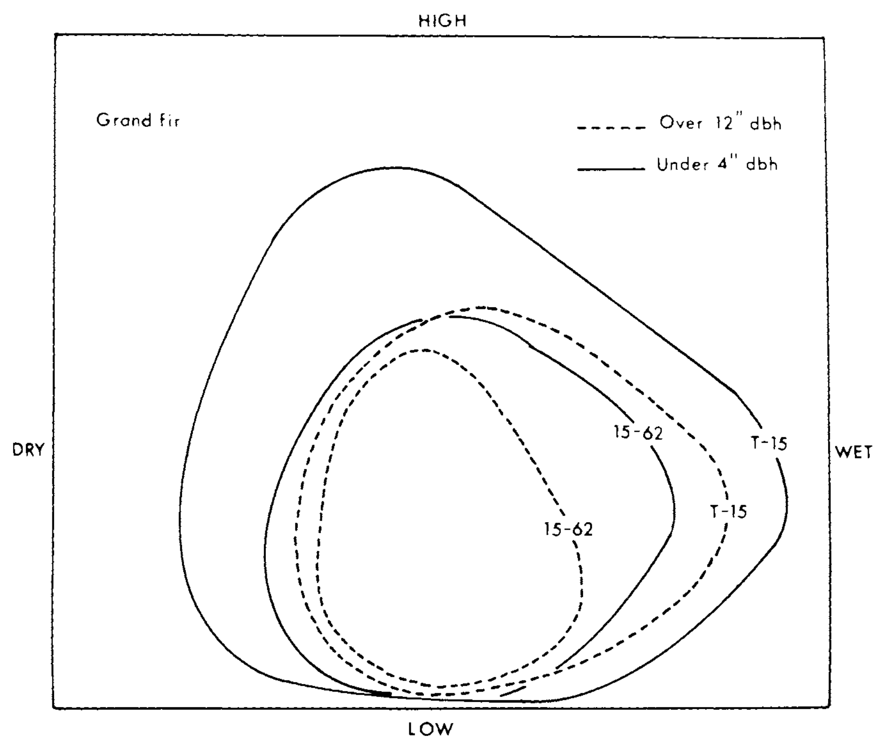

Fig. 9. Ordinational analysis of grand fir populations. See Figure 7 and text for explanations.

tion currently exists in stands not now supporting grand fir of larger size. In fact, it is noted that grand fir saplings are occurring within warmer, dry sites; higher, cooler sites; and even wetter, streamside sites dominated by redcedar. It is not fully understood why grand fir is expanding itself in all directions. The expansion of the fire-sensitive grand fir into the drier ponderosa pine/Douglas-fir stands (left-hand side of ordination) may be a relatively recent event that is associated with fire exclusion. Its expansion into sites dominated by redcedar may be the consequence of redcedar failing to reproduce itself well in streamside habitats located within the lower reaches of the river drainages. Its extension into high elevations, and mixing with subalpine fir, may reflect altered burning regimes too.

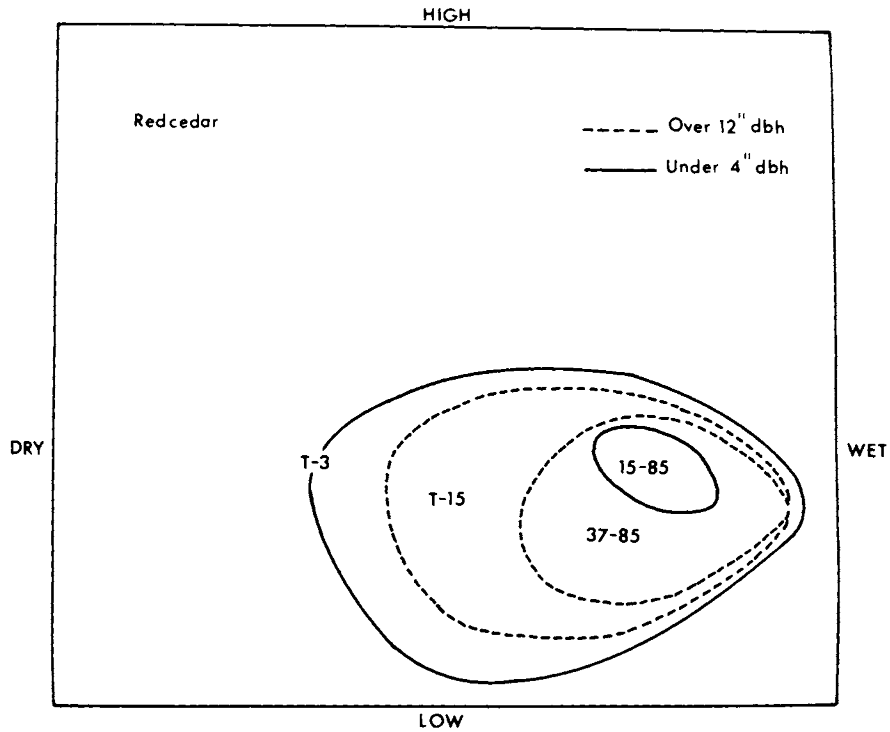

Fig. 10. Ordinational analysis of western redcedar populations. See Figure 7 and text for explanations.

The fourth species, redcedar, is much different (Fig. 10) from the other species discussed. There is a pronounced restriction of cedar-dominated stands to the right-hand section of the ordination, although mature cedar trees are not uncommonly found occurring in grand fir stands on better-drained sites. Redcedar reproduction was observed to be successful in only a few of the cedar-dominated stands. The stands where this was observed (15-85% cover) are those found in the mid- and upper segments (3500 ft/1100 m or higher) of the wilderness drainage systems. Redcedar reaches its southern range limits within the SBW, and this may account for its reproductive difficulties in stands where mature cedars, centuries old, are currently established.

Subalpine fir, Engelmann spruce and lodgepole pine, whose individual cover values are not illustrated, attain their maximum dominance within the stands located in the upper portion of the ordination (Community Types 7 and 8, Fig. 6). All three of these tree species do occur at lower elevations however. Lodgepole pine functions as a post-fire pioneer species on both stream terraces and mesic, lower slopes; Engelmann spruce is often present in small amounts in most of the streamside and ravine stands dominated by grand fir and/or redcedar; subalpine fir shows the greatest degree of restrictiveness to elevations above 5600 ft (1700 m), but occasionally has been noted in cedar-dominated stands at elevations down to 4000 ft (1200 m).

Several cases have been noted, at elevations above 5600 ft (1700 m), where lodgepole pine displays several age classes in the same stand, with one or two fire scars present on the older, larger lodgepole pines.

Examination of the upper elevation stand data reveals that of ten stands that support populations of lodgepole pine 4-12″ dbh or greater, eight also have some amount (few to many) of lodgepole reproduction in the smaller and younger seedling and sapling categories. At lower elevations, between 4300 and 5500 ft (1300 to 1650 m), five out of ten stands with older lodgepole pine also have some younger lodgepole reproduction present. Among five stands below 4300 ft (1300 m) exhibiting some older lodgepole pine, only one also has younger lodgepole pine present. Thus at lower elevations lodgepole pine assumes the more classical single-generation behavior.

Understory Vegetation:—Well over 200 species of vascular understory species have been recorded in the stands that have been investigated up to this time. Only 10 to 15 percent of these contribute to the major understory cover within the various forest community types. Table 1 provides a listing of the major shrub and herbaceous species characteristic of one or more of the forest types arbitrarily delineated. The somewhat open canopied ponderosa pine/Douglas fir communities generally have well developed understories dominated by forbs and bunch grasses or combinations of grasses, forbs

Table 1. Distributional occurrences of major shrub and herbaceous species within each of the forest community types. M=Major Importance; m=Minor Importance; t=Uncommon Occurrences.

	Forest Community Types				
Species & Life Form	Ponderosa Pine Douglas fir	Douglas fir Grand fir	Grand fir Redcedar	Redcedar Groves	Subalpine fir/Spruce
Festuca idahoensis/grass	M				
Agropyron spicatum/grass	M				
Balsamorhiza sagittata/forb	M				
Carex geyeri/sedge	M				
Achillea millefolium/forb	m				
Physocarpus malvaceus/shrub	M	m			
Ligusticum verticillatum/forb	M	M			
Rosa gymnocarpa/shrub	m	m			
Calamagrostis rubescens/grass	m	m			
Symphoricarpos albus/shrub	M	m	m	t	
Amelanchier alnifolia/shrub	M	m	t	t	t
Spiraea betulifolia/shrub	M	M	m	m	
Berberis repens/shrub	m	m	m	m	
Vaccinium globulare/shrub		M	M	m	M
Lonicera utahensis/shrub		m	m	t	t
Acer glabrum/shrub		m	m		
Linnaea borealis/herb		M	M	t	
Rubus parviflorus/shrub		m	m	m	
Coptis occidentalis/herb		M	M	M	m
Xerophyllum tenax/herb		t	t	t	M
Clintonia uniflora/herb		m	M	M	
Menziesia ferruginea/shrub			t	m	M
Circaea alpina/herb			t	M	
Athyrium filix-femina/fern				M	
Vaccinium scoparium/shrub					M
Ledum glandulosum/shrub					m

and various shrub species. Within the more mesic and more heavily-shaded grand fir and cedar communities, the shrub layers are only poorly developed, and the ground layer is generally characterized by shade-tolerant herbs, including an assortment of fern species. The subalpine fir communities display many of the same species found at lower elevations, but there is often a pronounced shift in species abundance, either increasing or decreasing in coverage percentage at elevations above 6000 ft (1800 m).

Collectively, the vascular plants included in this 115 stand sample each display individualistic distribution patterns, which further supports the view that the SBW vegetation exists as a continuum. Species diversity among these stands is highly variable. The stands sampled at higher elevations generally have ten or fewer vascular plants; the richest array of species (about 50) occurs within old-aged cedar/grand fir communities located on streamside sites. Among the stands studied up to this time, it appears that understory species diversity increases under the following circumstances: from higher to lower elevations; from drier to wetter habitats; and from younger to older communities. Thus, young lodgepole pine stands on well-drained slopes at higher elevations have the lowest diversity; and old-aged, stream-level cedar groves have the richest flora. The data in Figure 11 provide further illustration of these relationships.

Forest Succession:—Although early stages of forest development (0-50 years) are not readily found in all of the SBW zones, the 115 stands that were sampled do show an age gradient from less than 50 years to over 500 years. Within each of the forest community types (Fig. 6), it is possible to separate the stands into younger, developing communities and older, mature forests (Table 2). When structural and compositional data are averaged for the stands in these developing and mature groupings, distinct differences are evident. A summary of these results for each community type are presented in Tables 3-7.

A. Ponderosa Pine-Douglas Fir

The stands dominated by mixtures of ponderosa pine and Douglas fir have been partitioned into four categories as shown in Table 3. Stands occurring on warm, southern aspects (S, SE, SW) are summarized separately from stands occurring on cooler aspects (E, NE, N, NW). A further separation is made within these warm-aspect and cool-aspect stand groupings based on an estimated time since fire last affected the stands. Very few of the stands summarized in Table 3 have experienced completely destructive fires during the past century, although ground fires have occurred periodically. It was not possible to separate stands into younger and older categories based on tree aging. All of the stands averaged in Table 3 support pon-

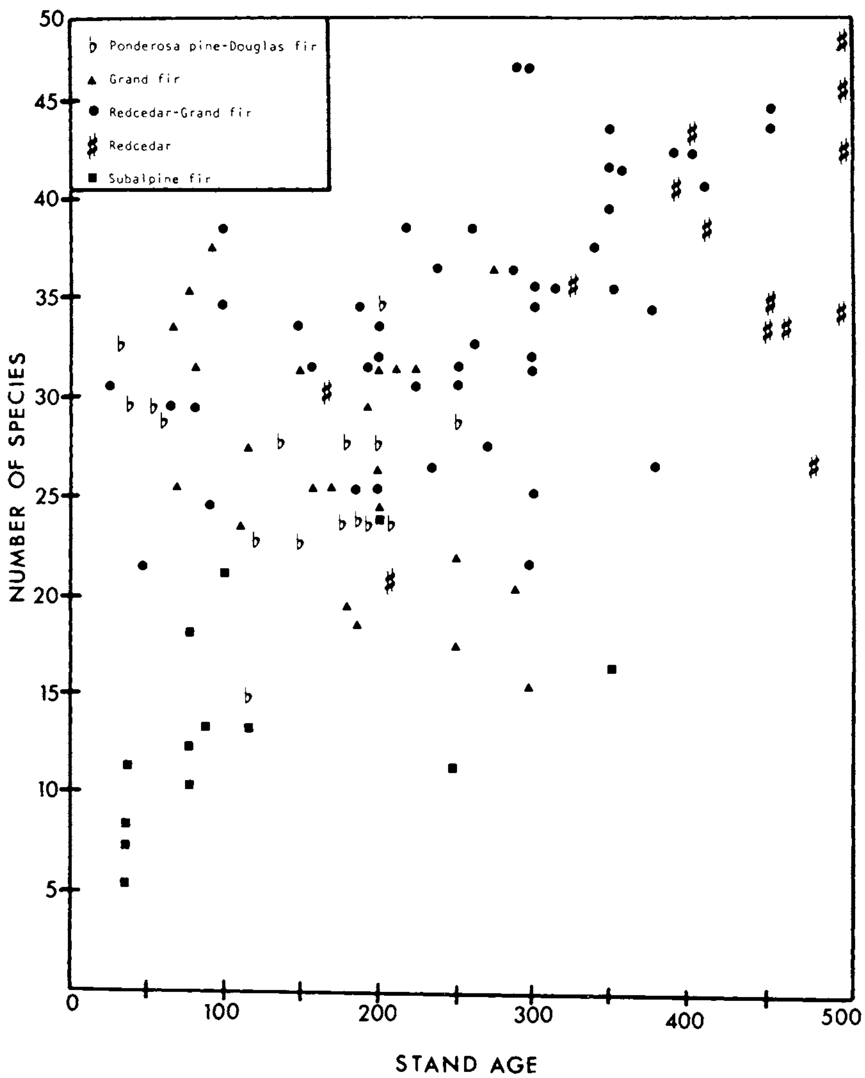

Fig. 11. Vascular species diversity related to stand ages. Young forests at high elevations have the lowest diversity; old-aged cedar stands have the richest vascular floras.

Table 2. General characteristics of forest fuel groupings partitioned in the Figure 12 ordination. Tree Density: Number of trees, over 4.5 feet in height, per acre. Basal Area: number of square feet per acre. Species Diversity: Number of vascular plant species.

Grouping	Tree Dominants and Features	Average Age	Tree Density	Basal Area	Species Diversity
1	Ponderosa pine/Douglas fir; duff<1 cm	**	75	75	23
2	Ponderosa pine/Douglas fir; duff>1 cm	**	185	115	20
3	Douglas fir/Ponderosa pine; duff<1 cm	**	93	40	27
4	Douglas fir/Ponderosa pine; duff>1 cm	**	140	120	29
5	Grand fir/Douglas fir; Young; Over 4000′	125	320	95	25
6	Grand fir/Douglas fir; Mature, Over 4000′	250	500	130	20
7	Grand fir/Douglas fir; Young, Below 4000′	105	200	72	31
8	Grand fir/Douglas fir; Mature, Below 4000′	170	315	217	28
9	Redcedar/Grand fir; Young; Over 4000′	65	430	99	31
10	Redcedar/Grand fir; Mature, Over 4000′	240	355	145	32
11	Redcedar/Grand fir: Young, Below 2600′	190	400	230	28
12	Redcedar/Grand fir; Mature, Below 2600′	360	300	500	39
13	Redcedar Groves; less than 450 years old	315	350	340	28
14	Redcedar Groves, older than 450 years	485	125	600	33
15	Lodgepole/Subalpine fir; pioneer	40	360	45	8
16	Subalpine fir/Lodgepole; developing	85	390	90	11
17	Subalpine fir/Lodgepole; moist site seral	100	330	95	15
18	Subalpine fir/Spruce; mature, moist sites	250	240	140	17

**Average age about 200 years; duff layer depth, above or below 1.0cm, used as index of time since stands were last influenced by ground fire. See text.

derosa pine and/or Douglas-fir that are approximately 200 years old; many of these older, larger trees exhibit one to three external fire scars. Based on detailed field observations and interpretations of data originating from other SBW forests where stand aging was less of a problem, a separation among these ponderosa pine/Douglas-fir stands was based on depth of the duff layer.

Stands exhibiting duff layer depths less than 1.0 cm were considered to have experienced ground fire more recently than those with duff layers over 1.0 cm. Utilizing this criterion, the four subgroupings of stands were established (Table 3). Within each, stand structural and compositional features have been averaged. The stand organization achieved in this manner provides further insight into the differences among these communities induced by site conditions and by past fire.

Table 3. Summary of compositional features for a series of stands dominated by *Pinus ponderosa* and *Pseudotsuga menziesii.* The stands have been partitioned into two groups: A=warm aspect communities with grass-forb understories, and B=cool aspect stands with grass-shrub understories. Within each of these groups comparison is made between stands with duff layer depths below 1.0 cm, and stands with duff layer accumulations above 1.0 cm.

	A. Warm Aspect Stands		B. Cool Aspect Stands	
Stand Features	(1) Duff Depth Under 1 cm	(2) Duff Depth Over 1 cm	(3) Duff Depth Under 1 cm	(4) Duff Depth Over 1 cm
Number of Stands	3	3	3	4
Tree Coverage Percentages:				
Pinus ponderosa:				
Over 12" dbh	11.0	30.0	2.0	18.0
4-12" dbh	14.3	7.0	2.0	1.5
Under 4" dbh	1.7	0.7	5.3	0
Pseudotsuga menziesii:				
Over 12" dbh	1.0	5.3	0.7	11.5
4-12" dbh	0.3	2.0	21.3	20.7
Under 4"dbh	0.3	21.0	1.0	2.5
Abies grandis:				
Under 4"dbh	0	0.3	0	1.2
Percentage Coverage--Major Understory Species:				
Balsamorhiza sagittata	13.7	1.7	5.3	0
Agropyron spicatum	11.0	1.3	17.3	0.7
Festuca idahoensis	11.0	1.0	1.0	0
Calamagrostis rubescens	t	1.0	5.0	9.0
Carex geyeri	18.3	2.3	12.7	3.7
Physocarpus malvaceus	0.3	0	22.3	40.2
Symphoricarpos albus	0.3	5.0	10.0	12.0
Holodiscus discolor	0	0	5.0	13.2

t=trace

Ponderosa pine achieves its highest coverage values on the warmer aspects. Pine reproduction is more common on sites that have been influenced by fire in recent decades, and is nearly absent on sites where fire has not been a recent influence. Douglas-fir occurs on both warm and cool aspects, but is clearly more dominant on the cooler sites. Douglas-fir reproduction has become very common in warm-aspect stands not recently affected by ground fires. The coverage data for both species clearly reflects a shift or potential shift from an earlier dominance by ponderosa pine to a current or future dominance by Douglas-fir. Although grand fir is only occasionally found in these drier community types, it may be significant that the small amount of grand fir reproduction that was noted occurs only in the stands that have not experienced recent fire.

Tree density and tree basal area values also differ markedly between the stands subject to recent fires versus those not so influenced. The abrupt shifts in coverage values for grasses, forbs and shrubs are probably directly related to increased tree densities and increased shading that occurs when fire is removed as a forest influence. Among the cool-aspect stands grasses are nearly eliminated in the absence of fire, and shrub cover greatly increases. Among the warm-aspect stands, grasses and forbs are also reduced, but there is not a concurrent increase in shrub species.

B. Grand Fir-Douglas-Fir

Table 4 provides a summary of data originating from a group of stands dominated by grand fir and Douglas-fir. The 20 stands composing this group occupy a wide elevational range; based on interpretations of the original stand ordination (Figs. 5 and 6) and differences in understory compositions, these stands were initially separated into a group composed of stands occurring at or above 4000 ft (1200 m) and a second group of stands occurring at elevations below this level. Then a separation was made within each of these elevational groupings based on stand development. Developing stands, less than a century in age, were averaged separately from older stands well over a century in age.

Among the data for tree species (Table 4) it is evident that ponderosa pine exists as a residual pioneer species only in the stands at lower elevations, whereas lodgepole pine is significantly more abundant in the higher stands, particularly in the developing stands. Both grand fir and Douglas-fir are well represented in the developing communities at both higher and lower elevations. Douglas-fir, however, is reproducing itself only poorly in the mature stands. Past fires led to dominance of lodgepole pine, ponderosa pine and Douglas fir, but current successional patterns appear to favor the ultimate dominance of grand fir.

Table 4. Summary of compositional features for a series of stands dominated by *Abies grandis* and mixtures of *Abies grandis* and *Pseudotsuga menziesii*. The data are averages of values for stands occurring (A) above 1200 meters and (B) stands located below 1200 meters. Within each of these groups, data are averaged separately for developing communities and mature communities.

	A. Over 1200 meters		B. Under 1200 meters	
Stand Features	(5) Developing Stands	(6) Mature Stands	(7) Developing Stands	(8) Mature Stands
Number of Stands	4	4	6	6
Tree Coverage Percentages:				
Abies grandis:				
Over 12″ dbh	5.7	13.5	11.0	20.5
Under 4″ dbh	28.5	32.2	6.0	18.0
Pseudotsuga menziesii:				
Over 12″ dbh	13.2	14.8	10.3	4.6
Under 4″ dbh	13.7	0.7	6.7	0.7
Pinus ponderosa:				
Over 12″ dbh	0	0	1.0	15.2
Under 4″ dbh	0	0	0	0
Pinus contorta:				
4-12″ dbh	13.0	4.0	0	0.5
Under 4″ dbh	1.0	3.7	0	0.1
Major Understory Species Percentage Cover:				
Vaccinium globulare	55.0	35.0	0.7	0.2
Xerophyllum tenax	22.2	11.0	0	0.3
Menziesia ferruginea	9.7	0.2	0	0
Coptis occidentalis	34.0	26.0	23.0	24.0
Symphoricarpos albus	0	0	4.7	8.3
Acer glabrum	0.	0	6.5	7.3

Understory species exhibit pronounced shifts in abundance both among the higher and lower elevational groupings, and between the developing and mature stages of development. Huckleberry *(Vaccinium globulare)* is very common in the developing, high elevation stands, but is reduced in later stages of succession. Huckleberry is uncommon among the lower stands. Beargrass *(Xerophyllum tenax)* shows a very similar set of responses. Goldthread *(Coptis occidentalis)* is notable for its relative lack of change among these sets of stands.

C. Redcedar-Grand Fir

Table 5 provides summarized averages for stands dominated by redcedar and grand fir. Here too, among the stands sampled it appeared useful to separate the stands initially on the basis of site elevation—those above 4000 ft (1200 m) and those below 2600 ft (800 m). Field observations indicate that stands of this community type do occur between 2600 and 4000 ft (800 to 1200 m), but none are included in the data presently available.

Again, within each of the elevational groupings, subgroupings based on age and successional development were delineated. The

Table 5. Summary of compositional features for a series of stands dominated by *Abies grandis* and *Thuja plicata*. The data are averages of values for stands occurring (A) above 1200 meters elevation, and (B) stands below 800 meters. Within each of these groups, data are averaged separately for developing communities, and mature communities.

	A. Over 1200 Meters		B. Under 800 Meters	
Stand Features	(9) Developing Stands	(10) Mature Stands	(11) Developing Stands	(12) Mature Stands
Number of Stands	2	2	7	5
Tree Coverage Percentage:				
Abies grandis:				
Over 12″ dbh	0.5	15.0	19.4	19.5
Under 4″ dbh	37.0	26.0	16.6	4.9
Thuja plicata:				
Over 12″ dbh	0.5	2.0	10.7	52.2
Under 4″ dbh	9.0	3.0	1.3	0.4
Pseudotsuga menziesii:				
Over 12″ dbh	19.0	3.0	1.7	0.6
Under 4″ dbh	18.5	7.5	0.3	0
Percentage Coverage—Major Understory Species:				
Xerophyllum tenax	7.5	9.0	0.1	0.2
Vaccinium globulare	20.0	9.0	0	0.6
Clintonia uniflora	1.0	9.0	8.8	30.7
Linnaea borealis	1.0	9.0	24.0	40.0
Coptis occidentalis	20.0	38.5	25.0	49.5
Asarum caudatum	0	0	0.1	11.2
Tiarella trifoliata	0	0	0.6	18.3
Galium triflorum	0	0	3.0	9.6

ɪrray of stands sampled at lower elevations does not include many hat are less than a century in age, and thus the developing stands, ɜveraging only 10 years less than 2 centuries, are not directly comparable to the developing stands sampled at higher elevations (average: 65 years). The redcedar-grand fir communities at lower elevations occupy moist stream terraces where fire frequencies appear to be low, and numerous stands over 3 centuries in age were encountered.

Although redcedar and grand fir jointly dominate most of these stands, the proportion of each does vary between upper and lower elevational sites. Redcedar is certainly more common at lower elevations. Grand fir is not uncommon among the lower stands, but appears to be more common at the higher elevations where it often shares stand dominance with Douglas fir. Douglas-fir becomes only a minor associate of grand fir in the upper, mature stands, and is nearly absent in the lower, mature stands.

One of the most interesting features in this set of data relates to redcedar's rather poor reproductive capacity within the lower, stream-terrace stands. Large redcedars make a major contribution to the high average basal area for the mature, lower stands, but redcedar seedlings and saplings are not exhibiting a capability of assuring perpetuation of cedar in these stands. This may be indicative of a potential range reduction of redcedar in this part of northern Idaho.

The understory data reveal elevational preferences among some of the species, as well as significant increments or reductions in cover between developing and mature stages of the forest communities. This latter type of change is even evident when the nearly 2-century-old developing stands at low elevations are compared with the nearly 4-century-old mature stands.

D. Redcedar Groves

Table 6 summarizes data available for a series of streamside redcedar groves. The sites for all of the stands reported are located immediately adjacent to rivers and streams active throughout the year, and positioned on topographically level terrain, referred to as

Table 6. Compositional features for a series of stands dominated by *Thuja plicata,* and minor amounts of *Abies grandis.* All occur on moist streamside sites. The stands have been divided into two groups: A=stands with estimated ages below 450 years, and B=with ages over 450 years.

Stand Features	Stands Under 450 Years (13)	Stands Over 450 Years (14)
Number of Stands	6	8
Tree Coverage Percentages:		
Thuja plicata:		
Over 12″ dbh	38.0	58.6
4-12″ dbh	14.3	5.5
Under 4″ dbh	31.3	5.0
Abies grandis:		
Over 12″ dbh	6.3	3.4
4-12″ dbh	15.7	4.9
Under 4″ dbh	9.8	3.2
Pseudotsuga menziesii:		
Over 12″ dbh	3.2	0
Percentage Cover—Major Understory Species:		
Taxus brevifolia	11.8	11.2
Vaccinium globulare	6.3	0.1
Menziesia ferruginea	6.7	0.4
Clintonia uniflora	13.0	8.0
Coptis occidentalis	37.5	26.1
Adiantum pedatum	0.1	13.7
Athyrium filix-femina	0.5	16.2
Gymnocarpium dryopteris	0.3	49.7
Circaea alpina	0	65.4

"cedar flats." The older cedar groves are majestic-looking communities composed nearly exclusively of cedars that have achieved advanced age (over 450 years to an estimated 600 years) and very large size (50 to 70″ dbh). No really young cedar grove stands are included in Table 6; the youngest individual stand is about 2 centuries in age. The 14 stands sampled have been divided into stands less than 450 years and those over 450 years.

The data in Table 6 reveal that redcedar is well represented in all size classes in the stands less than 450 years old, but among the oldest stands, redcedar reproduction is drastically reduced. In fact, cedar reproduction is only well represented in two of the eight older stands averaged together. Both of these older groves are located in upper drainages, above 3500 ft (1200 m), whereas the remaining six stands displaying only minimal cedar reproduction are located in the lower reaches of the SBW river and stream drainages.

Grand fir has always been observed to be present in some amounts in the redcedar groves. It is a common associate of cedar in the younger groves, and remains a minor, but constant associate even in the oldest groves. Grand fir is a highly shade tolerant tree species, but is not as long-lived as redcedar. Stem and root rot cause a moderate amount of mortality among grand firs of all ages and sizes. It does have a high reproductive capacity, however, on a wide range of moisture and light conditions, and appears capable of maintaining itself in low numbers even in old-age cedar stands.

Among the understory species, one of the notable compositional shifts seen between the two age-classes of stands involves the responses of fern species. Although the same assortment of ferns can be found in both age groups, it is within the oldest groves that fern cover greatly increases. Another common species, western yew *(Taxus brevifolia)*, show very little change, but the enchanter's night-nightshade *(Circaea alpina)* displays a complete confinement to the older cedar grove communities.

E. Subalpine Fir-Lodgepole Pine:

The last set of summarized community data for stands dominated by subalpine fir, Engelmann spruce and lodgepole pine, is presented in Table 7. Forests occurring above 5600 feet (1700 m) have been subjected to frequent fire in the past, and with a few exceptions these have been fires that have led to the complete replacement of the burned forests. Poorly drained sites and sites that are only gently sloping have often carried only light ground fires, or have been affected by fire less frequently. In moist depressions and ravines old-aged subalpine fir-Engelmann spruce stands are encountered often surrounded by pioneer or early seral stands dominated by lodgepole pine. On gently rolling terrain, light ground fires have produced multiple-aged lodgepole pine communities.

The data in Table 7 are divided into two sections representing

Table 7. Summary of compositional features for a series of stands dominated by *Abies lasiocarpa* and *Pinus contorta*, occurring at elevations between 1700 and 2000 meters. These stands have been divided into a group occupying well-drained sites, and a second group occurring in moist habitats. Within each of these two groups, younger stands and older stands are separated.

	Well-Drained Sites		Moist Habitats	
Stand Features	(15) Pioneer Stands	(16) Developing Stands	(17) Developing Stands	(18) Mature Stands
Number of Stands	4	3	3	3
Tree Coverage Percentages:				
Abies lasiocarpa:				
Over 12″ dbh	0	0	1.0	25.0
Under 4″ dbh	28.5	14.3	45.6	22.3
Pinus contorta:				
4-12″ dbh	26.0	38.0	18.0	1.0
Under 4″ dbh	14.5	5.7	1.0	0
Picea engelmannii:				
Over 12″ dbh	0	0	0	34.0
Under 4″ dbh	1.0	2.3	6.0	0.7
Pseudotsuga menziesii:				
Over 12″ dbh	1.0	12.7	5.0	0
Under 4″ dbh	1.7	10.3	0.3	0
Percentage Coverage Major Understory Species:				
Xerophyllum tenax	50.0	37.0	26.0	10.0
Vaccinium scoparium	50.0	37.0	18.0	5.0
Vaccinium globulare	8.0	70.0	37.0	38.0
Menziesia ferruginea	0.7	1.0	22.0	45.0
Coptis occidentalis	0	0.7	5.0	13.3
Pyrola secunda	0	0	0	2.3

well-drained, open-slope stands, and moist habitat types. Within each of these site categories, the stands sampled have been segregated into developmental stages and older stands. Most of the drier-site stands are less than 100 years old; most of the stands originating from moist sites are older than 100 years. Additional field work is required to search out older stands on well-drained sites, and younger stages of development on moist sites.

The data in Table 7 clearly reveal the present and/or potential dominance of subalpine fir in these high elevation forest communities. Engelmann spruce was occasionally observed to be an equal co-dominant with subalpine fir within the older moist-site stands. Observations in other areas of the SBW indicate that Engelmann spruce can achieve complete stand dominance in some moist, upper ravine sites. In these instances it is not uncommon to witness the usually prostrate western yew take on nearly tree-size shape and size (8-10″ dbh). Douglas-fir does play the role of a minor or major seral species among these stands up to an elevation of 6500 feet (2000 m), but becomes rare or absent in stands above this elevation.

Species diversity is markedly reduced in the subalpine fir-lodgepole pine communities. The fewer species, however, exhibit much higher average cover percentages. Beargrass *(Xerophyllum tenax)* and grouseberry *(Vaccinium scoparium)* dominate the understories of the pioneer stands on well-drained slopes. Both become reduced at later stages of forest development. Huckleberry *(Vaccinium globulare)* becomes more common in intermediate-aged stands on open slopes; this same species displays a moderate level of cover in all of the older stands located on moist sites. Menziesia *(Menziesia ferruginea)* appears to have a definite preference for the cooler, moist sites, and reaches its highest cover values in the oldest stands.

Analysis of Forest Fuels:—The forest community ordination approach which proved useful in the basic description and interpretation of the patterns of distribution and composition of the SBW vegetation, was used further in the analysis of the fuel loading data. Such data are presently available for 72 of the 115 stands discussed earlier. A series of subdivisions was established among the 72 stands (Fig. 12) that directly relates to the groupings discussed earlier and represented in Tables 2-7. Figure 12 is composed of nine pairs of stand clusters (numbered 1 to 18). Group 1 and group 2 comprise a pair of stand clusters that enclose the ordinated communities dominated by Douglas-fir and ponderosa pine and occupy warm aspects. Groups 3 and 4 comprise a cluster pair, as do 5 and 6, and so on.

The stands enclosed by solid lines are those that have experienced fire more recently than those of the other paired stands enclosed by dashed lines. Although a wide range of forest types have been subjected to fuel inventory sampling, most of the designated clusters are composed of but 4 or 5 stands; groups 9 and 10 are represented

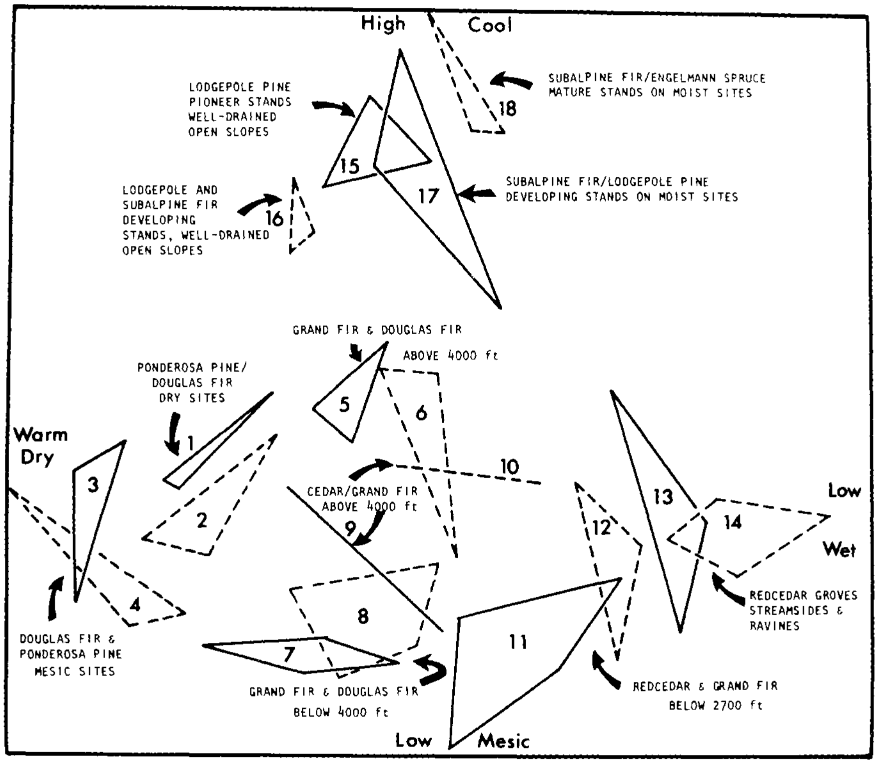

Fig. 12. Stand groupings (clusters) delineated within forest ordination, based on composition, developmental status and in several instances site elevations. The group delineations provide the basis for making comparisons of stand changes related to composition and fuel loadings as summarized in Tables 2-12. Adjacent paired groupings (1 and 2, 3 and 4, etc) include stands (solid lines) that have burned more recently, and stands (dashed lines) that have not burned in recent times. Note that in many instances the younger forests are located to the left, towards the warmer, drier side of the ordination. See text for further explanation.

at this time by two stands each. The ordinational analysis of the presently available data has been valuable in recognizing where additional fuel loading data need to be collected.

The two-dimensional view of the 18 forest/fuel groupings appears to indicate that a high degree of over-lapping exists among the paired stand clusters. There is, of course, compositional similarity among the stands making up these pairings; this is evident in the

Table 8. Summary of fuel loading data from stands dominated by ponderosa pine and Douglas fir. The stands are arranged in the same manner as those in Table 3. Fuel weights are expressed in metric tons per hectare.

	A. Warm, Dry Stands		B. Cool, Mesic Stands	
Fuel Categories	(1) Duff Depth Under 1 cm	(2) Duff Depth Over 1 cm	(3) Duff Depth Under 1 cm	(4) Duff Depth Over 1 cm
Branchwood 0-0.5 cm	0.2	0.5	0.3	0.6
Branchwood 0.5-1.6 cm	0.2	0.7	0.3	0.6
Branchwood 1.6-10.0 cm	0.6	1.8	0.8	3.4
Branchwood over 10.0 cm Sound+Rotten	0.3	52.1	0.6	0.8
Branchwood over 10.0 cm Rotten material only	0.1	0	0.6	0.6
Litter layer	1.3	1.2	0.7	1.6
Weight Live Shrub Fuel	0.3	0.5	1.2	3.8
Weight Dead Shrub Fuel	0.1	0.1	0.4	0.1
Live Grass-forb Fuel	0.6	0.2	0.3	0.2
Dead Grass-forb Fuel	0.1	0.4	0.1	0.1
Total Fine Fuels	1.7	2.5	1.4	2.7
Total 0-10.0 cm Fuels	2.3	4.3	2.2	6.2
Weight Duff Layer Fuel	5.4	25.1	5.1	35.1
Total Fuel Loadings	8.8	82.2	9.4	46.1
Depth of Green Layer (cm)	10.9	18.2	40.0	74.0
Depth of Dead Layer (cm)	8.2	8.4	13.9	15.6
Litter Layer Depth (cm)	0.4	1.7	0.2	1.1
Duff Layer Depth (cm)	0.3	1.9	0.3	2.1

data summarized in Tables 2-7. However, when these groups were further examined within a three-dimensional model (following the construction of a tertiary axis), the amount of overlap is not great. Since the cluster pairs are basically age or stand development separations within the same community types, it is not expected that complete spatial discontinuities would occur.

A detailed summary of averaged fuel loading data for each of the 18 stand groupings is presented in Tables 8-12. Even a cursory examination of these values indicates that groundlayer fuels accumulate over time, in the absence of periodic fire. The magnitudes of accumulation are variable among the various forest community types that were included in this sample. Stands dominated by ponderosa pine and Douglas-fir exhibit some of the lowest total fuel

Table 9. Summary of fuel loadings from stands dominated by grand fir and mixtures of grand fir and Douglas fir. The columns of data are arranged as in Table 4. Fuel weights are expressed in metric tons per hectare.

	A. Stands Over 1200 m		B. Stands Under 1200 m	
Fuel Categories	(5) Developing Stands	(6) Mature Stands	(7) Developing Stands	(8) Mature Stands
Branchwood 0-0.5 cm	0.5	0.9	0.5	0.6
Branchwood 0.5-1.6 cm	0.6	0.6	0.3	0.5
Branchwood 1.6-10.0 cm	5.4	4.8	2.5	3.8
Branchwood over 10.0 cm Sound+Rotten	2.5	4.3	1.0	77.0
Branchwood over 10.0 cm Rotten material only	0.7	3.3	0.6	39.6
Litter Layer	1.6	0.8	0.9	1.3
Weight Live Shrub Fuel	0.7	0.3	0.8	0.2
Weight Dead Shrub Fuel	0.1	0.1	0.3	0.1
Live Grass-forb Fuel	0.9	0.3	0.4	0.2
Dead Grass-forb Fuel	0.3	0.1	0.3	0.1
Total Fine Fuels	2.7	2.4	1.7	2.4
Total 0-10.0 cm Fuels	8.1	7.2	4.2	6.2
Weight Duff Layer Fuel	46.0	103.3	28.7	57.7
Total Fuel Loadings	58.2	115.4	35.1	141.4
Depth of Green Layer (cm)	60.0	20.0	65.0	30.0
Depth of Dead Layer (cm)	30.0	45.0	11.0	12.0
Litter Layer Depth (cm)	1.1	0.5	0.7	1.3
Duff Layer Depth (cm)	2.8	5.4	1.5	3.7

loadings in the SBW. Stands of this sort experienced fire more frequently over past centuries, and generally these were of low intensity.

All other forest community types have much higher fuel loadings, in total. Stands dominated by western redcedar and grand fir, that have reached ages over 250 years, often have fuel loadings that exceed 100 metric tons per hectare (about 100,000 lbs per acre), and occasionally over 400 metric tons per hectare. Old-aged subalpine fir-Engelmann spruce forests have fuel loadings approaching 200 metric tons/ha. Figure 13 illustrates the relationship between stand age and fuel loadings within each of the major forest community types. Individual stand data are plotted in this diagram. The gradual increase in total fuel loadings is demonstrated clearly, but other features are also worth noting. The grouping of five ponderosa pine-Douglas-fir stands at the 200 year mark illustrates instances where ground fires have reduced the fuel load in recent times without harming the overstory trees. Another aspect not clearly understood at this time is the wide ranging values among the redcedar-grand fir

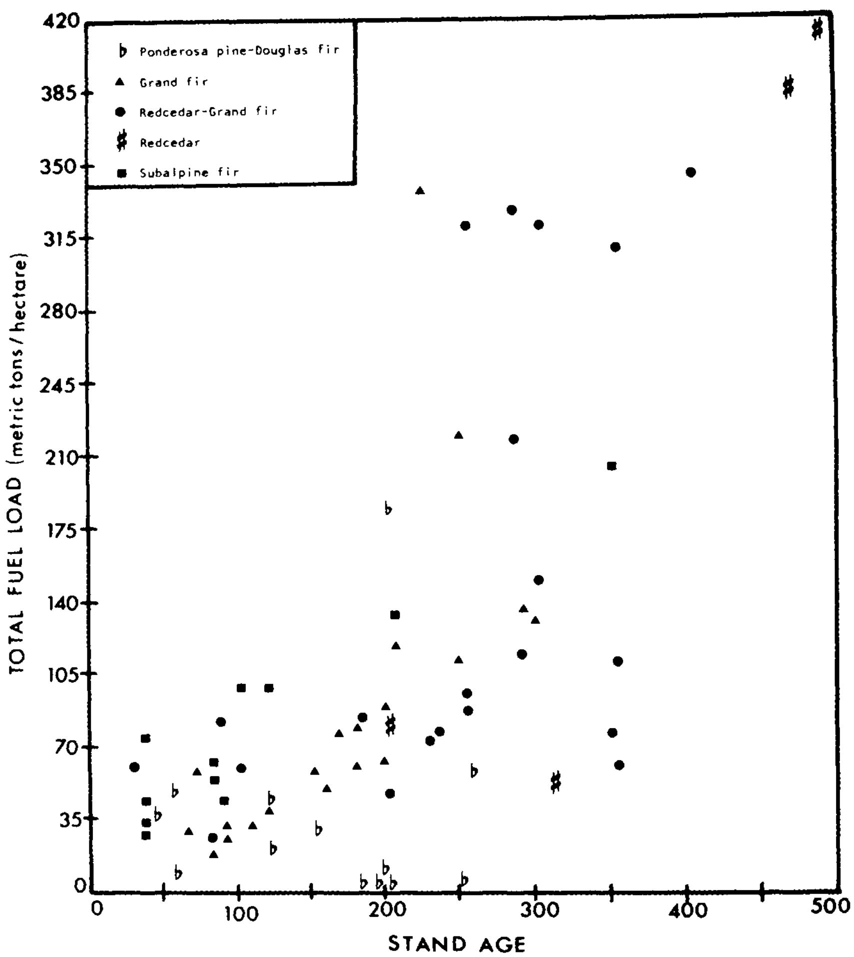

Fig. 13. Comparison of total fuel loadings to stand ages, among five forest community types.

Table 10. Summary of fuel loading data from stands dominated by grand fir and western redcedar. The columns of data are arranged as in Table 5. Fuel weights are expressed in metric tons per hectare.

	A. Stands Over 1200 m		B. Stands Under 800 m	
Developing Fuel Categories	(8) Developing Stands	(10) Mature Stands	(11) Developing Stands	(12) Mature Stands
Branchwood 0-0.5 cm	0.6	1.1	0.8	0.6
Branchwood 0.5-1.6 cm	0.3	0.6	0.4	0.3
Branchwood 1.6-10.0 cm	2.9	4.7	2.1	2.6
Branchwood over 10.0 cm Sound + Rotten	33.0	6.6	34.1	95.7
Branchwood over 10.0 cm Rotten material only	28.3	5.9	24.2	71.5
Litter Layer	1.3	1.0	0.8	0.5
Weight Live Shrub Fuel	1.1	0.3	0.2	0.1
Weight Dead Shrub Fuel	0.03	0.2	0.1	0.2
Live Grass-forb Fuel	0.1	0.4	0.2	0.3
Dead Grass-forb Fuel	0.2	0.2	0.07	0.03
Total Fine Fuels	2.4	2.9	2.0	1.4
Total 0-10.0 cm Fuels	5.2	7.7	4.2	4.0
Weight Duff Layer Fuel	53.9	104.5	62.9	82.7
Total Fuel Loadings	90.8	115.3	101.6	182.9
Depth of Green Layer (cm)	96.0	33.0	15.0	39.0
Depth of Dead Layer (cm)	13.0	30.0	7.0	7.0
Litter Layer Depth (cm)	6.6	7.7	0.9	1.3
Duff Layer Depth (cm)	3.1	5.2	4.2	5.4

stands 300 or more years old. The major difference among these stands is the presence or absence of larger diameter (over 10.0 cm) branch and stem fuels which, when present in either a sound or rotting condition, contribute significantly to the total fuel loadings. The production of such fuels is likely related to the intensity of past fires and consequent degree of tree destruction and fuel consumption at the time of burning. It is true that the stands occupying the wettest sites have the heaviest loads of large-diameter fuel particles.

Another feature illustrated in Tables 8-12 is the gradual increase in duff layer depth as forest succession progresses. This is graphically summarized in Figure 14 also. In many stands the weights of the duff layer account for a bulk of the total fuel load. Fuels contributed by shrub species increase over time in the ponderosa pine-

Table 11. Fuel loading data for four western redcedar grove communities. Stands 11 and 104 are less than 450 years of age; stands 11 and 12 are over 450 years. Fuel weights are expressed in metric tons per hectare.

	(13) Cedar Groves<450 Years		(14) Cedar Groves>450 Years	
Fuel Categories	Stand #14	Stand #104	Stand #12	Stand #11
Branchwood 0-0.5 cm	0.5	0.5	0.4	0.3
Branchwood 0.5-1.6 cm	0.1	0.5	0.4	0.4
Branchwood 1.6-10.0 cm	1.2	3.8	2.9	4.5
Branchwood over 10.0 cm Sound+Rotten	7.4	4.2	177.1	264.5
Branchwood over 10.0 cm Rotten material only	0	3.2	113.3	158.4
Litter Layer	0.4	0.5	0.3	0.2
Weight Live Shrub Fuel	0.4	0.3	0	0
Weight Dead Shrub Fuel	0.01	0.01	0	0
Live Grass-forb Fuel	0.2	0.2	0.1	0.1
Dead Grass-forb Fuel	0.01	0.01	0.01	0.01
Total Fine Fuels	1.1	1.5	1.1	0.9
Total 0-10.0 cm Fuels	2.3	5.4	3.9	5.4
Weight Duff Layer Fuel	40.4	68.4	104.5	125.8
Total Fuel Loadings	44.0	74.7	285.6	395.9
Depth of Green Layer (cm)	11.0	30.5	3.6	12.9
Depth of Dead Layer (cm)	1.0	28.0	3.7	10.7
Litter Layer Depth (cm)	0.7	0.5	2.2	1.4
Duff Layer Depth (cm)	3.9	4.6	5.6	6.7

Douglas-fir stands, but this is not the case in many of the more mesic forest types. Figure 15 illustrates the general reduction of shrub fuels over time in most of the forest types. Grass-forb fuels are reduced over time among many of the low elevation forest stands, but show an increase within the older subalpine fir stands at higher elevations.

Generally the weights of fine fuels (summation of 0-1.6 cm branchwood fuel, litter and dead grass-forb fuels) and total 0-10.0 cm fuels (1.6-10.0 cm branchwood, dead shrub, plus total fine fuels) also increase over time. The fine fuel component appears to decrease among the streamside redcedar and grand fir stands that have reached or exceed 300 years of age; the 0-10.0 cm fuels continue to increase among the older, streamside stands, however.

Forest succession of course leads to a gradual increase in total basal area per acre (Table 2). Within the drier forests, tree densities

Table 12. Summary of fuel loading data from stands dominated by subalpine fir and lodgepole pine. The columns of data are arranged as in Table 7. Fuel weights are expressed in metric tons per hectare.

	A. Stands on Open Slopes		B. Stands in Moist Sites	
Fuel Categories	(15) Pioneer Stands	(16) Developing Stands	(17) Developing Stands	(18) Mature Stands
Branchwood 0-0.5 cm	0.2	3.1	0.5	0.4
Branchwood 0.5-1.6 cm	0.3	0.5	0.3	0.6
Branchwood 1.6-10.0 cm	3.9	5.2	3.7	5.8
Branchwood over 10.0 cm Sound+Rotten	7.4	2.6	3.6	7.8
Branchwood over 10.0 cm Rotten material only	4.5	1.3	2.2	2.8
Litter Layer	0.6	0.9	0.6	1.3
Weight Live Shrub Fuel	1.3	1.0	0.9	0.9
Weight Dead Shrub Fuel	0.6	0.3	0.2	0.6
Live Grass-forb Fuel	1.3	2.4	0.5	0.7
Dead Grass-forb Fuel	0.1	0.4	0.3	0.01
Total Fine Fuels	1.2	2.2	1.5	2.2
Total 0-10.0 cm Fuels	5.7	7.7	5.4	8.6
Weight Duff Layer Fuel	32.1	32.4	71.8	146.3
Total Fuel Loadings	48.0	46.1	82.1	164.3
Depth of Green Layer (cm)	40.0	39.0	54.0	69.0
Depth of Dead Layer (cm)	12.0	5.0	33.0	16.0
Litter Layer Depth (cm)	1.3	1.3	0.8	1.5
Duff Layer Depth (cm)	1.7	1.8	3.8	8.7

increase as these forests, once maintained in an open-canopied condition, are gradually invaded by conifer reproduction. Very often forests less than 100 years of age have tree densities higher than the mature forests. This feature is somewhat obscured in many mature stands that support grand fir, where sapling-sized individuals of this species (up to 4″ dbh) may be very common.

The near absence of random wildfire in the SBW during the past several decades has been leading to yet another feature that is not revealed in the tables of fuel data, but is of extreme importance in assessing the interrelationships between forests, fuels and fire in the SBW. This relates to the spatial distribution or patternization of the forest/fuel complex on the wilderness landscape. The aerial photo comparisons that have been made (Fig. 4) reveal that the pristine

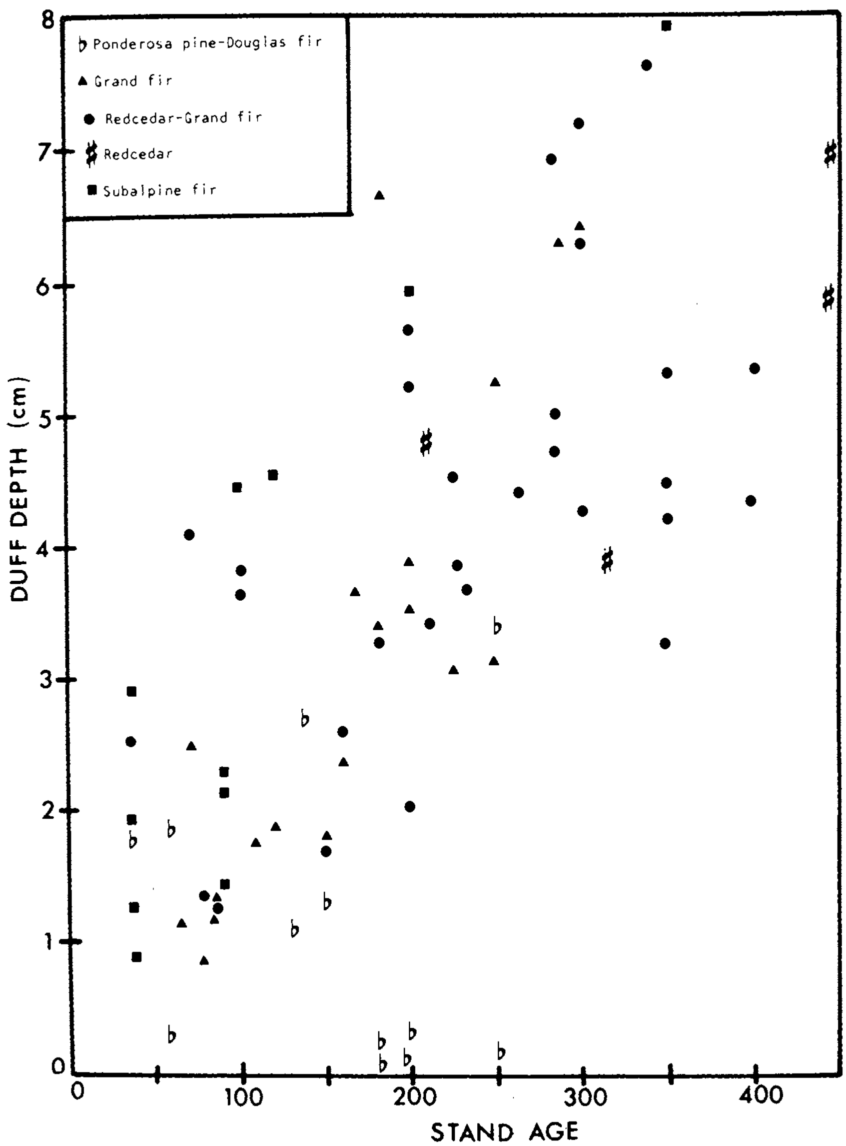

Fig. 14. Relationship between duff layer depth and stand ages among five forest community types.

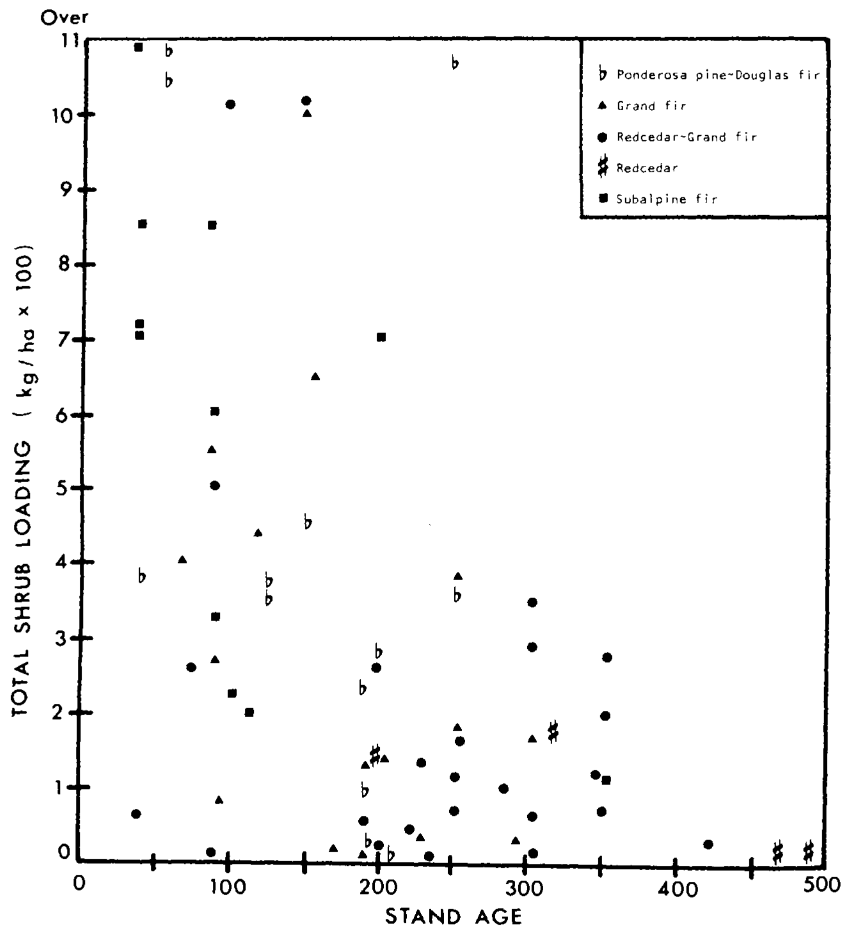

Fig. 15. Relationship between total shrub fuel loadings and stand ages among five forest community types.

mosaic that once characterized much of the SBW is gradually being lost. A more homogenous life-form is being assumed on a greater percentage of the total area. The data derived from fuel appraisal efforts provides a good quantitative measure of fuel loads in present-day forest stands, and an insight into the rates of accumulation over time. It is important to realize, in addition, that forest successional processes are operating continuously in all parts of the SBW leading to a broad-scale loss of fuel discontinuities; much that still exists is the result of topographic factors. A generally continuous green carpet of forest cover is likely to alter the character and behavior of future fires in the SBW.

Predictions of rate of fire spread in the present-day SBW forests have been made utilizing the methodology of Rothermel (1972) and Brown (1972). In general the old-aged, streamside stands have the lowest predicted fire spread rates, whereas the ponderosa pine-Douglas-fir forests would support more rapidly spreading fires. The older cedar-grand fir stands do have heavier total fuel loads, but a large proportion of this material is in the form of deep duff layers and downed, rotting log material. The warmer, drier forests have a higher proportion of their fuel loads in the form of litter, grass-forb and shrub materials through which fire spreads quickly.

Pioneer stages of forest development, often dominated by grasses and forbs (many of which are cured and highly flammable by mid-summer), as well as by shrubs and young conifer reproduction, have the highest predicted rates of fire spread, *viz.*, 10 ft/min (3 m/min), at wind speeds of 2 mph (3.3 km/hour); and 40 ft/min (12.2 m/min) at 10 mph (16.7 km/hour), based on a standardized 5.0 percent fuel moisture and a level 0° slope. In much of the SBW the steep slopes would lead to much greater rates of spread. Some reduction in fire spread rates occurs as canopy closure develops; such reduction is less in stands dominated by ponderosa pine and/or Douglas-fir compared to more mesic stands dominated by western redcedar and/or grand fir. In the latter stand types spread rates are less than 1 foot (0.3 m) per minute with minimum wind speeds, and only 1-4 ft/min (0.3-1.2 m/min) at winds of 10 mph. At higher elevations, developing and mature forests composed of lodgepole pine and subalpine fir have predicted fire spread rates of less than 5 ft/min (1.5 m/min) at lower wind speeds, and up to 15-20 ft/min (4.5-6.0 m/min) at greater wind speeds, again assuming level terrain and 5.0 percent fuel moisture.

Heavy fuel loadings per se are not prerequisite for rapid fire spread; ponderosa pine forests in the SBW are capable of supporting rapidly spreading ground fires with only 1 or 2 years' worth of litter accumulation. Old-aged cedar groves that possess heavy ground fuels composed of large diameter branches and downed logs in a rotting condition would support slow moving fires at best; once ignited however such heavy fuel materials would support longer-lasting fires. Ponderosa pine forests that supported periodic ground fires in the past are now potentially subject to crowning fires because of the establishment of invading conifers which would serve as fuel bridges from ground layers to tree canopies. This appears to have actually happened in a recent fire within the White Cap Creek drainage of the SBW (Mutch and Habeck, 1974); a fire occurring in 1973 in this area appeared to do little harm to open pine forests, but engendered greater mortality in areas where Douglas-fir had invaded former pine openings.

The highly dissected topography of the SBW partially mitigates the difficulties described as associated with total fuel increments and loss of fuel discontinuities. One cannot travel too far in any direction without encountering slope and aspect changes that induce alterations in community composition and forest fuel characteristics. Such topographically induced variations would certainly influence fire behavior, particularly on slope systems that include shifts from warm, dry aspects to cool, mesic exposures. On north-facing slopes dense forest cover prevails, and shifts from NW, N and NE aspects are not accompanied by major forest or fuel changes. Field examinations of north slope forests reveal that these types have been subject to fire less often (100-200 years), but when fires do occur they are frequently of the high intensity, "stand replacement" sort that leaves few or no surviving trees. The loss of the original vegetation mosaic pattern on northern aspects is thought to be of greater significance than elsewhere, because of the greater degree of fuel continuity developing on such slopes.

The lower reaches of the spruce-fir zone would potentially take on the same characteristics just described for the north slope forests; however at higher elevations the productivity of fuel biomass is much slower and a portion of the original mosaic pattern is still retained today. At the upper-most elevations the forests are often broken and disconnected by massive rock outcrops, talus slides, and snow avalanche tracts. Recovery from past fires has been very slow in the upper subalpine fir zone, and it is believed that the past ½ century of fire control has had the least total effect on these forest ecosystems.

CONCLUSIONS AND SUMMARY

The vegetation within the SBW represents a generally typical array of forest communities of the sort found in much of northern Idaho and western Montana. For tens of thousands of years the flora in this region has evolved in the presence of periodic fire, and many exhibit structural and reproductive features that appear to be related to their survival and perpetuation within a fire environment. In addition the flora and the forest communities it forms are spatially arranged in response to the well-developed environmental gradients (moisture, temperature, etc.) that any rugged, mountainous terrain exhibits. Fire and topography combined to form a highly diverse biotic system. The influence of topography remains, but the impact of fire has been very effectively altered during the past five decades. Forest communities at lower elevations, those that experienced frequent fire, appear to show the greatest compositional response to the reduction in fire. The coniferous forests at this latitude have rates of organic matter production that are higher than the rates of microbial decomposition. In the absence of fire as a decomposing process, fuel loadings gradually build up, and forest compositions change as stand maturity is achieved. The percentage of intermediate and old-aged communities occupying the SBW landscape is gradually increasing, and the diversity of community life forms is becoming reduced. Loucks (1970) has pointed out that perturbations such as fire tend to recycle the system, and are important in maintaining a periodic wave of peak biotic diversity.

Hope is held that the detailed, quantitative analysis of the Selway-Bitterroot Wilderness forests and fuels will provide further evidence that fire cannot be further ignored as an important ecosystem process in this region. Successful landscape management must give attention to all ecosystem components and processes, including fire. How fire is successfully returned to landscape management planning cannot be discussed at length here, however, it is suggested that for wilderness areas any fire management planning should allow for a conspicuous degree of randomness in future fire influence. Man is probably capable of developing and implementing plans that dictate the design of future landscape patterns, and such plans might even maximize biotic diversity. Although such a result might not be entirely unavoidable under any management plan, it is hoped that the highest degree of pristine wilderness qualities can be sustained.

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