United States
Department of
Agriculture

Forest Service

**Intermountain
Forest and Range
Experiment Station
Ogden, UT 84401**

General Technical
Report INT-141

May 1983

Fire Ecology of Montana Forest Habitat Types East of the Continental Divide

William C. Fischer and Bruce D. Clayton

THE AUTHORS

WILLIAM C. FISCHER is a research forester for the Fire Effects and Use Research and Development Program at the Intermountain Station's Northern Forest Fire Laboratory, Missoula, Mont. He earned his B.S. and B.S.F. degrees at the University of Michigan in 1956. Prior to 1966, he was employed as a forester (fire control) on the Boise National Forest in Idaho.

BRUCE D. CLAYTON earned an A.B. degree in botany and zoology from the University of California at Los Angeles in 1972, and a Ph.D. in plant ecology from the University of Montana in 1978. This report is based in part on a preliminary draft, of reduced scope, prepared by Dr. Clayton under Forest Service contract 43-0346-8-00050, Helena National Forest. He has since authored the nuclear survival manual **Life After Doomsday**, published by Paladin Press. Dr. Clayton now resides at Mariposa, Calif.

RESEARCH SUMMARY

This report summarizes available information on fire as an ecological factor for forest habitat types occurring east of the Continental Divide in Montana.

Forest habitat types of Montana are grouped into Fire Groups based primarily on fire's role in forest succession.

For each Fire Group, information is presented on (1) the relationship of major tree species to fire, (2) fire effects on undergrowth, (3) forest fuels, (4) the natural role of fire, (5) fire and forest succession, and (6) fire management considerations.

ACKNOWLEDGMENTS

This report is the result of a cooperative endeavor between the Intermountain Station's Fire Effects and Use Research and Development Program and the National Forest System's Northern Region. The support of Zone Fire Management Specialist Everett "Sonny" Stiger (of Beaverhead, Deerlodge, Lewis and Clark, and Helena National Forests) is gratefully acknowledged. He played a major role in the initiation of this report.

We also acknowledge the contributions of personal experiences and observations regarding eastside fire ecology by the following Forest Service personnel:

Gallatin National Forest—Randall W. Gay, Alfred S. "Sam" Gilbert, Larry Keown, and Roger M. Siemens (currently assigned to Deerlodge National Forest).

Custer National Forest—Horace F. "Ace" Goodwin, Walter Tomascak (currently assigned to Northern Region Headquarters, Missoula, Mont.), and Philip South.

Lewis and Clark National Forest—Herbert D. Holdorf.

Deerlodge National Forest—John Jay.

Helena National Forest—Bernard L. "Bud" Kovalchik (currently assigned to Deschutes National Forest).

Beaverhead National Forest—Arnold A. Royce.

Finally, contributions of personal knowledge of fire ecology by the following Intermountain Station scientists are acknowledged:

Northern Forest Fire Laboratory, Missoula, Mont.—Stephen F. Arno.

Forestry Sciences Laboratory, Bozeman, Mont.—Dennis M. Cole and Wyman C. Schmidt.

Forestry Sciences Laboratory, Missoula, Mont.—L. Jack Lyon and Robert D. Pfister (currently associated with the University of Montana School of Forestry, Missoula, Mont.).

CONTENTS

Fire Ecology of Montana Forest Habitat Types East of the Continental Divide

William C. Fischer and Bruce D. Clayton

INTRODUCTION

Purpose

This report is a summary of available fire ecology and management information that applies to forest habitat types occurring east of the Continental Divide in Montana; specifically, on the Beaverhead, Custer, Deerlodge, Gallatin, Helena, and Lewis and Clark National Forests; in the Bearpaw Mountains; the Little Rocky Mountains; and the Missouri River Breaks in Montana. The primary purpose of this report is to help forest managers understand the role of fire in east side Montana forests, especially the role of fire in forest succession. Primary attention is given to the tree component although undergrowth response is summarized.

Habitat types are arranged into 11 "Fire Groups" based on the response of the tree species to fire and the roles these tree species take during successional stages. The exception is Fire Group Zero, which is a description of miscellaneous vegetation types.

The Fire Groups defined in this report include a number of borderline cases. Differences in fire behavior and in successional patterns often depend on very small local changes in fuel, temperature, moisture, sunlight, topography, and seed availability. Thus it would be possible for stands that key to the same habitat type to fall into different Fire Groups. Assignment of habitat types to more than one Fire Group is kept to a minimum in this report. A certain reliance is placed on the judgment of the land manager in evaluating the local conditions of any particular site. The groups defined in this report are intended as a general guide, not a definitive treatment.

Where similar habitat types occur on lands adjoining those covered in this report, the information may be extrapolated with care.

Format

The report is patterned after *Fire Ecology of Lolo National Forest Habitat Types* (Davis and others 1980). Subject matter content is identical to the Lolo report except that this report contains a discussion of hypothetical successional pathways. A major difference in format is that in this report the relationships of major tree species to fire and fire effects on undergrowth are discussed in separate sections rather than under each Fire Group. The change was made to eliminate unnecessary repetition. Since publication of the Lolo report, downed dead woody fuel and biomass in the Northern Rocky Mountains has been summarized by Brown and See (1981). Consequently, in this report summaries of average downed woody fuel loads for east side forests are included in a preliminary section on forest fuels that precedes the Fire Group discussions.

The following are the major topics to be covered in this report:

RELATIONSHIP OF MAJOR TREE SPECIES TO FIRE

This section is devoted to a discussion of each important tree species in east side forests with regard to its resistance or susceptibility to fire and its role as a successional component of forest communities. Particular attention is given to special adaptations to fire, such as corky bark, serotinous cones, or seeds that require mineral soil for germination.

UNDERGROWTH RESPONSE TO FIRE

This section is a summary of the effect of fire on the response of important understory grass, forb, and shrub species. Particular attention is given to fire-adaptive traits or survival strategies that determine whether fire generally increases or decreases species cover in the immediate postfire period.

HABITAT TYPES AND PHASE, ADP CODES AND FOREST REGION

The Fire Groups are defined with reference to *Forest Habitat Types of Montana* (Pfister and others 1977); *Forest Habitat Types of the Bear's Paw Mountains and Little Rocky Mountains, Montana* (Roberts 1980); and *Forest and Woodland Habitat Types of North Central Montana, Volume 2: The Missouri River Breaks* (Roberts and Sibbernsen 1979). A complete list of the habitat types occurring east of the Continental Divide in Montana is included as appendix A.

Habitat types are designated in the standard format of "series/type-phase," in which "series" designates the potential climax dominant tree, "type" designates a definitive undergrowth species, and "phase" provides a further subdivision where needed. The "ADP codes" are the automatic data processing codes for National Forest System use in the Forest Service Northern Region. ADP codes have not been assigned for those habitat types that do not occur on the National Forests.

The forest region designation refers to those described for Montana by Arno (1979) as illustrated in figure 1.

FOREST FUELS

For each Fire Group, we discuss the kind and amount of dead, woody material likely to be found on the forest floor. The discussion is based on fuel inventory data (Brown 1974) from two sources. The prime source is a photo series for appraising natural fuels in wild stands on Montana National Forests (Fischer 1981a, 1981b). The other source is a summary of downed dead woody fuel on east side National Forests in Montana (Brown and See 1981), which is presented in a separate section preceding the Fire Group discussions.

It is important to remember that these discussions are about dead, woody material on the forest floor. Live fuel and standing dead fuel are treated casually, if at all, because fuel data on this material were not collected as part of the inventories mentioned above.

Cover type names used in this section are those suggested by the Society of American Foresters (1980).

ROLE OF FIRE

Information on the important trees and forest fuel is integrated with available fire history studies to describe the role of fire in shaping the vegetative composition of a particular Fire Group. This section is mainly a literature review covering succession and fire in the appropriate habitat types.

For the purpose of this report three levels of fire severity are recognized: low or cool, moderate, and high or severe. A **low severity** or **cool fire** is one that has minimal impact on the site. It burns in surface fuels consuming only the litter, herbaceous fuels, and foliage and small twigs on woody undergrowth. Very little heat travels downward through the duff. A **moderate fire** burns in surface fuels also but may involve a tree understory as well. It consumes litter, upper duff, understory plants, and foliage on understory trees. Individual and groups of overstory trees may torch out if fuel ladders exist. A **severe fire** is one that burns through the overstory and consumes large woody surface fuels and/or removes the entire duff layer over much of the area. Heat from the fire impacts the upper soil layer and often consumes the incorporated soil organic matter.

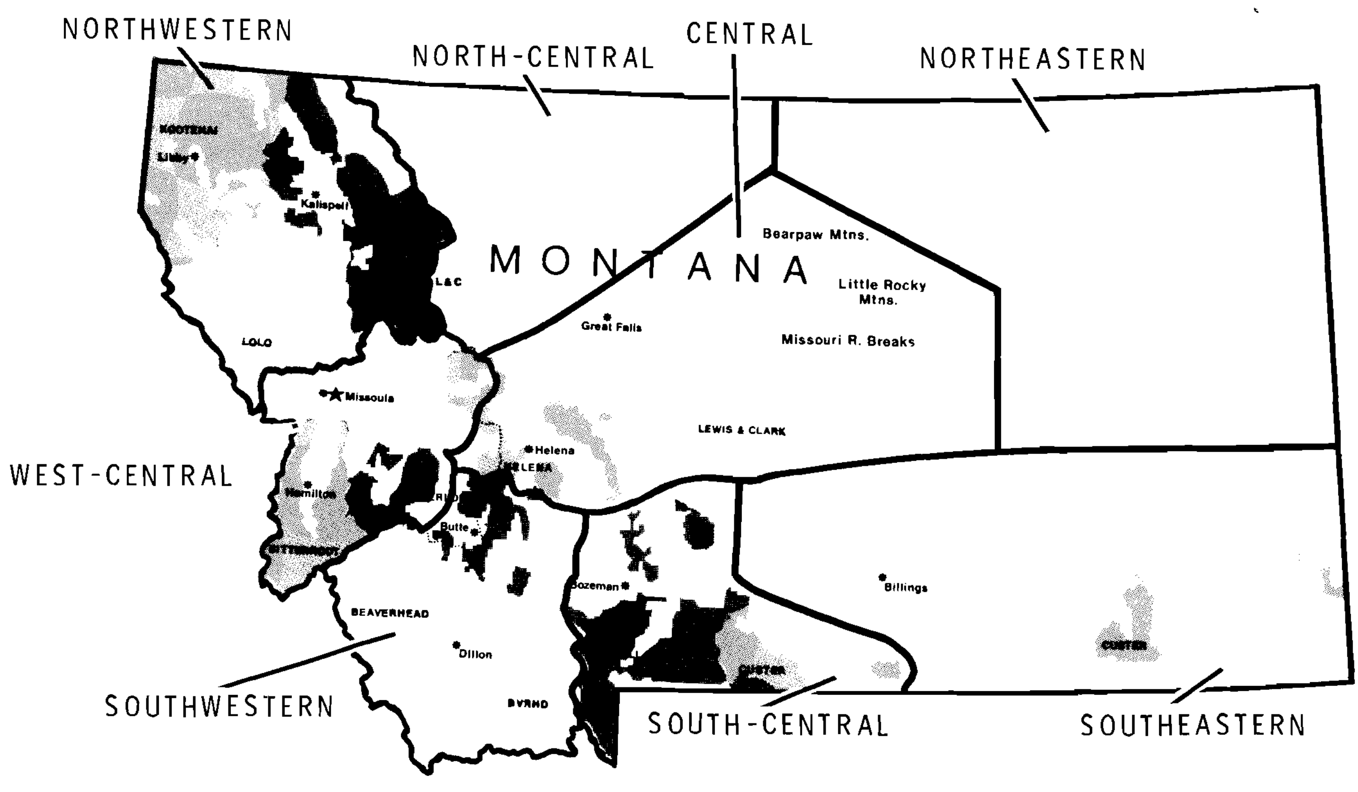


Figure 1.—Forest regions of Montana (source: Arno 1979).

GENERALIZED FOREST SUCCESSION

The succession diagram and associated text represent a simplified, synthetic overview of fire's role in succession for all habitats of each Fire Group. For clarity, no literature references are given in this section since it is intended to serve as a graphic and uncomplicated presentation of the material covered earlier in the chapter.

The diagram in each of these sections represents a visual summary of the effects that fires of varying intensity can have on the habitat types. Secondary succession begins with the lowest seral form, but the diagram can be used from any stage of stand development. In habitat types with aggressive seral conifers, the shrub/herb stage is short lived. Numerous facts that may influence the vegetation on the landscape have been neglected in order to emphasize the potential influences of fire and fire suppression.

The conifer species are symbolized in order to simplify the diagrams. The symbols are defined as follows:

Abies lasiocarpa, subalpine fir (ABLA)
Juniperus scopulorum, Rocky Mountain juniper (JUSC)
Larix lyallii, alpine larch (LALY)
Picea engelmannii, Engelmann spruce (PICEA)
Pinus albicaulis, whitebark pine (PIAL)
Pinus contorta, lodgepole pine (PICO)
Pinus flexilis, limber pine (PIFL)
Pinus ponderosa, ponderosa pine (PIPO)
Pseudotsuga menziesii, Douglas-fir (PSME)

SUCCESSIONAL PATHWAYS

This section provides a more detailed discussion of potential forest succession than the previous section. It is a synthesis of confirmed knowledge and unconfirmed speculation that forms a complex series of hypotheses about the many possible influences fire may have on the vegetation of the Fire Groups. The flow charts follow the method suggested by Kessell and Fischer (1981).

FIRE MANAGEMENT CONSIDERATIONS

This section suggests how the preceding information can be used to develop fire management plans that support land and resource management objectives. The discussion is intended to be suggestive, not dogmatic. Each individual manager is in a much better position than are the authors to relate the information presented in this report to a particular management situation.

The Fire Groups

The forest habitat types of Montana have been assembled into 12 Fire Groups (table 1) that are defined as follows:

Fire Group Zero: A miscellaneous, heterogeneous collection of special habitats. On eastern Montana National Forests these sites exist as scree, forested rock, meadow, grassy bald, aspen grove, and alder glade.

Fire Group One: Dry limber pine habitat types. These occur almost exclusively east of the Continential Divide in Montana.

Fire Group Two: Warm, dry ponderosa pine habitat types. This group consists of open ponderosa pine stands with a predominantly grass undergrowth and dense mixed-aged stands of ponderosa pine. These sites may exist as fire-maintained grasslands, and do not support Douglas-fir, except as "accidental" individuals.

Fire Group Three: Warm, moist ponderosa pine habitat types. These sites occur exclusively east of the Continental Divide in Montana. These sites often exist as stagnant, overgrown thickets of ponderosa pine saplings.

Fire Group Four: Warm, dry Douglas-fir habitat types. These are areas that exist in nature as fire-maintained ponderosa pine stands that develop Douglas-fir regeneration beneath the pine in the absence of fire.

Fire Group Five: Cool, dry Douglas-fir habitat types. Douglas-fir is often the only conifer that occurs on these sites. In the absence of fire, dense Douglas-fir sapling understories may develop.

Fire Group Six: Moist Douglas-fir habitat types. These habitat types will support substantial amounts of Douglas-fir even when subjected to periodic fire.

Fire Group Seven: Cool habitat types usually dominated by lodgepole pine. This group includes stands in which fire maintains lodgepole pine as a dominant seral as well as those in which it is a persistent dominant species.

Fire Group Eight: Dry, lower subalpine habitat types. This is a collection of habitat types in the spruce and subalpine fir series that usually occurs as mixed Douglas-fir/lodgepole pine stands.

Fire Group Nine: Moist, lower subalpine habitat types. This is a collection of habitat types in which fires are infrequent but severe, with long-lasting effects. Spruce is usually a major component of seral stands.

Fire Group Ten: Cold, moist upper subalpine and timberline habitat types. This is a collection of high-elevation habitats in which fires are infrequent. Fires are small in areal extent because of the fuel situation. Severe fires have long-term effects. Spruce, subalpine fir, whitebark pine, and alpine larch are the predominant conifers.

Fire Group Eleven: Moist grand fir, western redcedar, and western hemlock habitat types. These are moist habitats in which fires are infrequent and often severe. In Montana they occur exclusively west of the Continential Divide.

All these except Fire Group Eleven occur on eastern Montana National Forests. Fire Group Eleven, consequently, will not be discussed in this report. A detailed listing of the Fire Groups by habitat type is provided in appendix B.

Table 1.—Summary of Montana forest habitat type fire groups (see Appendix C for formal listing of habitat types).

Habitat type[1]	Forest region[2]
FIRE GROUP ONE	
PIFL/AGSP	NC, C, SW, SC
PIFL/FEID-FEID	NC, C, SW, SC
PIFL/FEID-FESC	NC,C
PIFL/JUCO	NC, C, SW, SC
FIRE GROUP TWO	
PIPO AND	SE
PIPO/AGSP+	NW, WC, C, SE
PIPO/FEID-FEID	WC, C, SE
PIPO/FEID-FESC+	NE, WC, C
PIPO/PUTR-AGSP	WC, C
PIPO/PUTR-FEID	NW, WC, C
PIPO/SYAL-SYAL	NW, WC, C, SE
PIPO/SYOC*	C
PIPO/ARUV*	C
PIPO/JUHO*	C
PIPO/JUSC**	C
FIRE GROUP THREE	
PIPO/SYAL-BERE	C, SE
PIPO/BERE*	C
PIPO/AMAL*	C
PIPO/PRVI-PRVI	SE
PIPO/PRVI-SHCA	SE
FIRE GROUP FOUR	
PSME/AGSP	NW, WC, C, SW, SC
PSME/FESC	NW, WC, C
PSME/PHMA-CARU	NW, WC
PSME/SYAL-AGSP	NW, WC, C
PSME/SYOC-CHVI*	C
PSME/SYOC-SHCA*	C
PSME/CARU-AGSP	NW, WC
PSME/CARU-PIPO	NW, WC, C
PSME/SPBE	NW, WC, C, NC
PSME/ARUV+	C, SC
PSME/BERE-ARUV*	C
PSME/BERE-BERE*	C
PSME/JUSC**	C
PSME/MUCU**	C
FIRE GROUP FIVE	
PSME/FEID	NW, WC, SW, SC
PSME/CARU-AGSP	C
PSME/CAGE	WC, C, SC, SW
PSME/ARCO	C, SW
PSME/SYOR	SW
PICEA/SEST-PSME	NC, C, SW
FIRE GROUP SIX	
PSME/PHMA-PHMA	NW, WC, C, SW, SC
PSME/VICA*	C
PSME/VAGL-VAGL	NW, WC, C, SW, SC
PSME/VAGL-ARUV	NW, WC, C
PSME/VAGL-XETE	NW, WC, C
PSME/LIBO-SYAL	NW, WC, C
PSME/LIBO-ARUV*	C
PSME/LIBO-CARU+	NW, WC, C, SW
PSME/LIBO-VAGL	WC, C
PSME/SYAL-CARU	NW, WC, C, SW, SC
PSME/SYAL-SYAL	NW, WC, NC, C, SW, SC
PSME/AMAL*	C
PSME/CARU-ARUV	NW, WC, C
PSME/CARU-CARU	NW, WC, NC, C, SW, SC
PSME/VACA	NW, WC
PSME/JUCO	NC, C, SW
FIRE GROUP SEVEN	
PSME/JUCO	NC, C, SW
PSME/VACA	NW, WC, NC, C
PSME/COCA-LIBO*	C
PSME/COCA-VAMY*	C
PICEA/VACA	NW, NC
PICEA/LIBO	WC, C, SC, SW
ABLA/VACA	NW, WC, C, SW
ABLA/CACA-VACA	NW, WC, C, SW
ABLA/LIBO-VASC	NW, WC, NC, C, SC, SW
ABLA/XETE-VASC	NW, WC, NC, SW
ABLA/VAGL	WC, C, SC, SW
ABLA/VASC-CARU	C, SC, SW
ABLA/VASC-VASC	NW, WC, C, SC, SW
ABLA/CAGE-CAGE	NC, SW
PICO/PUTR	SC
PICO/VACA	WC, NC, C, SW
PICO/LIBO+	NW, WC, C, SC, SW
PICO/VASC	NW, WC, C, SC, SW
PICO/CARU	C, SC, SW
PICO/JUCO	C
FIRE GROUP EIGHT	
PICEA/LIBO*	C
PICEA/PHMA	SC
PICEA/SMST	WC, C, SW, SC
ABLA/XETE-VAGL	NW, WC, NC, SW
TSME/XETE	NW
ABLA/VASC-THOC	C, SW
ABLA/CARU	NC, C, SW, SC
ABLA/CLPS	NC, C, SW, SC
ABLA/ARCO	NC, C, SW
ABLA/CAGE-PSME	C, SW, SC
FIRE GROUP NINE	
PICEA/EQAR	NW, NC, C, SW, SC
PICEA/CLUN-VACA	NW
PICEA/CLUN-CLUN	NW
PICEA/GATR	WC, C, SW, SC
ABLA/OPHO	NW
ABLA/CLUN-CLUN	NW, WC, NC
ABLA/CLUN-ARNU	NW, WC, NC
ABLA/CLUN-VACA	NW, WC
ABLA/CLUN-XETE	NW, WC, NC
ABLA/CLUN-MEFE	NW, WC, NC
ABLA/GATR	WC, NC, C, SC
ABLA/CACA-CACA	WC, C, SW, SC
ABLA/CACA-GATR	WC, C, SW
AGLA/LIBO*	C
ABLA/LIBO-LIBO	NW, WC, NC, C, SW, SC
ABLA/LIBO-XETE	NW, WC
ABLA/MEFE	NW, WC, NC, SW, SC
TSME/MEFE	NW, WC
ABLA/ALSI	WC, NC, SW, SC
FIRE GROUP TEN	
PICEA/SEST-PICEA	C
PICEA/JUCO*	C
ABLA/RIMO	SW, SC
ABLA-PIAL/VASC	WC, NC, C, SW, SC
ABLA/LUHI-VASC	NW, WC, NC, SW
ABLA/JUCO*	C
TSME/LUHI-VASC	NW
TSME/LUHI-MEFE	NW
PIAL—ABLA h.t.s.	NW, WC, NC, C, SW, SC
LALY-PIAL h.t.s.	NW, WC, SW
PIAL h.t.s.	WC, C, SW, SC
FIRE GROUP ELEVEN	
ABGR/XETE	NW, WC
ABGR/CLUN-CLUN	NW, WC
ABGR/CLUN-ARNU	NW, WC
ABGR/CLUN-XETE	NW
ABGR/LIBO-LIBO	NW, WC
ABGR/LIBO-XETE	NW
THPL/CLUN-CLUN	NW, WC
THPL/CLUN-ARNU	NW, WC
THPL/CLUN-MEFE	NW, WC
THPL/OPHO	NW
TSHE/CLUN-CLUN	NW
TSHE/CLUN-ARNU	NW

[1]Habitat types are as described by Pfister and others (1977) except those designated as follows:
*habitat types of Bearpaw and Little Rocky Mountains (Roberts 1980)
**habitat types of Missouri River Breaks (Roberts and Sibbernsen 1979)
+common to both Pfister and others (1977) and Roberts (1980).

[2]Forest regions are as described by Arno (1979).

Nomenclature

Trees and undergrowth plants are identified by their common names throughout the text of this report. The list of habitat types at the beginning of each Fire Group discussion reflects the common practice of noting scientific names, abbreviations, and common names. Habitat types are most often identified by abbreviation in the text. Appendix C is a complete list of scientific plant names corresponding to the common plant names used in the text.

RELATIONSHIP OF MAJOR TREE SPECIES TO FIRE

Wildfire has played a major role in forest succession throughout the Northern Rocky Mountains, including those forests east of the Continental Divide in Montana. Lodgepole pine, for example, owes its present widespread occurrence to past fire. Without fire Douglas-fir would occupy areas where ponderosa pine now occurs but is not climax. Similarly, Douglas-fir occupies many sites where it is not climax because of past fire. Fire has favored the distribution of Engelmann spruce at the expense of subalpine fir (Wellner 1970).

Fire may or may not favor a given species depending on certain physical characteristics of the species and its regeneration strategy. Physical characteristics determine a species' susceptibility or resistance to fire damage, while regeneration strategy determines whether a species' continued presence on a site is enhanced or curtailed by fire.

Table 2 summarizes the relative fire resistance of the more silviculturally important conifers in east side Montana forests. A more complete review and summary of comparative autecological characteristics of northwestern tree species is provided by Minore (1979).

Nine coniferous forest trees are discussed in this report. They are limber pine, ponderosa pine, Rocky Mountain juniper, Douglas-fir, Engelmann spruce (including Engelmann spruce and white spruce hybrids), lodgepole pine, subalpine fir, whitebark pine, and alpine larch. The relationship of each tree species to fire is discussed below. Order of presentation corresponds to the order in which the species are encountered in the Fire Groups.

Limber Pine (*Pinus flexilis*)

The degree of stem scorch usually determines the extent of fire injury to limber pines. Young trees are usually killed by any fire that scorches their stems. The bark of young limber pine is too thin to prevent cambium injury, even from a cool fire. Older trees are better able to withstand stem scorch from low severity fires because the bark around the base of mature trees is often 2 inches (5 cm) thick. The needles of limber pine form into tight clusters around the terminal buds. This shields the buds from heat associated with crown scorch.

Keown (1977) conducted prescribed fire studies on Group One habitat types in the central forest region of Montana (Lewis and Clark National Forest). The study results indicate a strong relationship between fuel type, fire severity, and fire injury to limber pine. On sites where grass was the primary fuel and where trees were present as scattered individuals or open stands, fire severity was low and limber pine mortality was light (about 20 percent) even though basal limbs commonly extended to the ground. In similar situations but with a dense undergrowth of shrubs (primarily shrubby cinquifoil) rather than a grass understory, fire severity was high and limber pine mortality often reached 80 percent. The final situation reported by Keown (1977) was where a closed canopy forest bordered grassland or shrubland. Trees in these transition zones were often less than 10 ft (3 m) tall with lower branches intermingled with ground fuels. The most severe fires occurred on these sites. These results are from spring fires when temperatures, relative humidities, and winds were moderate, fuel moistures low, and soil moistures high.

There is no evidence to suggest that fire is necessary to prepare seedbeds for limber pine. Many limber pine habitats are characterized by scattered patches of bare soil. Some sites are heavily covered by bunchgrasses. In the Blacktail Hills area of the Lewis and Clark National Forest, limber pine invades sites occupied by grass and shrubs. On the Hogback Ridge area

Table 2.—Relative fire resistance of the more silviculturally important conifers occurring east of the Continental Divide in Montana[1] (source: Wellner 1970)

Species	Thickness of bark of old trees	Root habit	Resin in old bark	Tolerance: Branch habit	Tolerance: Stand habit	Relative inflammability of foliage	Lichen growth	Degree of fire resistance
Ponderosa pine	Very thick	Deep	Abundant	Moderately high and open	Open	Medium	Medium to light	Very resistant
Douglas-fir	Very thick	Deep	Moderate	Moderately low and dense	Moderate to dense	High	Heavy medium	Very resistant
Lodgepole pine	Very thin	Deep	Abundant	Moderately high and open	Open	Medium	Light	Medium
Engelmann spruce	Thin	Shallow	Moderate	Low and dense	Dense	Medium	Heavy	Low
Subalpine fir	Very thin	Shallow	Moderate	Very low and dense	Moderate to dense	High	Medium to heavy	Very low

[1]From Flint (1925).

of the Helena National Forest (also in the central forest region), limber pine is becoming established in mats of common juniper on a PIFL/JUCO h.t., which last burned more than 60 years ago. Limber pine has large, wingless seeds incapable of wind dispersal. A recent study by Lanner and Vander Wall (1980) indicates that limber pine regeneration on burns is largely a result of seeds planted by Clark's nutcrackers. These birds store limber pine seed in the soil for food. No other reliable dispersal agent of limber pine seed has been identified.

Limber pine occurs primarily in Fire Group One but is also present as a minor species in Fire Groups Six and Eight.

Ponderosa Pine (*Pinus ponderosa*)

Ponderosa pine has many fire-resistant characteristics. Seedlings and saplings are often able to withstand relatively high temperatures, whether from a light surface fire during dormancy or from the severe thermal stress inherent in becoming established on hot, dry exposures. Development of insulative bark and the tendency for meristems to be shielded by enclosing needles and thick bud scales, contribute to the temperature resistance of pole-sized and larger trees.

Propagation of fire into the crown of pole-sized and larger trees growing in relatively open stands (dry sites) is unusual because of three factors. First, the thick bark is relatively unburnable and does not easily carry fire up the bole or support residual burning. Resin accumulations, however, make the bark more flammable. Second, the tendency of ponderosa pine to self-prune lower branches keeps the foliage separated from burning surface fuels. Third, the open, loosely arranged foliage does not lend itself to combustion or the propagation of flames.

On moist sites, ponderosa pine often forms two-storied stands that may be quite susceptible to crown fire. The tendency for regeneration to form dense understories, or "dog hair" thickets, on such sites creates fuel ladders that can carry ground fires to the crowns of overstory trees. Crown fires are, consequently, more frequent on moist sites than they are on dry sites. Understory ponderosa pine may also be more susceptible to fire damage because crowded conditions can result in slower diameter growth. Such trees do not develop their protective layer of insulative bark as early as would otherwise be expected. They remain vulnerable to cambium damage from ground fires longer than their counterparts in open stands. The thick, overcrowded foliage of young stands or thickets also negates the fire-resisting characteristic of open, discontinuous crown foliage normally found in this species. The thinning effect of fire is therefore much more pronounced in dense stands than it is in open stands.

Ponderosa pine seedling establishment is favored when fire removes the forest floor litter and grass and exposes mineral soil. Fire resistance of the open, parklike stands is enhanced by variable light fuel quanities. Heavy accumulations of litter at the base of trunks increase the intensity and duration of fire, often resulting in a fire scar or "cat face." Flammable resin deposits around wounds can make the tree susceptible to fire damage and usually cause an enlargement of the scar.

Ponderosa pine is the most fire-resistant tree growing east of the Divide in Montana. It has, consequently, a competitive advantage over other species when mixed stands burn.

Ponderosa pine occurs primarily in Fire Groups One, Two, Three, and Four.

Rocky Mountain Juniper (*Juniperus scopulorum*)

Young juniper trees are easily killed by fire primarily because of their small size, thin bark, and compact crown. Fire has long been recognized as a means to control juniper because it does not resprout. Often young trees are killed just by scorching the crown and stem.

As juniper ages, the bark thickens and the crown develops a bushy, open habit. A hot fire can kill or severely damage such a tree, but the same tree may survive a cool fire. Low, spreading branches can provide a route for fire to enter the crown, thereby increasing the potential for damage. Often large junipers will survive a number of fires (four to six).

The different effects of fire on young and old juniper trees are largely a function of the site. The species commonly occupies dry, subhumid environments that support limited undergrowth. When surface fuels are sparse, fire damage is minimal.

Rocky Mountain juniper occurs primarily in Fire Groups One, Two, Three, and Four.

Douglas-Fir (*Pseudotsuga menziesii*)

Mature Douglas-fir is a moderately fire-resistant tree; saplings, however, are vulnerable to surface fires because of their thin, photosynthetically active bark, resin blisters, closely spaced flammable needles, and thin twigs and bud scales. The moderately low and dense branching habit of saplings enables surface fires to be carried into the crown layer. Older trees develop a relatively unburnable, thick layer of insulative corky bark that provides protection against cool to moderately severe fires, but this protection is often offset by a tendency to have branches the length of the bole. The development of "gum cracks" in the lower trunk that streak the bark with resin, can provide a mechanism for serious fire injury.

Douglas-fir does occur in open-growth stands, but it also grows in denser stands with continuous fuels underneath. Dense sapling thickets can form an almost continuous layer of flammable foliage about 10 to 26 ft (3 to 8 m) above the ground that will support wind-driven crown fires. Even small thickets of saplings provide a route by which surface fires can reach the crowns of mature trees.

As with ponderosa pine, heavy fuel accumulations at the base of the tree increase the probability of fire injury. Also, resin deposits usually enlarge old scars.

Douglas-fir regeneration is favored by fire, which reduces vegetation cover and exposes mineral soil so shallow taproots of seedlings can take hold. Douglas-fir is, however, better able than its competitors to regenerate on unburned sites.

Douglas-fir occurs in Fire Groups One, Four, Five, Six, Seven, Eight, and Nine.

Engelmann Spruce (*Picea engelmannii*)

Engelmann spruce—including Engelmann spruce and white spruce (*Picea glauca*) hybrids—readily succumbs to fire. The dead, dry, flammable lower limbs, low-growing canopy, thin bark, and lichen growth in the branches contribute to the species' vulnerablility. The shallow root system is readily subject to injury from fire burning through the duff. Older trees that have deep accumulations of resinous needle litter around their bases are particularly susceptible. Trees that do survive fire are often subjected to successful attack by wood-destroying fungi that easily enter through fire scars. The high susceptibility of spruce to fire damage is mitigated in part by the generally cool and moist habitats where it grows.

Spruce is not an aggressive pioneer. It is a moderate seeder, but seeds are viable over extended periods. Initial establishment and early growth of seedlings may be slow, but usually good when encouraged by shade and abundant moisture. Spruce seedlings will occur as members of a fire-initiated stand with lodgepole. Spruce's shade tolerance allows it to establish and grow beneath a lodgepole pine canopy. On sites where it is the indicated climax species, spruce will eventually dominate the stand, but it takes a long period without any fire before this situation can occur.

Restocking will occur more quickly if some spruce trees survive within the burn than if regeneration is dependent on seed from trees at the fire edge. Pockets of spruce regeneration often become established around such surviving seed trees up to a distance of 300 ft (90 m), the effective seeding distance for spruce. Successful regeneration diminishes 100 to 150 years after establishment due to insufficient sunlight at ground level and to accumulating duff. At this point, the more tolerant subalpine fir begins to successfully regenerate.

Engelmann spruce occurs primarily in Fire Groups Five, Seven, Eight, Nine, and Ten.

Lodgepole Pine (*Pinus contorta*)

Individual mature lodgepole pine trees are moderately resistant to surface fires. Lodgepole's thin bark makes it susceptible to death from cambium heating. Lodgepole pine stands alone, however, in its ability to perpetuate itself on a site despite fire. Indeed, on most sites where lodgepole grows, fire is necessary for the species continued dominance.

Lodgepole pine's key fire survival attribute is cone serotiny. Although there are exceptions, most lodgepole stands in eastern Montana are composed of trees containing both serotinous and nonserotinous or open cones. The ratio of serotinous to nonserotinous cones seems to be related to the fire frequency for the site: the higher the fire frequency the greater the proportion of serotinous cones and vice versa (Perry and Lotan 1979).

A temperature of 113° F (45° C) is usually required to melt the resin that binds the scales of a serotinous cone. Heat from a fire is about the only way such temperatures will occur in the crown of a standing lodgepole pine. Large quantities of highly viable seed are therefore available to regenerate a site following a stand-destroying fire.

Aside from serotinous cones, other silvical characteristics (USDA Forest Service 1965) that contribute to lodgepole pine's success in dominating a site following fire are:

1. **Early seed production**. Cones bearing viable seed are produced by trees as young as 5 years in open stands and by trees 15 to 20 years old in more heavily stocked stands. This feature not only allows relatively young stands to regenerate a site following fire, but also the seed from open cones can fill in voids left by the orginal postfire seeding from serotinous cones.
2. **Prolific seed production**. Good cone crops occur at 1- to 3-year intervals with light crops intervening.
3. **High seed viability**. Seed in 80-year-old serotinous cones, for example, have been found to be viable.
4. High seedling survival and rapid early growth, especially on mineral soil seedbeds exposed to full sunlight.

Lodgepole pines' success in revegetating a site following fire often results in dense, overstocked stands. Such stands are susceptible to stagnation, snow breakage, windthrow, dwarf mistletoe (*Arceuthobium americanum*) infestation, and mountain pine beetle (*Dendroctonus ponderosae*) attack. The combined effect of these factors is extreme buildup of downed, dead woody fuel on the forest floor. Thus, the stage is set for another stand-destroying wildfire.

Lodgepole pine occurs primarily in Fire Groups Six, Seven, Eight, and Nine.

Subalpine Fir (*Abies lasiocarpa*)

Subalpine fir is rated as the least fire-resistant Northern Rocky Mountain conifer because of its thin bark, resin blisters, low and dense branching habit, and moderate-to-high stand density in mature forests. As a result, fire most often acts as a stand-replacement agent when it burns through a subalpine fir forest. Even light ground fires can cook the cambium or spread into the ground-hugging branches and from there up into the crown.

Subalpine fir may begin producing cones when only 20 years old, but maximum seed production is by dominant trees 150 to 200 years old. Subalpine fir has the ability to germinate and survive on a fairly wide range of seedbeds.

Subalpine fir can occur in a fire-initiated stand with Douglas-fir, lodgepole pine, and other seral species because it germinates successfully on a fire-prepared seedbed. Subalpine fir is usually, however, a slower growing minor component, and is usually not as conspicuous as the less tolerant species.

In a closed canopy situation, establishment and early survival of fir are not hampered by deep shade. Subalpine fir can exist under low light conditions better than most associated species. Engelmann spruce will, however, often grow faster than subalpine fir where light intensity exceeds more than 50 percent of full sunlight. Subalpine fir is shade tolerant and is the indicated climax species on many sites containing lodgepole pine. Where a seed source exists, the fir will, consequently, invade and grow in the understory of lodgepole stands. Given a long enough fire-free period, subalpine fir will take over from lodgepole pine on sites where it is the indicated climax.

Subalpine fir occurs in Fire Groups Seven, Eight, Nine, and Ten.

Whitebark Pine (*Pinus albicaulis*)

Whitebark pine is a semitolerant or midtolerant seral species (Arno and Hoff 1981) that has been observed as a pioneer inhabiting burn sites. It is moderately fire resistant. Whitebark pine has a relatively thin bark and is susceptible to fire injury from hot surface fires that heat the cambium. Its dry, exposed habitat and open structure tend to reduce its vulnerability. The fact that whitebark pine often reaches ages of 500 years or more reflects the reduced fire threat.

Whitebark pine may occur as small groups of trees especially near its lower elevational limit where it appears with subalpine fir and Engelmann spruce. The general impression of whitebark pine habitat types, however, is that of open stands where the undergrowth is predominantly continuous low shrubs, forbs, and grasses. Occasionally larger shrubs and stunted trees occur.

Fires that burn in the undergrowth are usually of low-to-moderate severity. The low, ground-hugging crowns of associated conifers can provide a fuel ladder, and the downfall in the vicinity of mature trees locally increases crown fire potential; hence, severe fires are possible.

Severe wildfires starting in lower elevations can spread throughout the upper elevation forests to timberline. Although the open nature of a whitebark pine forest acts as a firebreak, many trees can be killed under these conditions. The most common fires are lightning fires that do not spread far nor do much damage.

Whitebark pine has a large, wingless seed that does not disperse by wind. Regeneration on burned sites is usually the result of seed germination from Clark's nutcracker and rodent seed caches.

Whitebark pine occurs in Fire Groups Six, Eight, Nine, and Ten.

Alpine Larch (*Larix lyallii*)

Alpine larch is a thin-barked species easily damaged by fire. However, it is moderately fire-resistant primarily because of its stand habit. It grows only on the highest elevations inhabiting rock faces, talus slopes, shallow soils, and moist, marshy sites. Alpine larch can grow in pure groves, in small groups, or as isolated individuals. In the lower portion of its elevational distribution, it occurs with subalpine fir, Engelmann spruce, and whitebark pine.

In the timberline zone, fire is a cause of tree mortality, but is less frequent and widespread than in contiguous forests below. Severe fires may enter the alpine larch stands from lower forests; however, they do not always adversely affect alpine larch stands. For example, the severe Sundance Fire of 1967 swept the ridges of Roman Nose Mountain burning most of the whitebark pine and killing much of the spruce and fir in the cirques, but caused only minor damage to isolated stands of alpine larch (Arno 1970). Sparse vegetation and rocky slopes curtail the intensity of fire in these areas.

When alpine larch grows in association with a vigorous stand of supalpine fir, Engelmann spruce, and whitebark pine, it is an intolerant seral species that dies out when overtopped by other conifers. Arno (1970) stated that fire allowed alpine larch to remain a major forest component with these species in some areas.

Alpine larch occurs only in Fire Group Ten.

UNDERGROWTH RESPONSE TO FIRE

Many of the common shrubs and herbaceous plants that grow on the forest floor of Montana forests can renew themselves from surviving plant parts following fire. Some plants are quite susceptible to fire kill and often must reestablish from off-site seed or invasion from unburned patches within or immediately adjacent to the burned area.

Table 3 is a summary of existing knowledge of plant response to fire for some species that occur in east side Montana forests. The fire response information is generalized. Plant response to fire depends on many factors including soil and duff moisture, physiological stage of the plant, and the severity of the fire, especially in terms of the amount of heat that travels downward through the duff and upper layer of soil.

Our primary concern in this report is with tree response to fire. Undergrowth response is, consequently, treated lightly in the Fire Group discussions that follow.

Table 3.—**Summary of postfire survival strategy and fire response information for some shrubs and herbaceous plants occurring in forest east of the Continental Divide in Montana (source: Daubenmire and Daubenmire 1968; Lotan and others 1981; Lyon and Stickney 1976; McLean 1969; Miller 1977; Mueggler 1965; Stickney 1981; Volland and Dell 1981; Wright 1980, 1978, 1972, Wright and Bailey 1980; Wright and others 1979).**

Species	Fire Group(s)	Postfire survival strategy	Comments on fire response
SHRUBS:			
Alnus sinuata Sitka alder	9	Sprouts from surviving root crown.	Usually increases on site following fire. Early seed production (after 5 years) aids in this increase.
Amelanchier alnifolia Serviceberry	3, 4, 6	Sprouts from surviving root crown.	Pioneer species usually survives even severe fires especially if soil is moist at time of fire. Coverage usually increases following fire.
Arctostaphylos uva-ursi Kinnikinnick	2, 4, 6, 7, 9	Sprouts from surviving root crown which is located below soil surface. Fibrous roots and stolons (runners) at soil surface.	Susceptible to fire-kill. Will survive some low severity fires when duff is moist and therefore not consumed by fire. May invade burned area from unburned patches.
Artemesia tridentata Big sagebrush	5	Wind dispersed seed	Very susceptible to fire-kill. Recovery is hastened when a good seed crop exists before burning.
Berberis repens Oregon grape	3, 4, 7, 8	Sprouts from surviving rhizomes which grow 0.5 to 2 in (1.5 to 5 cm) below soil surface.	Moderately resistant to fire-kill. Usually survive all but severe fires that remove duff and cause extended heating of upper soil.

(con.)

Table 3.—Continued

Species	Fire group(s)	Postfire survival strategy	Comments on fire response
Cornus canadensis Bunchberry dogwood	9	Sprouts from surviving rhizomes which grow 2 to 5 in (5 to 13 cm) below soil surface.	Moderately resistant to fire-kill. Will survive all but severe fires that remove duff and cause extended heating of upper soil.
Cornus stolonifera Redosier dogwood	9	Sprouts from surviving rhizomes or stolons (runners).	Susceptible to fire-kill. Will often invade burned area from adjacent unburned area or unburned patches. usually a slight increase following most fires.
Holodiscus discolor Oceanspray	6	Sprouts from surviving root crown.	Moderately resistant to fire-kill. Is often enhanced by fire.
Juniperus communis Common juniper	1, 4, 5, 6, 7, 8, 10	Bird dispersed seed.	Very susceptible to fire-kill. Seed requires long germination period.
Juniperus horizontalis Creeping juniper	1, 2	Similar to *J. communis*.	See *J. communis*
Linnaea borealis Twinflower	6, 7, 8, 9	Sprouts from surviving root crown located just below soil surface. Fibrous roots and stolons (runners) at soil surface.	Susceptible to fire-kill. May survive some cool fires where duff is moist and not consumed. Can invade burned area from unburned patches.
Lonicera utahensis Utah honeysuckle	9	Sprouts from surviving root crown.	Often a reduction in cover and frequency following fire.
Menziesia ferruginea Rusty menziesia	9, 10	Sprouts from surviving root crown.	Susceptible to fire-kill. Moderate to severe fires reduce survival and slow redevelopment.
Pachistima myrsinites Mountain lover	8	Sprouts from surviving root crown and from buds along taproot.	Moderately resistant to fire-kill. Usually survives low to moderate severity fires that do not consume the duff and heat soil excessively. Usually increases.
Physocarpus malvaceus Ninebark	6, 8	Sprouts from surviving root crown.	Susceptible to fire-kill. Shallow roots may be damaged by moderate to severe fires. Often a slight decrease following fire.
Potentilla fruticosa Shrubby cinquefoil	1		Susceptible to fire-kill
Prunus virginiana Chokecherry	3, 4	Sprouts from surviving root crown.	Usually increases coverage following fire.
Purshia tridentata Antelope bitterbrush	2, 4, 7	A weak sprouter. Animal-dispersed seed and seed caches present on area prior to fire.	Very susceptible to fire-kill, especially in summer and fall. Decumbent growth form sprouts vigorously, columnar form does not. Spring burns enhance sprouting, fall burns are best for regeneration by seed.
Ribes lacustre Prickly currant	9	Sprouts from surviving root crown which is located beneath soil surface, and from surviving rhizomes.	Resistant to fire-kill. Usually increase even after a severe fire.
Shepherdia canadensis Russet buffaloberry	3, 4, 5, 7, 8, 9	Sprouts from surviving root crown and from buds along taproot.	Moderately resistant to fire-kill. Will usually survive cool to moderately severe fires that fail to consume duff and heat soil extensively.
Spiraea betulifolia White spiraea	3, 4, 5, 6, 7, 8	Sprouts from surviving root crown and from rhizomes which grow 2 to 5 in (5 to 13 cm) below surface.	Resistant to fire-kill. Will usually survive even a severe fire. Generally increases coverage following fire.

(con.)

Table 3.—Continued

Species	Fire group(s)	Postfire survival strategy	Comments on fire response
Symphoricarpos albus Common snowberry	2, 3, 4, 6, 7, 8, 9	Sprouts vigorously from surviving rhizomes which are located between 2 and 5 in (5 and 13 cm) below soil surface.	Resistant to fire-kill. Will usually survive even severe fires. Greatly enhanced by cool to moderately severe fires.
Symphoricarpos occidentalis Western snowberry	2, 4		Increases coverage after spring burning.
Symphoricarpos oreophilus Mountain snowberry	5	Weak sprouter from surviving root crown.	Moderately resistant to fire-kill. Usually maintains prefire frequency and coverage.
Vaccinium scoparium Grouse whortleberry	6, 7, 8, 9, 10	Sprouts from surviving rhizomes which grow in duff layer or at surface of soil.	Moderately resistant to fire-kill. Will usually survive cool to moderately severe fires that fail to consume the lower layer of duff.
FORBS:			
Apocynum androsaemifolium Spreading dogbane	4	Sprouts from surviving rhizomes.	Generally maintains prefire frequency following fires.
Aralia nudicaulis Wild sarsaparilla	9	Sprouts from surviving rhizomes.	
Arnica cordifolia Heartleaf arnica	5, 6, 7, 8	Sprouts from surviving rhizomes which creep laterally from 0.4 to 0.8 in (1 to 2 cm) below soil surface. Wind dispersed seed.	Susceptible to fire-kill. Shoots produce small crowns within the duff which are easily killed by all but cool fires which occur when duff is moist. May rapidly invade burned area via windborne seed.
Arnica latifolia Broadleaf or mountain Arnica	6, 7, 8, 9, 10	Sprouts from surviving rhizomes which creep laterally in the soil.	Susceptible to fire-kill. Will usually survive cool to moderately severe fires. May exhibit rapid initial regrowth accompanied by heavy flowering and seedling establishment.
Aster conspicuus Showy aster	8	Sprouts from surviving rhizomes which mostly grow from 0.5 to 2 in (1.5 to 5 cm) below soil surface.	Moderately resistant to fire-kill. Will usually survive cool to moderately severe fires that do not result in excessive soil heating. May rapidly increase following fire.
Astragalus miser Timber milkvetch	5, 8	Sprouts from buds along surviving taproot which may be 2 to 8 in (5 to 20 cm) below the root crown.	Resistant to fire-kill. Can regenerate from taproot even when entire plant crown is destroyed. Can send up shoots and set seed the first year. May increase dramatically following fire. Note: Milkvetch is poisonous to sheep and cattle.
Balsamorhiza sagittata Arrowleaf balsamroot	4, 5	Regrowth from surviving thick caudex.	Resistant to fire-kill. Will survive even the most severe fire.
Clintonia uniflora Queencup beadlily	9	Sprouts from surviving rhizomes.	Usually decreases following fire. Postfire environment evidently not conducive to rapid recovery.
Fragaria virginianas Wild strawberry	5, 8	Sprouts from surviving stolons (runners) at or just below soil surface.	Susceptible to fire-kill. Will often survive cool fires that do not consume duff because of high duff moisture content.
Galium triflorum Sweetscented bedstraw	8, 9	Sprouts from surviving rhizomes.	Susceptible to fire-kill. Usually a sharp decrease following severe fire. Can increase following spring and fall fires.
Pyrola secunda sidebells pyrola	5, 6, 8	Sprouts from surviving rhizomes which grow mostly in the duff or at soil surface.	Susceptible to fire-kill. Coverage frequently reduced following fire. May survive cool fires when duff moisture is high.

(con.)

Table 3.—Continued

Species	Fire group(s)	Postfire survival strategy	Comments on fire response
Smilacema racemosa Feather or false Solomon's seal	8	Sprouts from surviving stout creeping rhizomes.	Moderately resistant to fire-kill. May be killed by severe fires that remove duff and heat soil excessively. Usually maintains prefire frequency.
Smilacema stellata Starry Solomon's seal	6, 8	Sprouts from surviving creeping rhizomes.	Moderately resistant to fire-kill. May be killed by fires that remove duff and heat upper soil. Frequency often reduced following fire.
Thalictrum occidentale Western meadowrue	5, 6, 7, 8	Sprouts from surviving rhizomes.	Susceptible to fire-kill. Frequency usually reduced following fire. May survive cool fires that do not consume duff.
Xerophyllum tenax Beargrass	6, 7, 8, 9, 10	Sprouts from a surviving stout surface rhizome.	Susceptible to fire-kill. Will survive cool fires that do not consume duff. Sprouts will flower vigorously after a fire until new overstory canopy develops.
Zigadenus elegans Death camas	8	Sprouts from surviving tunicated bulb.	Resistant to fire-kill.
GRASSES:			
Agropyron spicatum Bluebunch wheatgrass	1, 2, 4, 5	Seed germination and some sprouts from surviving rhizomes.	Usually not seriously damaged by fire. Response depends on severity of fire and physiological state of plant. Damage will be greatest following dry year.
Calamagrostis rubescens Pinegrass	4, 5, 6, 7, 8	Sprouts from surviving rhizomes which grow within the top 2 in (5 cm) of soil.	Moderately resistant to fire-kill. Will usually survive cool to moderately severe fires that do not completely consume duff. Burned areas are often successfully invaded by pinegrass.
Carex geyeri Elk sedge	5, 7, 8	Sprouts from surviving rhizomes.	Invades burned areas and forms dense stands. Often increases following fire.
Carex rossi Ross sedge	10	Seed stored in duff or soil which germinates when heat treated. Sprouts from surviving rhizomes.	Increased coverage usually results following most fires severe enough to heat but not completely consume duff. Often increases.
Festuca idahoensis Idaho fescue	1, 2, 4, 5, 10	Seed germination and survival of residual plant.	Susceptible to fire-kill. Response will vary with severity of fire and phsiological state of plant. Can be seriously harmed by hot summer and fall fires. Only slightly damaged during spring or fall when soil moisture is high.
Festuca scabrella Rough fescue	1, 2, 4, 5	Seed germination and residual plant survival.	Usually harmed by spring burning.
Koeleria cristata Junegrass	4	Seed germination and residual plant survival.	Susceptible to fire-kill. Response will vary according to fire severity and physiological state of plant.
Luzula hitchcockii Smooth woodrush	10	Sprouts from surviving rhizomes.	Often a slight increase following fire.

SUMMARY ON DOWNED, DEAD FUEL

Downed, dead woody fuel consists of dead twigs, branches, stems, and boles of trees and shrubs that have fallen and lie on or near the ground (Brown and See 1981). Table 4 is a summary of such fuel for east side forests based on inventories conducted by the Forest Service's Northern Region over 6 years on the Deerlodge, Gallatin, and Helena National Forests.

The values in table 4 are group averages. Habitat type averages are shown in figure 2, which also shows how habitat type loadings compare. Brown and See (1981) provide additional summaries of east side fuel loads that should be useful aids for fire management.

Table 4.—Average downed woody loadings and duff depths for east side forests by fire groups (source: Brown and See 1981)

Habitat type groups[1]	Equivalent fire groups	Downed woody			Duff depth
		Small	Large	Total	
		Tons/acre			*Inches*
1	1 & 2	2.3	8.5	10.8	1.1
2	3, 4, & 5	2.5	10.5	13.0	1.0
3	6	2.1	11.3	13.4	0.9
4	7 & 8	2.4	17.0	19.4	1.2
5	9	1.9	16.9	18.8	1.0
6	10	2.1	9.4	11.5	0.7

1 = Limber pine; ponderosa pine and Douglas-fir/bunchgrass types.
2 = Dry site Douglas-fir and moist site ponderosa pine.
3 = Moist site Douglas-fir.
4 = Cool sites dominated by lodgepole pine; dry, lower elevation subalpine fir.
5 = Moist site, lower elevation subalpine fir.
6 = Cold, moist site upper elevation subalpine fir.

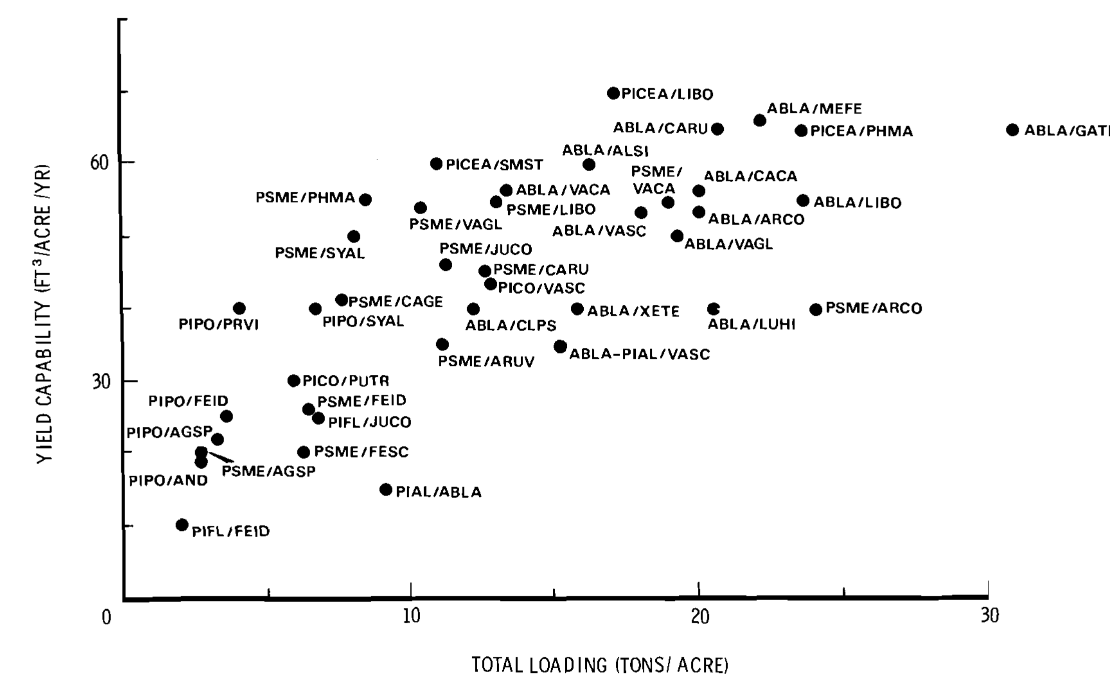


Figure 2.—Ordination of habitat types by yield capability and total downed woody fuel loading for eastside forests. Yield capabilities are from Pfister and others (1977). (Source: Brown and See 1981.) See table 1 for fire group assignment of habitat types.

FIRE GROUP ZERO: MISCELLANEOUS SPECIAL HABITATS

Group Zero is a miscellaneous collection of habitats that have fire ecology and management implications, but that do not fit into the Montana habitat type classifications.

Scree

The term "scree" refers to slopes covered with loose rock fragments, usually lying almost exactly at the maximum possible angle of repose so that any disturbance causes miniature rock slides down the face of the slope. Scree slopes may be treeless or they may support scattered trees with sparce undergrowth (fig. 3). Usually scree communities are regarded as special environments where the vegetation is in an uneasy equilibrium with the shifting substrate.

In these sites the top layer of talus is moving downhill gradually and is forcing the deep-rooted trees to tilt in the downhill direction. Since the trees continually strive to grow upward, their trunks may become bowed at the base. Surface instability and xeric site conditions at the surface combine to make climax vegetation rare on scree slopes.

The trees most often associated with scree at lower elevations are ponderosa pine, limber pine, Rocky Mountain juniper, and Douglas-fir. At higher elevations, where scree is a major component, these habitats are occupied by lodgepole pine, Engelmann spruce, subalpine fir, or whitebark pine.

The lack of continuous fuel, or of fuel of any kind, often makes scree slopes unburnable. Individual trees or islands of vegetation may ignite, but fire spread is limited. A wind-driven holocaust fire could pass over the intervening open spaces and destroy a scree community, but this rarely happens. Due to the harsh environment, these sites do not revegetate well, and revegetation following a fire can take a very long time.

Figure 3.—Scree and forested rock are habitats where the influence of fire is minimal (Storm Lake, Deerlodge National Forest). (Bruce Clayton photo.)

Forested Rock

Forested rock is usually a very steep canyon wall or mountain side composed of rock outcrops, cliffs, and occasional clumps of trees clinging to ledges and crevices. Forested rock is especially prominent along the canyons of major rivers and in rugged upper subalpine areas near timberline. These sites bear a certain similarity to scree sites, but the substrate is solid and climax species frequently become established.

Surface fires do not burn well because of the vertical and horizontal discontinuity of ground fuels. The probability of crown fires depends on the density and arrangement of trees on the rock face. In some cases the islands of vegetation are so widely scattered as to be almost immune to wildfire. In other cases, particularly low elevation Douglas-fir forested rock communities, a continuity of foliage from the base to the top of a cliff can occur. Each tree forms a ladder into the lower branches of the next higher tree upslope. In such cases crown fires can occur over ground that would not support a less severe surface fire.

Revegetation of rocky sites proceeds at a rate characteristic of the site and depends on the severity of the fire, the age and depth of the soil on ledges and in pockets of rock, erosion if any, and the availability of seeds.

Meadow

A meadow is an opening in the forest that is characterized by herbaceous vegetation and abundant water. Subirrigation is common during at least some part of the growing season. Mountain meadows are frequently too wet to burn during the fire season. Meadows sometimes act as natural firebreaks, but may carry grass fires during the driest part of the summer and fall.

It is the nature of streamside meadows to gradually become drier in the course of primary succession from the hydric to the mesic condition. The buildup of organic material and trapped sediments from the flowing water, combined with a possible deepening of the streambed and lowering of the water table, can leave former meadows in an intermediate condition between true meadow and grassland. In some such sites the meadow becomes bordered by fire-maintained grassland. Fire suppression has allowed conifers to invade these sites where they would not normally be found.

Grassy Bald

A grassy bald is a grass-covered opening within an otherwise continuous coniferous forest. Balds may act as firebreaks and can be maintained as grassland by light fires, but usually their fire ecology is less obvious. Billings and Mark (1957) theorize that balds are caused by severe fires that kill all the trees in a stand that happens to lie at the ecotonal limits of a tree species. Following the fire, according to this theory, the new environment is too severe to permit regeneration except under rare circumstances. Reforestation of the area may then be delayed, and evidence of the preceding forest eventually is lost. It is also possible that grassy balds are natural grasslands that have little potential for forest development. Balds may also reflect differences in underlying geologic structures that influence soil moisture retention. Caution is indicated in management of stands adjacent to grassy balds until conditions perpetuating the local balds are determined.

Aspen Grove

Groves of quaking aspen or quaking aspen and black cottonwood can occur as local climax vegetation on streamside sites or as fire-maintained stands in areas that would otherwise be dominated by conifers. In the fire-maintained areas, the absence of fire can result in the gradual elimination of aspen due to lack of successful regeneration.

Alder Glade

An alder glade is an opening in the forest occupied by alder. Such sites usually appear on local areas that are too wet for associated conifers. Because they are wet, alder glades burn infrequently, but they also burn very intensely and then resprout from surviving underground stems. Burning tends to make the stand more dense because each burned plant puts up several new shoots during recovery. Alder, like aspen, can exist as a fire-maintained stand in areas where conifer invasion is possible.

Fire Management Considerations

Group Zero habitats will not burn readily under normal summertime weather conditions. Fire managers can take advantage of this fact when developing preattack plans and when delineating fire management areas, units, or zones. These areas can also serve as anchor points for fuel breaks and firebreaks.

Meadows and aspen groves can be important wildlife habitats. Prescribed fire is a suitable tool for maintaining desired forage conditions in these habitats.

FIRE GROUP ONE: DRY LIMBER PINE HABITAT TYPES

ADP code	Habitat type-phase (Pfister and others 1977)	Montana forest region (Arno 1979)
040	*Pinus flexilis/Agropyron spicatum* h.t. (PIFL/AGSP), limber pine/bluebunch wheatgrass.	North-central, central, southwestern, and south-central.
051	*Pinus flexilis/Festuca idahoensis* h.t.-*Festuca idahoensis* phase (PIFL/FEID-FEID), limber pine/Idaho fescue-Idaho fescue phase.	North-central, central, southwestern, and south-central.
052	*Pinus flexilis/Festuca idahoensis* h.t.-*Festuca scabrella* phase (PIFL/FEID-FESC), limber pine/Idaho fescue-rough fescue phase.	North-central and central.
070	*Pinus flexilis/Juniperus communis* h.t. (PIFL/JUCO), limber pine/common juniper.	North-central, central, southwestern and south-central.

Group One habitat types occupy some of the driest sites capable of supporting trees. Stands are dominated by limber pine, which is often the only tree present. Douglas-fir may occur as a codominant or subordinate species in some stands. Where it does occur on Group One sites, Douglas-fir is often slow growing and of short stature (stunted). These characteristics make it more susceptible to fire damage than it is on most other sites. Ponderosa pine and Rocky Mountain juniper may occur as minor stand components in some areas. Rarely, whitebark pine is a minor climax associate in higher elevation stands. Lodgepole pine and spruce may occur as accidentals.

Group One stands occur below the forest proper as woodlands that extend from the foothills to the adjacent Great Plains (fig. 4A). They also occur on steep, dry, rocky mountain slopes at lower to midelevations (fig. 4B). Trees occupying Group One habitats are usually stunted. Mature trees often are only 20 ft (6 m) and rarely more than 50 ft (15 m) tall.

Bluebunch wheatgrass dominates the undergrowth in lower elevation stands on dry rocky sites. With increasing moisture, Idaho fescue or rough fescue dominate the undergrowth. At the highest elevations occupied by Group One habitat types, the undergrowth is dominated by common juniper, creeping juniper, and dry-site forbs.

Forest Fuels

Downed, dead, woody fuel loads range between 5 tons/acre (1 kg/m^2) and 15 tons/acre (3.4 kg/m^2) in Group One stands. These values are consistent with those calculated by Brown and See (1981) for these habitats (table 4 and fig. 2). About 80 percent or more of the downed woody fuel is usually 3 inches (7.6 cm) in diameter or larger, regardless of the total load. This material is often the result of the falling of snags created by a previous fire. Downed, dead, woody fuels rarely create a serious fire hazard in this group because loadings are usually light and the material is usually scattered about the site (fig. 4). Where hazardous fuel conditions exist, they are often the result of dead herbaceous fuels.

Role of Fire

Reported fire frequencies for Fire Group One habitats are low. The meager existing evidence suggests that fires hot enough to scar trees occurred 50 to 100 years apart. Arno and Gruell (1983) investigated a PIFL/AGSP stand in southwestern Montana that showed evidence of five fires, the earliest in 1588 and the latest in 1877, for a mean fire interval of 74 years. Pfister and others (1977) sampled 100- to 200-year-old stands in which there was no apparent sign of fire. The available information does not consistantly differentiate between the more severe sites where fuels are light and discontinuous, and the more productive sites where more frequent fire might be expected. Keown's (1977) study was, however, on a productive site, and he reported a fire frequency of 100 years.

Limber pine invasion of adjacent seral grass and shrublands is a slow process because these sites are so dry. The fire susceptibility of young limber pine and Douglas-fir would seem to preclude successful invasion of sites that experience normal grassland fire frequencies of 5 to 25 years (see Fire Groups Two

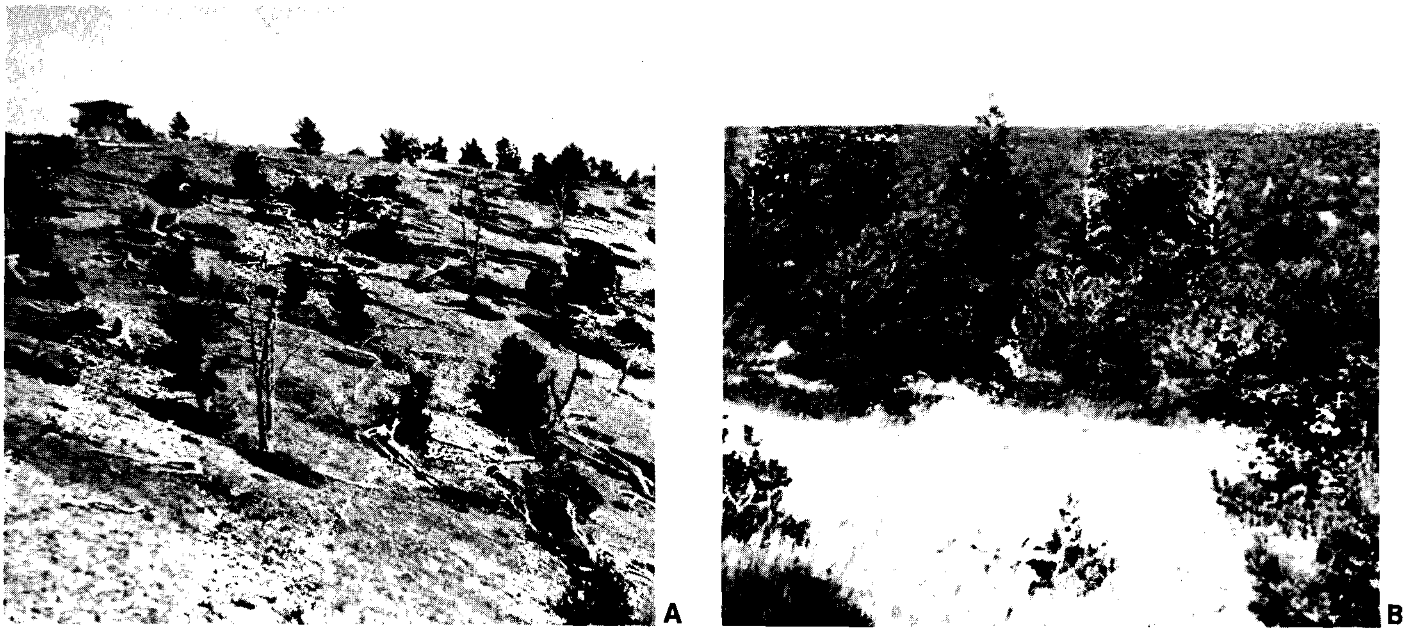


Figure 4.—Examples of two limber pine forests in eastern Montana. (A) A woodland type forest on a limber pine/Idaho fescue h.t.-rough fescue phase at the western edge of the Great Plains, northwest of Choteau in central Montana. Trees are a mixture of limber pine and stunted Douglas-fir. (B) A limber pine/common juniper h.t. near the Hogback Lookout, Helena National Forest. A fire swept this ridge 60 or more years ago. The resulting grass and herb undergrowth is slowly being filled in by mats of common juniper and occasional limber pines that may have been planted by Clark's nutcrackers. The standing and down snags indicate the former density of the stand. (Bruce Clayton photo.)

and Four). It is, however, conceivable that successful invasion could occur under a frequent fire regime if those fires were always of low intensity. As noted earlier, Keown's (1977) light fires only killed 20 percent of the invading limber pines, while his high intensity fires killed 80 percent of the invaders.

Frequent cool, surface fires could actually favor development of limber pine stands by keeping fuels from reaching levels that would support severe tree-killing fires. The possibility that Group One sites have been subjected to frequent fires that produce very slight effects (no scarring) cannot be ruled out. The existing evidence, however, seems to favor the interpretation of infrequent fires.

The presence of open stands of mature limber pine and Douglas-fir suggest that these more fire-resistant growth forms can be maintained by periodic fires that clean out the intervening regeneration. Fire can act as a thinning agent that slightly favors limber pine over Douglas-fir in the younger age classes.

As the old burn on Hogback Ridge testifies (fig. 4B), holocaust fires on Fire Group One sites are a possible if rare event. A wind-driven crown fire can destroy a stand, especially if enough time has passed since the last ground fire to allow a layer of regeneration, shrubs, or litter and other debris to form under the trees. Several of the Group One sites sampled for the Montana habitat type data base showed signs of origin following fire. Limber pine probably reestablished on these sites as a result of seed cached in the soil by Clark's nutcrackers (Lanner and Vander Wall 1980).

Generalized Forest Succession

A generalized concept of forest succession in Group One habitats and how fire affects this succession is shown in figure 5 (subsequent numbers in this section refer to fig. 5).

Grassland sites that are potential PIFL habitat types are maintained as grassland by frequent grass fires (No. 1). It is uncertain to what extent this effect is taking place, and also the frequency of fire required to prevent conifer invasion of the grassland is not known. Where conifers have succeeded in growing to maturity, the apparent frequency of fire is low (once or twice a century).

A shrub stage following the grassland stage has been implied in certain PIFL habitats but not in others. The shrub stage is, for example, usually lacking on PIFL/AGSP and PIFL/FEID h.t.'s. The shelter provided by the shrubs when they do occur apparently helps limber pine and Douglas-fir seedlings to become established. A thinning fire in the sapling period eliminates the shrubs (temporarily) and tends to favor limber pine over Douglas-fir (No. 2). Further regeneration may require the reestablishment of the shrub cover in habitats where shrubs are a factor. A severe fire in sapling stage can kill most of the trees, reverting the site to the grassland condition (No. 3).

If a fire-free period occurs long enough (it usually does), the limber pine and Douglas-fir trees reach maturity and acquire some fire resistance due to their thick bark. Subsequent fires tend to thin the stand, leaving the mature trees in an open fire-maintained stand (No. 4).

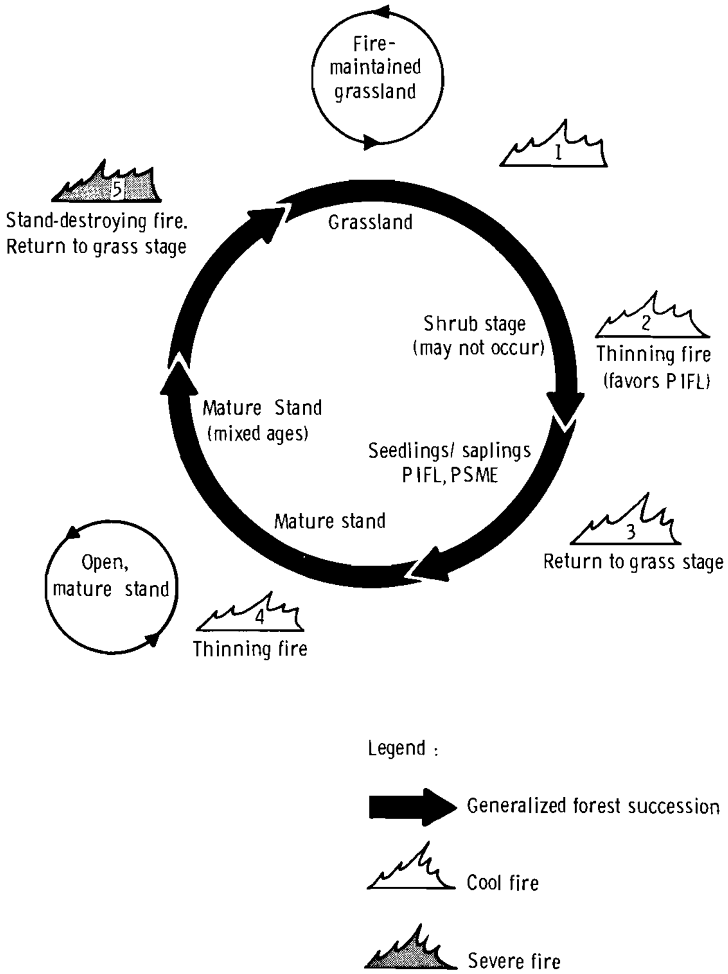


Figure 5.—Generalized forest succession in Fire Group One: limber pine climax series habitat types.

If fire does not thin the mature forest over a very long period (possibly centuries), then accumulating regeneration and litter could eventually contribute to a wind-driven, stand-destroying wildfire (No. 5). Such a severe fire reverts the site to a grassland condition, possibly for a very long time. Regeneration depends on the local availability of seed and the subsequent fire history.

Successional Pathways

Forest succession on this group's habitat types is not well understood. Research is especially needed to define fire frequency, rates of succession, and limber pine fire resistance. The role of fire in limber pine seedling establishment also needs investigation. Hypothetical successional pathways that may be followed by Fire Group One communities are shown in figure 6 (subsequent states and numbers in this section refer to fig. 6). Six states or stages of vegetative development are recognized for Group One habitats.

State A is grassland. Frequent fire at relatively short intervals maintains this state (No. 1).

Low fire frequency may result in establishment of a shrub stage (state B). Any fire occurring during this stage will revert the site to grassland (No. 2).

Absence of fire for a long interval allows the successful invasion of limber pine and Douglas-fir seedlings (state C). A moderate to severe fire during this state reverts the site to grassland (No. 3). A light surface fire in the sapling stage may merely thin out some individual trees and not significantly affect succession (No. 4).

State D is the mature forest. A severe fire in this state reverts the site to grassland (No. 5). Light ground fires burning through mature stands tends to thin out regeneration and undergrowth, leaving open stands of mature trees (No. 6). The resulting coniferous woodland is shown as state F. Periodic low severity fires will maintain the coniferous woodland state (No. 7). A severe fire during state F will revert the site to grassland (No. 7).

In the absence of fire, the mature stand (state D) will develop into a dense, mixed-age climax stand of limber pine, Douglas-fir, and Rocky Mountain juniper (state E). This state will perpetuate itself in the continued absence of fire. A cool fire during state E thins out regeneration, undergrowth, and some overstory trees (No. 8). This has the effect of creating the coniferous woodland state (state F). A severe fire during state E reverts the site to grassland (No. 9).

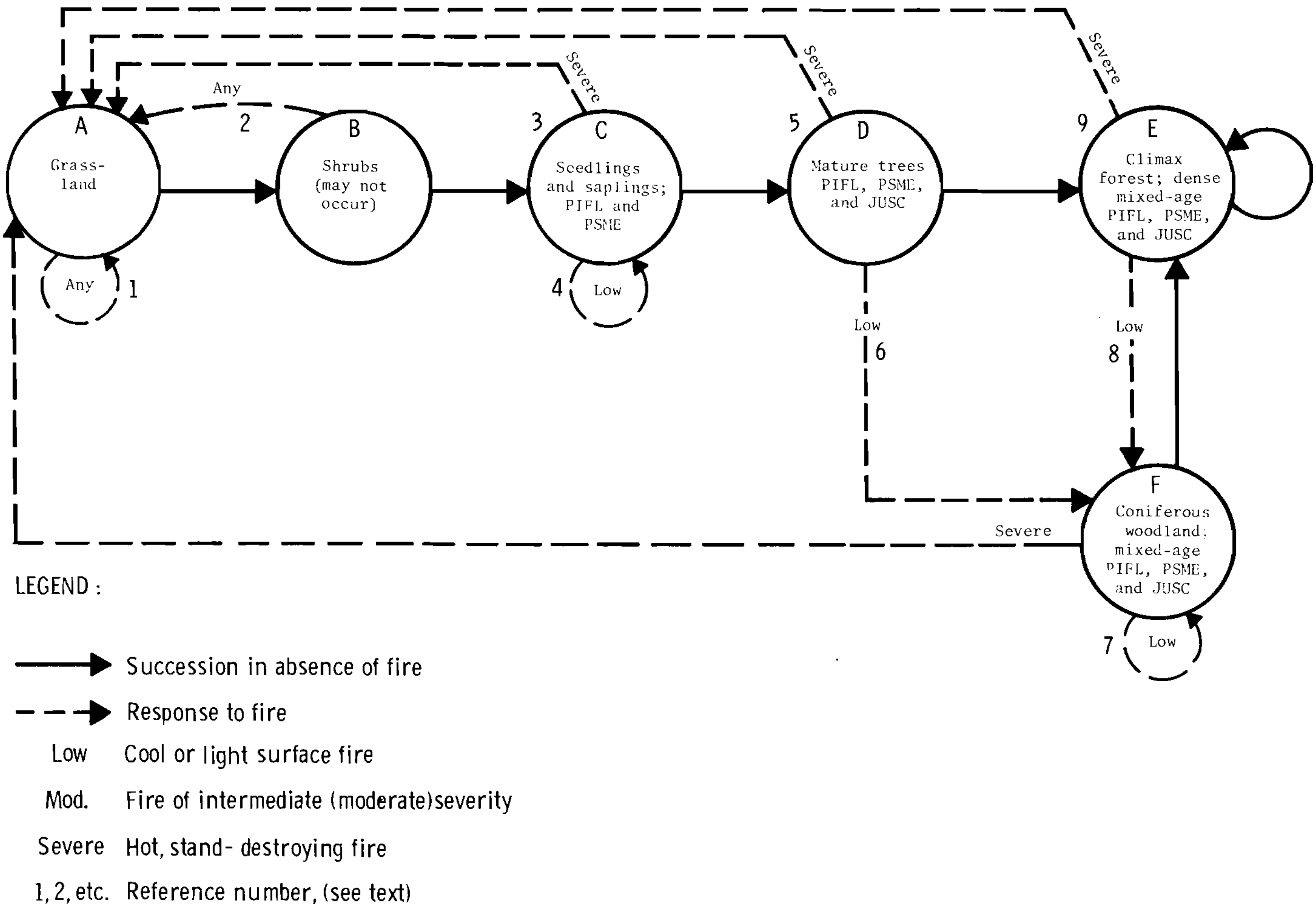


Figure 6.—Hypothetical fire-related successional pathways for Fire Group One habitat types.

Fire Management Considerations

Resource productivity is usually low on Group One habitats. Consequently, high fire suppression expenditures are rarely justified except when life, private property, adjoining areas of high value resources, or improvements are seriously threatened. Open stands with sparse ground cover often act as firebreaks under most burning conditions.

Periodic light surface fires can benefit browse and forage production for wildlife and domestic livestock on those sites where this is an important management objective. Keown (1977) has demonstrated the use of prescribed fire for checking conifer invasion and otherwise improving range and wildlife habitat on certain Group One sites. He received good results using the following prescription:

Temperature	greater than 50° F (10° C)
Relative humidity	30 percent or less
Wind	5-15 mi/h (8-24 km/h)
Fuel moisture	5-10 percent
Soil moisture	damp

The most significant prescription condition was sun shining on the burn unit. Humidity recovery at night was important for cooling smoldering logs and duff. Wind had to be strong enough to spread the fire but light enough to allow the heat from the fire to scorch crowns of unwanted trees.

Results of spring burning according to the above prescription included a definite stimulation of grass, forbs, shrubs, and aspen. Comparison of prefire and postfire vegetative cover showed a 50 percent increase in forb coverage, a 40 percent decrease in grass coverage, and a 47 percent decrease in shrub coverage the first season after fire. A general increase in the protein content of browse plants important to wildlife was noted (Keown 1977).

FIRE GROUP TWO: WARM, DRY PONDEROSA PINE HABITAT TYPES

ADP code	Habitat type-phase (Pfister and others 1977, Roberts 1980, Roberts and Sibbernsen 1979)	Montana forest region (Arno 1979)
110	*Pinus ponderosa/Andropogon* spp. h.t. (PIPO/AND), ponderosa pine/bluestem.	Southeastern.
130	*Pinus ponderosa/Agropyron spicatum* h.t. (PIPO/AGSP), ponderosa pine/bluebunch wheatgrass.	Central and southeastern (including Bearpaw Mountains).
141	*Pinus ponderosa/Festuca idahoensis* h.t.-*Festuca idahoensis* phase (PIPO/FEID-FEID), ponderosa pine/Idaho fescue-Idaho fescue phase.	Central and southeastern.
142	*Pinus ponderosa/Festuca idahoensis* h.t.-*Festuca scabrella* phase (PIPO/FEID-FESC), ponderosa pine/Idaho fescue-rough fescue phase.	Central (including Bearpaw Mountains).
161	*Pinus ponderosa/Purshia tridentata* h.t.-*Agropyron spicatum* phase (PIPO/PUTR-AGSP), ponderosa pine/bitter-brush-bluebunch wheatgrass phase.	Central.
162	*Pinus ponderosa/Purshia tridentata* h.t.-*Festuca idahoensis* phase (PIPO/PUTR-FEID), ponderosa pine/bitter-brush-Idaho fescue phase.	Central.
171	*Pinus ponderosa/Symphoricarpos albus* h.t.-*Symphoricarpos albus* phase PIPO/SYAL-SYAL), ponderosa pine/snowberry-snowberry phase.	Central and southeastern.
	Pinus ponderosa/Juniperus horizontalis h.t. (PIPO/JUHO), ponderosa pine/horizontal juniper.	Central (Little Rocky Mountains only).
	Pinus ponderosa/Symphoricarpos occidentalis h.t. (PIPO/(PIPO/SYOC), ponderosa pine/western snowberry.	Central (Little Rocky Mountains only).
	Pinus ponderosa/*Arctostaphylos uva-ursi* h.t. (PIPO/ARUV), ponderosa pine/kinnikinnick.	Central (Little Rocky Mountains only).
	Pinus ponderosa/Juniperus scopulorum (PIPO/JUSC), ponderosa pine/Rocky Mountain juniper.	Central (Missouri River Breaks only).

Fire Group Two consists of ponderosa pine stands with predominantly grass undergrowth. These habitats may exist as fire-maintained grassland and will support limber pine, Rocky Mountain juniper, and Douglas-fir as accidental individuals. In some habitat types, juniper may be a minor climax species. Sites are typically hot, dry, south- and west-facing slopes at low elevations, forming the lower timberline in the area. Slopes are often steep with poorly developed soils. Extensive stands also occur on flats and rolling topography at the lowest elevation of forest distribution. Moisture stress is a critical factor for plant growth during summer months. Stockability limitations often result in low productivity although some sites regenerate readily and form dog hair thickets.

Forest Fuels

Downed and dead fuel loads in Group Two stands are often light. The amount of material less than 3 inches (7.6 cm) in diameter rarely exceeds 5 tons/acre (1 kg/m^2). The amount of material greater than 3 inches (7.6 cm) varies according to stand condition but usually accounts for 75 percent or more of the total load (table 4). The large fuels result from the downfall of dead trees that were unsuccessful competitors in dense stands, from deadfall following fire, and from mechanical damage caused by wind, snow, or overstory removal (fig. A).

Live fuels may contribute to fire hazard in Group Two stands. Dense ponderosa pine understories often develop beneath scattered overstory trees on some Group Two sites (fig. 7B). Fires that start in such stands often burn vigorously in the crowns of the understory trees. Consequently, fast spreading, severe fires result despite relatively light downed and dead fuel loadings.

Figure 8 shows actual stand conditons on some Fire Group Two habitat types on the Custer National Forest. Corresponding fuel loads are given in table 5.

A B

Figure 7.—Fire Group Two ponderosa pine stands, Ashland-Fort Howes Ranger District, Custer National Forest. (A) Stand with large diameter downfall. (B) Dense understory beneath scattered overstory. (Bruce Clayton photo.)

Table 5.—Fuel loading by size class for Fire Group Two stands shown in figure 8.

Stand number	Habitat type	Age	Duff depth	Size class (inches) 0-1/4	1/4-1	1-3	3-6	6-10	10-20	Total
		Years	*Inches*	*Tons/acre*						
33A	PIPO/SYAL-SYAL	180	1.7	0.3	1.0	0.5	0.5	0.2	3.2	5.7
30A	PIPO/SYAL-SYAL	60	1.1	0.2	0.6	1.9	0.7	2.4	0.9	6.7
32A	PIPO/FEID-FEID	58	1.1	0.5	1.9	4.5	1.0	2.5	0	10.4
31A	PIPO/FEID-FEID	148	0.8	0.2	0.4	0.7	1.0	2.8	5.5	10.7
29A	PIPO/FEID-FEID	100	0.4	0.2	1.3	3.2	3.4	0.9	2.4	11.4

A

B

C

D

Figure 8.—Examples of Fire Group Two ponderosa pine stands, Ashland-Fort Howes Ranger District, Custer National Forest. Stands 33A and 30A (A and B) are on a ponderosa pine/snowberry h.t.-snowberry phase. Stands 32A, 31A, and 29A (C, D, and E) are on ponderosa pine/Idaho fescue h.t.-Idaho fescue phase. Stand 29A was recently burned. The cat face in stand 31A (D) is evidence of past fire.

E

Role of Fire

The role of fire in Group Two habitats is threefold:

1. **To maintain grasslands**. Grassland areas capable of supporting juniper and ponderosa pine may remain treeless through frequent burning.

2. **To maintain open pine stands**. The open condition is perpetuated by periodic fires that either reduce the number of seedlings, remove dense understories of sapling or pole-sized trees, or thin overstory trees.

3. **To encourage ponderosa pine regeneration**. Fire exposes mineral soil, reduces seedling-damaging cutworm populations, reduces competing vegetation, and increases nutrient availability. Depending on the subsequent seed crop, weather, and continuity of the seedbed, regeneration may appear as dense stands, separated thickets, or scattered individuals. Periodic fires can create uneven-aged stands comprised of various even-aged groups. Severe fires will result in a predominantly even-aged stand.

Natural fire frequencies in forests adjacent to grasslands were fairly high, according to numerous fire history studies conducted in the ponderosa pine forest types throughout the Western States. These studies have shown fire to have been a frequent event, occurring at intervals of from 5 to 25 years in most locations. In Group Two habitat types of the Bitterroot National Forest, Arno (1976) reported a range of 2 to 20 years and mean fire-free intervals of 6 to 12 years for fires occurring somewhere in small stands, 50 to 100 acres (20 to 40 ha) (Arno 1981). Fire history investigators caution that these figures are conservative estimates of past mean fire-free intervals. Intervening light ground fires could have effects on stand development without leaving scars on trees.

A fire frequency of 50 years or more is suggested by Wright (1978) for the PIPO/PUTR h.t. He bases this hypothesis on observation and current knowledge of the susceptibility of bitterbrush to fire (Nord 1965; Weaver 1967; Wright 1978). Other investigators, however, suggest that ponderosa pine communities with shrub understories experienced fire frequencies of considerably less that 50 years (Gruell and others 1981; Weaver 1957, 1959, 1961).

Successful fire control during the 20th century has undoubtedly affected some Group Two stands. A primary effect is the increased presence of two-storied stands on some sites where the understory is a dense stand of pole-sized or larger trees (fig. 7). When fire control eventually fails in such stands, large, severe fires often result. Another effect of fire control is an increase in the acreage covered by Group Two stands as a result of successful juniper and ponderosa pine invasion of formerly fire-maintained grasslands. In hot, dry areas where natural regeneration is extremely slow and stocking is limited, the effect of fire control has often been minimal.

Generalized Forest Succession

A generalized concept of forest succession in Fire Group Two habitats and how fire affects this succession is shown in figure 9 (subsequent numbers in this section refer to fig. 9).

Very frequent fires tend to maintain the grassland community by killing pine seedlings (No. 1). Grasses dominate the

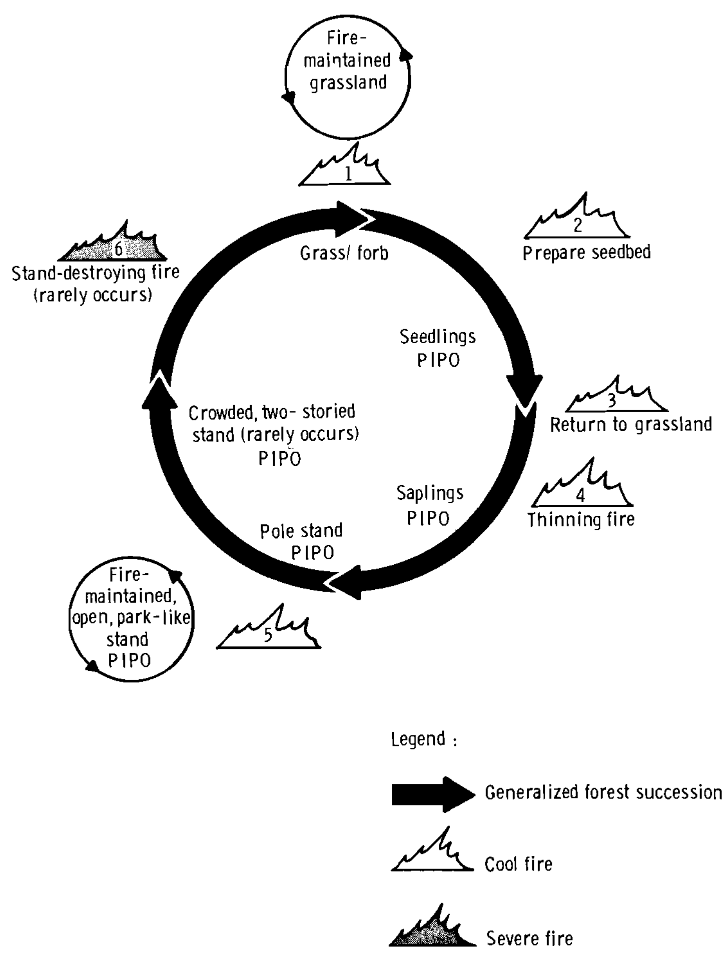


Figure 9.—Generalized forest succession in Fire Group Two: warm, dry ponderosa pine habitat types.

undergrowth, but other herbs and small shrubs may be present. Ponderosa pine seedlings may become established gradually over a long fire-free period resulting in an all-aged, all-sized stand; or as a single age class following a seedbed-preparing fire (No. 2). In the absence of further burning, the seedlings develop into saplings. Fires during this period may have the effect of killing the young trees (No. 3) or thinning them (No. 4).

With sufficient time the remaining trees mature to pole-size saplings. Subsequent light ground fires tend to produce an open stand of mature trees (No. 5). The open nature of the stand is a direct result of the fires and stocking limitations, and deteriorates if the fires are suppressed. The stand may then (in theory) become overstocked and accumulate enough fuel to support a severe stand-destroying fire (No. 6). In practice this situation is seldom observed in Group Two stands.

Successional Pathways

The combined effects of fire, plant succession, and fire exclusion are hypothesized in figure 10 (subsequent states and numbers in this section refer to fig. 10). Starting with an open, parklike stand (state A), and assuming a long fire-free interval, ponderosa pine seedlings of various ages and sizes will become established (state B1). Any fire during state A will create a mineral soil seedbed and likely result in the establishment of even-aged ponderosa pine seedlings (state B2).

UNEVEN-AGED SUCCESSION

Any fire occurring in the uneven-aged seedling state (state B1) will return the site to state A, the open, parklike stand (No. 1). The absence of fire will allow the development of a

I. SUCCESSION FROM THE OPEN, PARKLIKE, OLD GROWTH PONDEROSA PINE STATE

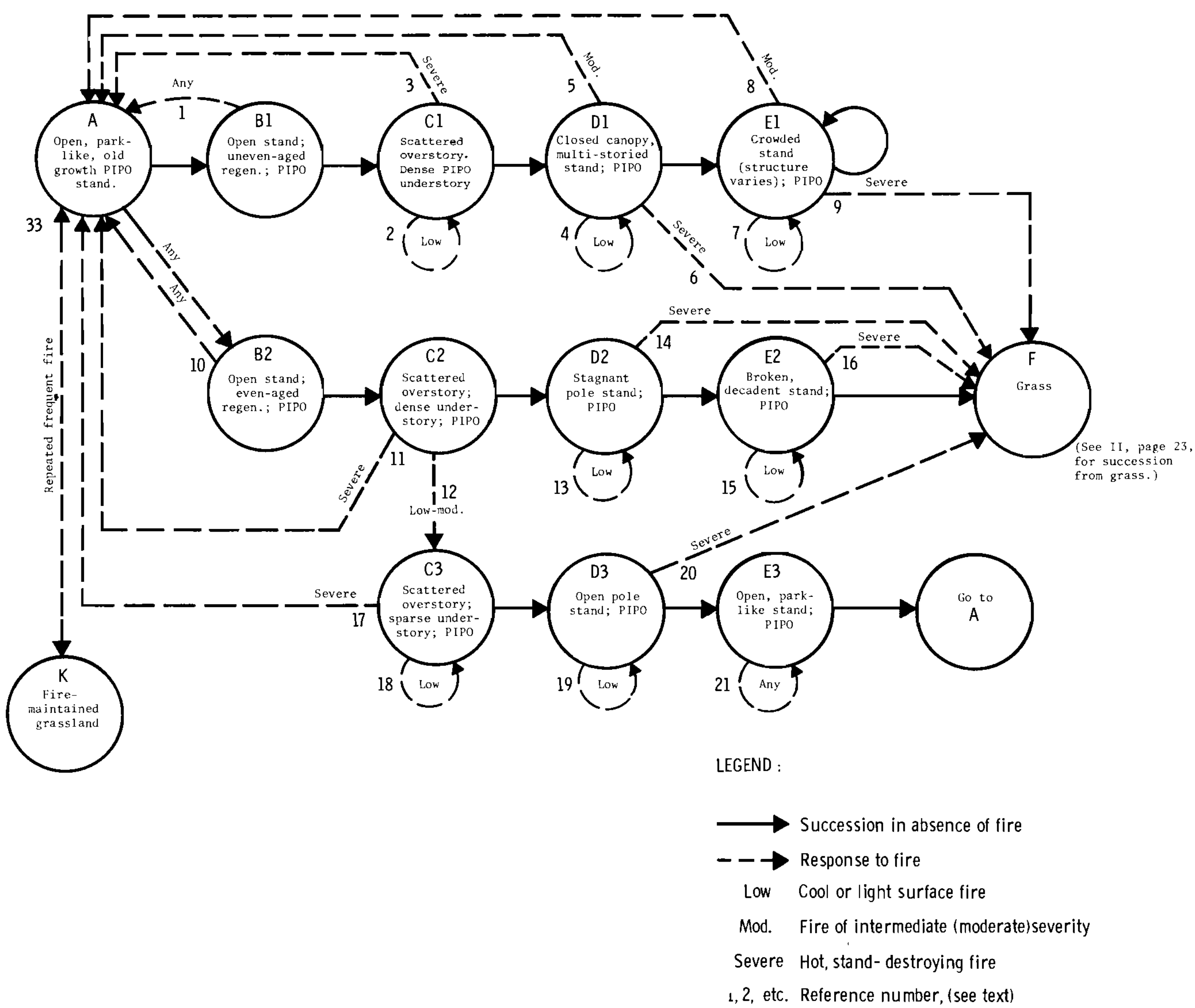


Figure 10.—Hypothetical fire-related successional pathways for Fire Group Two habitat types.

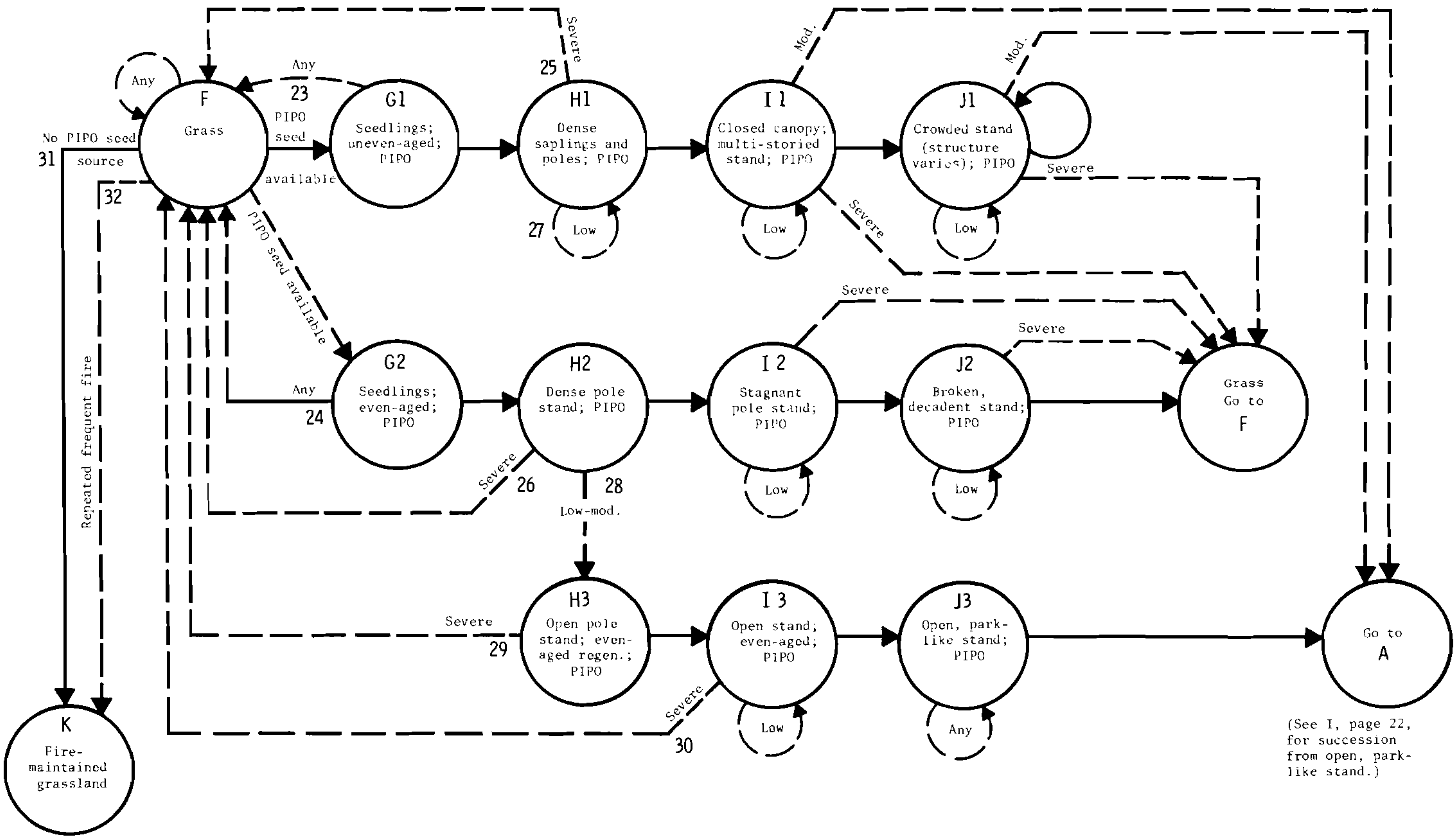


Figure 10.—(con.)

dense uneven-aged understory of ponderosa pine saplings and poles (state C1). A light surface fire at this state would act as a thinning fire removing some saplings from the stand (No. 2). A severe fire would return the site to the open parklike state (No. 3). Continued absence of fire allows a multistoried stand with a closed canopy to develop (state D1). A cool fire would have little impact on such a stand (No. 4). A moderate to severe fire could remove undergrowth and understory trees, and kill many overstory trees. This would result in the development of an open, parklike stand (No. 5). A severe, wind-driven crown fire might kill all trees and leave the site in grass (No. 6). Without fire, a crowded stand of mature ponderosa pine with a varied understory could develop and persist on the site (state E1). A cool fire would not have much impact except in the undergrowth (No. 7). A moderate to severe fire could remove much of the vegetation and leave an open, parklike stand (No. 8). A fire that kills all the trees would leave the site in grass (No. 9).

EVEN-AGED SUCCESSION

Succession following the establishment of even-aged seedlings (state B2) can be quite different from that occurring in the uneven-aged seedling state. Any fire during the even-aged seedling state will maintain the open, parklike conditions (No. 10). The absence of fire will allow a dense even-aged understory to develop (state C2). A severe fire in this state will revert the site to the open, parklike condition (No. 11), but a low to moderately severe fire might thin out the dense understory (No. 12) and leave an open stand with a sparce understory (state C3). Without a thinning fire, the dense, even-aged understory state (C2) could develop into a stagnant stand of even-aged, pole-sized trees (state D2). A light surface fire would have minimal impact on this condition (No. 13), and a severe fire would destroy the stand and leave the site in grass (No. 14). A continued absence of fire would result in a broken, decadent stand (state E2). A light surface fire in this state (E2) would do little to change stand conditions (No. 15). A severe fire (No. 16) or a continued lack of fire would lead to the grass state (state F). If fire thins out the dense understory associated with state C2 (No. 12), a different succession is likely. The resulting scattered overstory/sparse understory state (state C3) will revert to the open, parklike condition if severely burned (No. 17). A light surface fire should have little effect (No. 18). The absence of fire, however, will allow the development of an open pole stand (state D3), which could eventually develop into a open parklike stand (state E3). A surface fire would not interfere with this succession (No. 19), but a severe fire would likely destroy the stand (No. 20). Any fire occurring in the open, parklike stand would have little effect on the overstory trees (No. 21).

SUCCESSION FROM THE GRASS STATE

If a seed source is present, the grass state (state F) is eventually replaced by forest. Tree regeneration may occur as even-aged seedlings following a fire (state G2) or as uneven-aged seedlings on undisturbed grass sites (state G1). Any fire occurring during the seedling state (No. 23 and 24) will return the site to grass.

If fire is absent for long enough, dense stands of uneven-aged saplings and poles (state H1) or even-aged poles (state H2) develop. Severe fires return the sites to grass (No. 25 and 26). A cool fire will reduce the density of both the uneven-aged and the even-aged stands (No. 27 and 28).

Succession proceeds as outlined for open, parklike stands except that severe fires in states H3 and I3 return the sites to grass (No. 29 and 30) rather than to the open, parklike condition.

If a site becomes dominated by grass following a fire that destroys the only available seed source, a grassland may be created (No. 31). Frequent fire at intervals short enough to keep seedlings from attaining sapling or pole size will also maintain a site as grassland (No. 32). An open, parklike stand may also revert to grassland if repeated fire maintains the site in grass until the overstory trees die (No. 33).

Fire Management Considerations

Fire can be used to accomplish a variety of forest management objectives in Fire Group Two stands. These objectives include wildfire hazard reduction, forage production, site preparation for tree regeneration, stocking control, and development and maintenance of recreation sites.

WILDFIRE HAZARD REDUCTION

Prescribed fire can reduce dense patches of small trees and accumulated dead grass, needles, and woody debris in stands of pole-sized and larger trees, thereby lessening the chance of tree-killing wildfires. Similarly, slash hazard can be reduced by broadcast burning after cutting. In order to maintain a low level of flammability in Group Two stands, fire must be applied periodically whenever sufficient fuel accumulates to carry fire. Where heavy fuel loads exist prior to the initial entry with prescribed fire, it is often best to plan several burns in successive years rather than to risk the cambium kill and crown scorch often associated with a hot fire. Fuels can also be reduced through firewood removals, and piling and burning during safe periods.

FORAGE PRODUCTION

Forage production for livestock and big game can be enhanced by proper application of fire on Group Two habitat types. On PIPO/AND h.t.'s, PIPO/AGSP h.t.'s, and PIPO/FEID h.t.'s, grasses can be rejuvenated by removing dead grass and releasing stored nutrients. Fire can result in an increased production of nutrient-rich forbs. On PIPO/SYAL h.t.'s, light surface fires will rejuvenate shrubs through fire-simulated sprouting and cause a temporary increase in grass and forb production. Fire may be difficult to apply on open, heavily grazed PIPO/PUTR h.t.'s, where percent cover by plants is low and litter is sparse. Where it will carry, fire can be used to rejuvenate the undergrowth by killing decadent bitterbrush and thereby regenerating the site from onsite sprouting or from offsite seed cached in the burn by rodents. As a general rule, luxuriant growth of shrubs will not result from fire use on Group Two habitat types.

SITE PREPARATION AND STOCKING CONTROL

Fire can create a mineral soil seedbed where this is necessary for successful ponderosa pine regeneration. Once a new stand is established and an adequate number of trees 10 to 12 ft (3 to 3.7 m) or taller comprise the overstory, fire can be used to remove unwanted understory trees (Wright 1978). Subsequent use of fire at 5- to 7-year intervals will remove unnecessary reproduction and accumulated dead woody fuel, thereby increasing stand vigor, reducing fire hazard, and increasing grass, forb, and shrub production (Wright 1978). Siemens[1] suggests the following schedule of prescribed fire use for silvicultural purposes in Group Two ponderosa pine stands:

1. Use fire to prepare seedbed.
2. Protect regeneration from fire for 10 years.
3. Use a cool fire to remove smaller trees and thin some taller trees.
4. Protect stand for approximately 10 more years or until it is ready for precommercial thinning.
5. One year before commercial thinning, use fire to remove surface fuels and kill some of the trees.
6. Thin stand and protect from fire for about 5 years to allow slash to settle.
7. When slash is settled, use fire to consume these fuels.
8. Conduct cool fires about every 10 years to keep stand fuel free.

RECREATION SITE DEVELOPMENT

Prescribed fire can be used to create parklike openings underneath mature stands of ponderosa pine in which campgrounds and picnic areas can be installed. Periodic use of fire in spring or fall will maintain such openings and reduce fire hazard.

---

[1]Roger M. Siemens, District Forest Ranger Big Timber Ranger District Gallatin National Forest, Big Timber, Montana. Personal communication, Feb. 2, 1979.

FIRE GROUP THREE: WARM, MOIST PONDEROSA PINE HABITAT TYPES

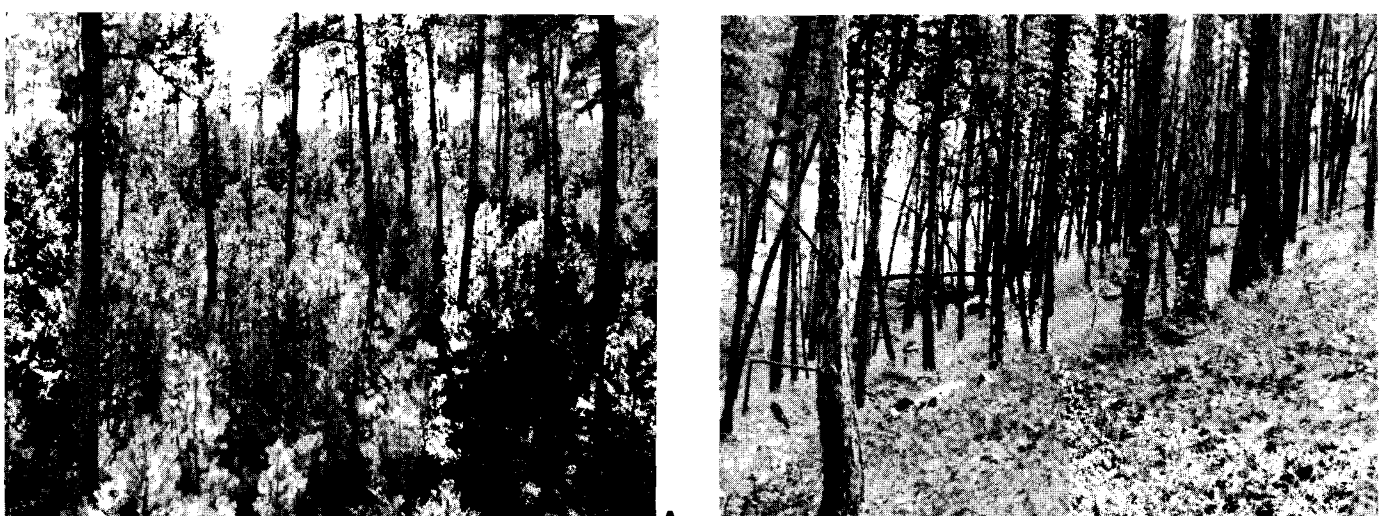
ADP code	Habitat type-phase (Pfister and others 1977, Roberts 1980)	Montana forest region (Arno 1979)
172	*Pinus ponderosa/Symphoricarpos albus* h.t.-*Berberis repens* phase (PIPO/SYAL-BERE), ponderosa pine/snowberry-creeping Oregon grape phase.	Central and southeastern.
	Pinus ponderosa/Amelanchier alnifolia h.t. (PIPO/AMAL), ponderosa pine/serviceberry.	Central (Bearpaw Mountains only).
	Pinus ponderosa/Berberis repens h.t. (PIPO/BERE), ponderosa pine/creeping Oregon grape.	Central (Little Rocky Mountains only).
181	*Pinus ponderosa/Prunus virginiana* h.t.-*Prunus virginiana* phase (PIPO/PRVI-PRVI), ponderosa pine/chokecherry-chokecherry phase.	Southeastern.
182	*Pinus ponderosa/Prunus virginiana* h.t.-*Shepherdia canadensis* phase (PIPO/PRVI-SHCA), ponderosa pine/chokecherry-buffaloberry phase.	Southeastern.

Fire Group Three ponderosa pine stands are more moist and slightly cooler than those of Group Two. This is the result of increased growing season precipitation and the infrequency of severe drought. Group Three stands are usually found in ravines or on north slopes. A relatively deep duff layer of about 1.5 to 2.5 inches (46 cm) covers the characteristically rock-free silt loam soils of these stands. Ponderosa pine and occasionally Rocky Mountain juniper are the only successful conifers. A rather lush undergrowth of shrubs and the absence of stocking limitations for ponderosa pine reflect the favorable moisture conditions. Pine regeneration frequently forms dense dog hair thickets. Stand structure is variable. Some stands appear to be all-aged, with scattered regeneration and rather uniform representation of size classes. Other stands show two (fig. 11) or even three distinct size classes (Pfister and others 1977).

Forest Fuels

Downed and dead fuel loads in Group Three stands are light, not unlike those of Group Two stands (fig. 11). Total average loading is slightly higher than the Group Two average (table 4 and fig. 2). Downed woody material less than 3 inches (7.6 cm) in diameter averages less than 3 tons/acre (0.7 kg/m^2). The amount of material greater than 3 inches (7.6 cm) averages about 10 tons/acre (2.2 kg/m^2).

Live fuels in the form of dense dog hair thickets of ponderosa pine saplings create a definite fire hazard in Group Three stands. The tendency toward multistoried stands results in a high probability of crown fires (fig. 11).



A B

Figure 11.—Examples of Group Three ponderosa pine stands in eastern Montana. (A) A two-storied stand with a very dense understory. (B) Well-stocked ponderosa pine stand on a ponderosa pine/chokecherry h.t. Forest floor is shrub covered and downed woody fuel loading is light.

Role of Fire

Authoritative information about the role of fire in Fire Group Three stands during presettlement times is scant. It seems, however, that fire:

1. Prepared seedbeds favorable for ponderosa pine regeneration,
2. Controlled stocking levels during the seedling and sapling stage of tree development,
3. Thinned out suppressed pole-sized ponderosa pine trees,
4. Maintained mature stands in an open, parklike condition,
5. Provided some browse for wildlife, and
6. Destroyed dense, stagnant, and multistoried stands,

Fire's present role is essentially the same as during presettlement times. The major difference is the frequency of stand-replacement fires. This is due in large part to successful fire exclusion programs during modern times. Such programs have allowed the rather widespread development of dense, stagnant, and multistoried stands on Group Three sites. When fire suppression fails and burning conditions are favorable, severe wind-driven crown fires often occur in such stands. Periodic cool surface fires minimized the occurrence of such high-hazard stand conditions during presettlement times.

Generalized Forest Succession

Existing mature stands on Fire Group Three sites tend to be all-aged with scattered regeneration or stands with two or even three distinct size classes (Pfister and others 1977). Broken stands of stagnant poles, the remnants of dog hair thickets, can also be considered a mature forest situation. A severe fire in such stands results in destruction of the stand and preparation of a mineral soil seedbed, as shown in figure 12, No. 1 (subsequent numbers in this section refer to fig. 12). Shrubs and herbs already present on the site will dominate following fire. Frequent fires (double or triple burns) occurring during this stage could maintain the site in shrubs and herbs (fig. 12, No. 2). This is, however, an uncommon occurrence. Abundant ponderosa pine seedlings usually become established following fire and eventually dominate the site. A fire at this stage of succession returns the site to a shrub/herb condition (No. 3). Depending on initial seedling densities and subsequent mortality, the sapling stage may or may not take the form of a dog hair thicket. Fires occurring in such thickets can be more severe than those occurring in less dense sapling stands. Such a fire would return the site to shrubs and herbs (No. 4). A light

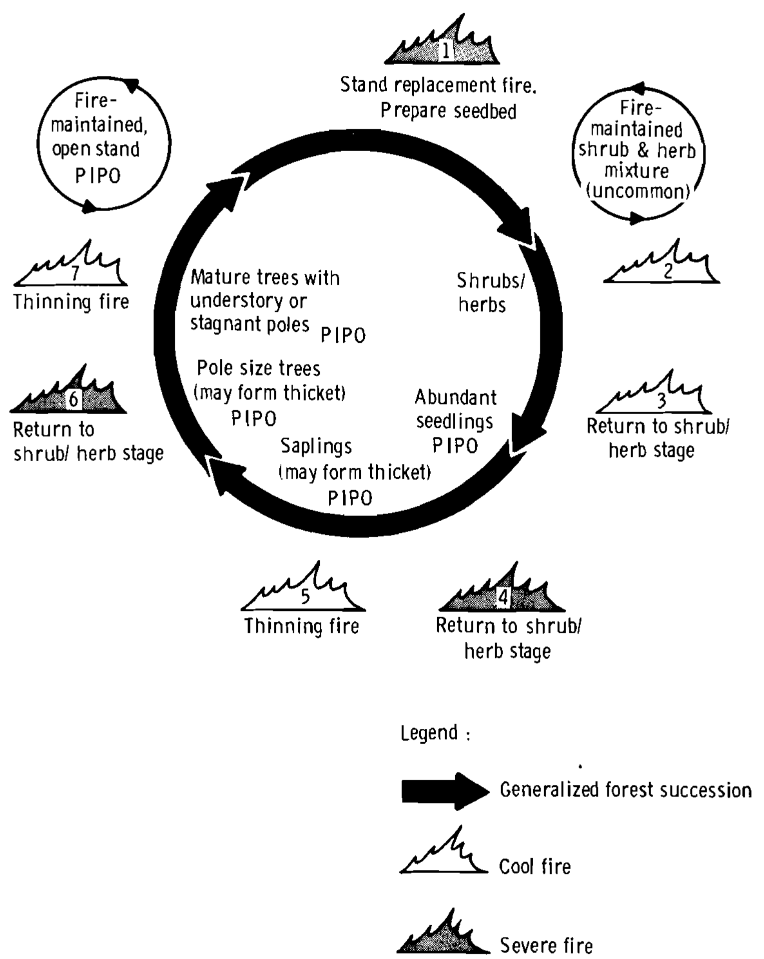


Figure 12.—Generalized forest succession in Fire Group Three: warm, moist ponderosa pine habitat types.

surface fire would likely thin out susceptible stems thereby reducing stocking (No. 5). The effect of fire is similar in pole-size and mature stands of ponderosa pine on Group Three sites. Severe fires are likely in thickets and would result in a return to the shrub/herb state (No. 6). A moderate severity fire will either reduce stocking levels in crowded pole-size trees or remove regeneration in mature stands (No. 7). Frequent cool to moderate fires can maintain stands in an open, parklike condition. Surface fires in the climax stage would perpetrate the all-age or multistory condition by preparing seedbed for ponderosa pine regeneration.

Successional Pathways

Many of the successional states and pathways hypothesized for Fire Group Two ponderosa pine stands (fig. 10) also apply to Fire Group Three stands. The major difference is that Group Three stands tend more toward the dense all-age and multistory condition than to the open, parklike condition shown for Group Two.

On Group Three sites a shrub/herb state usually follows a stand replacement fire, as shown in figure 13, state A (subsequent states and numbers in this section refer to fig. 13). This state could be maintained by frequent fire (No. 1). Very frequent repeated fires favor grass at the expense of shrubs. Abundant ponderosa pine seedlings usually become established and soon dominate the postfire community (state B). The abundance and subsequent mortality of seedlings is an important factor in determining succession. If the site is greatly overstocked with seedlings, a dense dog hair thicket may develop (state C3). If the number of surviving seedlings approximates a fully stocked condition, succession will follow a different path

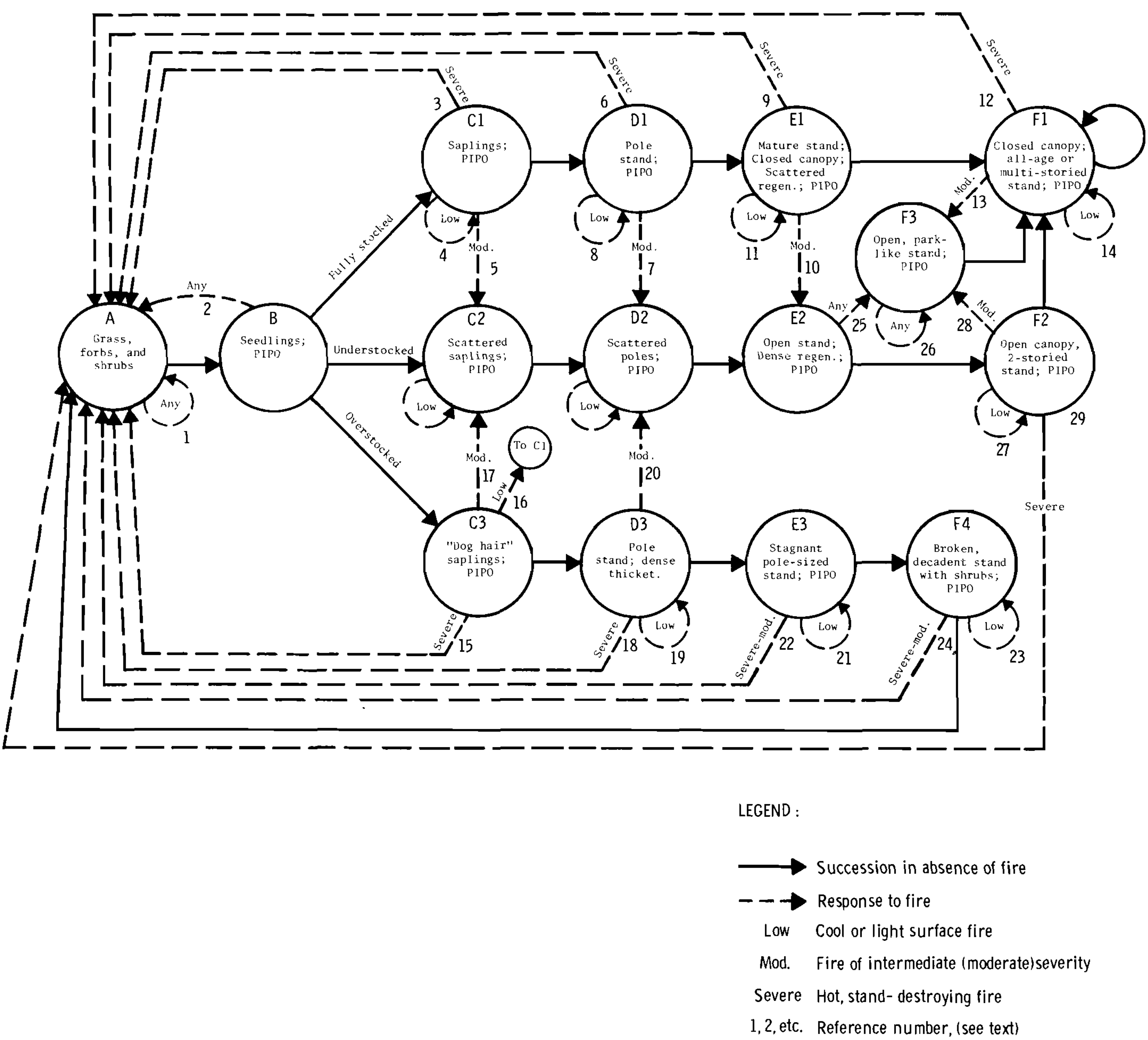


Figure 13.—Hypothetical fire-related successional pathways for Fire Group Three habitat types.

(state C1). Understocking is not common on fire-created mineral soil seedbeds on these sites. Understocking can occur, however, as a result of fire or other factors (for example, red belt injury caused by extreme winter weather conditions). The understocked condition is state C2.

FULL STOCKING CONDITION

A severe fire would likely destroy a sapling stand and return the site to shrubs and herbs (No. 3). A light surface fire would have minimal effect (No. 4), but a moderately severe fire might kill a majority of the saplings (No. 5) and leave an understocked condition (state C2).

In the absence of fire a fully stocked pole stand will develop (state Dl). A severe fire could destroy such a stand and return the site to shrubs and herbs (No. 6) but a less severe fire might leave scattered live trees on the site (No. 7). A light surface fire would have little impact (No. 8). The lack of fire in a fully stocked pole stand should result in a closed canopy stand of mature trees with scattered regeneration in the understory (state E1). Again, a severe fire could recycle the site to shrubs and herbs (No. 9). A fire of moderate severity might thin out the overstory and leave an open stand (No. 10). Dense regeneration would probably develop on the fire-prepared seedbed. A light surface fire during state E1 would do little more than kill scattered regeneration (No. 11).

A fully stocked mature stand would develop into a closed canopy all-aged or multistoried climax stand (state F1) in the continued absence of fire. Such a stand would be highly susceptable to a stand replacement fire that would return the site to shrubs and herbs (No. 12). A less severe fire (No. 13) could leave an open, parklike stand (state F3). A cool fire would thin out some understory trees that in time would be replaced by new seedlings (No. 14).

DOG HAIR THICKETS.

Dense dog hair thickets of ponderosa pine saplings (state C3) burn readily and are destroyed by a hot fire (No. 15). Under less than severe burning conditions, fire might cause either a light thinning of stems resulting in a fully stocked state (No. 16), or a heavy thinning that leaves only scattered saplings on the site (No. 17). In the absence of fire, dog hair sapling thickets become dense stands of pole-sized trees (state D3). Severe fire will likely revert the site to shrubs and herbs (No. 18) and a cool fire may have little or no effect (No. 19). A moderately severe fire could leave scattered pole-sized trees on the site (No. 20). If fire or some other thinning agent does not affect the stand, it will stagnate (state E3). A light surface fire will do little to alter this state (No. 21), and a severe fire will likely return the site to shrubs and herbs (No. 22). The stagnant stand will break up over time in the absence of fire (state F4). Insects, disease, snow and wind breakage, and suppression mortality will all take their toll. As the stand opens up, a light surface fire may prepare a seedbed for ponderosa pine seedlings and rejuvenate shrubs (No. 23). A severe fire will return the site to shrubs and herbs (No. 24).

UNDERSTOCKED CONDITION

As mentioned previously, the understocked condition usually results from seedling or sapling mortality rather than from lack of seedlings following site preparation. Severe fires would be unlikely in understocked stands, and cool fires would do little more than kill occasional stems and prepare a seedbed. Succession would, therefore, progress from the scattered sapling state (state C2) through the scattered pole state (state D2) to the open stand with dense regeneration in the understory (state E2). Any fire at this stage of succession would clear out the understory (No. 25) and leave an open, parklike stand (state F3). This open condition would be maintained by frequent fire (No. 26) and tend toward the all-age or multistoried condition (state F1) in the absence of fire.

If fire does not occur during state E2, a two-storied stand will develop (state F2) that would be (1) maintained by a cool fire (No. 27); (2) changed to the open, parklike condition by a moderate severity fire that removes the understory (No. 28); or (3) returned to shrubs and herbs by a severe fire (No. 29). In the absence of fire the stand would tend toward the all-age or multistoried state (state F1).

Fire Management Considerations

Fire management considerations for Group Three stands are similar to those described for Fire Group Two stands. They include fire suppression, fuel management, and the use of fire for browse production, site preparation, stocking control, and recreation site development.

WILDFIRE SUPPRESSION

Wildfire hazard is high in many existing Fire Group Three stands. Dense understories, dog hair thickets, and multistoried stands with continuous fuels from the forest floor to the crowns of overstory trees comprise this hazard. The flammability of these live fuels can reach serious levels during drought. Fire suppression is difficult under average burning conditions. When burning conditions are extreme, fire suppression is practically impossible. The only reasonable way to protect high-hazard Group Three stands from unwanted fire is to emphasize fuel management rather than fire suppression.

FUEL MANAGEMENT

Fuel management should be an important part of stand management on Group Three habitats. The fuel management must go beyond treatment of slash following logging and thinning activities. It must include stocking control because live fuels are the crux of the wildfire problem. This should be easy to accomplish in stands that are being managed for timber production. In these stands, good silviculture is good fuel management, provided slash hazard is adequately reduced following silvicultural treatments. The fuel management objective should be to avoid large unbroken areas that are overstocked. Two-storied stands are easier to keep in a low-hazard condition than three-storied stands or all-aged stands. Fuel management programs aimed at stocking control should recognize the need to leave scattered thickets for wildlife cover.

FIRE USE

Prescribed fire can be effectively used to reduce slash hazard following logging and thinning. It can be used to thin out overstocked sapling stands and to eliminate dog hair thickets. Fire may not be an appropriate thinning agent if uniform spacing of stems is desirable. Also, fire can damage many trees without killing (thinning) them.

Fire can be used safely to periodically reduce both live and dead surface fuels after potential crop trees have reached a height of 10 to 12 ft (3 to 3.7 m). Fuel reduction fires may also stimulate shrub production.

The use of fire under standing timber entails some risks to the residual trees. Crown scorch can be a problem when burning during the growing season. A light wind and low flames will usually reduce the risk of crown scorch.

Crown scorch may set the stage for bark beetle attack. Fire managers should consider the probability of beetle attack and write fire prescriptions that minimize its occurrence.

More specifically, fire managers should (Fischer 1980):

1. Become familiar with signs of bark beetle activity so the presence of beetles can be detected during field reconnaissance of areas proposed for burning (Martin and Dell 1978). Remember, however, just because you don't see signs of beetles doesn't mean they are not present within their attack range.

2. Become familiar with the timing of beetle flights in the area to be burned. Whenever possible, schedule prescribed fires around these high-risk periods. This is especially important if you plan to thin ponderosa pine stands with fire. Crown scorch is inherent in such a treatment.

3. Avoid scorching tree crowns (unless your objective is to thin the stand). Crown scorch can be predicted. Albini (1976) used equations developed by Van Wagner (1973) to graphically relate crown scorch to flame length for different windspeeds. He also provides aids for estimating flame length. Norum (1977) suggests a procedure for using Albini's charts to estimate crown scorch when writing a fire prescription. This procedure works for any tree species. Fire managers should use these aids when planning fire use in ponderosa pine stands.

If severe crown scorching does occur, the fire manager has a dilemma. Should he or she immediately remove the scorched trees, thereby avoiding the possibility of a beetle infestation? Or should a wait-and-see approach be followed?

Season of the year is important. Ponderosa pine are often only slightly affected by crown scorching that occurs in early spring or late fall. When ponderosa pine are scorched outside the active growing season, cambium injury becomes an important factor, especially with the thinner bark, pole-sized trees. During a certain period of active growth in spring, ponderosa pine is rather easily killed by scorching. Hare (1960, 1965) has suggested several techniques for detecting cambium injury. Unless local experience indicates otherwise, or if severe cambium injury is detected, the fire manager is well advised to go slow with the saw. Scorched trees should be watched closely, especially for signs of *Ips*; if they become infested, the trees should be removed to lessen the chance of adjacent standing green trees being infested.

One final point: as a general rule, ponderosa pine are more susceptible to bark beetle attack during drought. Consequently, the degree of scorching that a tree can sustain and still survive beetle attack is less than it is under more normal moisture conditions.

Another risk associated with understory burning in this group's ponderosa pine stands is the risk of increasing live fuel hazard. An understory burn may, among other things, prepare a mineral soil seedbed. If the stand is open and seed producers are present, a dense seedling understory may develop. This may or may not be desirable depending on the silvicultural prescription under which the stand is being managed.

FIRE GROUP FOUR: WARM, DRY DOUGLAS-FIR HABITAT TYPES

ADP code	Habitat type-phase	Montana forest region
	(Pfister and others 1977, Roberts 1980, Roberts and Sibbernsen 1979)	(Arno 1979)
210	*Pseudotsuga menziesii/ Agropyron spicatum* h.t. (PSME/AGSP), Douglas-fir/ bluebunch wheatgrass.	Central, southwestern, and south-central.
230	*Pseudotsuga menziesii/Festuca scabrella* h.t. (PSME/FESC), Douglas-fir/rough fescue.	Central.
311	*Pseudotsuga menziesii/ Symphoricarpos albus* h.t.-*Agropyron spicatum* phase (PSME/SYAL-AGSP), Douglas-fir/snowberry-bluebunch wheatgrass phase.	Central.
	Pseudotsuga menziesii/Symphoricarpos occidentalis h.t.-*Chrysopsis villosa* phase (PSME/SYOC-CHVI), Douglas-fir/western snowberry-hairy goldenaster phase.	Central (Bearpaw Mountains only).
	Pseudotsuga menziesii/Symphoricarpos occidentalis h.t.-*Shepherdia canadensis* phase (PSME/SYOC-SHCA), Douglas-fir/western snowberry-russet buffaloberry phase.	Central (Little Rocky Mountains only).
324	*Pseudotsuga menziesii/Calamagrostis rubescens* h.t.-*Pinus ponderosa* phase (PSME/ CARU-PIPO), Douglas-fir/ pinegrass-ponderosa pine phase.	Central.
340	*Pseudotsuga menziesii/Spiraea betulifolia* h.t. (PSME/SPBE), Douglas-fir/white spiraea	Central and north-central.
350	*Pseudotsuga menziesii/Arctostaphylos uva-ursi* h.t. (PSME/ ARUV), Douglas-fir/kinnikinnick.	Central and south-central (including Little Rocky Mountains).
	Pseudotsuga menziesii/Berberis repens h.t.-*Arctostophylos uva-ursi* phase (PSME/BERE-ARUV), Douglas-fir/creeping holly grape-kinnikinnick phase.	Central (Little Rocky Mountains only).
	Pseudotsuga menziessi/Berberis repens h.t.-*Berberis repens* phase (PSME/BERE-BERE), Douglas-fir/creeping holly grape-creeping holly grape phase.	Central (Little Rocky Mountains only).
	Pseudotsuga menziesii/ *Juniperus scopulorum* h.t. (PSME/JUSC), Douglas-fir/ Rocky Mountain juniper phase.	Central (Missouri Breaks only).
	Pseudotsuga menziesii/Muhlenbergia cuspidata h.t. (PSME/ MUCU), Douglas-fir/plains muhly.	Central (Missouri Breaks only).

Group Four consists of Douglas-fir habitat types where ponderosa pine usually occurs as a major seral or climax associate especially at lower elevations. Group Four stands may exist as fire-maintained ponderosa pine stands that develop Douglas-fir regeneration beneath the pine in the absence of disturbance. Douglas-fir is usually present in seral stands, but ponderosa pine often dominates. These habitat types are too droughty for most other conifer species. Some Group Four sites (PSME/FESC h.t.) extend to elevations above the cold limits of ponderosa pine. Where such situations exist, Douglas-fir dominates most states of succession. Except on the better sites, stands are usually quite open regardless of species composition.

Rocky Mountain juniper may be a minor climax species on PSME/AGSP h.t.'s, and occasionally limber pine may occur. Group Four stands are generally quite open, but dense stands or thickets can occur where fire has been excluded or where good seed years and favorable moisture conditions have followed fire. The understory is usually sparse because of lack of moisture. Major herbs include bluebunch wheatgrass, rough and Idaho fescue, pinegrass, arrowleaf balsam root, western gromwell, Plains muhly, junegrass, and spreading dogbane. The most prevalent shrubs are snowberry, kinnikinnick, white spiraea, common juniper, bitterbrush, chokecherry, and serviceberry.

Forest Fuels

Downed woody fuel loads average between 5 and 10 tons/acre (1 and 2 kg/m^2) in this group. Fuel loads in the grassy habitats usually average less than in the shrubby habitats. Fuel loads of 15 to 20 tons/acre (3.4 to 4.5 kg/m^2) are not uncommon. Brown and See (1981) show a value of 13 tons/acre (2.9 kg/m^2) as the average downed woody load for Groups Three, Four, and Five combined (table 4).

Fuel conditions and associated fire hazard are usually determined by stand development that in turn is governed by fire history. This is illustrated by the two stands in figure 14. Both stands are about 100 years old (table 6) and both are on Douglas-fir/kinnikinnick h.t.'s (PSME/ARUV). Stand 40A (fig. 14A) has two times as much downed woody fuel and three times as much duff (table 6) as does stand 37A (fig. 14B).

Overall fire potential was rated low for stand 37A and meduim for stand 40A (Fischer 1981a). Although stand histories were not documented, onsite inspection indicated more frequent and more recent fire in stand 37A than in stand 40A.

Live fuels can be a significant factor in Group Four stands. Dense thickets of Douglas-fir regeneration may become established during fire-free periods. Overstories become susceptible to stand-destroying crown fire when such situations are allowed to develop in the understory.

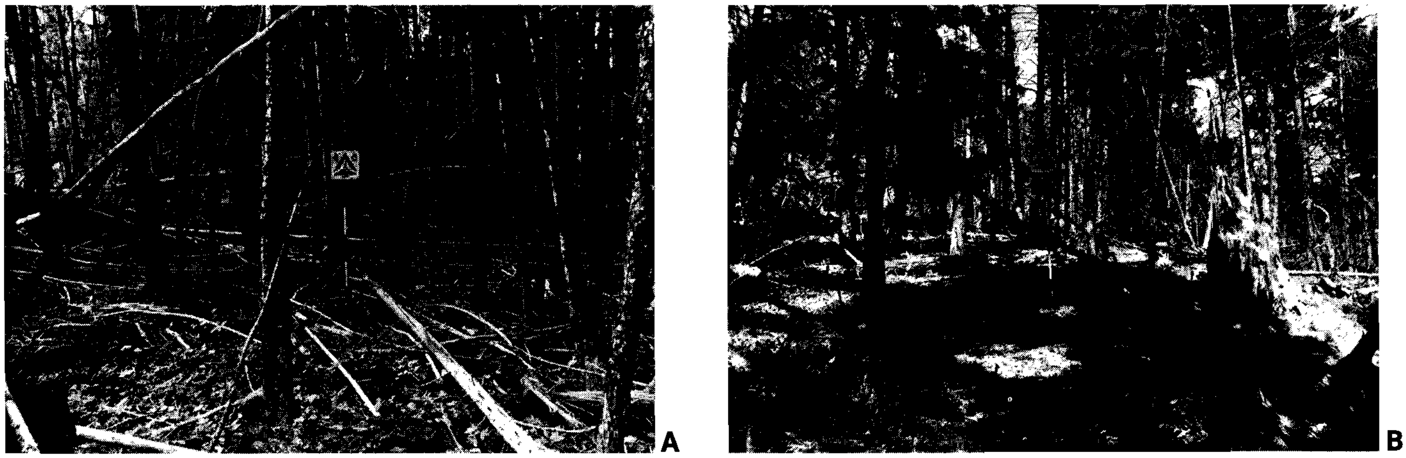


Figure 14.—Examples of Fire Group Four stand and fuel conditions near White Sulphur Springs, Mont., Lewis and Clark National Forest. Both stands are on a Douglas-fir/kinnikinnick h.t. Stand age, total fuel load, fuel load by size class, and duff depths are given in table 6.

Table 6.—Fuel loading by size class and duff depth for Fire Group Four stands shown in figure 14 (source: Fischer 1981a)

Stand number	Habitat type	Age	Duff depth	Size class (inches) 0-1/4	1/4-1	1-3	3-6	6-10	10-20	Total
		Years	*Inches*	*Tons/acre*						
37A	PSME/ARUV	112	1.1	0.3	1.9	2.9	2.3	2.5	3.3	13.2
40A	PSME/ARUV	105	3.0	0.4	1.9	6.0	7.7	2.6	7.0	25.6

Role of Fire

Fire in the Douglas-fir climax series habitat types of Group Four maintains grasslands, opens stands of Douglas-fir or of seral ponderosa pine, and prepares seedbeds (see Group Two). But there are additional effects (Davis and others 1980):

1. Frequent fires in seral stands can maintain a ponderosa pine "fire climax" condition by killing fire-susceptible Douglas-fir seedlings before they become established. In this role, fire frequency largely determines the stand composition.

2. Following a prolonged fire-free period, Douglas-fir regeneration becomes established beneath the canopy. A ground or surface fire that reaches a thicket of saplings and small poles can ascend into the overstory, killing or injuring adjacent mature trees through the vegetative "fuel ladder." Fuel ladders increase the potential destructiveness of a fire by providing access to the canopy. During periods of high fire danger, this can result in a stand-destroying crown fire.

Historic fire frequency in Group Four habitat types probably was not very different from that of Group Two—that is, 5 to 20 or more years between fires. Successful suppression of surface fires in open, fire-maintained stands over the last few decades has altered the sites toward a more flammable condition that has increased the fire potential.

Generalized Forest Succession

The theoretical climax forest on Group Four habitats is an all-aged or multistoried Douglas-fir forest, as shown in figure 15 (subsequent numbers in this section refer to fig. 15). Such a forest is unlikely to be achieved because of the prolonged fire-free period necessary for its development. Most old-growth forests will be open stands with varying understories depending on the stand's fire history. A grass/forb community with shrubs and conifer seedlings becomes established following a severe stand-destroying fire (No. 1). Frequent fire during this stage can result in a fire-maintained grassland (No. 2). A light burn during the grass/forb/shrub stage can prepare a seedbed favorable to conifer seedlings but may be a minor factor where seedling establishment is not hindered by ground cover.

In the absence of fire, the grass/forb/shrub stage will give way to conifer seedlings. Except on those high elevation sites above its cold limits, ponderosa pine will dominate initially if it dominated the prefire stand. Douglas-fir seedlings will also be present. Variation in seed crops is a factor in regeneration. A poor seed year will often retard regeneration. A fire at this stage will revert the site to grass/forb (No. 3).

In the absence of fire, ponderosa pine and Douglas-fir saplings will develop. Species composition and density of stems

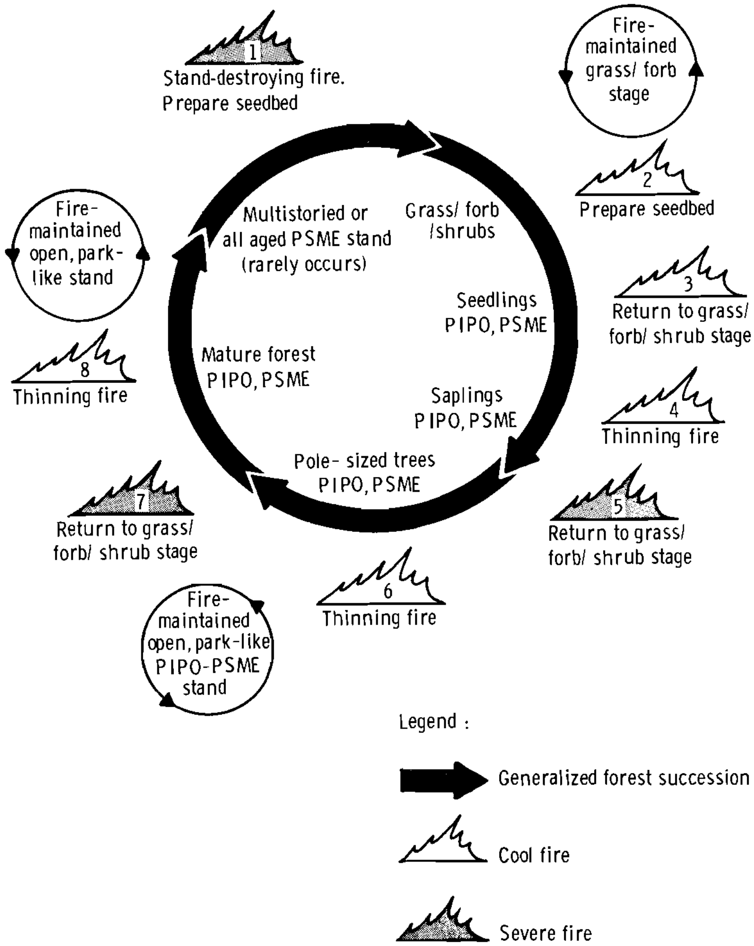


Figure 15.—Generalized forest succession in Fire Group Four: warm, dry Douglas-fir habitat types.

will depend on site conditions, length of the regeneration period, and how long fire has been absent. Not much ponderosa pine, for example, will be present if fire is absent for a prolonged period. A severe fire will return the site to the grass/forb/shrub stage (No. 5). A light to moderate severity fire will tend to thin out Douglas-fir saplings and badly suppressed ponderosa pine saplings (No. 4). A cool fire at this stage will also remove any recent seedlings.

The pole-sized tree stage can be represented by: (1) a rather open stand of Douglas-fir and ponderosa pine poles with a scattered seedlings and sapling understory, (2) a predominatly ponderosa pine or Douglas-fir pole stand with varying understory, or (3) a scattered pole stand with grass/forb/shrub understory. A light to moderately severe fire at this stage will thin the stand, removing understory vegetation and susceptible Douglas-fir stems (No. 6). Frequent fire will maintain an open, parklike stand of ponderosa pine on most Group Four habitats. A severe fire will revert the site to the grass/forb/shrub state (No. 7).

A mature forest of ponderosa pine, Douglas-fir, or a combination of the two, will eventually develop. Periodic fire at this stage will maintain the stand in an open, parklike condition (No. 8). Douglas-fir and some ponderosa pine regeneration may form in the understory of such stands during fire-free intervals. If fire is excluded for an unusually long period, the theoretical climax situation could develop.

Successional Pathways

Hypothetical succession following fire and the absence of fire in this group is presented in figure 16 (subsequent states and numbers in this section refer to fig. 16). The elevation and geographic location of the site is a major determinant of species composition. Ponderosa pine will play a major role in plant succession on most Group Four sites. Some sites are, however, beyond the geographic range or above the cold limits of ponderosa pine. These sites will be dominated by Douglas-fir at all stages of development.

SUCCESSION WITH PONDEROSA PINE

Frequent fire over long periods can maintain Group Four sites in a grass, forb, and shrub state (state A). In the absence of fire, ponderosa pine and Douglas-fir seedlings become established (state B). Any fire will probably kill these seedlings and maintain the grassy state (No. 1). Given a long enough fire-free interval, seedlings develop into saplings (state C). Many

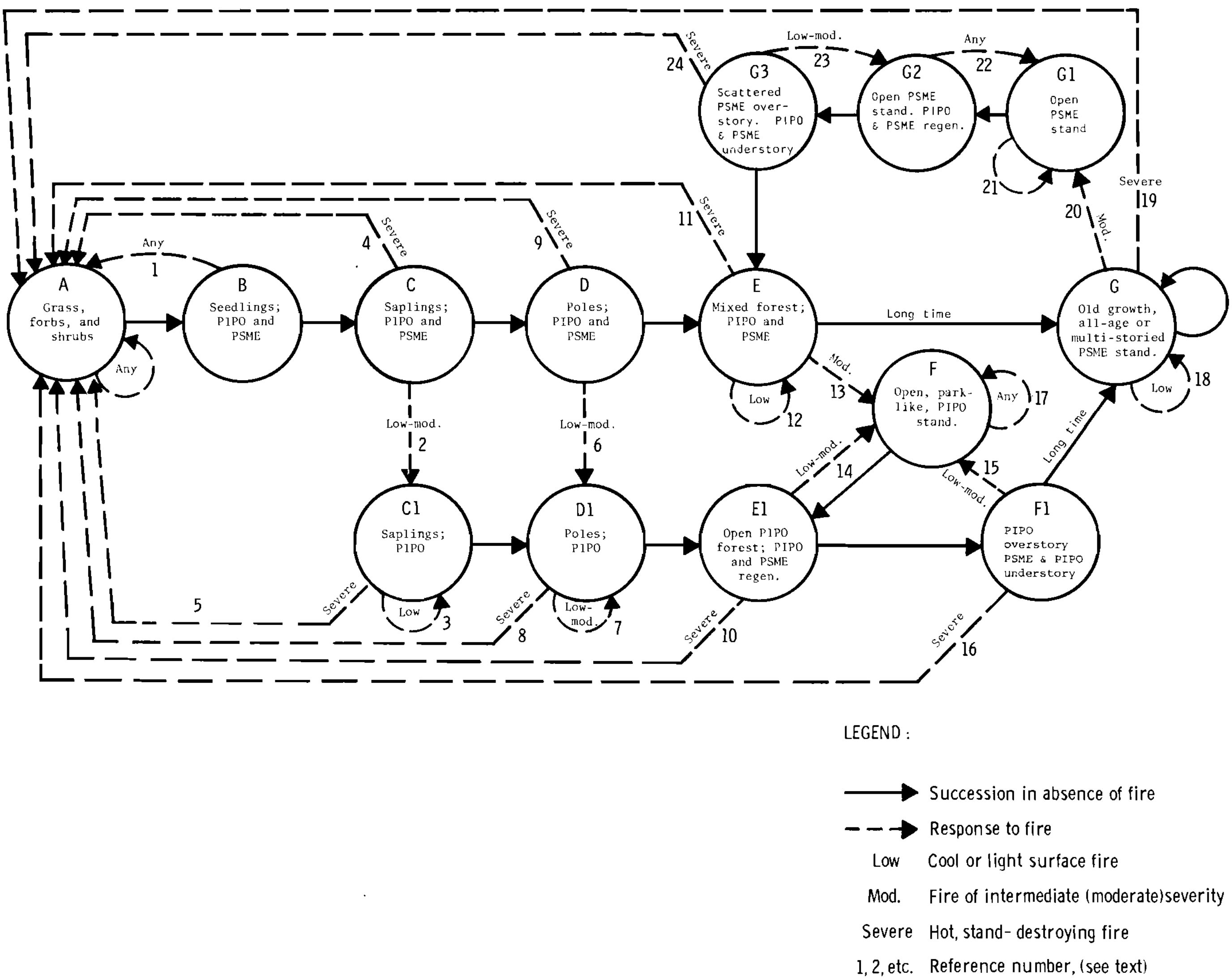


Figure 16.—Hypothetical fire-related successional pathways for Fire Group Four habitat types.

ponderosa pine saplings may survive a low to moderate fire (No. 2). This would result in a sapling stand devoid of Douglas-fir (state C1). A subsequent cool fire would have little impact on stand composition (No. 3), but a severe fire would revert the site to grass (No. 4).

If fire does not occur in the sapling state (state C), a ponderosa pine and Douglas-fir pole stand will develop (state D). Again, a severe fire may revert the site to grass (No. 5), and a low to moderately severe fire (No. 6) could result in the loss of Douglas-fir (state D1). Subsequent cool fires would merely affect undergrowth (No. 7). A severe fire would be unlikely because of lack of fuel, but if it did occur it could conceivably revert the stand to grass (No. 8).

A ponderosa pine/Douglas-fir pole stand (state D) will develop into a mixed species forest in the absence of fire (state E). The ponderosa pine pole stand (state D1) will develop into an open ponderosa pine forest (state E1). Both stands may have ponderosa pine and Douglas-fir regeneration in the understory. Both stands can also be destroyed by a severe fire (No. 10 and 11), although the open stand would be less susceptible to such a fate. A cool fire would thin out the understory of the mixed forest (No. 12), but a fire of moderate severity (No. 13) could kill the Douglas-fir while leaving enough pine to end up with an open, parklike ponderosa pine stand (state F). A light to moderately severe fire in states E1 and F1 would have the same effect (No. 14 and 15). A severe fire in state F1 could destroy the stand (No. 16).

Any fire occurring in state F would probably maintain the open, parklike condition (No. 17). During fire-free intervals, regeneration would likely develop (state E1) and succession would tend toward a two-storied stand (state F1). Unusually long fire-free periods would allow stands to develop toward a theoretical Douglas-fir climax condition (state G). Such a condition is rare. Stands tending toward the climax condition would not be seriously impacted by a cool fire (No. 18) and would probably be destroyed by a severe fire (No. 19). If the development toward the climax condition has progressed to the

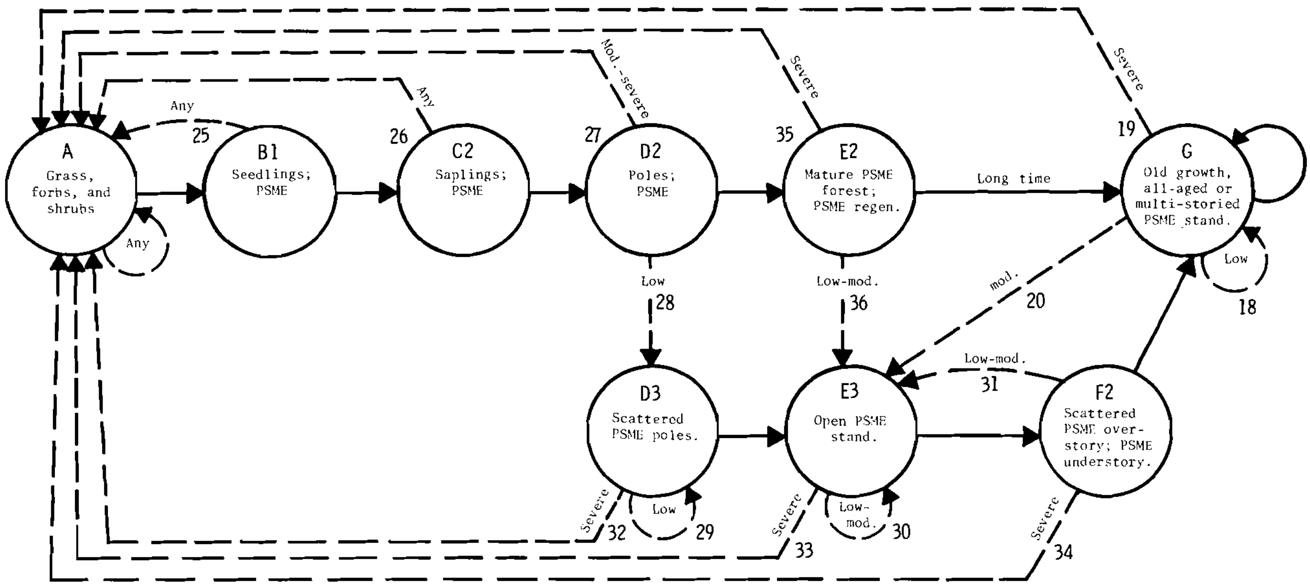


Figure 16.—(con.)

point where ponderosa pine has been eliminated from the stand, a fire of moderate severity (No. 20) could result in an open, parklike Douglas-fir stand (state G1). Such a stand could develop back to the mixed forest state (state E) in the absence of fire or be maintained in the open condition with frequent fire (No. 21, 22, and 23). If an understory does develop in the absence of fire (state G3), a severe stand destroying fire could occur and revert the site to grass (No. 24).

SUCCESSION WITHOUT PONDEROSA PINE

Succession on Group Four sites located above the cold limits of ponderosa pine will be dominated by Douglas-fir. Succession will progress through a seedling, sapling, and pole stage (states B1, C2, and D2). Any fire during these stages will revert the site back to grass, forbs, and shrubs (No. 25, 26, and 27), except that some pole-sized Douglas-fir could survive a light burn (No. 28). A scattered pole stand (state D3) would result from such a situation. The scattered pole stand would develop into an open Douglas-fir stand (state E3), and then a two-storied stand (state F2) as seedlings become established and developed. Cool fires would tend to perpetuate the open condition (No. 29, 30, and 31), while severe fires would return the site to the grass/forb/shrub state (No. 32, 33, and 34).

If a fire does not occur during the pole stage (state D2), a Douglas-fir forest with a Douglas-fir understory will develop (state E2). A severe fire could destroy such a stand (No. 35), while a cool to moderately severe fire (No. 36) would remove the understory and perhaps thin the overstory leaving an open stand (state E3).

If fire is absent for an unusually long period, a climax forest could develop (state G). Such a forest would be affected by fire just as described for the habitats with ponderosa pine, except that ponderosa pine, of course, will be absent (states G, E3, and F2).

Fire Management Considerations

Fire management considerations and opportunities for Group Four stands involve hazard reduction, seedbed preparation, control of species composition, safeguarding recreation sites, improving wildlife habitat, and enhancing esthetic values.

WILDFIRE HAZARD REDUCTION

In the absence of fire, hazardous fuel situations often develop in Group Four stands. The combination of dense Douglas-fir (or ponderosa pine) understories, accumulated deadfall, decadent shrubs, and other accumulated litter and debris can produce fires severe enough to scorch the crowns and kill the cambium of overstory trees. Although they were developed in western larch/Douglas-fir forests (Fire Groups Five and Six), Norum's (1977) guidelines can be used to write fire prescriptions for safely reducing this hazard. Prescribed fire can also be used to reduce the hazard associated with logging slash resulting from clearcuts and partial cuts in Group Four stands. Most fire prescriptions can be written so as to accomplish silvicultural, range, and wildlife objectives as well as hazard reduction.

SILVICULTURE

Where timber management is the objective, fire can be used to dispose of slash, prepare seedbeds, control species composition, and to reduce the probability of stand-destroying wildfires. Ponderosa pine is often a favored timber species on Group Four habitat types. It may, for example, be deemed desirable to maintain ponderosa pine dominance in stands where Douglas-fir is plagued with severe mistletoe or chronic budworm damage. Fire can be used to remove unwanted Douglas-fir regeneration once the ponderosa pine reaches about 5 inches (about 13 cm) in diameter. Wright (1978) recommends that there be an adequate number of trees 10 to 12 ft (3 to 3.7 m) tall before regular prescribed burning begins, although light surface fires will leave trees 6 to 8 ft (1.8 to 2.4 m) tall unharmed. Larger Douglas-fir trees will also survive most light surface fires; so there need be no concern about completely eliminating Douglas-fir from the stand. Where butt rot is common on overstory Douglas-fir, however, increased mortality should be expected.

RANGE AND WILDLIFE HABITAT MANAGEMENT

Big game winter and spring range can be rejuvenated with properly applied prescribed fire, especially in the spring. Such fires can reduce encroachment by Douglas-fir, remove accumulated dead plant materials, recycle nutrients, regenerate mature and decadent shrubs, and increase distribution and production of nutrient-rich grasses, forbs, and legumes. Prescribed fire can be used to increase the nutritional value of critical wintering and fawning habitat, and thereby reduce neonatal fawn losses of mule deer (Schneegas and Bumstead 1977). Willms and others (1980) found that deer and cattle preferred forage from burned Douglas-fir/bluebunch wheatgrass communities over unburned control areas.

RECREATION AND ESTHETICS

Prescribed fire can be used to fireproof the areas immediately adjoining campgrounds. Such treatment not only reduces fire hazard, but also improves viewing and travel from the campground to the surrounding forest.

FIRE GROUP FIVE: COOL, DRY DOUGLAS-FIR HABITAT TYPES

ADP code	Habitat type-phase (Pfister and others 1977)	Montana forest region (Arno 1979)
220	*Pseudotsuga menziesii/Festuca idahoensis* h.t. (PSME/FEID), Douglas-fir/Idaho fescue.	Southwestern and south-central.
321	*Pseudotsuga menziesii/Calamagrostis rubescens* h.t.-*Agropyron spicatum* phase (PSME/CARU-AGSP), Douglas-fir/pinegrass-bluebunch wheatgrass phase.	Central.
330	*Pseudotsuga menziessi/Carex geyeri* h.t. (PSME/CAGE), Douglas-fir/elk sedge.	Central, south-central and southwestern.
370	*Pseudotsuga menziesii/Arnica cordifolia* h.t. (PSME/ARCO), Douglas-fir/heartleaf arnica.	Central and southwestern.
380	*Pseudotsuga menziesii/Symporicarpos oreophilus* h.t. (PSME/SYOR), Douglas-fir/mountain snowberry.	Southwestern.
461	*Picea/Senecio streptanthifolius* h.t.-*Pseudotsuga menziesii* phase (PICEA/SEST-PSME), spruce/cleftleaf groundsel-Douglas-fir phase.	North-central, central, and southwestern.

Fire Group Five habitat types support Douglas-fir stands even under the influence of periodic fire. Douglas-fir is the indicated climax species on all Group Five habitats except spruce/cleft-leaf groundsel. Douglas-fir dominates most Group Five seral communities and often is the only conifer present. Group Five sites are generally too dry for lodgepole pine and usually too cold for ponderosa pine. Rocky Mountain juniper, spruce, whitebark pine, lodgepole pine, limber pine, and subalpine fir may occur as accidental individuals, minor seral species, or minor climax species.

Regeneration is often difficult on these habitats. On north- and northeast-facing slopes, however, heavily overstocked stagnant stands often develop. Undergrowth may be sparse. Forbs often dominate the undergrowth, but grass and shrubs are usually present. Common undergrowth forbs include pussytoes, heart-leaf arnica, timber milkvetch, arrowleaf balsamroot, virgin's bower, strawberry, sweet cicely, pyrola, cleft-leaf groundsel, and western meadow rue. Common grasses include bluebunch wheatgrass, pinegrass, elk sedge, Idaho fescue, rough fescue, wheller bluegrass, and spike trisetum.

Group Five shrubs include big sagebrush, common juniper, wax current, russett buffaloberry, white spiraea, and mountain snowberry.

Forest Fuels

Downed, dead fuel loads for this group average about 10 tons/acre (about 2 kg/m^2). Downed woody fuel loadings calculated by Brown and See (1981) are shown in table 4 and in figure 2.

While downed, dead woody fuel loadings are greater in Group Five than in the previous four groups, live fuels are less of a problem. Both undergrowth and regeneration are usually sparce in Group Five stands. This factor plus the usual open nature of the stands results in a low probability of crown fire. Individual trees will often have branches close to the ground (fig. 17). If sufficient fuels are available on the ground, torching can occur.

Figure 17.—A Fire Group Five stand on a Douglas-fir/Idaho fescue h.t. This 100-year-old Douglas-fir stand on the Lewis and Clark National Forest has a total downed, dead fuel load of 6.6 tons/acre (1.5 kg/m^2). Material less than 3 inches (7.6 cm) in diameter accounts for 2.8 tons/acre (0.62 kg/m^2), and material more than 3 inches (7.6 cm) accounts for the remaining 3.8 tons/acre (0.85 kg/m^2). Duff depth is 0.9 inches (2.3 cm).

Role of Fire

The role of fire in Group Five is not well defined. Fire probably occurred less frequently than it did in ponderosa pine habitat types (Groups Two and Three) or in the warmer Douglas-fir habitat types (Group Four). The relatively light fuel loads, sparse undergrowth, and generally open nature of the stands would appear to favor long fire-free intervals. However, Arno and Gruell (1983) estimate a mean fire interval of 35 to 40 years in presettlement stands in southwestern Montana.

Fire probably played an important role in favoring ponderosa pine on PSME/CARU-AGSP sites. Without fire, ponderosa pine would be slowly replaced by Douglas-fir on these sites. Fire's role in seedbed preparation on most Group Five sites is confounded by the difficulty of regeneration to progress beyond the seedling stage on these droughty sites because of undergrowth and overstory competition. Where dense regeneration does occur, fire probably played a role as a thinning agent in sapling and pole-sized stands. Ground fire probably maintained many mature stands in an open, parklike condition. Many presettlement stands were actually scattered groves. Fire suppression has allowed these groves to become forest stands (Arno and Gruell 1983).

Generalized Forest Succession

The generalized forest succession discussed here and illustrated in figure 18 assumes sites are above the cold limits of ponderosa pine. (On sites where ponderosa pine is a major seral species [PSME/CARU-AGSP] refer to figure 15 [Fire Group Four] and the associated discussion of "Generalized Forest Succession.")

Frequent fire could maintain Group Five sites as grassland, as shown in figure 18, No. 1 (subsequent numbers in this section refer to fig. 18). A fire in the grass/forb/shrub stage will prepare a seedbed (No. 2) for Douglas-fir seedlings. Seedling establishment is usually slow and probably requires favorable combination of adequate seedbed, adequate moisture, and abundant seed. When favorable conditions for seedling establishment do occur, an even-aged stand usually develops. Any fire in either the seedling stage or the sapling stage reverts the site to grass (No. 3).

A light surface fire in a pole-sized stand would thin out the more susceptible stems (No. 4). A severe fire in pole-sized stands (No. 5) would likely kill all trees and again revert the site to the grassy stage. A less than severe fire in a mature stand (No. 6) could act as an underburn and thin the stand and

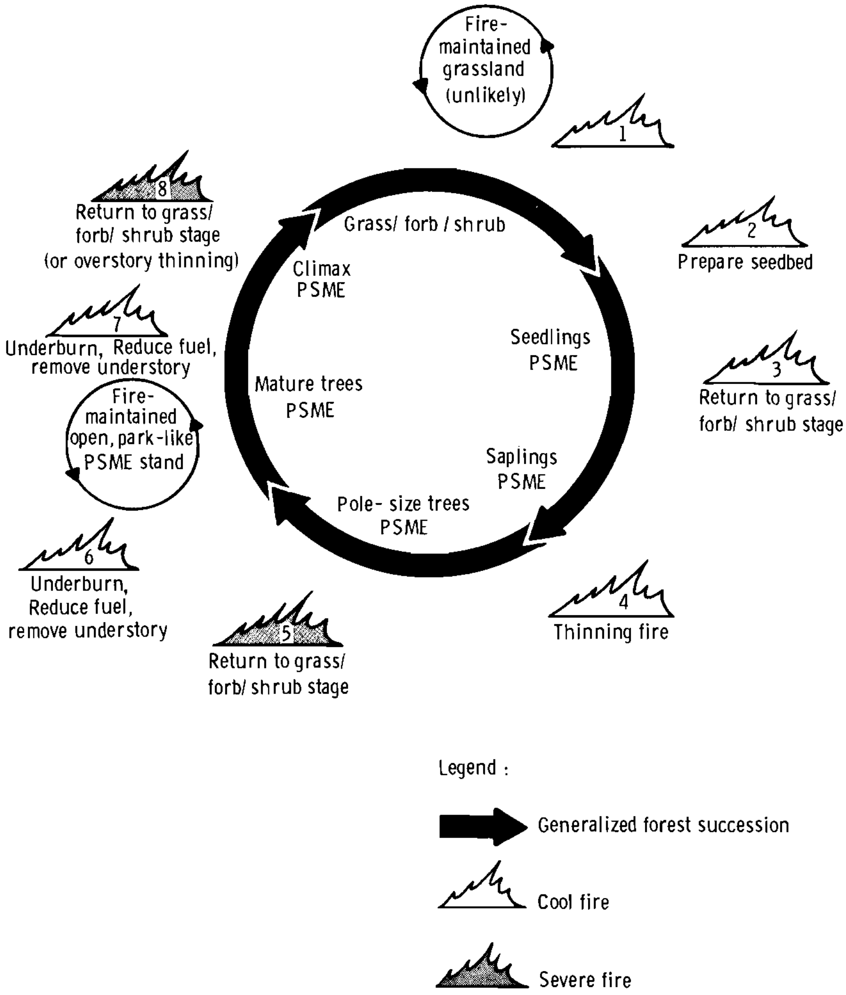


Figure 18.—Generalized forest succession in Fire Group Five: cool, dry Douglas-fir habitat types.

create an open stand condition. Subsequent light burns could maintain this open condition and result in a parklike Douglas-fir stand. If a stand escapes fire and nears the climax situation, it will likely have a Douglas-fir understory, sparse undergrowth, and moderate amounts of dead fuel on the forest floor. A light fire would remove the undergrowth and reduce dead woody fuel (No. 7). A severe fire in a climax or near climax stand would either destroy the stand and revert the site to the grass/forb/shrub state, or thin the overstory and leave an open, parklike stand (No. 8).

Successional Pathways

Hypothetical succession following fire and the absence of fire on most Group Five habitat types is presented in figure 19 (subsequent states and numbers in this section refer to fig. 19). This discussion does not pertain to those Group Five sites on which ponderosa pine is a major seral component (PSME/CARU-AGSP). (Succession on those sites is more nearly that presented in fig. 16 and the associated discussion of "Successional Pathways" for Fire Group Four.)

State A is a grass, forb, and shrub mixture of varying composition depending on site. Any fire at this state will perpetuate the treeless condition (No. 1). In the absence of fire, Douglas-fir seedlings and saplings will develop on the site (state B). Development of this state is not well understood, as indicated in the previous discussion of the role of fire in Group Five habitat types. Any fire in the seedling or sapling state will usually return the site to a treeless condition (No. 2). Sufficient fuel for a fire during the seedling state would be unlikely.

Pole-sized Douglas-fir trees will develop in the absence of fire (state C). Pole stands may be dense on some north- and northeast-facing slopes, but these are not the common situation in this group. A moderate to severe fire will revert the pole stand to the grass/forb/shrub condition (No. 3). A light ground fire, however, will thin out the stand and leave scattered poles (No. 4). Subsequent light fire will have little impact on a scattered pole stand (No. 5) while a severe fire (unlikely because of insufficient fuel) could destroy the stand (No. 6). In the absence of severe fire, the scattered pole condition (state C1) will mature into an open, parklike Douglas-fir stand (state D1). Periodic light to moderate fire will perpetuate this condition (No. 7). Again, a severe fire could occur and destroy the stand (No. 8) if sufficient fuel is available.

If a pole stand (state C) escapes fire, a mature stand of Douglas-fir with a scattered Douglas-fir understory will develop (state D). A light fire (No. 9) reduces fuel, thins understory, and prepares seedbed. A severe fire will destroy the stand and revert the site to the grass/forb/shrub condition (No. 10). A moderate fire at this stage (No. 11) could thin the overstory and remove the understory, thereby resulting in an open, parklike stand (state D1).

In the absence of fire, a climax condition would develop (state E). This condition would be characterized by varying degrees of crown closure in the overstory and by an understory of several layers. A severe fire (No. 12) would likely destroy such a stand, while a low intensity fire (No. 13) would affect only the understory. A moderately severe fire (No. 14) would torch out overstory trees and leave an open, parklike condition (state D1). Most old-growth Douglas-fir stands on Group Five sites in eastern Montana tend more toward the open condition than otherwise.

Fire Management Considerations

Opportunities for fire use may be limited in some Group Five stands because of normally sparse fuels. Where sufficient surface fuels exist, fire can be used to accomplish timber, range, and wildlife management objectives.

On those sites where ponderosa pine is a major seral component, fire can be used to favor it over Douglas-fir as discussed for Fire Group Four habitats.

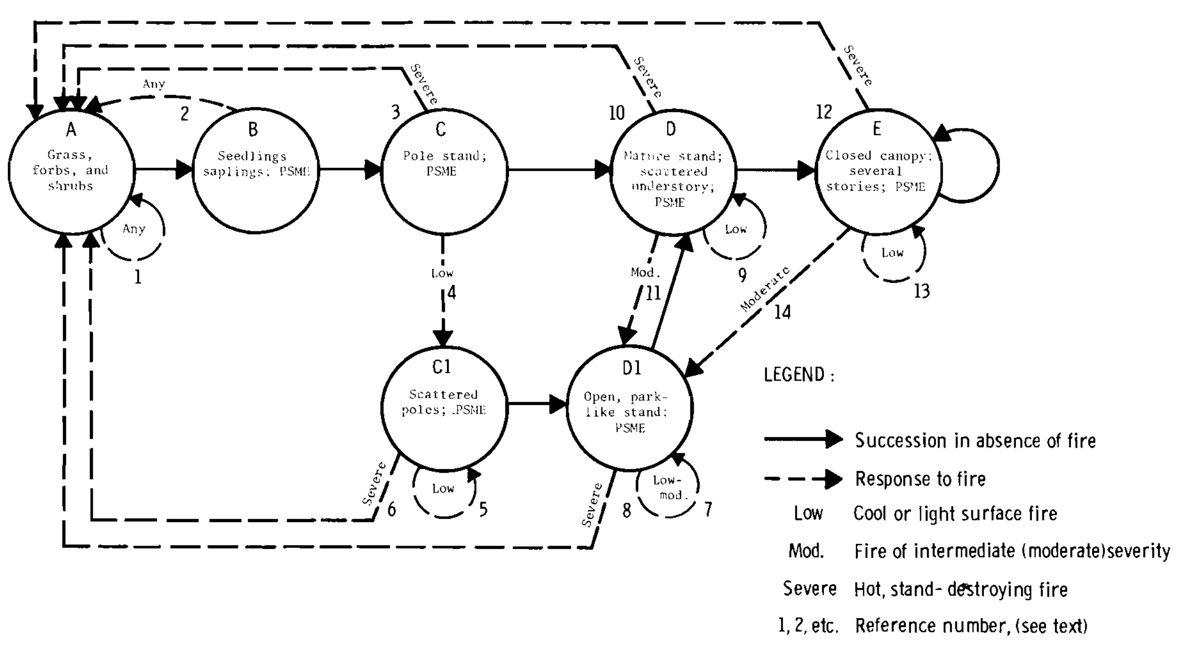


Figure 19.—Hypothetical fire-related successional pathways for Fire Group Five habitat types.

HAZARD REDUCTION AND SITE PREPARATION

Fire can be used following timber harvest in Group Five stands to prepare seedbed and to reduce wildfire hazard from the harvest related slash. Care must be taken to control fire intensity when burning in partial-cut stands. The hazard reduction objective in such situations should be to remove the fine fuels only. Attempts to burn the larger slash could result in fire damage to the residual trees.

FORAGE PRODUCTION

Periodic light surface fires in open canopy stands of mature trees can maintain parklike conditions and undergrowth species favorable to mule deer and domestic livestock. The use of fire for forage production may be difficult on some Group Five sites because the commonly sparse undergrowth will not carry fire. Caution should be used if timber milkvetch is present on grazed areas. This plant is poisonous to sheep and cattle and is highly resistant to damage by fire. It can send up shoots from the surviving taproot and set seed the first year following fire. If much mineral soil has been exposed, a good crop of seedlings are usually produced and the population of this species may greatly increase (McLean 1969).

FIRE GROUP SIX: MOIST DOUGLAS-FIR HABITAT TYPES

ADP code	Habitat type-phase	Montana forest region
	(Pfister and others 1977, Roberts 1980)	(Arno 1979)
261	*Pseudotsuga menziesii/Physocarpus malvaceus* h.t.-*Physocarpus malvaceus* phase (PSME/PHMA-PHMA), Douglas-fir/ninebark-ninebark phase.	Central, southwestern, and south-central.
	Pseudotsuga menziesii/*Viola canadensis* h.t. (PSME/VICA), Douglas-fir/Canadian violet.	Central (Bearpaw Mountains only).
281	*Pseudotsuga menziesii/Vaccinium globulare* h.t.-*Vaccinium globulare* phase (PSME/VAGL-VAGL), Douglas-fir/blue huckleberry-blue huckleberry phase.	Central, southwestern, and south-central.
282	*Pseudotsuga menziesii/Vaccinium globulare* h.t.-*Arctostaphylos uva-ursi* phase (PSME/VAGL-ARUV), Douglas-fir/blue huckleberry-kinnikinnick phase.	Central.
283	*Pseudotsuga menziesii/Vaccinium globulare* h.t.-*Xerophyllum tenax* phase (PSMA/VAGL-XETE), Douglas-fir/blue huckleberry-beargrass phase.	Central.
	Pseudotsuga menziesii/Linnaea borealis h.t.-*Arctostaphylos uva-ursi* phase (PSME/LIBO-ARUV), Douglas-fir/twin-flower-kinnikinnick phase.	Central (Little Rocky Mountains only).
291	*Pseudotsuga menziesii/Linnaea borealis* h.t.-*Symphoricarpos albus* phase (PSME/LIBO-SYAL), Douglas-fir/twinflower-snowberry phase.	Central.
292	*Pseudotsuga menziesii/Linnaea borealis* h.t.-*Calamagrostis rubescens* phase (PSME/LIBO-CARU), Douglas-fir/twin-flower-pinegrass phase.	Central and southwestern.
293	*Pseudotsuga menziesii/Linnaea borealis* h.t.-*Vaccinium globulare* phase (PSME/LIBO-VAGL), Douglas-fir/twin-flower-blue huckleberry phase.	Central.
312	*Pseudotsuga menziesii/Symphoricarpos albus* h.t.-*Calamagrostis rubescens* phase (PSME/SYAL-CARU), Douglas-fir/snowberry-pinegrass phase.	Central, southwestern, and south-central.
313	*Pseudotsuga menziesii/Symphoricarpos albus* h.t.-*Symphoricarpos albus* phase (PSME/SYAL-SYAL), Douglas-fir/snowberry-snowberry phase.	North-central, central, southwestern, and south-central.
	Pseudotsuga menziesii/Amelanchier alnifolia h.t. (PSME/AMAL), Douglas-fir/serviceberry.	Central (Bearpaw Mountains only).
322	*Pseudotsuga menziesii/Calamagrostis rubescens* h.t.-*Arctostaphylos uva-ursi* phase (PSME/CARU-ARUV), Douglas-fir/pinegrass-kinnikinnick phase.	Central.
323	*Pseudotsuga menziesii/Calamagrostis rubescens* h.t.-*Calamagrostis rubescens* phase (PSME/CARU-CARU), Douglas-fir/pinegrass-pinegrass phase.	North-central, central southwestern, and south-central.
360	*Pseudotsuga menziesii/Juniperus communis* h.t. (PSME/JUCO), Douglas-fir/common juniper. (Includes those stands on calcareous substrates. See Fire Group Seven for stands on granitic substrates.)	North-central, central, and southwestern.

Fire Group Six habitat types occur throughout eastern Montana usually at elevations of about 4,800 ft to 7,200 ft (about 1 525 m to 2 135 m). Douglas-fir is both the indicated climax species and a vigorous member of seral communities. It is not uncommon for Douglas-fir to dominate all stages of succession on these sites. Lodgepole pine is a major seral component in many Group Six stands. Whitebark pine is usually well represented at upper levels on PSME/CARU-CARU sites, and limber pine is common on limestone substrates on PSME/PHMA-PHMA sites in the south-central region. Subalpine fir and spruce are essentially absent on the habitat types. Ponderosa pine will occur at low elevations, but it is not a major component.

Shrubs and moist site forbs dominate the undergrowth along with pinegrass, beargrass, and elk sedge. Common shrubs include ninebark, snowberry, white spiraea, oceanspray, blue huckleberry, grouse whortleberry, kinnikinnick, twinflower, and common juniper. Forbs include sweet cicely, fairy bells, starry Solomon's seal, western meadow rue, heartleaf arnica, and mountain arnica. Undergrowth composition will vary by habitat type and phase.

Forest Fuels

Downed dead fuel loads in Group Six stands average about 13 tons/acre (about 3 kg/m^2) but can be much heavier. Fuel conditions will vary according to stand density and species composition. The most hazardous conditions occur in well-stocked stands with dense Douglas-fir understories (fig. 20). These stands are usually characterized by relatively large amounts of downed twigs and small branchwood less than 3 inches (7.62 cm) in diameter (table 7) beneath partially fallen and standing dead sapling and small pole-sized stems.

The absence of dense understories results in reduced fire hazard (fig. 21). However, the density of overstory trees and the presence of dead branches near ground level create a crown fire potential under severe burning conditions.

Fuel conditions in the stands dominated by lodgepole pine tend to be less hazardous than in stands dominated by Douglas-fir (fig. 22). Ladder fuels are much less prevalent, so the probability of fire going from the forest floor to the crowns is not as great.

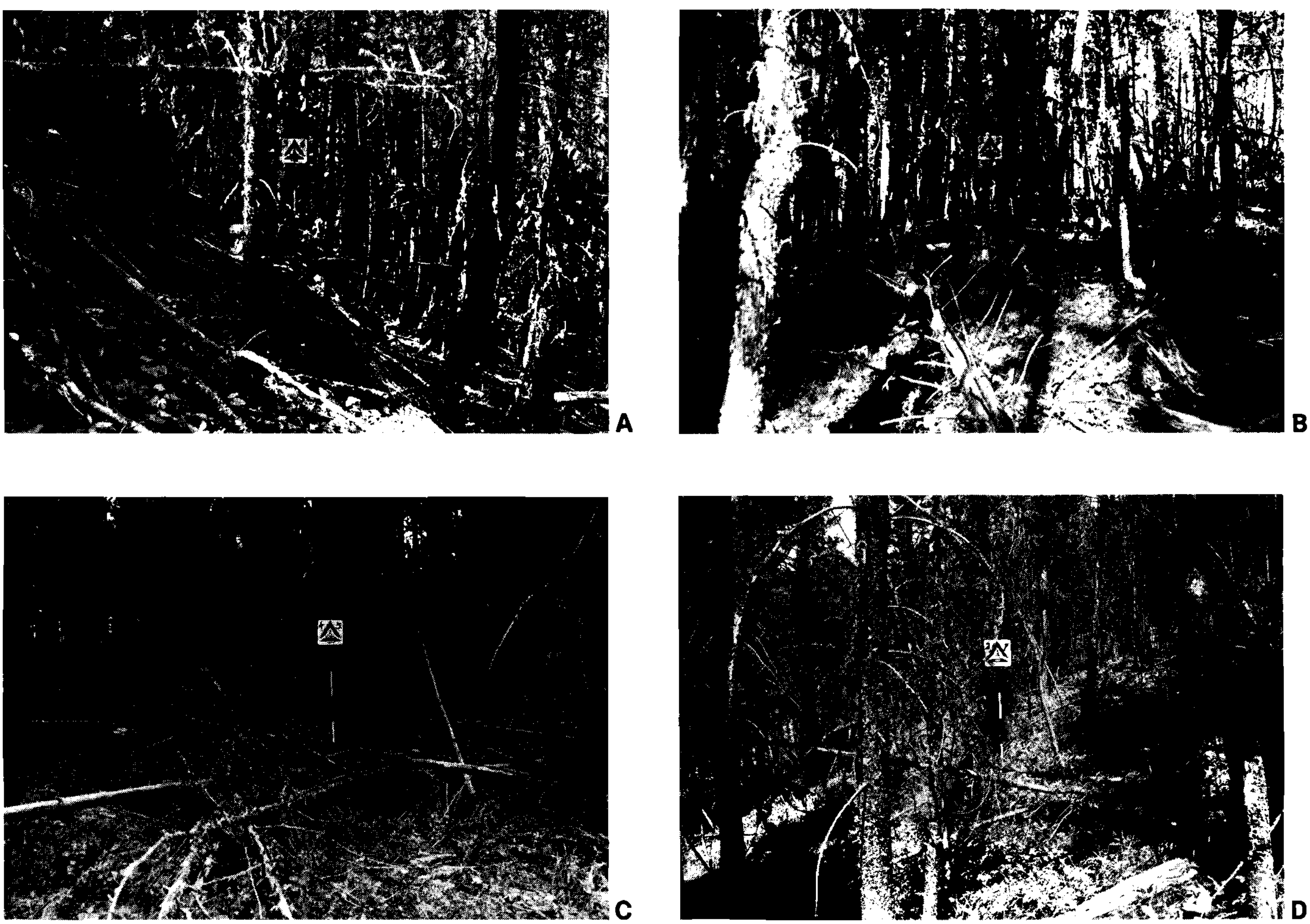


Figure 20.—Examples of high-hazard fuel conditions in Fire Group Six Douglas-fir stands. Stands 36A, 38A, and 43A (A, B, and C) are on the Lewis and Clark National Forest near White Sulphur Springs, Mont. Stand 27A (D) is near Lincoln, Mont., Helena National Forest. Stand descriptions and fuel loadings are given in table 7.

Table 7.—Fuel loading by size class and duff depth for Fire Group Six stands shown in figures 20, 21, and 22 (source: Fischer 1981a)

Stand number	Habitat type	Age	Duff depth	Size class (inches) 0-1/4	1/4-1	1-3	3-6	6-10	10-20	20+	Total
		Years	*Inches*	*Tons per acre*							
26A	PSME/VAGL-XETE	150	0.7	0.2	0.4	0.7	1.9	0.8	0	0	4.0
39A	PSME/SYAL-CARU	75	1.4	0.4	0.7	1.3	1.4	2.5	0	0	6.3
28A	PSME/CARU-CARU	77	2.4	0.4	1.1	3.6	2.0	0.8	0.4	0	8.3
36A	PSME/LIBO-CARU	109	2.8	0.5	1.5	4.2	2.3	1.9	0	0	10.4
27A	PSME/VAGL-XETE	86	1.9	0.2	0.8	1.2	1.9	5.2	1.7	0	11.0
25A	PSME/VAGL-XETE	120	1.0	0.2	0.8	3.7	6.7	1.4	0	0	12.8
42A	PSME/CARU-CARU	82	2.1	0.5	1.0	0.8	1.7	6.2	3.1	0	13.3
38A	PSME/CARU-CARU	104	2.0	0.4	2.4	5.0	3.4	2.6	2.0	0	15.8
43A	PSME/SYAL-CARU	92	2.7	0.5	2.7	8.7	3.6	1.8	0	0	17.3

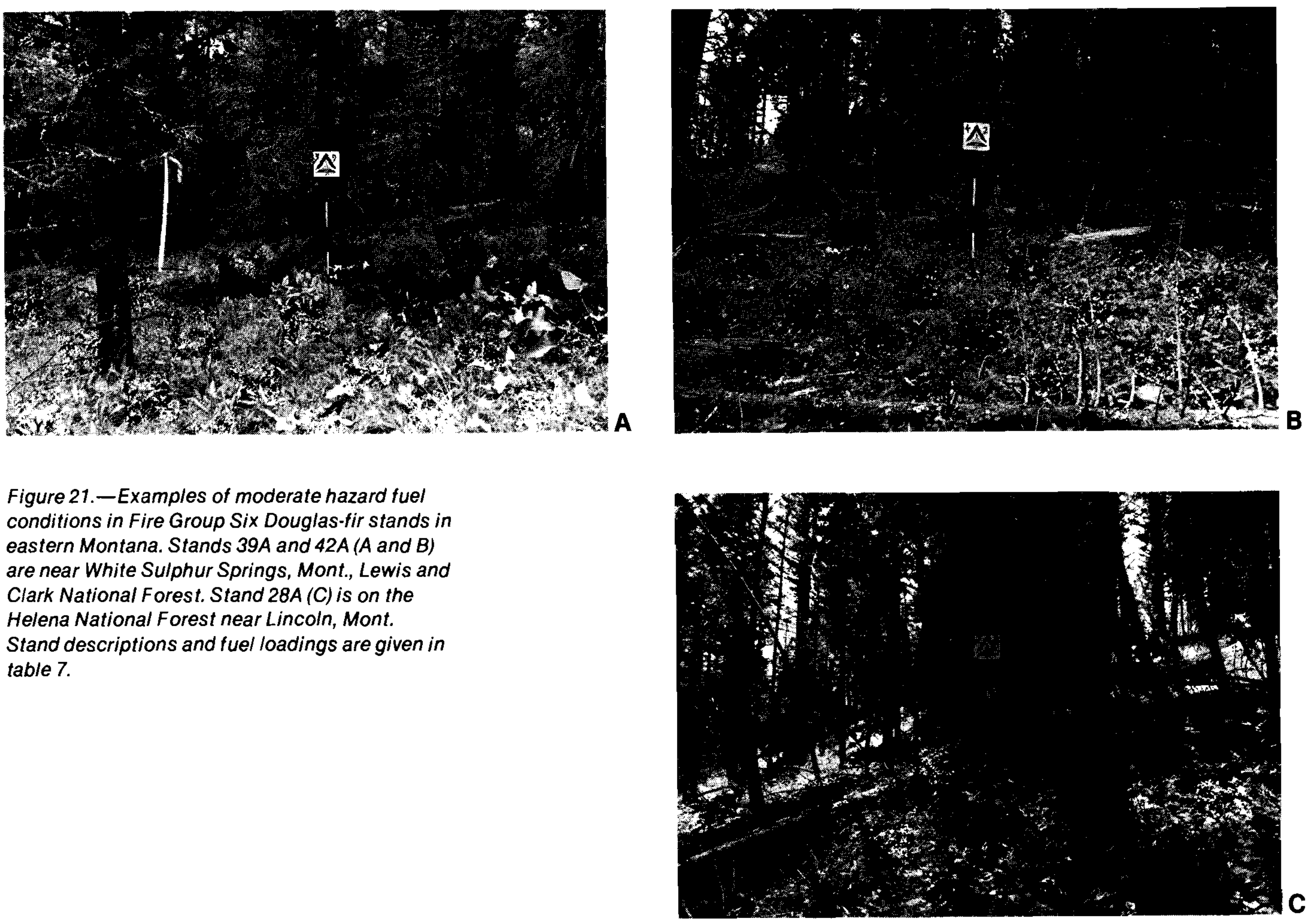
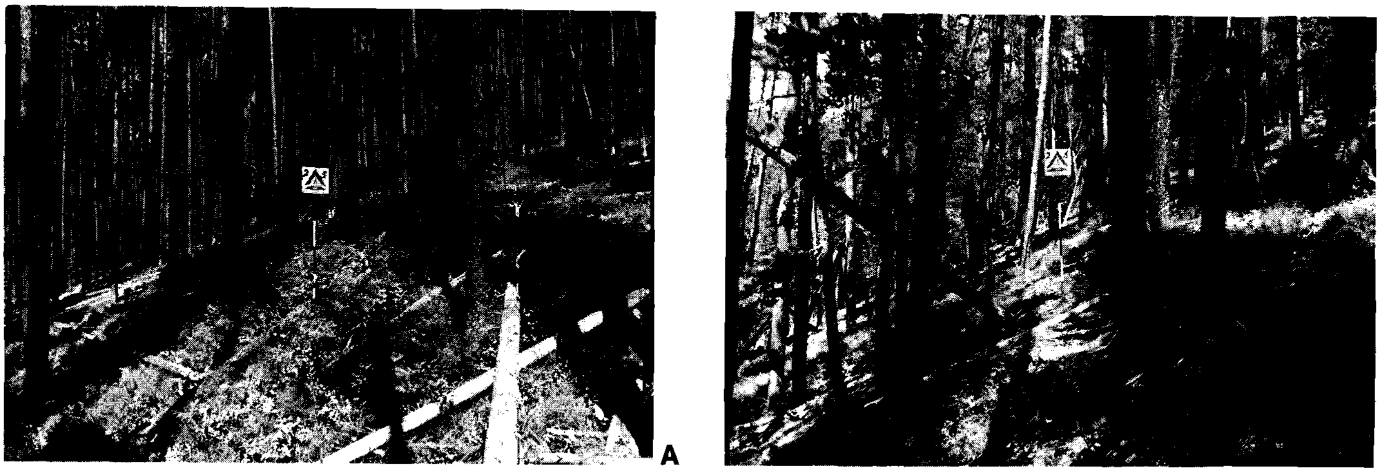


Figure 21.—Examples of moderate hazard fuel conditions in Fire Group Six Douglas-fir stands in eastern Montana. Stands 39A and 42A (A and B) are near White Sulphur Springs, Mont., Lewis and Clark National Forest. Stand 28A (C) is on the Helena National Forest near Lincoln, Mont. Stand descriptions and fuel loadings are given in table 7.



A B

Figure 22.—Examples of Fire Group Six lodgepole pine stands on the Helena National Forest near Lincoln, Mont. Stand descriptions and fuel loadings are given in table 7.

The tendency toward overstocking and the development of dense understories are main reasons for high-hazard fuel conditions in many Group Six stands. Suppression mortality, snow breakage, blowdown, and insect and disease mortality operate at a high level in many stands. Relatively deep duff develops and contains a lot of rotten logs. Fires often sit and smolder undetected in the duff until burning conditions become favorable for fire spread.

Role of Fire

Fire history studies conducted in Fire Group Six (PSME/CARU) stands in southeastern Montana indicate a mean fire interval of 42 years for presettlement stands (Arno and Gruell 1983).

Fire was important as a thinning agent and as a stand replacement agent. Low to moderate severity fires converted dense pole-sized or larger stands to a fairly open conditon. Subsequent light burning maintained stands in a parklike condition. Severe fires probably occurred in dense, fuel-heavy stands and resulted in stand replacement. Fire's role as a seedbed-preparing agent is less important in Group Six than in previously discussed fire groups.

Fire has a demonstrable effect on wildlife habitat in Group Six through its effects on food plants. The combination of opening up stands by killing overstory trees, reducing competition by removing understories, and rejuvenating sprouting plants through top kill, can significantly increase the availability of palatable browse and forage.

Fire's role as a stand replacement agent becomes more pronounced when the natural fire-free interval is increased through fire suppression, unless corresponding fuel reduction occurs.

Generalized Forest Succession

The theoretical climax condition on Group Six sites is a multistoried Douglas-fir stand, although a fire-maintained open forest condition was the normal situation during the presettlement period, as shown in figure 23 (subsequent numbers in this section refer to fig. 23). Following a severe, stand-destroying fire (No. 1), grass forbs and shrubs dominate the site. Subsequent fires in this stage perpetuate grass, forbs, and shrubs (No. 2). Douglas-fir seedlings become established on most sites in the absence of fire. Lodgepole pine may also become established or even dominate the seedling stage if a seed source is available or if lodgepole was present in the previous stand.

A fire in the seedling stage (No. 3) will return the site to grass, forbs, and shrubs. Similarly, a fire in the sapling and pole stage (No. 4 and 5) will revert the site to the herbaceous condition.

A severe fire in the pole stage (No. 5) will either revert the site to grass, forbs, and shrubs, or if serotinous cone bearing lodgepole pine are present, the fire will help establish a lodgepole pine stand. A light fire (No. 6) in a large-diameter pole stand or a small-sawtimber-sized stand would thin out Douglas-fir and leave an open, parklike stand.

A severe fire in older stands (No. 7) will revert the site to grass, forbs, and shrubs. A low to moderately severe fire (No. 8) will often result in an open, parklike Douglas-fir stand.

Successional Pathways

Group Six habitat types tend to support either mixed stands of Douglas-fir and lodgepole pine or nearly pure stands of Douglas-fir. These two major successional pathways are indicated in figure 24 (subsequent states and numbers in this section refer to fig. 24).

DOUGLAS-FIR SITES

Starting with the site dominated by grass, forbs, and shrubs (state A), Douglas-fir seedlings and then saplings (state B1) eventually take over the site. Any fire will destroy the tree regeneration and allow herbaceous plants to again dominate (No. 1). In the absence of fire, a generally overstocked pole stand will develop (state C1). Depending on density of stems, a moderate to severe fire will revert the site to the herbaceous state (No. 2). A light to moderate surface fire (No. 3) may merely thin the stand, leaving scattered pole-sized trees on the site (state C2).

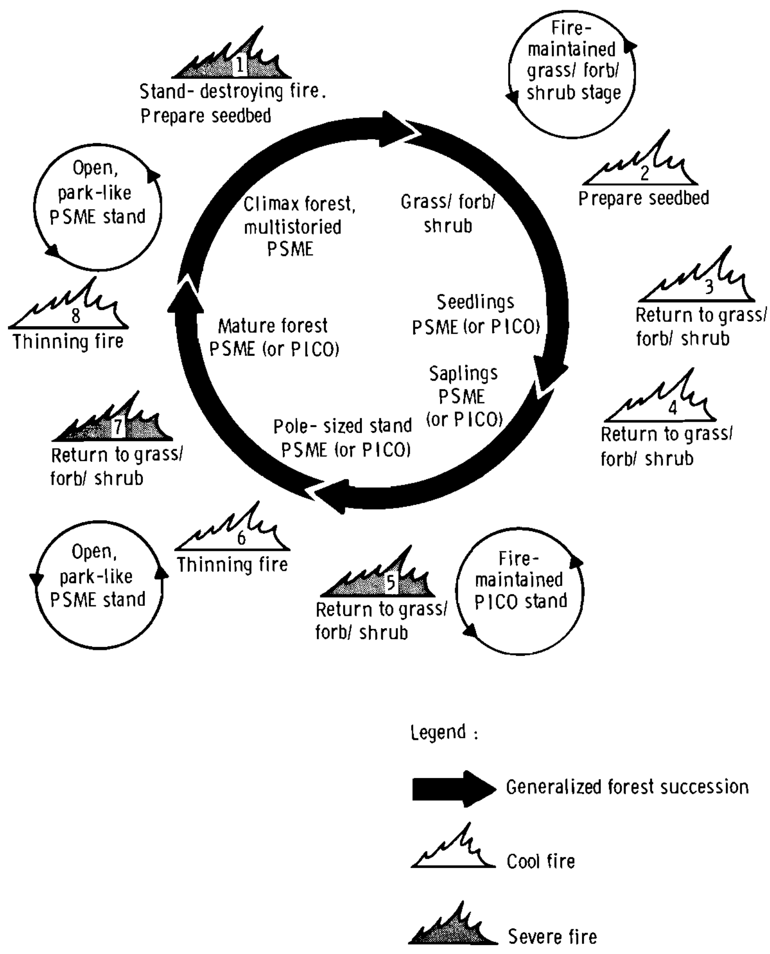


Figure 23.—Generalized forest succession in Fire Group Six: moist Douglas-fir habitat types.

I. SITES SUPPORTING ESSENTIALLY PURE STANDS OF DOUGLAS-FIR

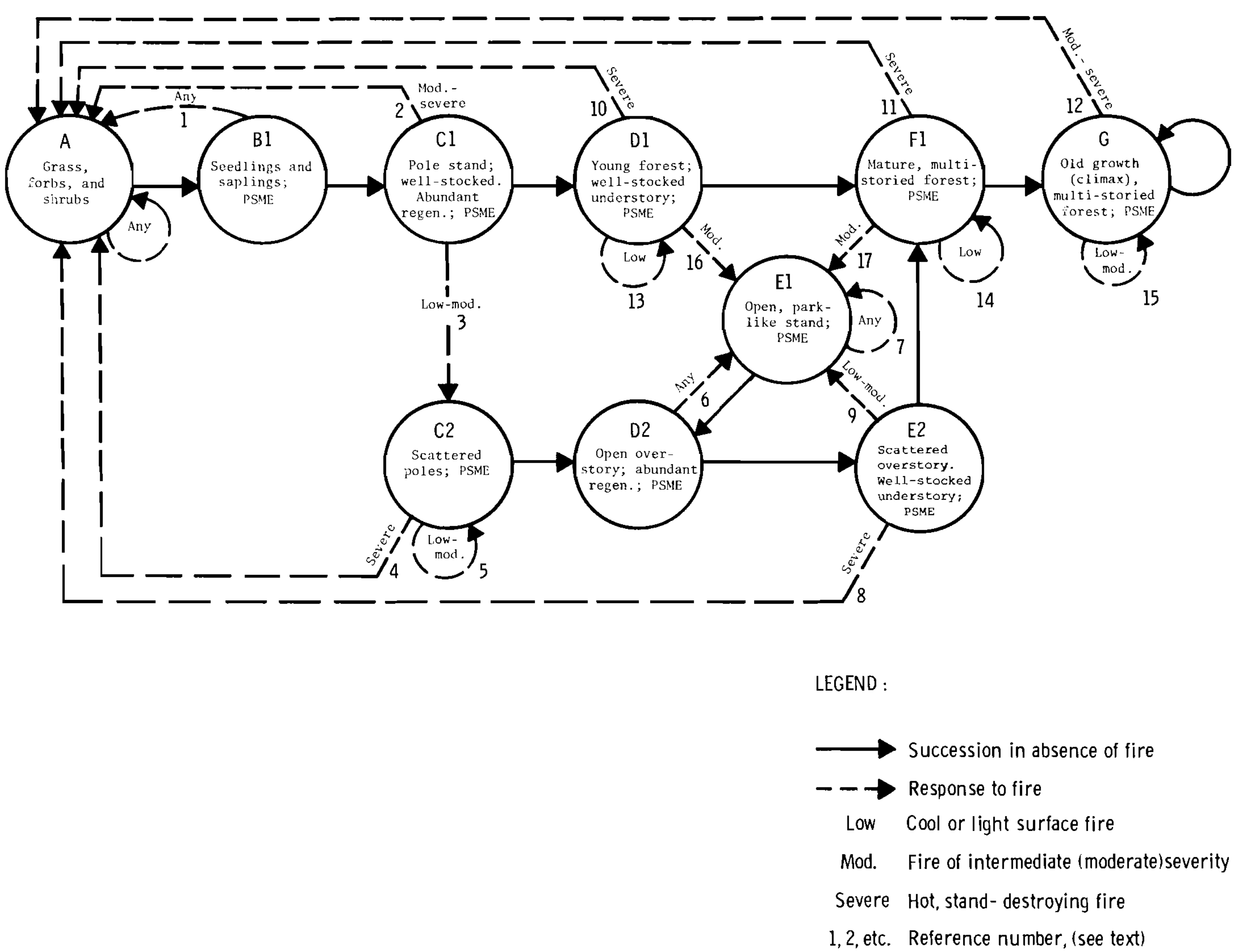


Figure 24.—Hypothetical fire-related successional pathways for Fire Group Six habitat types.

A subsequent severe fire (No. 4) is unlikely in state C2 because of the probable lack of fuel and distance between stems. If one did occur, the site would revert to grass, forbs, and shrubs. A low to moderate severity fire (No. 5) would maintain an herbaceous undergrowth beneath the scattered poles. In the absence of fire, an open overstory with Douglas-fir regeneration will develop (state D2). Any fire in this state (No. 6) would result in an open, parklike stand (state E1) that would be maintained by subsequent fires (No. 7). The absence of fire will allow the development of a well-stocked Douglas-fir stand beneath the scattered overstory trees (state E2). Such a stand would be susceptible to destruction by a severe fire (No. 8), while a low to moderately severe fire (No. 9) would result in the open, parklike condition (state E1). The absence of fire would allow the development of a mature Douglas-fir forest (state F1).

If fire fails to occur in the well-stocked pole state (state C1), a young Douglas-fir forest with a Douglas-fir understory will develop (state D1). Subsequent fire-free development will result first in a mature forest (state F1) and eventually in the climax situation (state G). Severe fires in any of these states will likely result in stand destruction (No. 10, 11, and 12). Moderate severity fires (No. 16 and 17) may result in the open, parklike condition (state E1). Low severity fire will have little effect on these stands (No. 13, 14, and 15).

DOUGLAS-FIR/LODGEPOLE PINE SITES

On Group Six sites that will support lodgepole pine as well as Douglas-fir, succession in the absence of fire is similar to that described for Douglas-fir sites, except that lodgepole pine is usually a major component of seral stands. Fire-free succession progresses from the herbaceous state (state A) to a mixed species seedling and sapling state, a pole-sized tree state, a young forest state, the mature forest, and eventually the climax forest (states B2, C3, D3, F2, and G respectively). Any fire in the seedling/sapling state (No. 18) reverts the site to the herbaceous condition (state A). Severe fires in states C3, D3, F2, and G have a similar result (No. 19, 20, 21, and 12). Light surface fires in young and mature forests (states D3 and F2) have little effect on succession (No. 22 and 23).

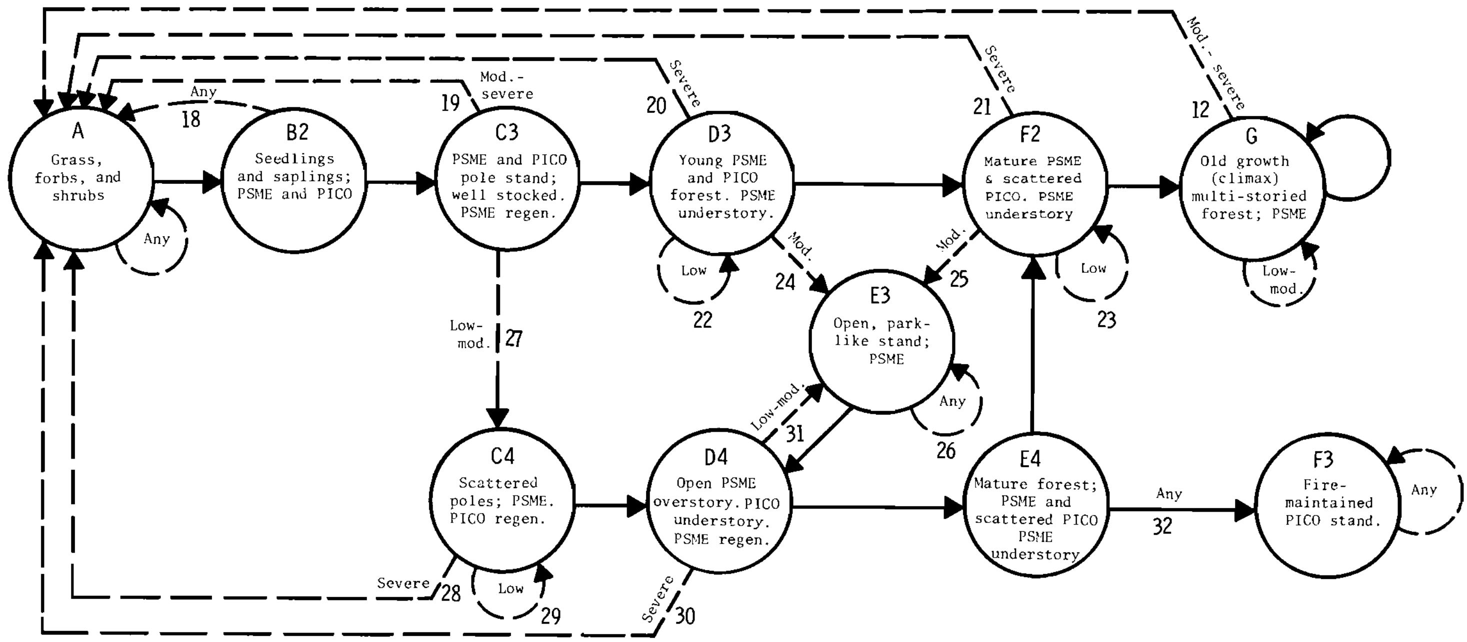


Figure 24.—(con.)

Moderately severe fires in these two states (No. 24 and 25) favor the more fire-resistant Douglas-fir trees over the lodgepole pines and can result in an open, parklike Douglas-fir stand or Douglas-fir/lodgepole pine stand (state E3) which will be maintained by subsequent fires (No. 26).

A low to moderately severe fire (No. 27) in the mixed-species pole state (state C3) can result in scattered Douglas-fir poles with abundant lodgepole pine regeneration (state C4), assuming that the burned lodgepole pine have serotinous cones. Lack of fuel would probably preclude a stand-destroying fire in this state (No. 28), and light surface fire would probably have minimal impact (No. 29). In the absence of fire, a lodgepole pine stand would develop beneath the scattered Douglas-fir overstory (state D4). Such a stand would be susceptible to destruction by a severe fire (No. 30). A cool to moderately severe fire could destroy the lodgepole pine understory (No. 31) and result in an open, parklike Douglas-fir stand (state E3). Subsequent fire would maintain this condition (No. 26), but the lack of fire would allow a lodgepole pine and Douglas-fir understory to develop (state D4). Continued lack of fire would allow the development of a mature lodgepole pine stand with a Douglas-fir understory (state E4). Subsequent fire (No. 32) can result in a fire-maintained lodgepole pine stand (state F3), while lack of fire allows a mature Douglas-fir forest to develop (state F2).

Fire Management Considerations

Fire Group Six stands are quite variable depending on site conditions, stand history, and successional stage. Fire management considerations must, therefore, be attuned to this variation.

WILDFIRE SUPPRESSION

Protection from unwanted fire may be a major fire management consideration in those stands where combinations of live and dead fuels result in a severe fire behavior potential. It may be difficult and impractical to abate the fire hazard in such stands except in conjunction with timber harvest operations. Preattack planning coupled with rapid detection and initial attack may be the only reasonable means to deal with such situations until such time as harvest operations can be scheduled.

HAZARD REDUCTION AND SITE PREPARATION

Fire can be used to prepare seedbeds and reduce hazard following logging. Care must be taken to control fire intensity when burning in partial cut stands. The diameter of residual Douglas-fir trees and their branching habit will dictate, to a large extent, the kind of fire that can be prescribed. Guidelines for fuel consumption and duff reduction developed for western Montana Group Six stands should be consulted (Norum 1977 and DeByle 1981).

FORAGE PRODUCTION

Fire can be used to enhance and maintain favorable forage for livestock and big game in open Douglas-fir stands. Periodic light fire will stimulate production of grass, forbs, and sprouting shrubs on many Group Six habitats.

FIRE GROUP SEVEN: COOL HABITAT TYPES USUALLY DOMINATED BY LODGEPOLE PINE

ADP code	Habitat type-phase (Pfister and others 1977, Roberts 1980)	Montana forest region (Arno 1979)
360	*Pseudotsuga menziesii/Juniperus communis* h.t. (PSME/JUCO), Douglas fir/common juniper. (Includes those stands on granitic substrates. See Fire Group Six for stands on calcarious substrates.)	North-central, central, and southwestern.
250	*Pseudotsuga menziesii/Vaccinium caespitosum* h.t. (PSME/VACA), Douglas-fir/dwarf huckleberry.	North-central and central.
	Pseudotsuga menziesii/*Cornus canadensis* h.t.-*Linnaea borealis* phase (PSME/COCA-LIBO), Douglas-fir/bunchberry dogwood-twinflower phase.	Central (Bearpaw Mountains only).
	Pseudotsuga menziesii/Cornus canadensis h.t.-*Vaccinium myrtillus* phase (PSME/COCA-VAMY), Douglas-fir/bunchberry dogwood-myrtle whortleberry phase.	Central (Bearpaw Mountains only).
450	*Picea/Vaccinium caespitosum* h.t. (PICEA/VACA), spruce/dwarf huckleberry.	North-central.
470	*Picea/Linnaea borealis* h.t. (PICEA/LIBO), spruce/twinflower.	Central, south-central, and southwestern.
640	*Abies lasiocarpa/Vaccinium caespitosum* h.t. (ABLA/VACA), subalpine fir/dwarf huckleberry.	Central and southwestern.
654	*Abies lasiocarpa/Calamagrostis canadensis* h.t.-*Vaccinium caespitosum* phase (ABLA/CACA-VACA), subalpine fir/bluejoint-dwarf huckleberry phase.	Central and southwestern.
663	*Abies lasiocarpa/Linnaea borealis* h.t.-*Vaccinium scoparium* phase (ABLA/LIBO-VASC), subalpine fir/twinflower-grouse whortleberry phase.	North-central, central, south-central, and southwestern.
692	*Abies lasiocarpa/Xerophyllum tenax* h.t.-*Vaccinium scoparium* phase (ABLA/XETE-VASC), subalpine fir/beargrass-grouse whortleberry phase.	North-central and southwestern.
720	*Abies lasiocarpa/Vaccinium globulare* h.t. (ABLA/VAGL), subalpine fir/blue huckleberry.	Central, south-central, and southwestern.
731	*Abies lasiocarpa/Vaccinium scoparium* h.t.-*Calamagrostis rubescens* phase (ABLA/VASC-CARU), subalpine fir/grouse whortleberry-pinegrass phase.	Central, south-central, and southwestern.
732	*Abies lasiocarpa/Vaccinium scoparium* h.t.-*Vaccinium scoparium* phase (ABLA/VASC-VASC), subalpine fir/grouse whortleberry-grouse whortleberry phase.	Central, south-central, and southwestern.
791	*Abies lasiocarpa/Carex geyeri* h.t.-*Carex geyeri* phase (ABLA/CAGE-CAGE), subalpine fir/elk sedge-elk sedge phase.	North-central and southwestern.
910	*Pinus contorta/Purshia tridentata* h.t. (PICO/PUTR), lodgepole pine/bitterbrush.	South-central.
920	*Pinus contorta/Vaccinium caespitosum* h.t. (PICO/VACA), lodgepole pine/dwarf huckleberry.	North-central, central, and southwestern.
930	*Pinus contorta/Linnaea borealis* c.t. (PICO/LIBO), lodgepole pine/twinflower.	Central, south-central, and southwestern (including Little Rocky Mountains).
940	*Pinus contorta/Vaccinium scoparium* c.t. (PICO/VASC), lodgepole pine/grouse whortleberry.	Central, south-central, and southwestern.
950	*Pinus contorta/Calamagrostis rubescens* c.t. (PICO/CARU), lodgepole pine/pinegrass.	Central, south-central, and southwestern.
	Pinus contorta/Juniperus communis h.t. (PICO/JUCO), lodgepole pine/common juniper.	Central (Little Rocky Mountains only).

Fire Group Seven contains two groups of habitat types. The first group consists of lodgepole pine climax series habitat types (and community types) that support essentially pure stands of lodgepole pine. There is insufficient evidence to indicate that other species constitute the potential climax on these sites. The other group consists of those Douglas-fir, spruce, and subalpine fir habitat types that, regardless of potential climax species, are usually found in nature supporting lodgepole pine-dominated stands. Apparently, these stands seldom reach a near-climax condition. Periodic wildfires seem to recycle the stands before a substantial amount of mature lodgepole pine dies out.

Subalpine fir, spruce, Douglas-fir, and whitebark pine occur in varying amounts with lodgepole pine on most Group Seven habitat types. They are, however, less likely to be found on the lodgepole pine habitat types than on the others.

Undergrowth in Group Seven stands often consists of dense mats or layers of grasses or shrubs. The most common graminoid species are pinegrass, bluejoint, and elk sedge. Common shrubs include grouse whortleberry, blue huckleberry, dwarf huckleberry, myrtle whortleberry, twinflower, kinnikinnick, white spiraea, bunchberry dogwood, snowberry, common juniper, bitterbrush, buffaloberry, and creeping Oregon grape. Heartleaf arnica, broadleaf arnica, and western meadow rue are among the more common Group Seven forbs.

Forest Fuels

The average downed, dead woody fuel load for Group Seven habitat types is about 15 tons/acre (about 3.4 kg/m^2), but maximum loads may greatly exceed this value. Group Seven fuel loads are characterized by relatively large amounts of material 3 inches (7.6 cm) or more in diameter. At least half the total weight is usually contributed by large material. As a general rule, the proportion of the total fuel load made up of material 3 inches or more in diameter increases as the total load increases. Brown and See (1981) show an average downed woody fuel load of 19 tons/acre (4.3 kg/m^2) for Fire Groups Seven and Eight combined (table 4 and fig. 2).

Live fuels can be a problem in Group Seven but not to the extent they are in some other fire groups. The primary live fuel consideration is related to the occurrence of dense patches or entire stands of young lodgepole with intermingled crowns and lower branches extending down to the surface fuels. When ignited under favorable burning conditions, such stands are usually destroyed in a few minutes.

Many mature stands are characterized by densely stocked, clean-boled trees with large amounts of deadfall on the forest floor (fig. 25 and table 8). An immediate source of deadfall in a young lodgepole stand is the snags created by the previous fire. Lyon (1977) found that after 2 years with little windthrow, lodgepole pine snags on the Sleeping Child Burn (Bitterroot National Forest) fell at an annual rate of 13.4 percent (fig. 26).

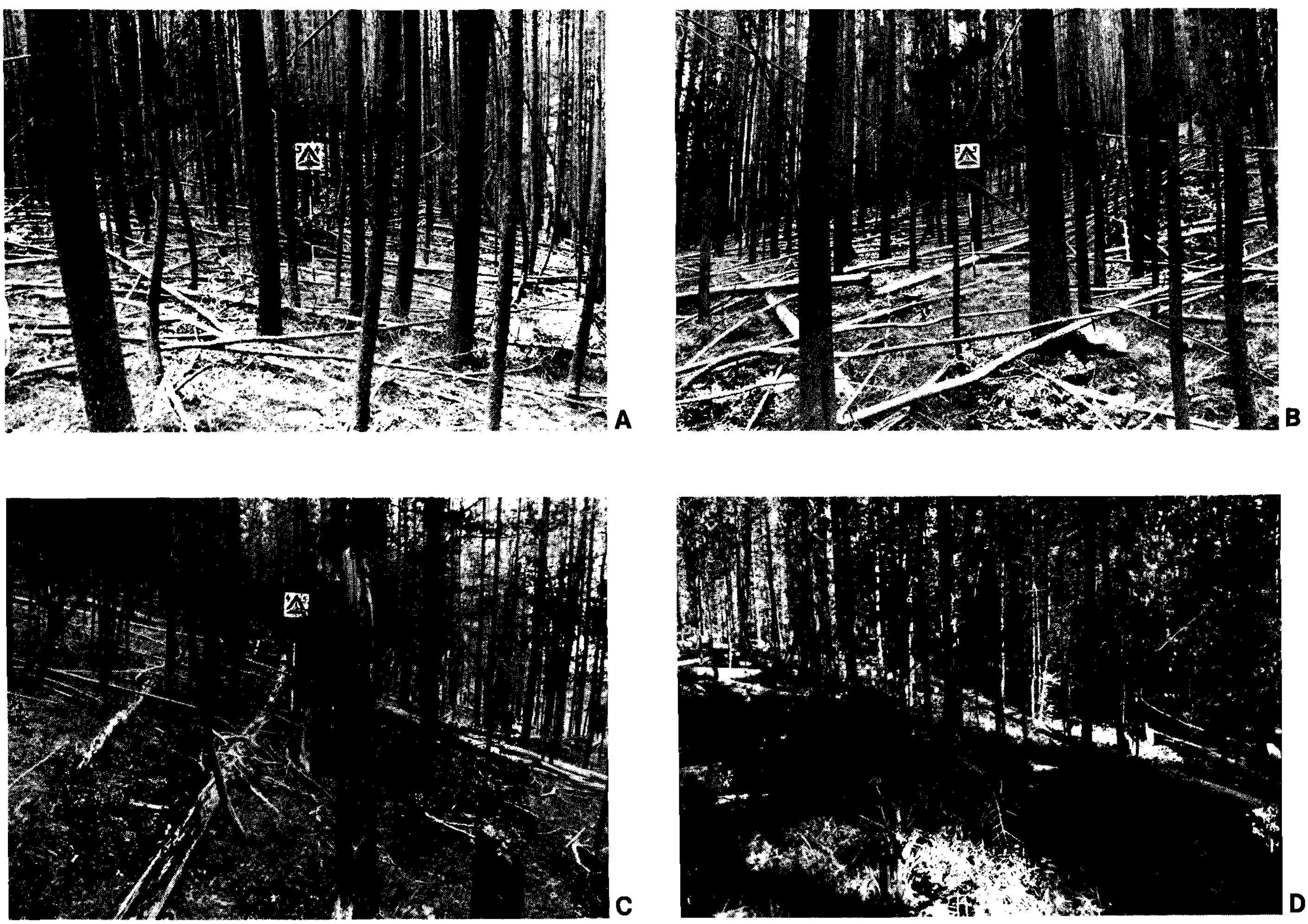
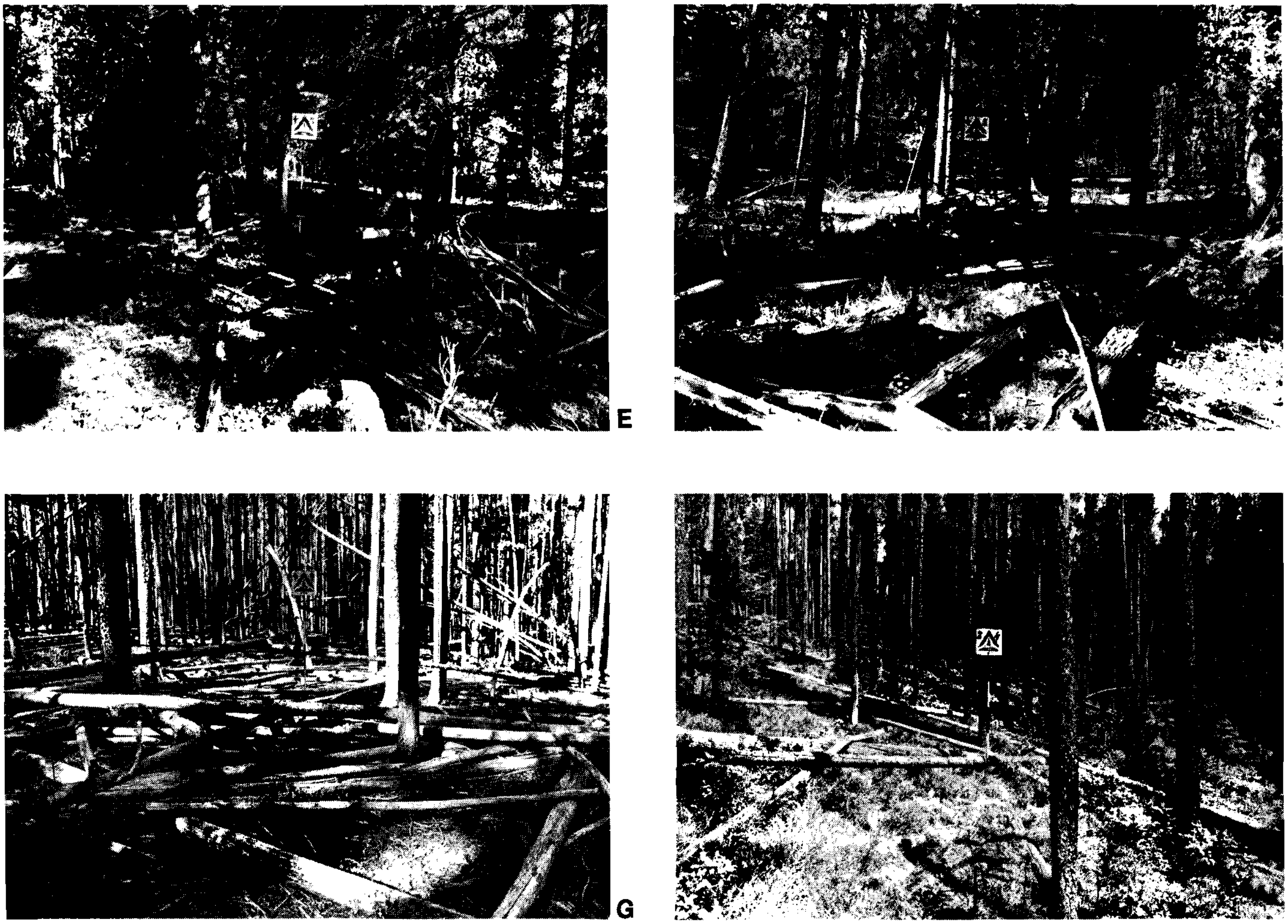


Figure 25.—Examples of Fire Group Seven fuel conditions on eastern Montana National Forests. Stands 34A and 35A (A and B) are on White Sulphur Springs Ranger District, Lewis and Clark National Forest. Stands 45A, 46A, 47A, 48A, and 49A (C, D, E, F, and G) are on Philipsburg Ranger District, Deerlodge National Forest. Stand 24A (H) is on Lincoln Ranger District, Helena National Forest. Duff and fuel loading and other stand information is in table 8. (Source: Fischer 1981b.)



E F G H

Figure 25.—(con.)

Table 8.—Fuel loading by size class and duff depth for Fire Group Seven stands shown in figure 25 (source: Fischer 1981b)

Stand number	Habitat type phase	Age	Duff depth	Size class (inches)						Total
				0-1/4	1/4-1	1-3	3-6	6-10	10-20	
		Years	*Inches*	*Tons per acre*						
35A	ABLA/VAGL	123	2.4	0.3	1.2	5.1	4.3	1.1	0	12.0
24A	ABLA/XETE-VASC	140	0.8	0.3	1.0	2.5	7.7	1.3	0	12.8
34A	PICO/VASC	85	1.9	0.4	1.9	8.5	2.1	0.2	0	13.1
45A	PSME/VACA	51	1.5	0.2	0.8	1.7	1.2	6.5	2.8	13.2
47A	PSME/VACA	180	2.5	0.1	1.0	3.3	3.3	5.4	4.0	17.1
49A	ABLA/VACA	162	2.3	0.3	1.4	8.1	11.8	1.0	0	22.6
48A	PSME/VACA	130	2.2	0.2	1.0	1.2	4.2	14.9	10.2	31.7
46A	PSME/VACA	55	2.5	0.2	0.7	1.2	10.7	17.0	2.5	32.3

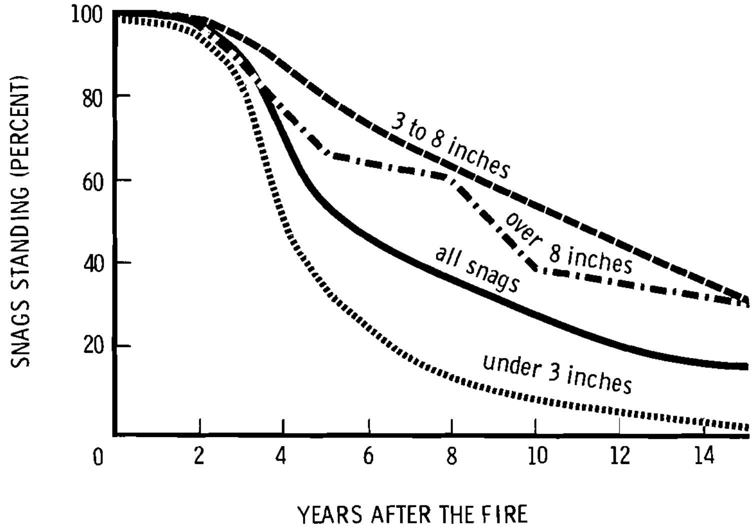


Figure 26.—Percentage of lodgepole pine snags still standing, by year and diameter class, Sleeping Child Burn, Bitterroot National Forest, Montana, 1962-1976 (Lyon 1977).

Table 9.—Average number of snags per acre by size class and year of count, Sleeping Child Burn, Bitterroot National Forest, Mont. (Lyon 1977) (totals may not agree because of rounding)

Size class (inches)	Year					
	1962	**1963**	**1966**	**1969**	**1971**	**1976**
Under 3	266	265	96	41	28	4
3 to 8	159	156	124	103	85	50
8 to 12	64	62	40	36	24	19
Over 12	7	7	7	6	4	3
Total	*497*	*390*	*268*	*186*	*141*	*75*

Snags less than 3 inches (7.6 cm) in diameter fell at a rate of 27.9 percent, and nearly all were down in 15 years. Snags larger than 3 inches fell at an annual rate of 8.4 percent, but those larger than 8 inches (20.3 cm) fell sporadically. Overall, an average of 497 snags per acre was reduced to an average of 75 snags per acre after 15 years (table 9).

Aside from fire-created snags, sources of deadfall are suppression mortality, snow breakage and windthrow of live trees, dwarf mistletoe-related mortality, and almost inevitably, mountain pine beetle attack and subsequent mortality. Mountain pine beetle attack is often the mechanism that causes the lodgepole stand to break up. Cumulative mortality during a mountain pine beetle epidemic (about 11 years) frequently amounts to 85 percent or more of the large, 8-inch (20-cm) diameter trees in a lodgepole pine stand (Cole and Amman 1980).

Brown (1975) has characterized fuel cycles and fire hazard in lodgepole pine stands, as shown in figure 27. Curve A of that figure corresponds to what Muraro (1971) describes as typical fire hazard in lodgepole pine where young stands, especially dense ones, are most hazardous. Least hazardous are moderately dense to open advanced immature and mature stands. Hazard increases as stands become overmature and ground fuels build up from downfall and establishment of shade-tolerant species. Curve C depicts conditions not uncommonly found. Ground fuel quantities and fire potential remain relatively low throughout the life of the stand until it undergoes decadence. Individual stands can vary anywhere between curves A and C during younger growth periods, and develop higher fire potential at later periods of growth (curve B).

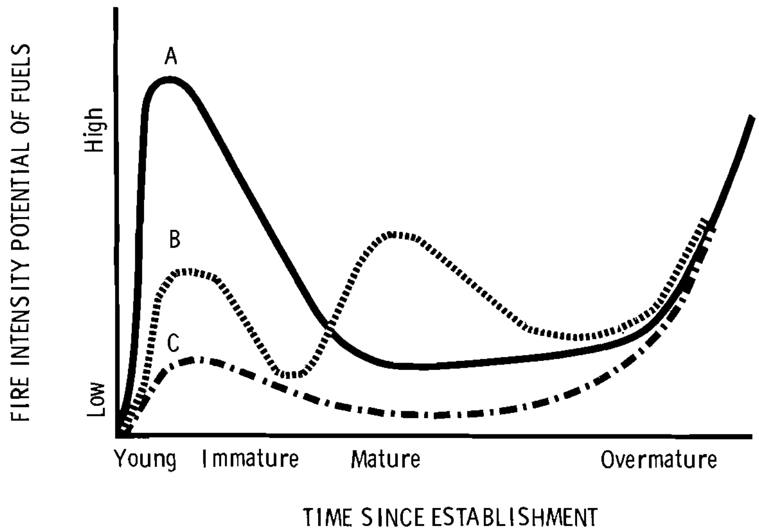


Figure 27.—Fuel cycles and fire intensity potential in lodgepole pine (Brown 1975).

Role of Fire

In habitats below about 7,500 ft (2 286 m) the role of fire in seral lodgepole forests is almost exclusively as an agent that perpetuates or renews lodgepole pine. Without periodic disturbance, the shade-tolerant species replace lodgepole because it does not regenerate well on duff or under shaded conditions. Fire interrupts the course of successsion and increases the proportion of lodgepole with each burn. Within 50 to 100 years following a severe fire in a lodgepole-dominated stand, a reestablished lodgepole pine forest will exist even though shrubs and herbaceous cover may become dominant immediately following the burn.

Holocaust (large stand-replacing) fires play a definite role in the ecology of lodgepole pine stands. The natural periodicity of fire in seral lodgepole stands probably ranges from less than 100 years to about 500 years (Hendrickson 1970). The interval between any two fires in one area might be only a few years (Brown 1975). Recurring cool fires may thin the stand or otherwise rejuvenate it without doing serious damage. Stands greater than 60 to 80 years old, however, become increasingly flammable due to overcrowding (suppression mortality), mountain pine beetle outbreaks, dwarf mistletoe infestations, and fire-killed timber (snags) from previous fires. Eventually a chance ignition sets off a major conflagration. In certain areas such a fire can cover thousands of acres. Vast tracts of lodgepole can develop in this way as the serotinous cones open and shower the burn with seeds. The Sleeping Child burn on the Bitterroot National Forest in western Montana is an extreme example in modern times.

The almost exclusive dominance of lodgepole pine in the lodgepole pine community types is attributed in large part to fire. Pfister and others (1977) suggest the following reasons for the absence of other species on lodgepole pine climax series sites:

1. Historic, repeated wildfires over large areas may eliminate seed sources of potential shade-tolerant competitors.

2. Light ground fires may remove invading shade-tolerant competitors from the understory.

3. Dense stands may prevent regeneration of all conifers for up to 200 years in the absence of disturbance or stand deterioration.

4. Sites may be unfavorable for the establishment of other conifers. (In Montana, the best example of this situation is the PICO/PUTR h.t.)

The PICO habitat type (PICO/PUTR) near West Yellowstone is an example of a true lodgepole pine climax situation. Fire's role in succession on these sites is poorly understood. Apparently, fire is not required for regeneration. The local soil, composed of almost pure obsidian sand, and the occurrence of severe yearlong frosts create physiological problems that lodgepole alone can tolerate. The forest in this area is fairly open with numerous age classes of self-replacing lodgepole pine and a low grass and shrub understory (fig. 28). Fuels are discontinuous both on the ground and in the canopy. Evidence of past fires exists throughout these stands in the form of charcoal, both on the surface and in the soil.

Figure 28.—A PICO/PUTR community type near West Yellowstone, Mont. (Gallatin National Forest). Special soil and climatic conditions allow lodgepole pine to dominate this site without serious competition from other species. Fire's role is poorly understood on such sites. (Bruce Clayton photo.)

Above 7,500 ft (2 286 m) the role of fire in lodgepole forests appears to differ from the classic pattern. At these altitudes the fire season is relatively short, productivity is low, mountain pine beetle activity is inhibited by low temperatures and the short growing season, and the overall pattern of fire dependence is correspondingly subdued. Fire frequency more closely resembles that of subalpine forests (about 150 years in the Northern Rockies). Romme (1980) has estimated a mean fire interval of 300 to 400 years for stand-destroying fires in subalpine forests of Yellowstone National Park. Ordinarily, the spread of fire is extremely limited. Small, lightning-caused fires burn out patches of forest several acres in area and then die out. The result is a mosaic of age classes, not the uniform single-aged forests prevalent on many lower elevation sites (Day 1972).

THE LODGEPOLE PINE FIRE CYCLE

Brown (1975) summarizes the lodgepole pine fire cycle and the many interrelated factors that influence it in figure 29. His discussion of fire cycles and community dynamics in lodgepole pine forests is an important source of information on the role of fire in lodgepole pine forests. Brown also discusses the differential effects of fires of varying severity on lodgepole pine forests. He emphasizes the critical role of fuel and duff moisture in determining fire severity and, consequently, fire effects.

FIRE AND THE MOUNTAIN PINE BEETLE

The roles of fire and mountain pine beetle are inextricable in most lodgepole pine forests. The following excerpt from Amman (1977) describes this interrelationship:

> *ROLE OF THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE ECOSYSTEMS*
> The role of the beetle differs in conjunction with the two basic ecological roles of lodgepole pine, where lodgepole pine is seral and where it is persistent or climax. The beetles' continued role in the seral stands will depend upon the presence of fire.
>
> *Role of Mountain Pine Beetle Where Lodgepole Pine Is Seral*
> **Absence of fire**: Lodgepole pine stands depleted by the beetle and not subjected to fire are eventually succeeded by the more shade-tolerant species consisting primarily of Douglas-fir at the lower elevations and subalpine fir and Engelmann spruce at the higher elevations throughout most of the Rocky Mountains. Starting with a stand generated by fire, lodgepole pine grows at a rapid rate and occupies the dominant position in the stand. Fir and spruce seedlings also established in the stand grow more slowly than lodgepole pine.

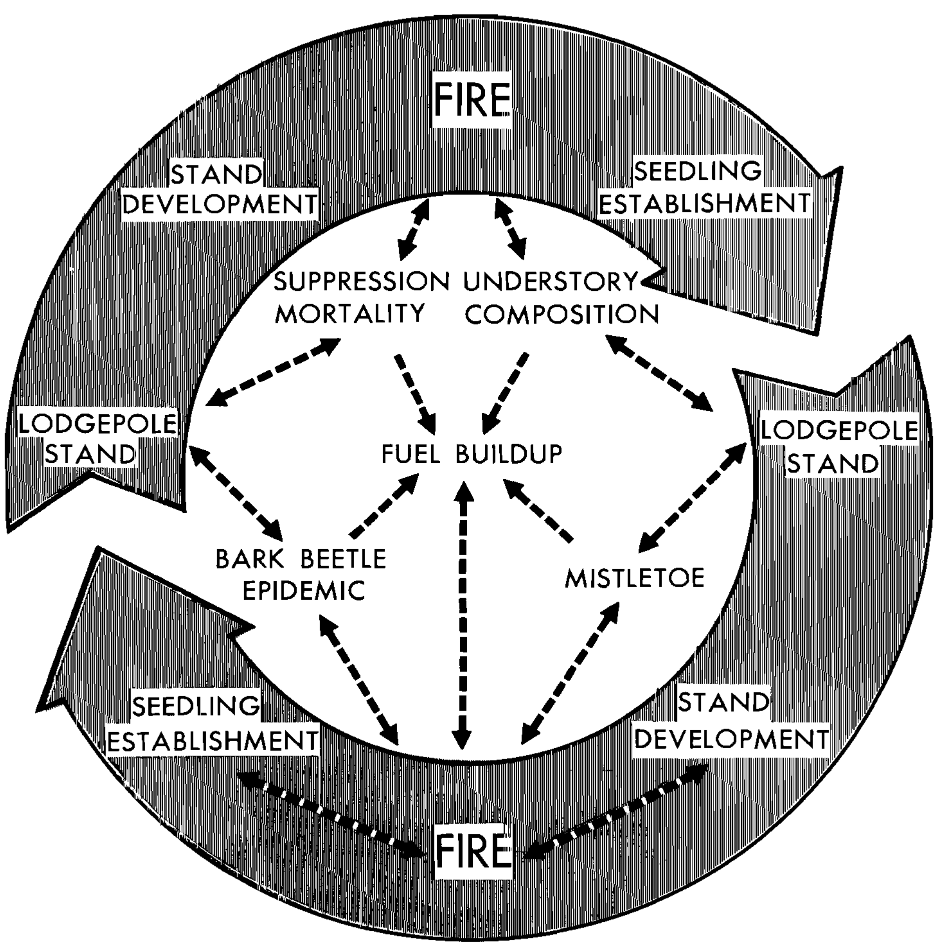


Figure 29.—Lodgepole pine fire cycle showing interrelationships among influences (Brown 1975).

With each infestation, the beetle kills most of the large, dominant lodgepole pines. After the infestation, both residual lodgepole pine and the shade-tolerant species increase their growth. When the lodgepole pines are of adequate size and phloem thickness, another beetle infestation occurs. This cycle is repeated at 20- to 40-year intervals depending upon growth of the trees, until lodgepole pine is eliminated from the stand.

The role played by the mountain pine beetle in stands where lodgepole pine is seral is to periodically remove the large, dominant pines. This provides growing space for subalpine fir and Douglas-fir, thus hastening succession by these species. The continued presence of the beetle in these mixed-species stands is as dependent upon fire as that of lodgepole pine. Without it both are eliminated.

Presence of fire: Where lodgepole pine is seral, forests are perpetuated through the effects of periodic fires (Tackle 1964a). Fires tend to eliminate competitive tree species such as Douglas-fir, the true firs, and spruces. Following fire, lodgepole pine usually seeds in abundantly. Serotinous cones attached to the limbs of the tree open because of the intense heat of the fire and release their seed (Clements 1910; Lotan 1975).

Large accumulations of dead material caused by periodic beetle infestations result in very hot fires when they do occur (Brown 1975). Hot fires of this nature eliminate Douglas-fir, which otherwise is more resistant to fire damage than lodgepole pine. The dominant shade-tolerant species are eliminated, resulting in a return to a pure lodgepole pine forest. On the other hand, light surface fires would not be adequate to kill large, thickbarked Douglas-fir and return lodgepole pine to a dominant position in the stand.

Following regeneration of lodgepole pine after fire, the mountain pine beetle-lodgepole interactions would be similar to those described in the absence of fire. A fire may interrupt the sere at any time, reverting the stand back to pure lodgepole pine. However, once succession is complete, lodgepole pine seed will no longer be available to seed the burned areas except along edges where the spruce-fir climax joins persistent or climax lodgepole pine.

Role of Mountain Pine Beetle Where Lodgepole Pine Is Persistent or Climax

Lodgepole pine is persistent over large acreages, and because of the number of shade-tolerant individuals of other species found in such persistent stands, the successional status is unclear (Pfister and Daubenmire 1975). In any case, lodgepole pine persists long enough for a number of beetle infestations to occur. In such cases and those of a more limited nature when lodgepole pine is climax because of special climatic or soil conditions, the forest consists of trees of different sizes and ages ranging from seedlings to a few overmature individuals. In these forests, the beetle infests and kills most of the lodgepole pines as they reach larger sizes. Openings created in the stand as a result of the larger trees being killed, are seeded by lodgepole pine. The cycle is then repeated as other lodgepole pines reach sizes and phloem thicknesses conducive to increases in beetle populations.

The result is two- or three-story stands consisting of trees of different ages and sizes. A mosaic of small clumps of different ages and sizes may occur. The overall effect is likely to be more chronic infestations by the beetle because of the more constant source of food. Beetle infestations in such forests may result in death of fewer trees per hectare during each infestation than would occur in even-aged stands developed after fires and in those where lodgepole pine is seral.

Fires in persistent and climax lodgepole pine forests should not be as hot as those where large epidemics of beetles have occurred. Smaller, more continuous deposits of fuel are available on the forest floor. The lighter beetle infestations, and thus lighter accumulations of fuel, would result in fires that would eliminate some of the trees but probably would not cause total regeneration of the stand. This would be beneficial to the beetle because a more continuous supply of food would be maintained. Where large accumulations of fuel occur after large beetle epidemics, fire would completely eliminate the beetles' food supply from vast acreages for many years while the entire stand of trees grow from seedlings to sizes conducive to beetle infestation.

The mountain pine beetle's evolutionary strategies have been successful. It has exploited a niche that no other bark beetle has been able to exploit, that of harvesting lodgepole pine trees as they reach or slightly before they reach maturity. Such trees are at their peak as food for the beetle. Harvesting at this time in the age of the stand maintains the vigor of the stand, and keeps the stand at maximum productivity. (End of Amman 1977 excerpts.)

Generalized Forest Succession

The theoretical climax forest on Fire Group Seven sites will vary according to habitat type as shown in figure 30 (subsequent numbers in this section refer to fig. 30). Except for the lodgepole pine community types and the PICO/PUTR habitat type, however, the climax situation is rarely achieved. Fire almost always interrupts succession before a near climax condition develops.

Following a stand-destroying fire on a Group Seven site, a short-lived herb/shrub stage dominates. This stage is short-lived in the sense that lodgepole pine seedlings quickly become established and overtop the undergrowth. A fire in the herb/shrub stage (No. 1) will, however, extend its period of dominance. Recurring fire at frequent intervals could conceivably maintain the site in herbs and shrubs. A fire during the seedling/sapling stage will also return the site to herbs and shrubs (No. 2). The likelihood of a fire at this stage is not great on most Group Seven sites.

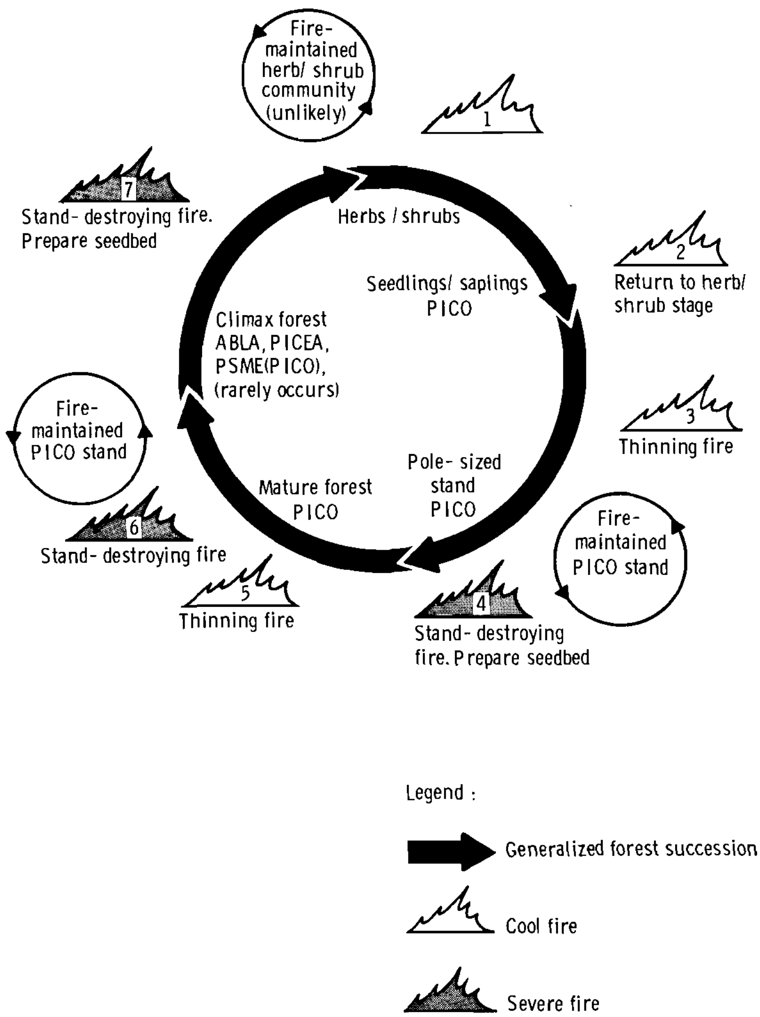


Figure 30.—Generalized forest succession in Fire Group Seven: cool habitat types usually dominated by lodgepole pine.

The effect of a fire during the pole stage will depend on fire severity. A cool fire (No. 3) will thin the stand while a severe fire (No. 4) will destroy the stand. Since pole-sized lodgepole pine usually contain serotinous cone crops, perodic fire at this stage can result in a fire-maintained lodgepole pine stand. The effect of fire in a mature lodgepole forest is essentially the same as in the pole forest. A cool fire thins the stand and a severe fire recycles the stand (No. 5 and 6). The probability of a severe stand-destroying fire greatly increases as a previously unburned mature stand starts to break up and an understory of climax species develops. It is usually at this stage rather than the climax stage that fire destroys the stand (No. 7).

Successional Pathways

Hypothetical successional pathways for Fire Group Seven forests are illustrated in figure 31 (subsequent states and numbers in this section refer to fig. 31).

Starting with a herb/shrub state (state A) two major paths exist depending on whether the site is classified as a lodgepole pine community type or habitat type, or whether the site is a potential Douglas-fir, spruce, or subalpine fir climax.

LODGEPOLE PINE CLIMAX TYPES

Lodgepole pine is essentially the only tree species present on PICO climax types. Consequently, succession is dominated by lodgepole pine regardless of fire occurrence. Stand characteristics may, however, reflect fire history. The herbaceous state (state A) is followed by a seedling/sapling state (state B1). Any fire in this state will return the site to a herbaceous condition (No. 1). In the absence of fire, a fully or overstocked lodgepole pine stand will develop (state C1). A moderate to severe fire can destroy such a stand (No. 2). Stand development, in the continued absence of fire, will progress to the mature forest condition (state D1). Depending on inital stand density and regeneration period, a lodgepole pine understory may or may not exist.

The next step in fire-free succession is the breaking up of the overstory due to insect attack, decadence, windthrow, and so forth (state E1). As openings are created, either understory trees assume overstory status or regeneration is initiated in the openings. A severe fire can occur during the mature forest state and result in total stand destruction (No. 3). Such a stand-destroying fire is more likely to occur after the stand begins to break up (No. 4) because of increased fuel loads and lower surface fuel moistures. If fire does not occur, a climax forest may

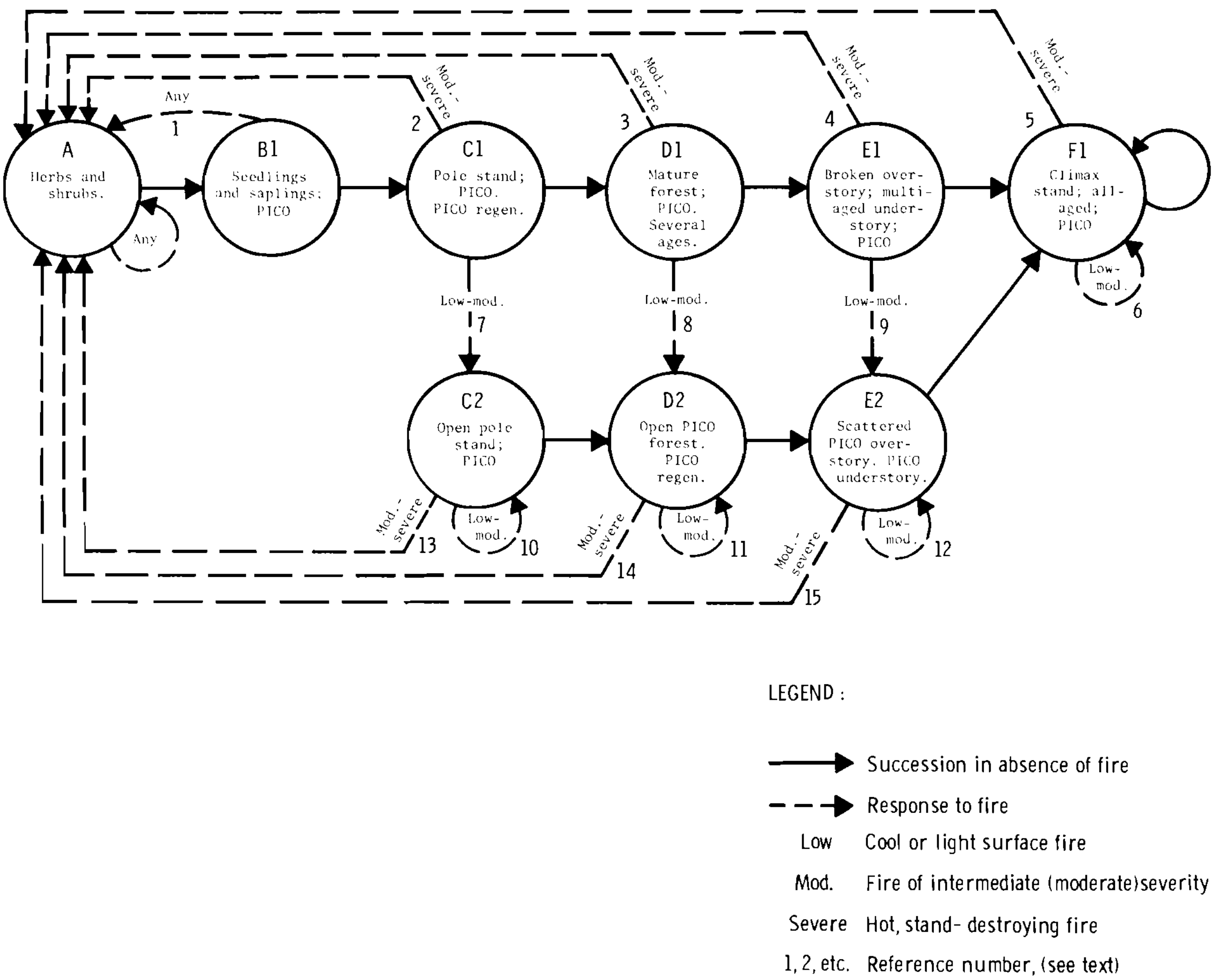


Figure 31.—Hypothetical fire-related successional pathways for Fire Group Seven habitat types.

develop on the site (state F1). A severe fire at this state would return the site to the herbaceous condition (No. 5). A cool to moderately severe fire would maintain the climax condition (No. 6).

A low to moderate intensity fire in a pole stand (state C1) would thin out the overstory and remove regeneration (No. 7). The resulting open pole stand (state C2) would develop into a open forest condition (state D2) in the absence of fire. This same condition would result from a cool or moderately severe fire in the mature forest state (No. 8). Eventually, if fire does not occur, a new lodgepole pine stand will develop beneath a scattered lodgepole overstory (state E2). This situation will also result from a cool to moderate fire in a stand undergoing breakup (No. 9). Subsequent low to moderate severity fires in any of the fire-created open stand conditions (states C2, D2, and E2) would primarily affect understory regeneration (No. 10, 11, and 12). Severe fires would likely result in stand replacement (No. 13, 14, and 15).

DOUGLAS-FIR, SPRUCE, AND SUBALPINE FIR CLIMAX TYPES

Forest succession in the presence and absence of fire on Group Seven Douglas-fir, spruce, and subalpine fir sites is only slightly different from that described for lodgepole sites. Lodgepole pine dominates most stages of succession regardless of indicated climax. As indicated in figure 31, stand development is essentially the same as for lodgepole climax sites. The major difference is in understory composition. The seedling/sapling state (state B2) is dominated by lodgepole pine, but some climax species seedlings will also be present. The pole state (state C3) is also dominated by lodgepole, but the understory is likely to be dominated by more shade-tolerant climax species. In the continued absence of fire, this trend will continue through the mature forest state (state D3) and the breakup state (state E3). Given a long enough time without fire, climax species will capture the overstory and maintain control of the site (state F2), even if low to moderate severity fires do occur (No. 16). Severe fires at any stage of development after seedling establishment, except the climax state, will return the site to the herbaceous state (No. 17, 18, 19, and 20).

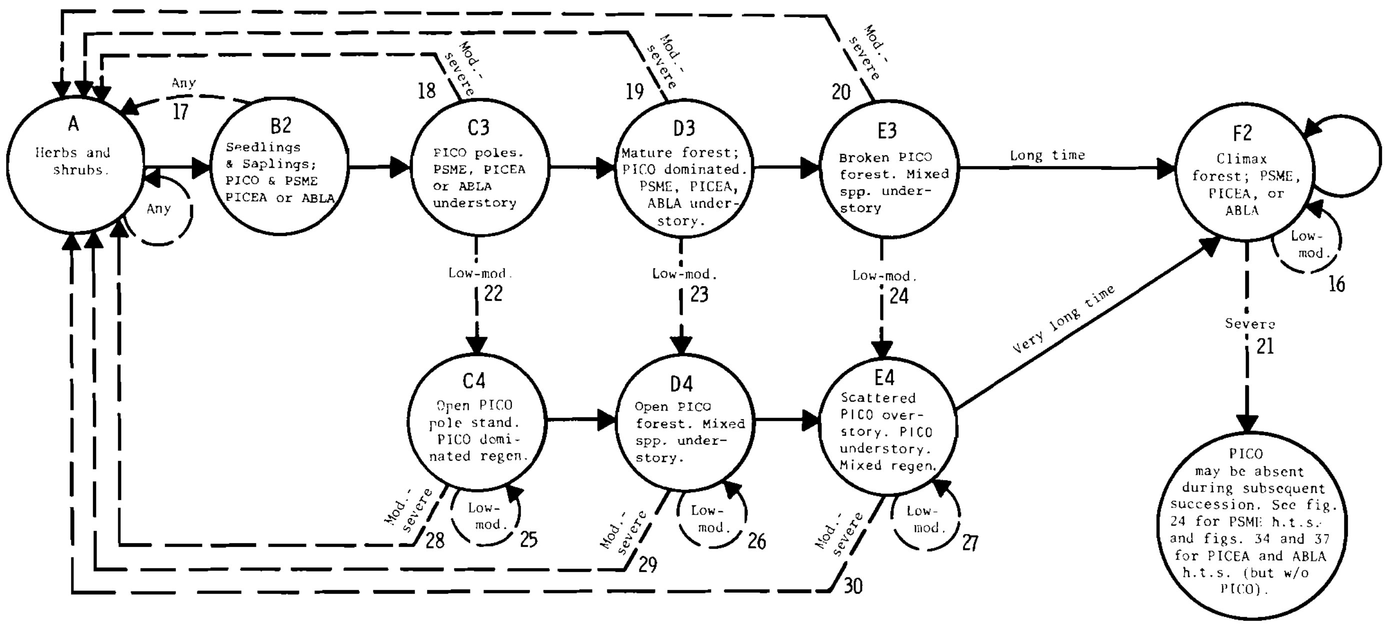


Figure 31.—(con.)

Lodgepole pine will be essentially absent during succession following a severe fire (No. 21) in the climax state (state F2). Lodgepole pine would be absent from a true climax stand; hence, no seed source would be available to place lodgepole pine in the postfire stand. Succession following a severe fire in state F2 would be similar to that described in figure 24 (Fire Group Six) for Douglas-fir habitat types or in figures 34 and 37 (Fire Group Eight and Nine) (see pages 59, 60, and 65) for subalpine fir and spruce habitat types, except that lodgepole pine would be absent.

Low to moderate severity fires in the pole, mature, or broken stand states (No. 22, 23, and 24) will result in open lodgepole stands with lodgepole dominated regeneration. Subsequent low to moderate fires (No. 25, 26, and 27) would insure lodgepole pine continued dominance. The absence of fire allows climax species to develop in the understory. This could lead, theoretically, to the eventual establishment of the climax forest (state F2) given a long enough fire-free period. Severe fires in the open stand conditions would return the site to herbs and shrubs (No. 28, 29, and 30).

Fire Management Considerations

Perhaps the primary fire management consideration in the group's habitat types is protection from unwanted fire during extended periods of drought and during severe fire weather conditions. Fires at such times often crown and become holocausts that result in complete stand mortality if the lodgepole stand is ready physiognomically to burn (Despain and Sellers 1977).

FIRE USE

Opportunities for fire use are limited in natural stands because of the low fire resistance of lodgepole pine, spruce, and subalpine fir. The other side of this problem is that during "safe" fire weather, it is often difficult to sustain a fire in Group Seven stands. Low to medium intensity surface fires, however, do occur in Group Seven stands. Thus, there may be opportunities to use prescribed fires to accomplish specific management objectives.

Prescribed fire has been suggested as a management tool for controlling dwarf mistletoe (*Arceuthobium* spp.). According to Alexander and Hawksworth (1975), prescribed burning, in relation to mistletoe control, can serve two purposes: (1) eliminate infected residual trees in logged-over areas, and (2) destroy heavily infected stands on unproductive sites so that they can be replaced by young healthy stands.

SLASH DISPOSAL AND SITE PREPARATION

The primary use of prescribed fire in this group has been and undoubtedly will continue to be for hazard reduction and site preparation in conjunction with tree harvesting. Broadcast burning and windrowing and burning have been the most often used methods of accomplishing these tasks. Successful broadcast slash burning in Group Seven stands will usually yield increased forage production for big game. Slash disposal of any kind will aid big game movement through these stands.

Managers should use the information contained in the two-volume proceedings of the "Management of Lodgepole Pine Ecosystems" symposium (Baumgartner 1975) as a guide for fire management actions in Group Seven habitat types. The following excerpt by Lotan (1975) from that proceedings summarizes current knowledge regarding slash disposal and seedbed preparation.

> Slash disposal methods are important in lodgepole pine management because harvesting overmature stands leaves large quantities of logging debris as a fire hazard, and for many areas, natural regeneration is obtained principally from serotinous cones in the slash. Methods

used to lower the fire hazard include broadcast burning, piling in "jack piles" or windrows and burning, breaking and flattening with rolling choppers, and lopping and scattering. More recently, there has been considerable interest in chipping and selling this material.

Broadcast burning results in varying densities of reproduction depending upon the distribution and intensity of the fire. Variations in fuel, humidity, slope, and other factors have made it difficult to obtain uniformly distributed reproduction of desired density. Piling and burning is a more direct method of slash disposal, but heat is concentrated and seed stored in the piled slash is likely to be destroyed. If slash is concentrated and not burned, seedlings may fail to come up through it, and the fire hazard will remain high for many years. Some windrowing was done in the pulpwood logging described by Curtis and Tackle (1954) on the Targhee National Forest. If natural regeneration is desired, special effort may be needed to scatter the slash to properly distribute the seed.

Lopping and scattering will provide more than adequate stocking, but may or may not reduce the fire hazard (Boe 1952). It is most advantageous when close utilization is practiced and where natural regeneration is marginal; i.e., where there is need to use as much of the stored seed as possible.

Tackle's (1954b) conclusions on slash disposal were: (1) burning is not essential to obtain adequate stocking, (2) time must be allowed between felling and piling to allow cones to open, (3) piling slash with toothed dozer blades will shake seed from the slash and prevent excessive soil disturbance, (4) burned areas should be kept to a minimum, and (5) cone opening is dependent upon factors such as cone height above ground and orientation toward solar heat.

Timing of slash disposal is important. To melt the resin bond holding the cone scales, slash must be exposed to radiant energy near the ground and must be dozer-piled before the seed germinates (Tackle 1954b, Lotan 1964a). On slash, closed cones that are well above ground behave like those on a tree—they remain closed, and stored seed stays viable for years. Closed cones on or near the ground vary in behavior: those that receive enough solar heat open and release seed (Lotan 1964a); others remain closed and their seed loses germinative capacity (Tackle 1954b, Ackerman 1966).

In the Northern Rocky Mountains, when seed is released in adequate amounts upon a favorable seedbed free of competing vegetation, seed germinates rapidly as soon as conditions become favorable. Seed dispersed during the fall and winter will often have optimum germinating conditions following snowmelt when both moisture and temperature are favorable. In our studies on the Targhee and Gallatin National Forests, 90 percent of germinating seedlings emerged the first 2 weeks in July, following snowmelt in late June (Lotan 1964b). From a management viewpoint, it is difficult to say what constitutes a favorable seedbed. In some localities, overstocking is a problem; in others, understocking is a problem.

Usually, treatments that remove competing vegetation and increase the odds of seed falling upon a favorable microsite will greatly increase numbers of seedlings that survive. We may or may not get enough trees on seedbeds that are undisturbed or burned, depending upon the amount of viable seed per acre and how much the seedbed is unfavorable. There are many types of burns and many different types of competing vegetation. In several studies where attempts have been made to remove cones or cone-bearing slash, stocking was frequently lower, but seldom significantly lower, than on areas where slash was handled normally. Apparently, seed was still dispersed during slash disposal. Frequently, burned areas were slower in returning to a stocked condition, but stocking eventually came close to management objectives (Tackle 1964b).

STOCKING CONTROL

Lotan's (1975) discussion of stocking control is also relevant to fire management in Group Seven lodgepole pine stands. Excerpts from this discussion follow:

> There are a number of possible opportunities to regulate stocking through manipulation of the seed supply or of the microenvironment. It is frequently possible to secure adequate stocking on areas where seed-seedling ratios and stored seed estimates indicate low levels of stocking. This might be accomplished by any one of the following: intensifying site preparation, treating slash to assure maximum seed release, treating an area to reduce seed loss to rodents, or by using a combination of these treatments. Conversely, stocking may be reduced by limiting site preparation, reducing disturbances of the soil surface during logging, or by treating slash to destroy a portion of the stored seed.
>
> Whether we want to reduce overstocking or increase understocking, there is much we can do to affect regeneration. Manipulating seedbed conditions usually brings dramatic results, particularly when some form of scarification is used.
>
> The seed available for natural regeneration varies considerably and is a major factor. It will account for much of the variability that we get, as shown in study of green vs. dry slash (Lotan 1964b):

	Gallatin N.F.	**Lewis and Clark N.F.**
	Seedlings per acre	
Green slash	7,067	22,175
Dry slash	1,967	10,475

> There were 3 to 5 times as many seedlings on the Lewis and Clark National Forest as on the Gallatin National Forest.

Next we can use seed-seedling ratios for different habitat types and seedbed conditions to account for our losses. For example, after 5 years, the best seedbed tested on the following sites varied considerably in seed-seedling ratios:

Site	Habitat type	Lowest seed-seedling ratio
Moose Creek Plateau	*Abies/Vaccinium*	30:1
Island Park Flat	*Pseudotsuga/ Calamagrostis*	50:1
West Yellowstone Flat	*Pinus/Purshia*	300:1

Knowledge of seed-seedling ratios for a particular site and seedbed condition can be used with information on seed supply to estimate feasibility of a particular regeneration method.

We need to distinguish between overstocking and understocking problems in lodgepole pine regeneration. Comparing again regeneration on the Gallatin National Forest and Lewis and Clark National Forest, we can readily see the implications in precommercially thinning. One stand is measured in thousands of stems and the other in tens of thousands. In areas like the Lewis and Clark and Bitterroot, overstocking is the problem. There is much we could do that would reduce stocking so fewer stems per acre need to be removed.

On the other hand, artificial regeneration has been required on the Gallatin National Forest and on many forests in Region 4, in some cases because of failure to recognize the dearth of seed stored in closed cones and the importance of cone serotiny, in others because of soil problems. (End of Lotan 1975 excerpts.)

The primary concern in the fire management of many lodgepole pine forests is the prevention of stand-destroying fires over large areas. Timber harvest for a variety of products and subsequent slash disposal are the primary means to this end. Harvest schedules should be developed and implemented to create age-class mosaics of lodgepole pine. This will minimize the areal extent of stand-destroying fires. Silvicultural practices designed to harvest trees susceptible to mountain pine beetle before the trees are attacked (Cole and Amman 1980) can greatly reduce the threat of severe fires in second-growth stands of lodgepole pine. The use of lodgepole pine for firewood, poles, posts, wood chips, and sawlogs provides ample opportunities for fuel management-related harvesting.

In some wilderness areas, periodic crown fires play a vital role in natural development of lodgepole pine ecosystems, and their use should be considered when consistent with the need to protect human life, property, and resource values outside wilderness.

FIRE GROUP EIGHT: DRY, LOWER SUBALPINE HABITAT TYPES

ADP code	Habitat type-phase (Pfister and others 1977, Roberts 1980)	Montana forest region (Arno 1979)
	Picea/Linnaea borealis h.t. (PICEA/LIBO), spruce/twinflower.	Central (Bearpaw Mountains only).
430	*Picea/Physocarpus malvaceus* h.t. (PICEA/PHMA), spruce/ninebark.	South-central.
480	*Picea/Smilacina stellata* h.t. (PICEA/SMST), spruce/starry Solomon's seal.	Central, southwestern, and south-central.
691	*Abies lasiocarpa/Xerophyllum tenax* h.t.-*Vaccinium globulare* phase (ALBLA/XETE-VAGL), subalpine fir/beargrass-blue huckleberry phase.	North-central and southwestern.
733	*Abies lasiocarpa/Vaccinium scoparium* h.t.-*Thalictrum occidentale* phase (ABLA/VASC-THOC), subalpine fir/grouse whortleberry-western meadow-rue phase.	Central, southwestern, and south-central.
750	*Abies lasiocarpa/Calamagrostis rubescens* h.t. (ABLA/CARU), subalpine fir/pinegrass.	North-central, central, southwestern, and south-central.
770	*Abies lasiocarpa/Clematis pseudoalpina* h.t. (ALBA/CLPS), subalpine fir/virgin's bower.	North-central, central, southwestern, and south-central.
780	*Abies lasiocarpa/Arnica cordifolia* h.t. (ABLA/ARCO), subalpine fir/heartleaf arnica.	North-central, central, and southwestern.
792	*Abies lasiocarpa/Carex geyeri* h.t.-*Pseudotsuga menziesii* phase (ABLA/CAGE-PSME), subalpine fir/elk sedge-Douglas-fir phase.	Central, southwestern, and south-central.

Fire Group Eight consists of dry, lower subalpine habitat types where spruce or subalpine fir are the indicated climax species but do not typically dominate seral stands. Douglas-fir alone, or more commonly a mixture of Douglas-fir, lodgepole pine, and often spruce, dominates most seral stands; subalpine fir, and on some sites spruce, are minor stand components. Exceptions to this general rule include ABLA/VASC-THOC sites where Douglas-fir is essentially absent and ABLA/CAGE-PSME sites where lodgepole pine and spruce are essentially absent. Limber pine is a long-lived seral dominant on ABLA/CLPS sites. Whitebark pine occurs as an accidental or minor seral species throughout the Fire Group and may be a major seral component in some ABLA/CLPS stands.

The dominance of Douglas-fir and lodgepole pine in this group may be in part due to periodic wildfire that sets back the invasion of spruce and subalpine fir.

Fire Group Eight stands usually produce luxuriant undergrowth. Common grasslike species are beargrass, pinegrass, and elk sedge. Shrub layers are dominated by one or more of the following species: Oregon grape, common juniper, mountain lover, ninebark, russet buffaloberry, twinflower, white spiraea, snowberry, blue huckleberry, and grouse whortleberry.

Among the more prevalent forbs are: heartleaf arnica, broadleaf arnica, sweet cicely, western meadowrue, pyrola, false Solomon's seal, and violet. Other forbs include: red baneberry, showy aster, timber milkvetch, wild strawberry, elkweed, sweetscented bedstraw, geranium, virgin's bower, northern bedstraw, fairy bells, valerian, starry Solomon's seal, mountain death camas, and cleft leaf groundsel.

Forest Fuels

Downed dead woody fuel loading in Fire Group Eight stands averages about 20 tons/ acre (about 4.5 kg/m^2). Maximum loads may greatly exceed this value.

Most of the dead woody fuel is greater than 3 inches (7.6 cm) in diameter. A large amount of material in the 10- and 20-inch (25- and 50-cm) diameter class is common in these stands (fig. 32 and table 10).

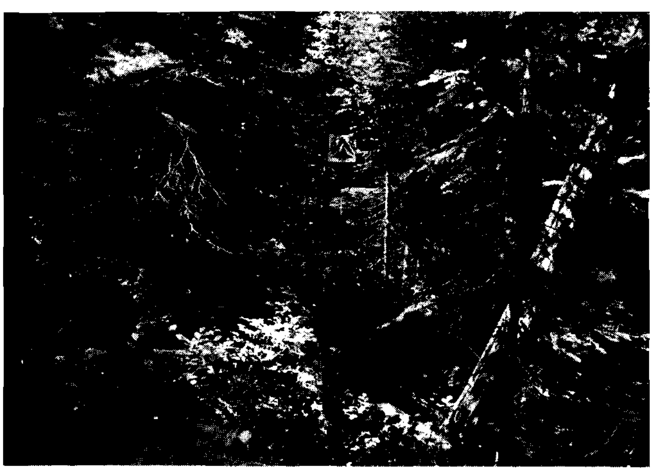
As is the case in many subalpine fir habitat types, live fuels can contribute significantly to overall fire hazard during dry conditions. Dense understories develop in many Group Eight stands and provide fuel ladders to the overstory tree crowns, although some stands are devoid of such understories (fig. 32).

Relatively deep duff layers may form in Group Eight stands (table 10). When dry, fire in the duff can cause considerable mortality by heating the shallow roots of subalpine fir and Engelmann spruce.

Role of Fire

Fire history data for Fire Group Eight habitat types east of the Continental Divide are lacking. Arno (1980) has, however, summarized available fire history data for lower subalpine forests from other parts of the Northern Rocky Mountains. For example, he reports that almost 60 percent of mature western Montana ABLA/XETE stands (greater than 100 years old) show obvious evidence of ground fire after stand establishment.

The occurrence of periodic low to moderate severity fires favors Douglas-fir and lodgepole pine. Such fires set back invasion by the more tolerant spruce and subalpine fir, which in the absence of fire form dense understories and eventually take over the site. Fires of moderate severity probably help Douglas-fir maintain a position of dominance or codominance with lodgepole in many Group Eight stands. The more fire-resistant Douglas-fir has a better chance of surviving such fires and is able to successfully regenerate in fire-created openings where



A

B

Figure 32.—Examples of Fire Group Eight stand and fuel conditions near Lincoln, Mont., Helena National Forest. Both stands are Engelmann spruce-subalpine fir stands on a subalpine fir/beargrass h.t.-blue huckleberry phase. Stand age, total fuel load by size class, and duff depths are given in table 10.

Table 10.—Fuel loading by size class and duff depth for Fire Group Eight stands shown in figure 15 (source: Fischer 1981b)

Stand number	Habitat type	Age	Duff depth	Size class (inches) 0-1/4	1/4-1	1-3	3-6	6-10	10-20	20+	Total
		Years	*Inches*	*Tons per acre*							
20A	ABLA/XETE-VAGL	165	3.4	0.5	1.4	3.8	16.7	22.0	6.6	0	51.0
23A	ABLA/XETE-VAGL	150	3.1	0.6	1.9	3.2	11.7	16.3	0	0	33.7

mineral soil has been exposed. Severe, stand-destroying fire will generally favor lodgepole pine on many of these sites. Some large, thick-barked Douglas-fir trees will often survive fires severe enough to kill all the lodgepole pine trees, thereby assuring the presence of Douglas-fir in the new stand.

Fire frequencies for this group probably fall between those reported for Fire Group Seven lodgepole pine stands (about 50 years) and those identified for the more moist lower subalpine types of Fire Group Nine (90 to 130 years).

Generalized Forest Succession

The theoretical climax forest on Fire Group Eight habitat types is either subalpine fir or spruce. Either climax situation requires a very long fire-free period to develop and is, consequently, rarely found. More common is a near-climax situation characterized by a dense forest of subalpine fir and spruce, with abundant Douglas-fir, lodgepole pine, and often spruce in the overstory.

A stand-destroying fire in the climax (or near-climax) stage results in a shrub/herb stage (as shown in fig. 33, No. 1) followed by a seedling and sapling stage (subsequent numbers in this section refer to fig. 33). On most Group Eight sites Douglas-fir, lodgepole pine, and, on some sites, spruce seedlings will dominate, but subalpine fir seedlings are likely on ABLA/VASC-THOC sites and lodgepole and spruce seedlings are usually absent on ABLA/CAGE-PSME sites. Limber pine may be abundant on ABLA/CLPS sites along with whitebark pine. Whitebark pine may also occur on some ABLA/XETE-VAGL and ABLA/ARCO sites.

Any fire in the seedling/sapling stage will revert the site to shrubs and herbs (No. 2). Pole-sized stands are usually mixed stands of Douglas-fir and lodgepole except as previously indicated. A low to moderate severity fire in such a stand will favor the more fire-resistant Douglas-fir over the more fire-susceptible lodgepole pine (No. 3). A severe fire, however, will destroy the stand, thereby favoring the early serotinous cone-producing lodgepole pine over Douglas-fir (No. 4). Periodic fire could result in a fire-maintained lodgepole pine stand on some sites.

In the continued absence of fire, a mature stand will develop. Lodgepole pine and Douglas-fir will dominate the overstory, but a dense understory of spruce and subalpine fir is likely on many sites. A cool fire will remove much of this fire-susceptible understory and some of the lodgepole overstory thereby favoring the Douglas-fir (No. 5). A severe fire can destroy the stand and revert the site to shrubs and herbs (No. 6). Again, the serotinous-coned lodgepole will have an advantage in regenerating itself in the new stand. Periodic fire could maintain a lodgepole stand on some sites. If fire is absent for very long, a near-climax or climax forest will develop.

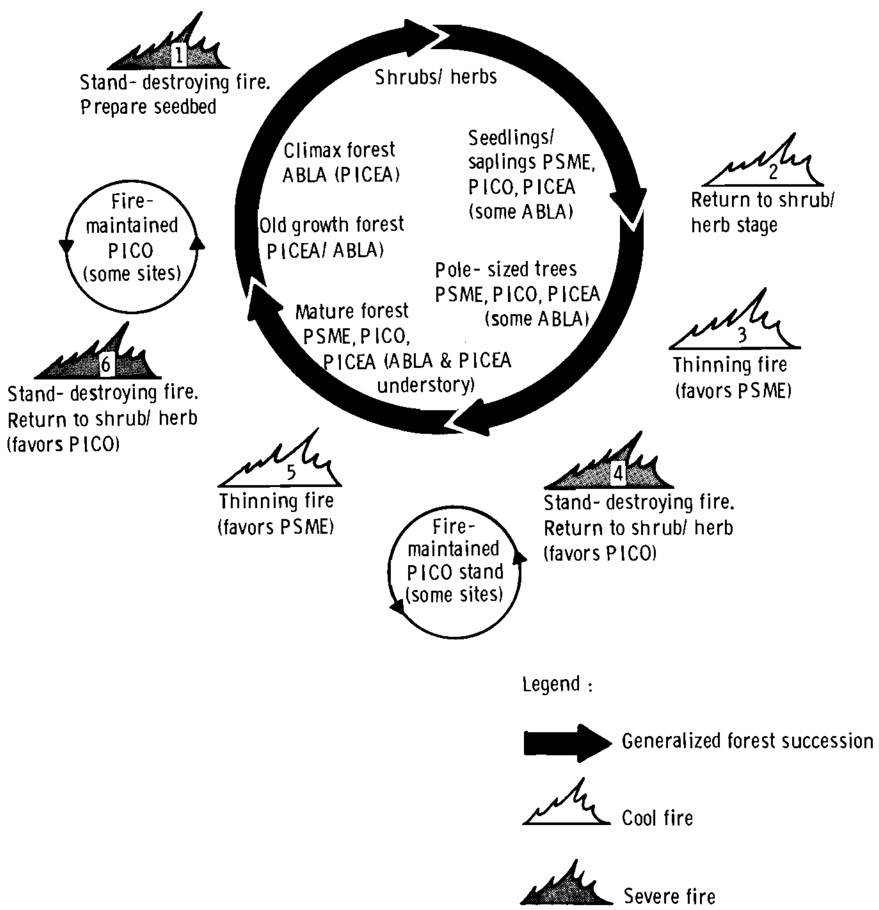


Figure 33.—Generalized forest succession in Fire Group Eight: dry, lower subalpine habitat types.

Successional Pathways

The Group Eight hypothetical successional pathway diagram is shown in figure 34 (subsequent states and numbers in this section refer to fig. 34). The diagram is complicated by the general absence of Douglas-fir on ABLA/VASC-THOC habitats and of lodgepole pine and spruce on ABLA/CAGE-PSME habitats. Three major successional pathways are, consequently, identified for this fire group.

MIXED SPECIES FOREST SUCCESSION

The mixed species pathway applies to all Group Eight habitat types except ABLA/VASC-THOC and ABLA/CAGE-PSME. Forest succession in the absence of fire proceeds from a transitional shrub/herb state (state A) to a seedling and sapling state in which Douglas-fir, lodgepole pine, spruce, and often subalpine fir are present (state B1). Any fire in state B1 will return the site to shrubs and herbs (No. 1). In the continued absence of fire, a mixed-species pole stand will develop (state C1) and eventually a mature mixed forest (state Dl). Douglas-fir and lodgepole often dominate the pole and mature states, but spruce is often a vigorous competitor on some sites. In the unlikely event that fire-free succession continues, a near-climax state would occur (state F1) where spruce and subalpine fir dominate the overstory with scattered long-lived Douglas-fir trees. The understory of such a stand would be dominated by spruce and fir. Eventually, in the continued absence of fire, the theoretical climax state (state G1) dominated by either spruce or subalpine fir would occur.

Severe fires in the pole, mature, near-climax, and climax states would probably destroy the stand and temporarily return the site to the shrub/herb state (No. 2 and 3). Subsequent succession following moderate to severe fire (No. 4 and 5) in the near-climax (state F1) and climax (state G1) states would be without lodgepole pine (states B2, C3, and D4). The effect of low and moderate severity fires varies by state. A low to moderately severe fire in the pole state (No. 6) would favor Douglas-fir over pine, spruce, and subalpine fir. An open Douglas-fir pole stand would likely result (state C2). Assuming cone-bearing lodgepole in the prefire stand, lodgepole pine regeneration would probably dominate the understory. In the absence of fire, such a stand (state C2) would progress to a mature Douglas-fir forest with a lodgepole understory (state D3). Over time lodgepole would dominate the overstory with a few scattered veteran Douglas-fir, while spruce and subalpine fir would form an understory (state E2). Severe fires would destroy these stands and return site to shrubs and herbs (No. 7 and 8). A cool to moderately severe fire would do little more than set back climax species regeneration and perhaps some understory thinning in the mature Douglas-fir stand (No. 9). A cool fire in the mature lodgepole stand would also have minor impact (No. 10). A moderately severe fire, however, could remove all trees except the more fire-resistant veteran Douglas-fir in the overstory (No. 11).

1. HABITATS SUPPORTING MIXED SPECIES (PSME, PICO, PICEA, & ABLA)

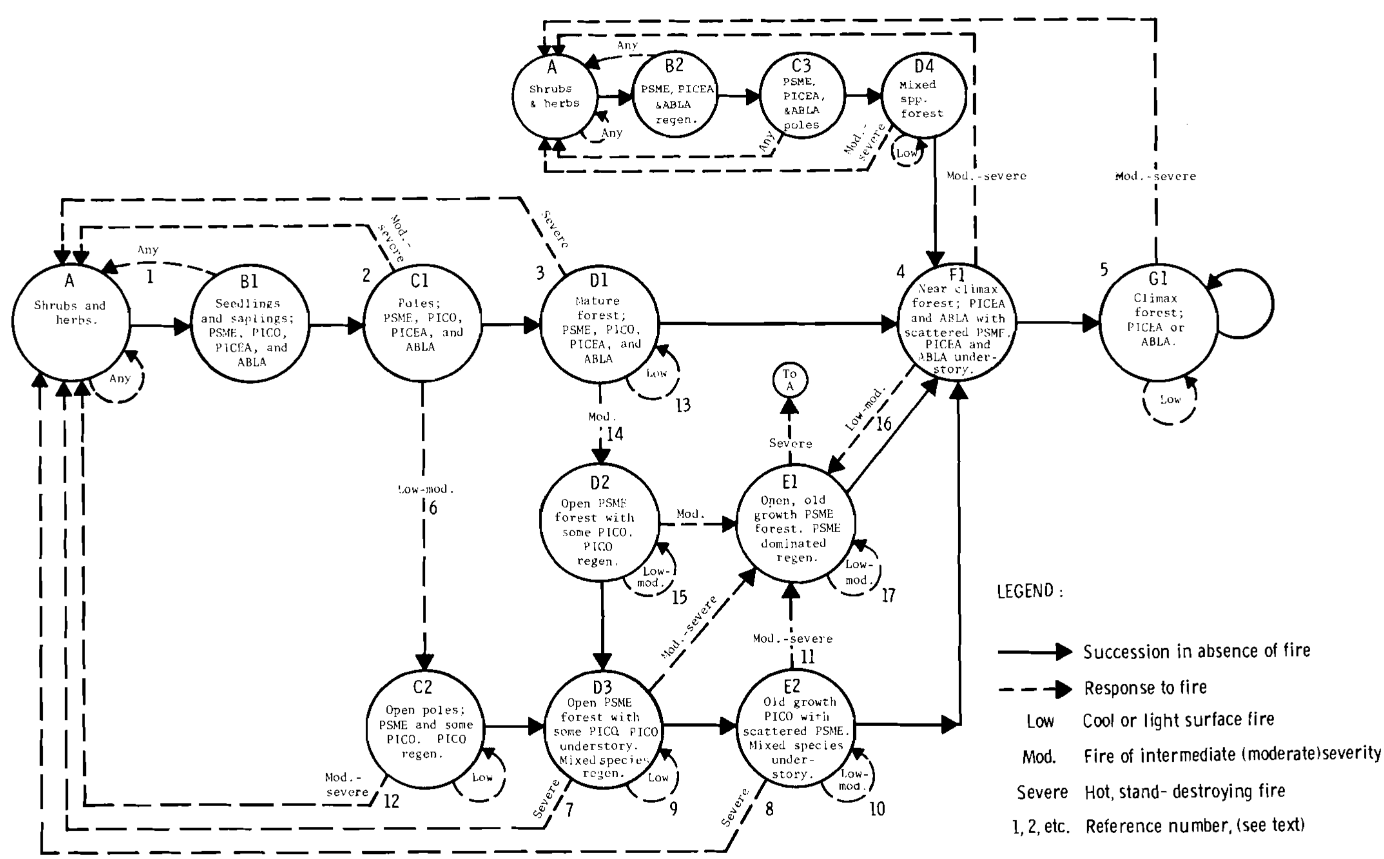


Figure 34.—Hypothetical fire-related successional pathways for Fire Group Eight habitat types.

II. ABLA/ CAGE-PSME HABITATS (lodgepole pine & spruce absent)

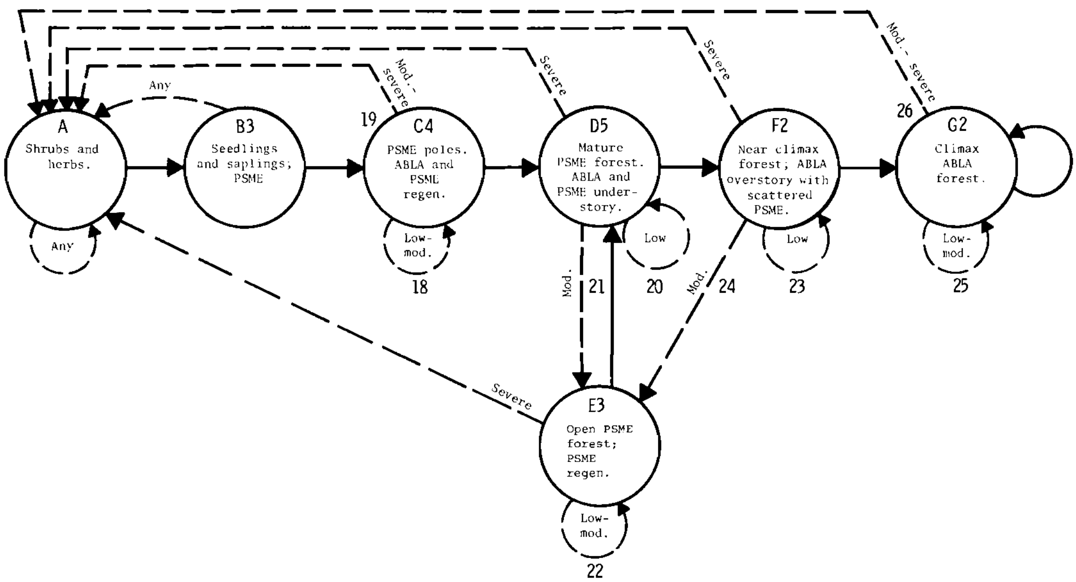


Figure 34.—(con.)

III. ABLA/ VASC-THOC HABITATS (Douglas-fir absent)

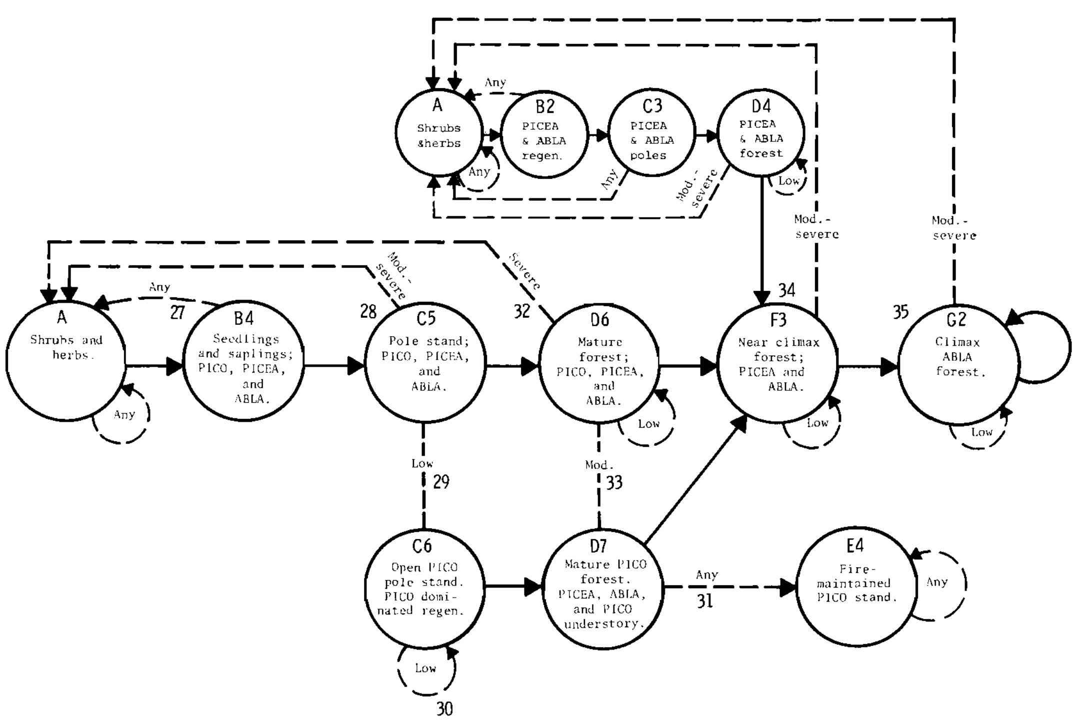


Figure 34.—(con.)

In the unlikely event that a fire in the pole state (state C2) is followed by a second moderate to severe fire (No. 12), the stand will revert to shrubs and herbs (state A). It is conceivable that a moderately severe fire could remove lodgepole pine from subsequent succession. For this to occur, lodgepole pine would have to be absent from the prefire stand.

A light surface fire in the mature forest state (state D1) will have little effect on overstory composition (No. 13). Some fir and spruce will be eliminated by a cool fire, but losses should not be widespread. A moderate fire (No. 14), however, could destroy much of the lodgepole, spruce, and subalpine fir leaving an open Douglas-fir overstory (state D2). Periodic cool to moderately severe fire would maintain the open Douglas-fir overstory (No. 15). A similar situation can occur with cool to moderately severe fire in the near-climax forest (No. 16), except that lodgepole regeneration may be absent in the postfire stand (state E1). Cool to moderate fire again would maintain an open Douglas-fir stand (No. 17).

SUCCESSION WITHOUT LODGEPOLE PINE AND SPRUCE

Fire Group Eight ABLA/CAGE-PSME habitats usually support stands dominated by Douglas-fir. Lodgepole pine and spruce are largely absent (state B3). Douglas-fir pole stands develop in the absence of fire (state C4). Douglas-fir and subalpine fir regeneration develops under such pole stands.

A less than severe fire can periodically remove this regeneration (No. 18). Severe fire will return the site to shrubs and herbs (No. 19). In the absence of fire a mature Douglas-fir forest develops (state D5) with a Douglas-fir and subalpine fir understory. A light surface fire will destroy most of the alpine fir understory and some Douglas-fir, (No. 20). A moderate fire could completely remove the understory (No. 21) leaving an open Douglas-fir forest (state E3). Subsequent low to moderate fire could maintain the open stand condition (No. 22).

Without fire, the mature Douglas-fir forest (state D5) will approach the near-climax state characterized by a subalpine fir overstory with scattered old Douglas-fir trees. Subalpine fir and some Douglas-fir will form the understory. Cool fire will tend to benefit the more fire resistant Douglas-fir trees in the understory (No. 23), and fires of moderate severity (No. 24) could remove all trees except the veteran Douglas-fir in the overstory (state E3).

Given an unlikely long fire-free interval, the climax subalpine fir forest will develop. Low to moderate fire will effect the often dense subalpine fir understory (No. 25), but a moderate to severe fire will destroy the stand (No. 26).

SUCCESSION WITHOUT DOUGLAS-FIR

Fire Group Eight ABLA/VASC-THOC habitats occur at the upper cold limits of Douglas-fir. Where Douglas-fir does occur on these habitats, it is often frost-stunted. The seedling/sapling state on such habitats will often be populated about equally with lodgepole pine, spruce, and subalpine fir (state B4). Fires occurring in this state will return shrubs and herbs to dominance (No. 27). In the absence of fire, a mixed species pole stand develops (state C5) that is susceptible to destruction by a moderate to severe fire (No. 28). Some lodgepole pine could survive a cool fire (No. 29) resulting in an open pole stand with predominantly lodgepole pine regeneration (state C6). Subsequent cool fire would keep the understory open (No. 30).

In the absence of fire, an open mature lodgepole forest would develop with a spruce and fir understory (state D7). Periodic fire in this state (No. 31) could maintain lodgepole on the site (state E4). In the absence of fire, the more tolerant spruce and fir will eventually attain dominance (state F3).

Without fire the original mixed species pole stand (state C5) will develop into a mature mixed species forest (state D6). A severe to moderately severe fire at this state could destroy the stand (No. 32). A moderate fire (No. 33) could, however, spare some lodgepole. The continued absence of fire will allow a near-climax spruce and subalpine fir forest to develop (state F3) and, theoretically, a climax subalpine fir forest (state G2). Both of these forests would be highly susceptible to severe to moderately severe fire (No. 34 and 35). Succession following such fires would be without lodgepole pine since lodgepole pine is not a member of the near-climax and climax forest.

Fire Management Considerations

Fire protection is usually an important fire management consideration during severe burning conditions especially where timber production is a management objective. At other times, fires may be of low to moderate severity and result in only moderate damage or no damage to overstory trees, despite the relatively low resistance of many of the species present.

Fire can be used to dispose of logging slash on harvest areas, but broadcast burning for site preparation is often hampered by high duff moisture and scarcity of acceptable burning days during traditional spring and fall prescribed burning periods.

Where timber production is not a management objective, opportunities may exist for implementing fire management prescriptions that allow the use of unscheduled fires. Properly prescribed and managed, such fires can create vegetative mosaics that in turn provide a diversity of wildlife habitats, diverse scenery, and enhanced recreational opportunities. Vegetative mosaics can also reduce the probability of widespread wildfire damage to watershed values.

FIRE GROUP NINE: MOIST, LOWER SUBALPINE HABITAT TYPES

ADP code	Habitat type-phase (Pfister and others 1977, Roberts 1980)	Montana forest region (Arno 1979)
410	*Picea/Equisetum arvense* h.t. (PICEA/EQAR), spruce/common horsetail.	North-central, central, southwestern, and south-central.
440	*Picea/Galium triflorum* h.t. (PICEA/GATR), spruce/sweet-scented bedstraw.	Central, southwestern, and south-central.
621	*Abies lasiocarpa/Clintonia* h.t.-*Clintonia uniflora* phase (ABLA/CLUN-CLUN), subalpine fir/queencup beadlily-queencup beadlily phase.	North-central.
622	*Abies lasiocarpa/Clintonia uniflora* h.t.-*Aralia nudicaulis* phase (ABLA/CLUN-ARNU), subalpine fir/queencup beadlily-wild sarsaparilla phase.	North-central.
624	*Abies lasiocarpa/Clintonia uniflora* h.t.-*Xerophyllum tenax* phase (ABLA/CLUN-XETE), subalpine fir/queencup beadlily-beargrass phase.	North-central.
625	*Abies lasiocarpa/Clintonia* h.t.-*Menziesia ferruginea* phase (ABLA/CLUN-MEFE), subalpine fir/queencup beadlily-menziesia phase.	North-central.
630	*Abies lasiocarpa/Galium triflorum* h.t. (ABLA/GATR), subalpine fir/sweetscented bed-bedstraw.	North-central, central, and south-central.
651	*Abies lasiocarpa/Calamagrostis canadensis* h.t.-*Calamagrostis canadensis* phase (ABLA/CACA-CACA), subalpine fir/bluejoint-bluejoint phase.	Central, southwestern, and south-central.
653	*Abies lasiocarpa/Calamagrostis canadensis* h.t.-*Galium triflorum* phase (ABLA/CACA-GATR), subalpine fir/bluejoint-sweetscented bedstraw phase.	Central and southwestern.
	Abies lasiocarpa/Linnaea borealis h.t. (ABLA/LIBO), subalpine fir/twinflower.	Central (Bearpaw Mountains only).
661	*Abies lasiocarpa/Linnaea* h.t.-*Linnaea borealis* phase (ABLA/LIBO-LIBO), subalpine fir/twinflower-twinflower phase.	North-central, central, southwestern, and south-central.
670	*Abies lasiocarpa/Menziesia ferruginea* h.t. (ABLA/MEFE), subalpine fir/menziesia.	North-central, southwestern, south-central.
740	*Abies lasiocarpa/Alnus sinuata* h.t. (ABLA/ALSI), subalpine fir/Sitka alder.	North-central, southwestern, and south-central.

Fire Group Nine is a collection of moist and wet lower subalpine habitat types in the spruce and subalpine fir climax series. Group Nine sites typically border streams and adjoin wet meadows. Other typical locations are flat sites with poor drainage, moist bottomlands, benches, northern exposures, and seepage areas on southern exposures. Soils are moist or wet (supersaturated with water) much of the year. Elevations of Group Nine sites range from about 5,800 ft (1 770 m) to 8,200 ft (2 500 m).

Engelmann spruce is usually a major component of seral stands along with lodgepole pine and Douglas-fir. Older stands are usually dominated by subalpine fir and spruce although Douglas-fir and lodgepole may be well represented in the overstory. Notable exceptions to this general pattern of species composition include the ABLA/CACA habitats, which are too wet for Douglas-fir, and the PICEA/EQAR habitats, where spruce is usually the only successful conifer. However, two broadleaf species, paper birch and black cottonwood, may be abundant in seral stands on PICEA/EQAR habitats. Whitebark pine occurs either accidentally or on some habitats as a minor seral component.

Abundant undergrowth occurs on the moist Group Nine habitats. The more common grass and forb species include: red baneberry, wild sarsaparilla, broadleaf arnica, bluejoint, pinegrass, queencup beadlily, common horsetail, sweetscented bedstraw, Richardson's geranium, sidebells pyrola, arrowleaf groundsel, twisted stalk, western round-leaved violet, beargrass, and many other wet-site forbs.

Among the shrubs that occur on more than one habitat type or phase are: Sitka alder, redosier dogwood, twinflower, Utah honeysuckle, smooth menziesia, thimbleberry, blue huckleberry, and grouse whortleberry. Less widespread but abundant on particular habitats are kinnikinnick, bunchberry dogwood, alpine wintergreen, swamp laurel, prickly currant, russet buffaloberry, snowberry, and dwarf huckleberry.

Forest Fuels

Fire Group Nine fuels are similar to those often encountered in Group Eight. Downed dead woody material on the forest floor averages about 20 tons/acre (about 4.5 kg/m^2) but may be much higher.

A large percentage of the downed woody fuel load is material greater than 3 inches (7.6 cm) in diameter (tables 4 and 11, fig. 35). The combination of deep duff and large amounts of dead, rotten fuel can result in a severe surface fire during unusually dry moisture conditions. Where dense understories exist, such fires can easily spread to the tree crowns and destroy the stand. Even if a severe surface fire does not crown, there is a good chance the overstory trees will be killed by cambium heating.

A

B

Figure 35.—Examples of Fire Group Nine stand and fuel conditions in eastern Montana National Forests. Duff and fuel loading and other stand information are in table 11. (Source: Fischer 1981b.)

C

Table 11.—Fuel loading by size class and duff depth for Fire Group Nine stands shown in figure 35 (source: Fischer 1981b)

Stand number	Habitat type phase	Age	Duff depth	Size class (inches) 0-1/4	1/4-1	1-3	3-6	6-10	10-20	Total
		Years	*Inches*	*Tons per acre*						
21A	ABLA/MEFE	173[1]	2.5	0.2	0.9	1.9	9.7	7.5	0	20.2
22A	ABLA/MEFE	184[2]	1.9	0.5	1.8	2.0	5.9	9.4	2.9	22.5
44A	PICEA/GATR	200[3]	4.9	0.4	1.8	4.1	3.0	5.5	28.7	43.5

[1]PICEA. Also ABLA 125 yrs and PIAL 160 yrs.
[2]ABLA. Also PIAL 145 yrs and PICO and PICEA 115 yrs.
[3]PICEA and PSME. Understory PICEA are 115 yrs.

Under normal moisture conditions for these sites, a lush undergrowth of shrubs and herbs usually serves as an effective barrier to rapid fire spread (fig. 35).

Role of Fire

Fire history information for moist, lower subalpine eastside forests is lacking. Mean fire-free intervals are probably less than those of the drier upland sites in Fire Group Eight. The mean fire-free intervals for Fire Group Nine sites (ABLA/CLUN h.t.) at Coram Experimental Forest in northwestern Montana were about 140 years (Sneck [Davis] 1977). Fires at Coram were reported to be small, moderately intense surface fires that occasionally crowned, especially near the ridgetops (Arno 1980). In Kananaskis Provincial Park in Alberta, Canada, stand-replacing fires were found to have occurred at average intervals of 90 years in relatively moist, lower subalpine types composed of subalpine fir, spruce, and lodgepole pine (Hawkes 1979). Relatively long fire-free intervals have been reported for spruce-fir forests on the Medicine Bow National Forest in southwestern Wyoming. Romme and Knight (1981) report average fire-free intervals of 350 to 400 years in moist drainage bottoms, 300 years for the drier lodgepole pine-covered upland sites.

The role of fire on Group Nine habitats east of the Divide in Montana is indicated by stand condition and species composition. The general absence of the spruce and subalpine fir climax condition indicates disturbance by past fires. The codominance of lodgepole pine, Douglas-fir, and spruce on many sites suggests these stands developed on a fire-created mineral seedbed. The abundance of spruce, lodgepole, and Douglas-fir in the overstory of many mature stands suggests the absence of frequent moderate to severe fires after the stand became established. The frequency of light surface fires in Group Nine stands is difficult to surmise. The moist nature of these sites would limit the opportunity for such fires to a brief period during the summer. It seems reasonable to assume that lightning did in fact start such fires and that a certain amount of fuel reduction was accomplished. Left undisturbed, these fires probably flared up occasionally and created openings that favored establishment of seral species.

Generalized Forest Succession

A general pattern of succession for Fire Group Nine forests is shown in figure 36 (subsequent numbers in this section refer to fig. 36). Secondary succession is initiated by a severe stand-destroying fire in a mature, near-climax, or climax stand (No. 4, 5, and 6). Grass, forbs, and shrubs dominate the burned area until seedlings and saplings become firmly established on the mineral soil seedbed. Lodgepole pine, Douglas-fir, spruce, and to a lesser extent, subalpine fir may be present in the initiating stand. Exceptions to this general pattern include the absence of subalpine fir on PICEA/GATR sites, the absence of all conifers except spruce on PICEA/EQAR sites, and the absence of Douglas-fir on ABLA/CACA sites.

A fire during the seedling/sapling stage is unlikely, but if one occurred the site would revert to the shrub/herb state (No. 1). A fire in the pole stage would likely be of low intensity because of the moisture of the site, lack of hazardous surface fuels, and lushness of the undergrowth. Such a fire would be a thinning fire, favoring the more resistant Douglas-fir (No. 2). A cool fire in a mature stand would also thin out some of the more susceptible stems and reduce accumulated surface fuels (No. 3). It is at this stage that stand replacement fires become likely (No. 4). Such fires usually occur before the near-climax situation is achieved. Should a near-climax condition develop, stand-destroying fire is almost certain before a climax forest develops (No. 5). The theoretical climax situation rarely occurs.

Successional Pathways

The pattern of tree succession in this group as displayed in figure 37 is relatively simple (subsequent states in this section refer to fig. 37). This simplicity is more a reflection of lack of knowledge than lack of vegetative complexity of this group's communities. Perhaps the most significant information gap has

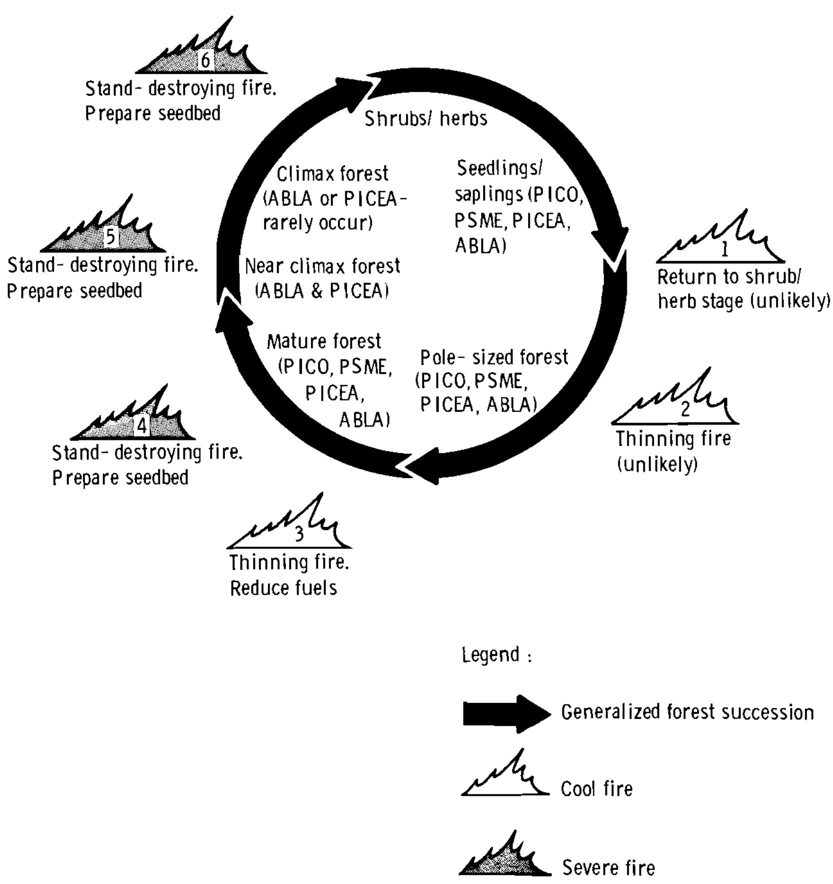


Figure 36.—Generalized forest succession in Fire Group Nine: moist, lower subalpine habitat types.

to do with the frequency of occurrence and related effects of cool to moderately severe fires on these moist sites. Figure 37 indicates a minimum impact for cool fire and does not consider a moderately severe fire. Intuitively, one might expect that fires of moderate severity do occur and thin out groups of trees rather than individual trees throughout the stand. If this in fact is the case, the effect of a moderately severe fire is the same as a severe fire, but on a small area within the stand.

The relative simplicity of figure 37 also reflects the assumption that Group Nine sites are as a general rule either too moist to burn or, under conditions of extended summer drought, susceptible to wind-driven crown fire. In simple terms, either the whole thing burns, or it hardly burns at all.

Six states are recognized: shrub/herb, seedling/sapling, pole stand, mature forest, near-climax forest, and the climax forest. Following a stand-destroying fire, shrubs and herbs dominate the site (state A), but seedlings are also becoming established on the mineral soil seedbed. After a relatively brief time, seedlings and then saplings dominate the site (state B). As a general rule, lodgepole pine, Douglas-fir, and spruce will be most abundant, but subalpine fir will also be present and, on some sites, whitebark pine. Lodgepole pine, Douglas-fir, and spruce will jointly dominate most pole stands (state C) and the overstory of the mature forest (state D). It is unlikely that fire will significantly affect succession up to this stage. The possible exception might be if a severe fire sweeps into a young forest from an adjoining area.

The mature forest may have a lush undergrowth of shrubs and herbs along with a developing understory of spruce and subalpine fir. As the stand matures, trees are killed through suppression mortality, mechanical injury (wind and snow), insects and disease, and, perhaps, cool surface fires. Downfall of dead trees results in hazardous fuel accumulation on the forest floor. The development of the understory creates fuel ladders to the overstory crowns. Stand replacement fires become highly probable. The near-climax condition (state E) is probably the most advanced stage of succession attained on these sites. Many Group Nine forests burn catastrophically before this condition is reached. The near-climax condition is characterized by scattered veteran spruce and Douglas-fir that rise above the main spruce-fir overstory. The understory is often dense spruce or fir. The theoretical climax (state F) is either a spruce or a subalpine fir forest, but this is rarely achieved. Light surface fires in states E and F will kill many understory trees, but regeneration will usually be spruce and fir.

Fire Management Considerations

Fire protection is usually necessary in undisturbed stands during severe burning conditions. This is especially true for areas where timber production is a management objective. At other times, fires may be of low to moderate severity and result in only moderate damage or no damage to overstory trees, despite the relatively low fire resistance of many of the species present. If slash is present, unacceptable tree mortality can result under quite easy burning conditions.

Broadcast burning is an effective method for reducing slash hazard and for preparing seedbeds in clearcuts, but not in partial cuts. Timing of a burn is important. Group Nine habitats are so cool and moist that times when effective broadcast burns can be achieved are limited. The moisture content of the duff must be low enough to allow the fire to bare mineral soil over much of the area. Often, such favorable moisture conditions only occur during the late summer when the threat of wildfire usually discourages managers from conducting prescribed fires.

Burning slash in large windrows or piles can create enough heat to alter the physical structure of the soil. Lower densities and slower growth of conifers on some burned pile and windrow sites can persist for 15 years or more (Vogl and Ryder 1969). Consequently, windrows should be narrow and piles should be small when these methods are used.

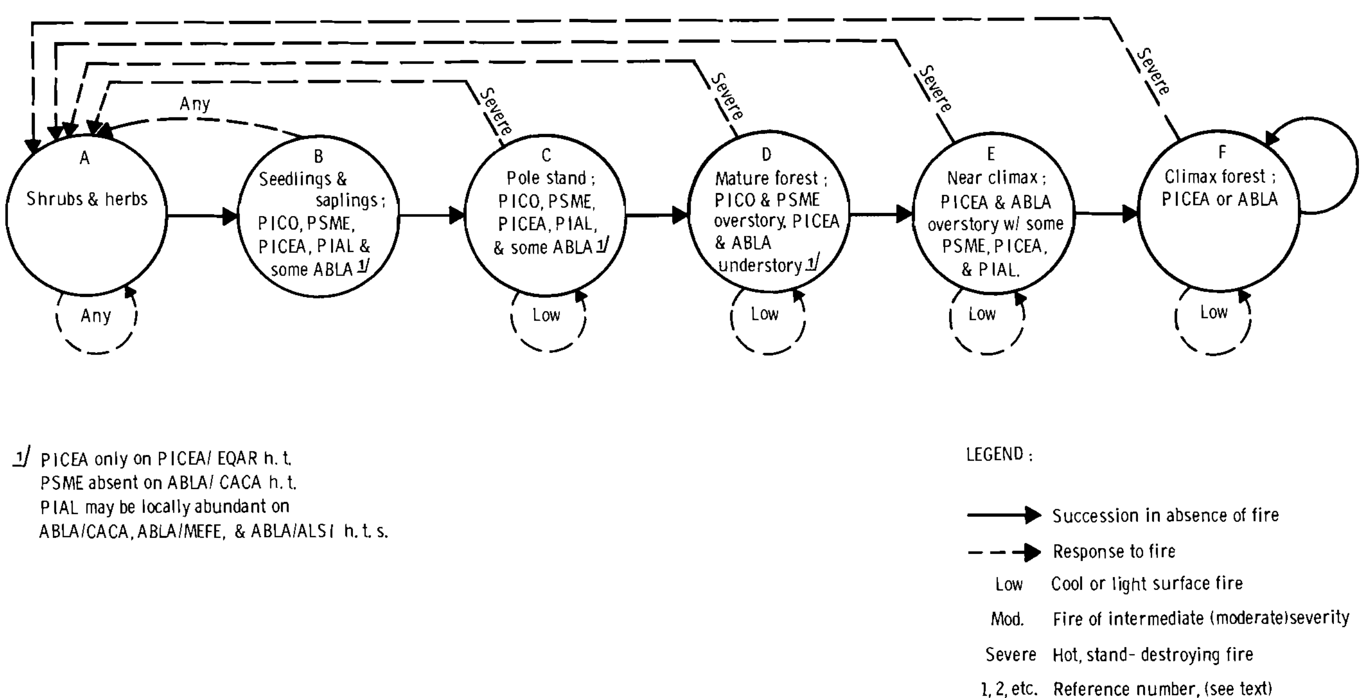


Figure 37.—Hypothetical fire-related successional pathways for Fire Group Nine habitat types.

Additional guidelines for fire use for slash disposal and site preparation and silviculture in Group Nine stands are provided by Roe and others (1970). This excellent reference should be consulted before planning fire use in these habitats.

Slash disposal plans should consider the need for some residues to remain on the site for nutrient cycling and as a source of shade for successful seedling development.

The often complex structure of subalpine forests reflects their fire history. These forests are what they are partly because of past patchy or uneven burns and partly because of their climate and soils. Their natural development has not, as a general rule, been affected by past fire suppression policies (Habeck and Mutch 1973). Management objectives for these habitat types are often oriented toward nonconsumptive use. These types usually have high watershed and big game sanctuary values. Many of the areas that contain these habitat types are roadless and may be destined to remain so. Many are in designated wilderness areas. Consequently, the appropriate fire management policy may be one that allows certain fires at certain times to burn as prescribed fires according to a predetermined fire management prescription. Often this policy must be constrained because of air quality considerations and because of the occasional threat of long distance spotting or wind-driven crown fires.

FIRE GROUP TEN: COLD, MOIST UPPER SUBALPINE AND TIMBERLINE HABITAT TYPES

ADP code	Habitat type-phase	Montana forest region
	(Pfister and others 1977, Roberts 1980)	(Arno 1979)
	Upper Subalpine	
462	*Picea/Senecio streptanthifolius* h.t.-*Picea* phase (PICEA/SEST-PICEA), spruce/cleftleaf groundsel-spruce phase.	Central.
	Picea/Juniperus communis h.t. (PICEA/JUCO), spruce/common juniper.	Central (Bearpaw Mountains only).
810	*Abies lasiocarpa/Ribes montigenum* h.t. (ABLA/RIMO), subalpine fir/mountain gooseberry.	Southwestern and south-central.
820	*Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium* h.t. (ABLA-PIAL/VASC), subalpine fir-whitebark pine/grouse whortleberry.	North-central, central, south-central, southwestern, and south-central.
831	*Abies lasiocarpa/Luzula hitchcockii* h.t.-*Vaccinium scoparium* phase (ABLA/LUHI-VASC), subalpine fir/smooth woodrush-grouse whortleberry phase.	North-central and southwestern.
832	*Abies lasiocarpa/Luzula hitchcockii* h.t.-*Menziesia ferruginea* phase (ABLA/LUHI-MEFE), subalpine fir/smooth woodrush-menziesia phase.	North-central.
	Abies lasiocarpa/Juniperus communis h.t. (ABLA/JUCO), subalpine fir/common juniper.	Central (Bearpaw Mountains only).
	Timberline	
850	*Pinus albicaulis-Abies lasiocarpa* h.t.'s (PIAL-ABLA h.t.'s), whitebark pine-subalpine fir.	North-central, central, southwestern, and south-central.
860	*Larix lyallii-Abies lasiocarpa* h.t.'s (LALY-ABLA h.t.'s) alpine larch-subalpine fir.	Southwestern.
870	*Pinus albicaulis* h.t.'s (PIAL h.t.'s) whitebark pine.	Central, southwestern, and south-central.

Fire Group Ten consists of high elevation forests near and at the timberline. All the stands lie above the climatic limits of Douglas-fir and many stands are above the cold limits of limber pine and lodgepole pine. Subalpine fir is the indicated climax in all but one of the upper subalpine habitat types. The exception is the PICEA/SEST-PICEA h.t. where Engelmann spruce is the indicated climax and the only conifer. Whitebark pine is usually well represented in this group's upper subalpine habitat types. Engelmann spruce is also a major long-lived seral species. Lodgepole pine may occur on some upper subalpine sites.

Timberline forests are composed of alpine larch, whitebark pine, Engelmann spruce, and subalpine fir. Trees characteristically grow in groups with open areas in between. Timberline habitat types are named for their tree component, not for the indicated climax species.

Undergrowth in this group is usually sparse and at timberline it is highly variable. Shrubs that may occur on Group Ten sites include smooth menziesia, red and yellow mountain heaths, white rhododendron, mountain gooseberry, grouse whortleberry, and common juniper.

Common forbs are broadleaf arnica, ballhead sandwort, and slender hawkweed. Grass and grasslike vegetation includes Ross sedge, Idaho fescue, Parry rush, smooth woodrush, and beargrass.

Forest Fuels

Fire Group Ten habitats are characterized by relatively heavy loadings of large diameter downed and dead woody fuels. Fuel inventory data from eastside forests show an average of about 2 tons/acre (0.45 kg/m^2) of small diameter materials, 0.25 to 3 inches (0.6 to 7.6 cm), and about 9 tons/acre (about 2 kg/m^2) of large material over 3 inches (7.6 cm) in diameter (table 4). These figures agree quite well with those reported for Group Ten sites in the Selway-Bitterroot Wilderness

(Davis and others 1980). Average fuel loadings on some habitat types may be twice the Fire Group average (fig. 2).

The downed and dead woody fuel loadings in Group Ten stands often take the form of scattered large diameter downfall resulting from wind and snow breakage, windthrow, and insect- and disease-caused mortality. Such heavy fuels do not necessarily reflect a serious fire hazard. The mitigating effects of the normally cool, moist site, the very short fire season, and the usually sparse and often discontinuous nature of fine surface fuels, must be considered when evaluating overall fire potential. Examples of Group Ten fuel and stand conditions are shown in figure 38.


A


B

Figure 38.—Examples of fuel and stand conditions in some Fire Group Ten habitats. (A) A PIAL-ABLA h.t. with scattered downed woody fuel and flammable thicket of fir. Snags shown will eventually add to surface fuel loads. (B) A PIAL h.t. with sparse surface fuels and clusters of whitebark pine. (C) An ABLA/LUHI h.t. showing lush surface vegetation and low-hanging branches. (D) An ABLA/LUHI-MEFE h.t. with heavy dead woody fuels intermingled with dense live fuels. (E) A typical LALY-ABLA habitat.


C


D


E

Role of Fire

Fire is secondary to site factors (climate and soil) as an influence on forest development on these sites. The cold, moist, rocky, snowbound, unproductive, and otherwise fire-resistant environment that makes up much of this group not only makes fires infrequent but severely limits their extent. Lightning does ignite fires, but the paucity of continuous fine surface fuels coupled with the rain that commonly accompanies thunderstorms effectively limits fire spread and severity. Fire frequencies ranging from 35 to 300 years have been reported for individual sites (Romme 1980). Such figures are difficult to interpret because a fire may involve only one or two trees in a stand. For this reason the concept of fire frequency does not apply well in upper subalpine and timberline sites.

In the more continuous forests of this group, the most pronounced fire effect is to produce stand-replacing fires at long intervals, perhaps 200 years or more. Stand-destroying fires in Group Ten are most likely to occur during extended drought conditions when severe wind-driven crown fires develop in the forests below and burn into the upper subalpine and timberline forests. Vegetation recovery following such fires is usually slow because of the extremely short growing season and cold climate.

Generalized Forest Succession

In Group Ten habitats, secondary succession begins with a mixture of herbs and shrubs probably including some conifer seedlings (fig. 38). It is likely that herbaceous plants will dominate for an extended period. Fire may initiate secondary succession, but it is unlikely that it has a role in maintaining it. Physical disruption of the stand by snow and wind, rock slides, and snow and talus slippage is more important on moist sites and north slopes than fire in maintaining early stages of succession.

It takes a long time before conifers dominate some Group Ten sites, perhaps 100 years. It may take another 100 years before a mature forest exists. It is unlikely that fuel or stand conditions will support a fire of any consequence during this period. Surface fires do occur, especially in whitebark pine stands on south slopes and ridges. Such fires act as underburns, reducing fuels and killing some overstory trees. Severe fires may occur over small areas, but their effect will usually be limited to the creation of vegetative mosaics. Eventually the mature forest will begin to break up under the impact of wind and snow breakage, windthrow, insect-and disease-related mortality, and senescence. Stand-destroying fires, especially those that invade from lower elevation forests, become a possibility during extended drought.

Without disturbance, the mature trees will progress into a climax stand. This advance successional stage requires decades, possibly two or three centuries. Low to moderate severity fires rarely have a significant impact on a mature stand because of the open structure and lack of continuous fine woody fuels; however, severe fires that enter the crowns and kill the cambium of trees return the site to the early successional stages (fig. 39).

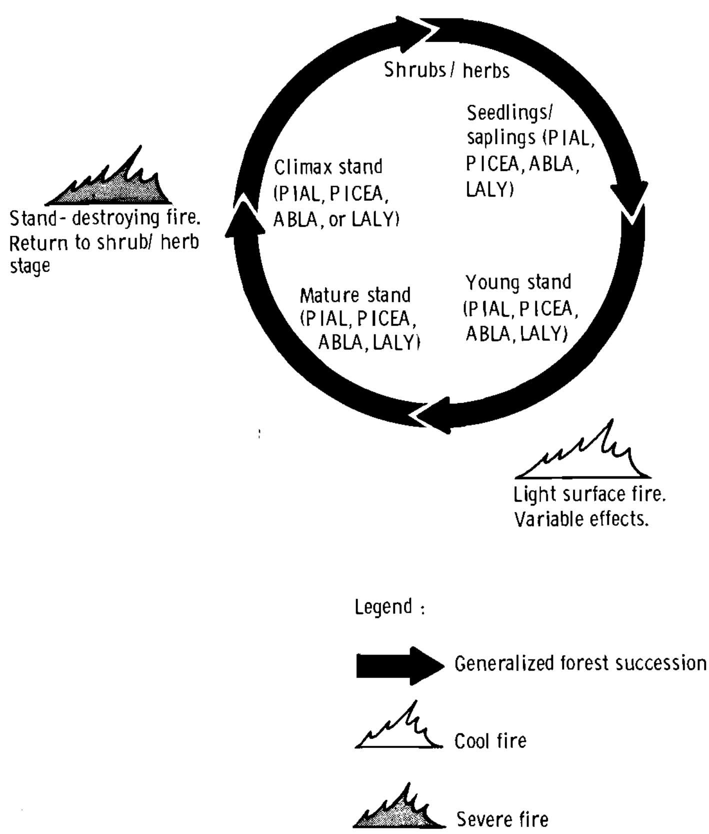


Figure 39.—Generalized forest succession in Fire Group Ten: cold, moist upper subalpine and timberline habitat types. Low-severity lightning fires may occur at any stage with little effect on succession.

Successional Pathways

A simple succession pattern postulated for Fire Group Ten is shown in figure 40 (subsequent states and numbers in this section refer to fig. 40). Shrubs and herbs are the initial stage of succession following disturbance (state A). In the unlikely event that a fire occurred in this state, the effect would be minimal (No. 1). Conifer regeneration will dominate the site after an extended regeneration period (state B). Again, a fire during this stage is unlikely, and if one occurs it will be low intensity and have little effect on vegetative succession (No. 2). A mature forest will develop after a long time (state C). Lightning fires may ignite individual trees and spread to adjoining trees (No. 3). The effect of such cool fires may be to create small openings in stands. Over time, a mosaic of successional stages may result. A severe fire could occur at this stage of succession (No. 4), especially one that originates in the lower elevation and burns into the Group Ten stand. Severe stand-replacing fires are also common in high ridgetop stands during lightning storms. Such fires revert the site to shrubs and herbs. If a major disturbance does not interfere, succession will continue until some stable state or climax is achieved (state D). Cool fires will have little effect on this state (No. 5). A severe stand-destroying fire will revert the site to the herbaceous state (No. 6).

Fire Management Considerations

Timber production is rarely an important management objective in this group's habitat types. Most of these areas are managed as watersheds, natural areas, and sanctuaries for wildlife. For example, whitebark pine forests have been found to be important food producers for jays, bears, squirrels, deer, and elk (Forcella and Weaver 1980). Most are roadless and many are in wilderness areas. Fire is an infrequent visitor and, when it does occur, damage in terms of management objectives is generally slight. These sites are, however, often fragile and can easily be damaged by modern, mechanized firefighting equipment.

The primary fire management considerations for Group Ten habitats should be the development of prescriptions that allow fire to more nearly play its natural role.

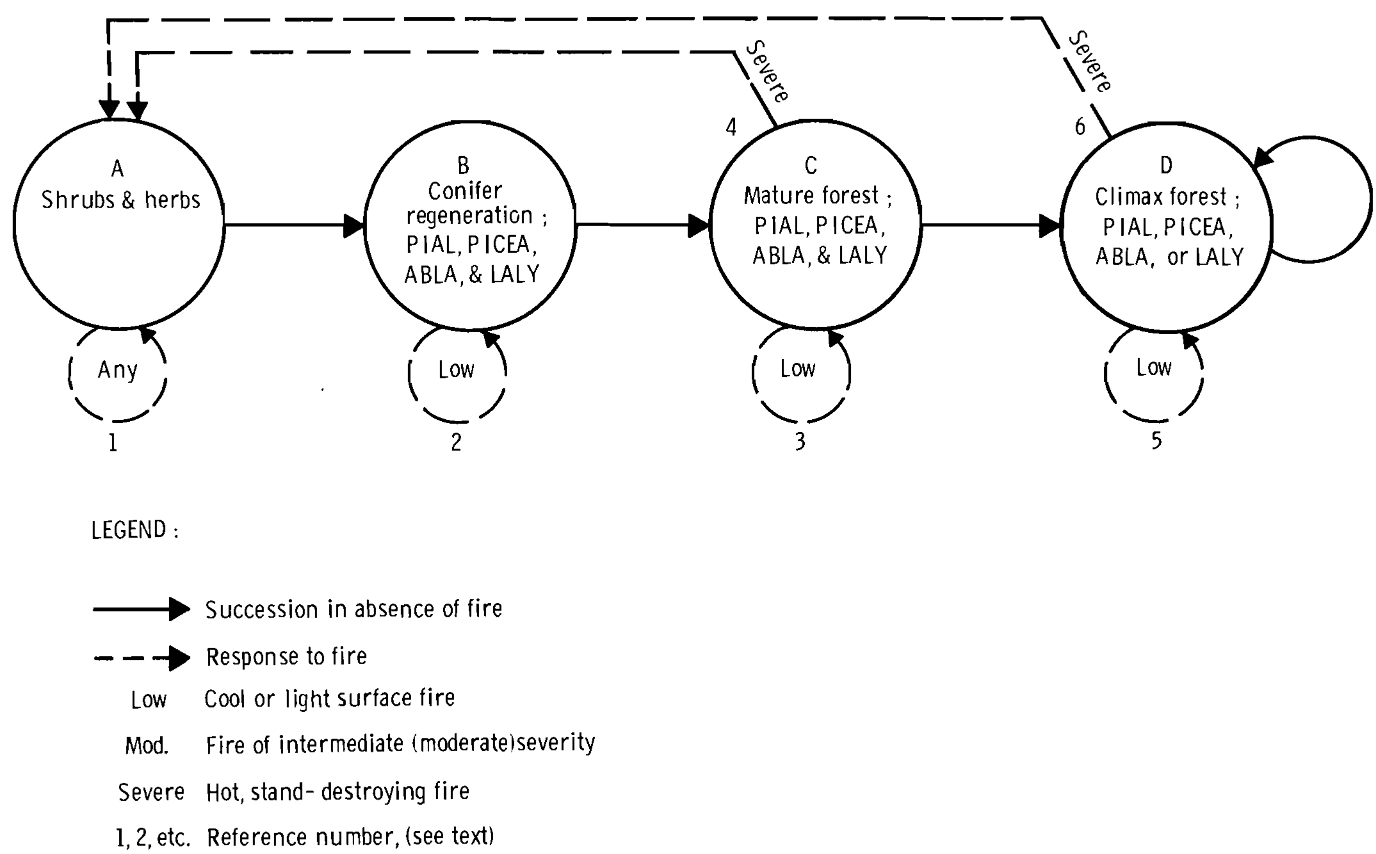


Figure 40.—Hypothetical fire-related successional pathways for Fire Group Ten habitat types.

PUBLICATIONS CITED

Ackerman, R. F. Effect of storage in slash on quantity and quality of lodgepole pine seeds available for regeneration. Inf. Rep. A-K-3. Canada: Canadian Department of Forestry and Rural Development; Alberta/Territories Region, Forest Research Laboratory, 1966. 22 p.

Albini, Frank A. Estimating wildfire behavior and effects. Gen. Tech. Rep. INT-30. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 92 p.

Alexander, M. E.; Hawksworth, F. G. Wildland fires and dwarf mistletoes: a literature review of ecology and prescribed burning. Gen. Tech. Rep. RM-14. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, 1975. 12 p.

Amman, G. D. The role of mountain pine beetle in lodgepole pine ecosystems: impact on succession. In: Mattson, W. J., ed. Proceedings in life sciences: the role of arthropods in forest ecosystems. New York, Heidelberg, Berlin: Springer-Verlag; 1977: 3-15.

Arno, Stephen F. Ecology of alpine larch (*Larix lyallii* Panl.) in the Pacific Northwest. Missoula, MT: University of Montana; 1970. 264 p.

Arno, Stephen F. The historical role of fire in the Bitterroot National Forest. Res. Pap. INT-187. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 29 p.

Arno, Stephen F. Forest regions of Montana. Res. Pap. INT-218. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 39 p.

Arno, Stephen F. Forest fire history in the northern Rockies. J. For. 78(8): 460-465; 1980.

Arno, Stephen F.; Gruell, George E. Fire history at the forest-grassland ecotone in southwestern Montana. Accepted for publication by J. Range Manage. (Sep. 1983).

Arno, S. F.; Hoff, R. J. Whitebark pine. In: Silvics of forest trees of the United States. Agric. Handbook. Washington, DC: U.S. Department of Agriculture, Forest Service. In press.

Baumgartner, D. M., ed. Managment of lodgepole pine ecosystems: symposium proceedings, volumes 1 and 2; 1973 October 9-11; Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service; 1975.

Beaufait, William R. Some effects of high temperatures on the cones and seeds of jackpine. For. Sci. 6: 194-199; 1960.

Billings, W. D.; Mark, A. F. Factors involved in the persistence of Montana treeless balds. Ecology. 38(1): 140-142; 1957.

Boe, Kenneth N. Effects of slash disposal on lodgepole pine regeneration. Montana Acad. Sci. Proc. 12: 27-33; 1952.

Brown, James K. Handbook for inventorying downed woody material. Gen. Tech. Rep. INT-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1974. 24 p.

Brown, James K. Fire cycles and community dynamics in lodgepole pine forests. In: Baumgartner, D. M., ed. Management of lodgepole pine ecosytems: symposium proceedings; 1973 October 9-11; Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service; 1975: 429-456.

Brown, James K.; See, Thomas. Downed dead woody fuel and biomass in the northern Rocky Mountains. Res. Pap. INT-117. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 48 p.

Clements, F. E. The life history of lodgepole pine burn forests. For. Serv. Bull. 79. Washington, DC: U.S. Department of Agriculture, Forest Service; 1910. 56 p.

Cole, Walter E.; Amman, Gene D. Mountain pine beetle dynamics in lodgepole pine forests. Part I: Course of an infestation. Gen. Tech. Rep. INT-89. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 56 p.

Curtis, James D.; Tackle, David. Pulpwood moves east from the Targhee. Timberman. 55(9): 2; 1954.

Daubenmire, R.; Daubenmire, J. B. Forest vegetation of Eastern Washington and North Idaho. Tech. Bull. 60. Pullman, WA: Washington Agricultural Experiment Station, Washington State University; 1968. 104 p.

Davis, Kathleen M.; Clayton, Bruce D.; Fischer, William C. Fire ecology of Lolo National Forest habitat types. Gen. Tech. Rep. INT-79. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 77 p.

Day, R. J. Stand structure succession and use of southern Alberta's Rocky Mountain forest. Ecology. 53(3): 472-477; 1972.

DeByle, Norbert V. Clearcutting and fire in the larch/Douglas-fir forests of western Montana: a multifaceted research summary. Gen. Tech. Rep. INT-99. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 73 p.

Despain, D. G.; Sellers, R. E. Natural fire in Yellowstone National Park. Western Wildlands. 4(1): 20-24; 1977.

Eyre, F. H., ed. Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters; 1980. 148 p.

Fischer, William C. Prescribed fire and bark beetle attack in ponderosa pine forests. Fire Management Notes. 41(2): 10-12; 1980.

Fischer, William C. Photo guide for appraising natural fuels in Montana forests: interior ponderosa pine, ponderosa pine—western larch—Douglas-fir, western larch—Douglas-fir, and interior Douglas-fir cover types. Gen. Tech. Rep. INT-97. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981a. 133p.

Fischer, William C. Photo guide for appraising natural fuels in Montana forests: lodgepole pine and Engelmann spruce—subalpine fir cover types. Gen. Tech. Rep. INT-98. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981b. 143 p.

Flint, R. Fire resistance of northern Rocky Mountain conifers. Idaho Forester. 7: 7-10, 4-43; 1925.

Forcella, Frank; Weaver, T. Food production in the *Pinus albicaulis-Vaccinium scoparium* association. Proc. Mont. Acad. Sci. 39: 73-80; 1980.

Gruell, George E.; Schmidt, Wyman C.; Arno, Stephen F.; Reich, William J. Seventy years of vegetative change in a managed ponderosa pine forest in western Montana—implications for resource management. Gen. Tech. Rep. INT-130. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 42 p.

Habeck, J. R.; Mutch, R. W. Fire-dependent forests in the Northern Rocky Mountains. Quat. Res. 3: 408-424; 1973.

Hare, R. C. Detecting dead cambium with a moisture meter. J. For. 58(10): 815-817; 1960.

Hare, R. C. Chemical test for fire damage. J. For. 63(12): 939; 1965.

Hawkes, Brad C. Fire history and fuel appraisal study of Kananaskis Provincial Park, Alberta. Edmonton, Alberta: Department of Forestry Science, University of Alberta; 1979. 172 p.

Hendrickson, William H. Consideration of natural fire, variance in viewpoint. In: The role of fire in the Intermountain West: proceedings of the Intermountain Fire Research Council symposium; 1970 October 27-29; Missoula, MT; 1970: 76-80.

Keown, L. D. Interim report: Blacktail Hills prescribed fire project, implementation and results. Great Falls, MT: U.S. Department of Agriculture, Forest Service, Lewis and Clark National Forest; 1977. 9 p. Mimeo.

Kessell, Stephen R.; Fischer, William C. Predicting postfire plant succession for fire management planning. Gen. Tech. Rep. INT-94. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 198l. 19 p.

Lanner, Ronald M.; Vander Wall, Stephen B. Dispersal of limber pine seed by Clark's nutcrackers. J. For. 78(10): 637; 1980.

Lotan, James E. Regeneration of lodgepole pine: a study of slash disposal and cone opening. Res. Note INT-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1964a. 4 p.

Lotan, James E. Initial germination and survival of lodgepole pine on prepared seedbeds. Res. Note INT-29. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1964b. 8 p.

Lotan, James E. Regeneration of lodgepole pine forests in the northern Rocky Mountains. In: Baumgartner, D. M., ed. Management of lodgepole pine ecosytems: symposium proceedings; 1973 October 9-11; Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service; 1975: 516-535.

Lotan, J. E.; Alexander, M. E.; Arno, S. F.; French, R. E.; Langdon, O. G.; Loomis, R. M.; Norum, R. A.; Rothermel, R. C.; Schmidt, W. C.; Van Wagtendonk, J. Effects of fire on flora: a state-of-knowledge review. Gen. Tech. Rep. WO-16. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981. 71 p.

Lyon, L. Jack. Attrition of lodgepole pine snags on the Sleeping Child Burn, Montana. Res. Note INT-219. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 4 p.

Lyon, L. Jack; Stickney, Peter F. Early vegetal succession following large northern Rocky Mountain wildfires. Proc. Tall Timbers Fire Ecol. Conf. 14: 355-375; 1976.

Martin, R. E.; Dell, J. D. Planning for prescribed burning in the Inland Northwest. Gen. Tech. Rep. PNW-76. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1978. 67 p.

McLean, Alastair. Fire resistance of forest species as influenced by root systems. J. Range Manage. 22(2): 120-122; 1969.

Miller, M. Response of blue huckleberry to prescribed fires in western Montana larch-fir forest. Res. Pap. INT-188. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 33 p.

Minore, Don. Comparitive autecological characteristics of northwestern tree species—a literature review. Gen. Tech. Rep. PNW-87. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 72 p.

Mueggler, W. F. Ecology of seral shrub communities in the cedar-hemlock zone of northern Idaho. Ecol. Monogr. 35: 165-185; 1965.

Muraro, S. J. The lodgepole pine fuel complex. Inf. Rep. BC-X-53. Victoria, BC: Forest Research LAboratory, Canadian Forest Service, Department of Fisheries and Forestry; 1971. 35 p.

Nord, E. C. Autecology of bitterbrush in California. Ecol. Monogr. 35: 307-334; 1965.

Norum, Rodney A. Preliminary guidelines for prescribed burning under standing timber in western larch/Douglas-fir forests. Res. Note INT-229. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 15 p.

Perry, David A.; Lotan. James E. A model of fire selection for serotiny in lodgepole pine. Evolution. 33(3): 958-968; 1979.

Pfister, R. D.; Daubenmire, R. Ecology of lodgepole pine, *Pinus contorta* Dougl. In: Baumgartner, D. M., ed. Management of lodgepole pine ecosytems: symposium proceedings; 1973 October 9-11; Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service; 1975: 27-46.

Pfister, Robert D.; Kolvalchik, Bernard L.; Arno, Stephen F.; Presby, Richard C. Forest habitat types of Montana. Gen. Tech. Rep. INT-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 174 p.

Roberts, D. W. Forest habitat types of the Bear's Paw Mountains and Little Rocky Mountains, Montana. Missoula, MT: University of Montana; 1980. 116 p. Thesis.

Roberts, D. W.; Sibbernsen, J. I. Forest and woodland habitat types of North Central Montana, volume 2: the Missouri River Breaks. Final Rep., Contract No. YA-512-CT6-84. Billings, MT: U.S. Department of the Interior, Bureau of Land Management; 1979.

Roe, A. L.; Alexander, R.; Andrews, M. D. Engelmann spruce regeneration practices in the Rocky Mountains. Prod. Res. Rep. 115. Washington, DC: U.S. Department of Agriculture, Forest Service; 1970. 32 p.

Romme, William H. Fire frequency in subalpine forests of Yellowstone National Park. In: Proceedings of the fire history workshop; 1980 October 20-24; Tucson, AZ. Gen. Tech. Rep. RM-81. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980: 27-30.

Romme, William H.; Knight, Dennis H. Fire frequency and subalpine forest succession along a topographic gradient in Wyoming. Ecology. 62(2): 319-326; 1981.

Schneegas, E. R.; Bumstead, R. S. Decline of western mule deer populations: probable cause and tentative solution. Presented at 57th Annual Conference Western Associated State Game and Fish Commission, 1977 July 12; Tucson, AZ. 15 p.

Sneck (Davis), Kathleen M. The fire history of Coram Experimental Forest. Missoula, MT: University of Montana; 1977. 134 p. Thesis.

Stickney, P. F. Vegetative recovery and development. In: DeByle, N. V. Clearcutting and fire in the larch/Douglas-fir forest of western Montana; a multifaceted research summary. Gen. Tech. Rep. INT-99. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 73 p.

Tackle, David. Viability of lodgepole pine seed after natural storage in slash. Res. Note 8. Ogden, UT: U. S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1954. 3 p.

Tackle, D. Ecology and silviculture of lodgepole pine. Washington, DC: Proceedings of the Society of American Foresters; 1964a: 112-115.

Tackle, David. Regenerating lodgepole pine in central Montana following clearcutting. Res. Note INT-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1964b. 7 p.

U.S. Department of Agriculture, Forest Service. Silvics of forest trees of the United States. Agric. Handb. 271. Washington, DC: U.S. Department of Agriculture; 1965. 762 p.

Van Wagner, C. E. Height of crown scorch in forest fires. Can. J. For. Res. 3(3): 373-378; 1973.

Vogl, Richard J.; Ryder, Calvin. Effects of slash burning on conifer reproduction in Montana's Mission Range. Northwest Sci. 43(3): 135-147; 1969.

Volland, L. A.; Dell, J. D. Fire effects on Pacific Northwest forest and range vegetation. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1981. 23 p.

Weaver, H. Fire and its relationship to ponderosa pine. Proc. Tall Timbers Fire Ecol. Conf. 7: 127-149; 1967.

Weaver, Harold. Effects of prescribed burning in second growth ponderosa pine. J. For. 55: 823-826; 1957.

Weaver, Harold. Ecological changes in the ponderosa pine forest of the Warm Springs Indian Reservation in Oregon. J. For. 57: 15-20; 1959.

Weaver, Harold. Implications of the Klamath fires of September 1959. J. For. 59: 569-572; 1961.

Wellner, C. A. Fire history in the northern Rocky Mountains. Proceedings of the role of fire in the Intermountain West symposium; 1970 October 27-29; Missoula, MT. Missoula, MT: Intermountain Fire Research Council, 1970: 42-64.

Willms, W.; Bailey, A. W.; McLean, A.; Tucker, R. The effects of fall grazing or burning bluebunch wheatgrass range on forage selection by deer and cattle in spring. Can. J. Anim. Sci. 60(1): 113-122; 1980.

Wright, H. A. Shrub response to fire. In: Wildland shrubs—their biology and utilization. Gen. Tech. Rep. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972: 204-217.

Wright, H. A. The effect of fire on vegetation in ponderosa pine forests: a state-of-the-art review. Sci. Publ. T-9-199. College Station, TX: Texas Tech University, College of Agriculture; 1978. 21 p.

Wright, H. A. The role and use of fire in the semidesert grass-shrub type. Gen. Tech. Rep. INT-85. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 24 p.

Wright, H. A.; Bailey, A. W. Fire ecology and prescribed burning in the Great Plains—a research review. Gen. Tech. Rep. INT-77. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 60 p.

Wright, H. A.; Neuenschwander, L. F.; Britton, C. M. The role and use of fire in sagebrush-grass and pinyon juniper plant communities; a state-of-the-art review. Gen. Tech. Rep. INT-58. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 48 p.

OTHER REFERENCES

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

Amman, G. D.; McGregor, M. D.; Cahill, D. B.; Klein, W. H. Guidelines for reducing losses of lodgepole pine to the mountain pine beetle in unmanaged stands in the Rocky Mountains. Gen. Tech. Rep. INT-36. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 19 p.

Antos, J. A. Grand fir (*Abies grandis* (Douglas) (Forbes)) forests of the Swan Valley, Montana. Missoula, MT: University of Montana; 1977. 220 p. Thesis.

Bates, C. G. Physiological requirements of Rocky Mountain trees. J. Agric. Res. 24: 97-164; 1923.

Biswell, H. H. Fire ecology in ponderosa pine grassland. Proc. Tall Timbers Fire Ecol. Conf. 12: 69-96; 1972.

Bloomberg, W. J. Fire and spruce. For. Chron. 26(2): 157-161; 1950.

Boldt, C. E. Black Hills ponderosa pine. In: Silvicultural systems for the major forest types of the United States. Agric. Handb. 445. Washington, DC: U.S. Department of Agriculture, Forest Service; 1973: 52-53.

Boyd, R. J.; Deitschman, G. H. Site preparation aids natural regeneration in western larch-Engelmann spruce strip clearcutting. Res. Pap. INT-64. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1969. 10 p.

Brown, A. A.; Davis, K. P. Forest fire control and use. New York: McGraw-Hill Book Company; 1973. 686 p.

Burkhardt, S. W.; Tisdale, E. W. Causes of juniper invasion in southwestern Idaho. Ecology. 57: 472-484; 1976.

Buttrick, P. J. The probable origin of the forests of the Black Hills of South Dakota. For. Quar. 12: 223-227; 1914.

Cary, M. Life zone investigation in Wyoming. North America Fauna 42. Washington, DC: U.S. Department of Agriculture, Bureau of Biological Survey; 1917. 95 p.

Cooper, S. An ecological study of forest vegetation in eastern Idaho and western Wyoming. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station and Washington State University; 1973. 2 p. Progress report.

Cooper, S. Forest habitat types of northwestern Wyoming and contiguous portions of Montana and Idaho. Pullman, WA: Washington State University; 1975. 190 p. Dissertation.

Critchfield, W. B. Geographic variation in *Pinus contorta*. Publ. 3. New York: Columbia University, Maria Moors Cabot Foundation; 1957. 118 p.

Dasmann, W. If deer are to survive. Harrisburg, PA: Stackpole Books; 1971. 128 p.

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

Daubenmire, R. Climate as a determinant of vegetation distribution in eastern Washington and northern Idaho. Ecol. Monogr. 26: 131-154; 1956.

Daubenmire, R. Structure and ecology of coniferous forests of the northern Rocky Mountains. In: Coniferous forests of the northern Rocky Mountains. Missoula, MT: Center for Natural Resources; 1968: 25-41.

Dealy, J. E. Habitat characteristics of the Silver Lake mule deer range. Res. Pap. PNW-125. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1971. 99 p.

Despain, D. G. Vegetation of the Big Horn Mountains, Wyoming, in relation to substrate and climate. Ecol. Monogr. 43(3): 329-335; 1973.

Eggler, W. A. Primary succession on volcanic deposits in southern Idaho. Ecol. Monogr. 11: 277-298; 1941.

Ellison, L. Subalpine vegetation of the Wasatch Plateau, Utah. Ecol. Monogr. 24: 89-104; 1954.

Foster, J. H. The spread of timbered areas in central Texas. Ecology. 12: 105-155; 1917.

Franklin, J.; Dyrness, C. T. Natural vegetation of Oregon and Washington. Gen. Tech. Rep. PNW-8. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1973. 417 p.

Gabriel, H. W., III. Wilderness ecology: the Danaher Creek drainage, Bob Marshall Wilderness, Montana. Missoula, MT: University of Montana; 1976. 224 p. Dissertation.

Gill, D.; Cordes, L. D. Winter habitat preference of porcupines in the Southern Alberta foothills. Can. Field Nat. 86(4): 349-355.

Glacier National Park. Draft environmental assessment: forest fire management. West Glacier, MT: U.S. Department of the Interior, National Park Service, Glacier National Park; 1977.

Gooding, L. N. An interesting area of limber pine extending into southwestern Nebraska. J. For. 21: 175-176; 1923.

Gruell, G. E.; Loope, L. L. Relationships among aspen, fire and ungulate browsing in Jackson Hole, Wyoming. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region; 1974.

Haasis, F. W.; Trupp, A. C. Temperature relations of lodgepole pine seed germination. Ecology. 12: 728-774; 1931.

Habeck, J. R. Fire ecology investigations in Glacier National Park. Missoula, MT: University of Montana, Botany Department; 1970. 80 p.

Habeck, J. R. Fire ecology investigation in the Selway-Bitterroot Wilderness— historical considerations and current observations. Publ. R172-001. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1972. 119 p.

Haig, I. T. Premature germination of forest tree seed during natural storage in duff. Ecology. 13: 311-312; 1932.

Haig, I. T.; Davis, K. P.; Widman, R. H. Natural regeneration in the western white pine type. Tech. Bull. 767. Washington, DC: U.S. Department of Agriculture; 1941. 99 p.

Hanna, L. A. The major plant communities of the headwater area of the Little Laramie River, Wyoming. Laramie, WY: University of Wyoming, Publications and Science, Botany 1: 243-266; 1934.

Hodson, E. R.; Foster, J. H. Engelmann spruce in the Rocky Mountains. Circular 170. Washington DC: U.S. Department of Agriculture, Forest Service; 1910. 23 p.

Hoffman, G. R.; Timken, R. L. Ecological observations on *Pinus ponderosa* Laws (Pinaceae) in its easternmost extension in South Dakota. Southwest Nat. 14(3): 327-336; 1970.

Horton, K. W. Causes of variation in stocking of lodgepole pine regeneration following fire. Silviculture Leafl. 95. Edmonton, Alberta: Canadian Department of Northern Affairs and Natural Resources, Forestry Branch, Forest Research Division; 1953.

Hosie, R. C. Native trees of Canada. Ottawa: Canadian Forest Service, Department of Fish and Forestry; 1969.

Houston, D. B. Wildfires in northern Yellowstone National Park. Ecology. 54(5): 1111-1117; 1973.

Humphrey, R. R. History of vegetational changes in Arizona. In: Your range—its management. Spec. Rep. 2. Tucson, AZ: Arizona Agriculture Experiment Station and Arizona Extension Service; 1959. 57 p.

Illingworth, K. Lodgepole pine provenance research and breeding in British Columbia. In: Baumgartner, D. M., ed. Management of lodgepole pine ecosytems: symposium proceedings; 1973 October 9-11; Pullman, WA. Pullman, WA: Washington State University, Cooperative Extension Service; 1975: 47-67.

Issac, L. A. Reproductive habitats of Douglas-fir. Charles Lathrop Pack Forestry Foundation; 1943.

Keen, F. P. Longevity of ponderosa pine. J. For. 38: 597-598; 1940.

Kotok, E. I. Fire, a major ecological factor in the pine region of California. Proc. Pac. Sci. Congr. 5: 4017-4022; 1933.

Krueger, T. Practices and problems in the disposal of brush resulting from thinnings in ponderosa pine in the Black Hills National Forest. J. For. 32: 757-759; 1934.

Larsen, J. A. Some characteristics of seeds of coniferous trees from the Pacific Northwest. Natl. Nurseryman. 30: 246-249; 1922.

Lawson, Bruce D. Fire spread in lodgepole pine stands. Internal Rep. BC-36. Victoria, BC: Pacific Forest Research Centre, Canadian Forest Service, Department of Environment; 1972. 119 p.

Leiberg, J. B. The Bitterroot Forest Reserve. In: 20th Annual Report Part V: Forest Reserves. Washington DC: U.S. Department of the Interior, Geological Survey; 1900a: 317-410.

Leiberg, J. B. Cascade Range Forest Reserve, Oregon. In: Annual Report 21, 1899-1900, Part V: Forest Reserves. Washington DC: U.S. Department of the Interior, Geological Survey; 1900b: 209-298.

Leiberg, J. B. Forest conditions in the Little Belt Mountain Forest Preserve Montana, and the Little Belt Mountains Quadrangle. Professional Paper 30, PI-75. Washington, DC: U.S. Geological Survey; 1904.

Leopold, A. Grass, brush, timber and fire in southern Arizona. J. For. 22: 1-10; 1924.

Leopold, A. S.; Cain, S. A.; Cottan, C. H.; Gabrielson, I. N.; Kimball, T. L. Wildlife management in the National Parks. Am. For. 69(4): 32-35, 61-63; 1963.

Lepper, M. G. *Pinus flexilis* James, and its environmental relationships. Davis, CA: University of California; 1974. 210 p. Dissertation. Diss. Abstr. 36B: 67-68.

Loope, L. L.; Gruell, G. E. The ecological role of fire in the Jackson Hole Area, northwestern Wyoming. Quat. Res. 3(3): 125-443; 1973.

Lotan, James E. Cone serotiny in *Pinus contorta*. Ann Arbor, MI: University of Michigan; 1970. 94 p. Dissertation. Lotan, J. E. Cone serotiny-fire relationships in lodgepole pine. In: Symposium proceedings: Montana tall timber fire ecology conference and fire and land management; 1974: 267-278.

Lotan, J. E.; Alexander, R. R. Lodgepole pine. In: Silvicultural systems for the major forest types of the United States Agric. Handb. 445. Washington, DC: U.S. Department of Agriculture, Forest Service; 1973: 42-43.

Lotan, J. E.; Perry, D. A. Seed per cone, seed weight, and germination of lodgepole pine in relation to parent tree characteristics. Paper presented at 47th Annual Meeting, Northwest Science, University of British Columbia, Vancouver; 1974. 1974.

Lunan, J. S.; Habeck, J. R. The effects of fire exclusion on ponderosa pine communities in Glacier National Park, Montana. Can. J. For. Res. 3: 574–579; 1973.

Lynch, D. W. Effects of a wildfire on mortality and growth of young ponderosa pine trees. Res. Note 66. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1959. 8 p.

MacKenzie, G. A. The fire ecology of the forest of Waterton Lakes National Park. Alberta, Canada: University of Calgary; 1973. 199 p. Thesis.

Marshall, R. The life history of some western white pine stands on the Kaniksu National Forest. Northwest Sci. 2(2): 48-53; 1928.

Mason, D. T. The life history of lodgepole pine in the Rocky Mountains. Agric. Bull. 154. Washington, DC: U.S. Department of Agriculture; 1915. 135 p.

McIntosh, A. C. Botanical features of the Northern Black Hills. Black Hills Engineer 18(1): 79–107; 1930.

McNeil, R. C. Vegetation and fire history of a ponderosa pine-white fir forest in Crater Lake National Park. Corvallis, OR: Oregon State University; 1975. 171 p. Thesis.

McSwain, G. A.; Alexander, R. R.; Markstrom, D. C. Engelmann spruce. American woods. Washingtion, DC: U.S. Department of Agriculture, Forest Service; 1970. 8 p.

Moir, W. H. Influence of ponderosa pine on herbaceous vegetation. Ecology. 47: 1045–1048; 1966.

Morris, W. G.; Mowat, E. L. Some effects of thinning of a ponderosa pine thicket with fire. J. For. 56: 203–209; 1958.

Munger, T. T. The growth and management of ponderosa pine in the Southwest. Agric. Monogr. 6, 37, 74, 78, 110, 117. Washington, DC: U.S. Department of Agriculture, Forest Service.

Myers, C. A.; Van Deusen, J. L. Growth of immature stands of ponderosa pine in the Black Hills. Stn. Pap. RM–61. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1961. 14 p.

Pase, C. P.; Hurd, R. M. Understory vegetation as related to basal area, crown cover and litter produced by immature ponderosa pine stands in the Black Hills. In: Proceedings of the Society of American Foresters; 1957: 156–158.

Pattern, D. T. Vegetational patterns in relation to environments in the Madison Range, Montana. Ecol. Monogr. 33: 375–406; 1963.

Pearson, G. A. Factors controlling the distribution of forest types. Ecology. l: 139-150, 289-308; 1920.

Pearson, G. A. Forest types in the southwest as determined by climate and soil. Tech. Bull. 247. Washington, DC: U.S. Department of Agriculture; 1931. 144 p.

Phillips, T. A. The effects of fire on vegetation and wildlife on a lodgepole pine burn in Chamberlain Basin, Idaho. McCall, Idaho: U.S. Department of Agriculture, Forest Service; 1971. 9 p. Progress report.

Potter, L. D.; Green D. L. Ecology of a northeastern outlying stand of *Pinus flexilis*. Ecology. 45(4): 866–868; 1964.

Progulske, D. R. Yellow ore, yellow hair, yellow pine. Agric. Ext. Bull. 6l6. Brookings, SD: South Dakota State University; July 1974.

Rafn, J. The testing of forest seed during 25 years, 1887-1912. Copenhagen, Denmark: J. Rafn; 1915.

Ralphs, M.; Schen, D.; Busby, F. Prescribed burning—effective control of sagebrush and open juniper. Utah Sci. Sept. 1975: 94–98.

Ream, R. R. The vegetation of the Wasatch Mountains, Utah and Idaho. Madison, WI: University of Wisconsin; 1964. 178 p. Dissertation.

Reed, J. F. The vegetation of Jackson Hole Wildlife Park, Wyoming. Am. Midl. Nat. 48(3): 700–729; 1952.

Reed, R. M. A study of vegetation in the Wind River Mountains, Wyoming. Pullman, WA: Washington State University; 1969. 77 p. Dissertation.

Roe, A. L.; Amman, G. D. The mountain pine beetle in lodgepole pine forests. Res. Pap. INT–71. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1970. 23 p.

Roeser, J. Transpiration capacity of coniferous seedlings and the problem of heat injury. J. For. 30: 381-395; 1932.

Schuler, J. H. The composition and distribution of Douglas-fir forest communities in the Pattee Canyon area, Missoula, Montana. Missoula, MT: University of Montana, Department of Botany; 1968. 84 p. Thesis.

Show, S. B.; Kotok, E. I. The role of fire in the California pine forests. Bull. 1924. Washington, DC: U.S. Department of Agriculture.

Smithers, L. A. Lodgepole pine in Alberta. For. Bull. 127. Ottawa: Canadian Department of Forestry; 196l. 153 p.

Soeriaatmadja, R. E. Fire history of the ponderosa pine forest of the Warm Springs Indian Reservation, Oregon. Corvallis, OR: Oregon State University; 1966. 132 p. Dissertation.

Stahelin, R. Factors influencing the natural restocking of high altitude burns by coniferous trees in the Central Rocky Mountains. Ecology. 24(): 19–30; 1943.

Starker, T. J. Fire resistance in the forest. J. For. 32: 462–467; 1934.

Steele, R.; Ondov, D.; Cooper, S. V.; Pfister, R. D. Preliminary forest habitat types of eastern Idaho and western Wyoming. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station and Intermountain Region; 1977. 147 p.

Stermitz, J. E.; Klages, M. G.; Lotan, J. E. Soil characteristics influencing lodgepole pine regeneration near West Yellowstone, Montana. Res. Pap. INT–163. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1974. 16 p.

Sudworth, G. B. Stanislaus and Lake Tahoe Forest Reserves, California, and adjacent territory. In: Annual Report 21, 1899–1900, Part V: Forest Reserves. Washington, DC: U.S. Department of the Interior, Geological Survey; 1900: 209–298.

Sudworth, G. B. Forest trees of the Pacific slope. Washington, DC: U.S. Department of Agriculture, Forest Service; 1908.

Tackle, David. Lodgepole pine management in the Intermountain Region, a problem analysis. Misc. Publ. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service; 1954. 53 p.

Tande, G. F. Forest fire history around Jasper townsite, Jasper National Park, Alberta. Edmonton: University of Alberta; 1977. 169 p. Thesis.

Taylor, A. R. Lightning effects on the forest complex. Proc. Tall Timber Fire Ecol. Conf. 9: 127–150; 1969.

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

Taylor, Dale L. Biotic succession of lodgepole pine forests of fire origin in Yellowstone National Park. Laramie, WY: University of Wyoming; 1969. 320 p.

Thilenius, J. F. An isolated occurrence of limber pine (*Pinus flexilis* James) in the Black Hills of South Dakota. Am. Midl. Nat. 84(2): 411–417; 1970.

Thorwaite, C. W. An approach toward a national classification of climate. Geogr. Rev. 38: 55–94; 1948.

U.S. Department of Agriculture, Forest Service. Annual report, 1943. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1944. 46 p.

Vogl, R. J. Fire and plant succession. In: Symposium proceedings: the role of fire in the Intermountain West. Missoula, MT: University of Montana, Forestry School; 1970: 65–75.

Wagner, W. W. Past fire incidence in the Sierra Nevada forests. J. For. 59: 734–747; 1961.

Weaver, H. Fire as an ecological and silvicultural factor in the ponderosa pine region of the Pacific slope. J. For. 41: 715; 1943.

Weaver, H. Fire—Nature's thinning agent in ponderosa pine stands. J. For. 45: 437–444; 1947.

Weaver, H. Fire as an ecological factor in the southwestern ponderosa pine forests. J. For. 49: 93–98; 1951.

Weaver, H. A preliminary report on prescribed burning in virgin ponderosa pine. J. For. 50: 662–667; 1952.

Weaver, H. Fire as an enemy, friend, and tool in forest management. J. For. 53: 499–504; 1955.

Weaver, H. Effects of prescribed burning in ponderosa pine. J. For. 55: 133–138; 1957.

Weaver, H. Effects of prescribed burning in second-growth ponderosa pine. J. For. 55: 823–826; 1957.

Weaver, H. Ecological changes in the ponderosa pine forest of the Warm Springs Indian Reservation in Oregon. J. For. 57: 15–20; 1959.

Weaver, H. Ecological changes in the ponderosa pine forest of Cedar Valley in southern Washington. Ecology. 42: 416–420; 1961.

Weaver, H. Implication of the Klamath fires of September 1959. J. For. 59: 569–572; 1961.

Weaver, H. Fire management problems in ponderosa pine. Proc. Tall Timbers Fire Ecol. Conf. 3: 61–79; 1964.

Weaver, H. Fire as a continuing ecological factor in perpetuation of ponderosa pine forests in the western United States. New Delhi, India: Advancing Frontiers of Plant Sciences 18: 137–154; 1967.

Weaver, H. Effects of fire on temperate forests western United States. In: Kozlowski. T. T.; Ahlgren, C. E., eds. Fire and ecosystems. New York: Academic Press.

Wellner, C. A. The history and role of fire in the Inland Empire Forests. In: Proceedings, Inland Empire Reforestation Council; 1965.

Wellner, C. A. and Ryker, R. A. Ponderosa pine and Rocky Mountain Douglas-fir. In: Silvicultural systems for the major forest types of the United States. Agric. Handb. 445. Washington, DC: U.S. Department of Agriculture, Forest Service; 1973: 35–37.

Wirsing, J. M. Forest vegetation in southeastern Wyoming. Pullman, WA: Washington State University; 1973. 170 p. Thesis.

Woodmansee, R. G. Clusters of limber pine trees—a hypothesis of plant-animal coaction. Southwest Nat. 21: 511-517; 1977.

Wright, H. E.; Heinselman, M. L. The ecological role of fire in natural conifer forests of western and northern North America—introduction. Quat. Res. 3(3): 319-328; 1973.

Youngberg, C. T.; Dahms, W. J. Productivity indices for lodgepole pine on pumic soils. J. For. 68: 90–94; 1970.

Zavitkovski, J. Role of brush on ponderosa pine establishment. In: Proceedings: regeneration of ponderosa pine symposium; 1969; Corvallis, OR.; 1970: 100–104.

APPENDIX A. FOREST HABITAT TYPES OCCURRING EAST OF THE CONTINENTAL DIVIDE IN MONTANA

ADP code[1]	Abbreviation	Habitat types and phases: Scientific names	Habitat types and phases: Common names
I. BEAVERHEAD, CUSTER, DEERLODGE, GALLATIN, HELENA, AND LEWIS AND CLARK NATIONAL FORESTS[2]			
010	SCREE		
000		PINUS FLEXILIS CLIMAX SERIES	
040	PIFL/AGSP h.t.	Pinus flexilis/Agropyron spicatum h.t.	limber pine/bluebunch wheatgrass
050	PIFL/FEID h.t.	Pinus flexilis/Festuca idahoensis h.t.	limber pine/Idaho fescue
051	-FEID phase	-Festuca idahoensis phase	-Idaho fescue phase
052	-FESC phase	-Festuca scabrella phase	-rough fescue phase
070	PIFL/JUCO h.t.	Pinus flexilis/Juniperus communis h.t.	limber pine/common juniper
		PINUS PONDEROSA CLIMAX SERIES	
110	PIPO/AND h.t.[2]	Pinus ponderosa/Andropogon spp. h.t.	ponderosa pine/bluestem
130	PIPO/AGSP h.t.	Pinus ponderosa/Agropyron spicatum h.t.	ponderosa pine/bluebunch wheatgrass
140	PIPO/FEID h.t.	Pinus ponderosa/Festuca idahoensis h.t.	ponderosa pine/Idaho fescue
141	-FEID phase	-Festuca idahoensis phase	-Idaho fescue phase
142	-FESC phase	-Festuca scabrella phase	-rough fescue phase
160	PIPO/PUTR h.t.	Pinus ponderosa/Purshia tridentata h.t.	ponderosa pine/bitterbrush
161	-AGSP phase	-Agropyron spicatum phase	-bluebunch wheatgrass phase
162	-FEID phase	-Festuca idahoensis phase	-Idaho fescue phase
170	PIPO/SYAL h.t.	Pinus ponderosa/Symphoricarpos albus h.t.	ponderosa pine/snowberry
171	-SYAL phase	-Symphoricarpos albus phase	-snowberry phase
172	-BERE phase	-Berberis repens phase	-creeping Oregon grape phase
180	PIPO/PRVI h.t.	Pinus ponderosa/Prunus virginiana h.t.	ponderosa pine/chokecherry
181	-PRVI phase	-Prunus virginiana phase	-chokecherry phase
182	-SHCA phase	-Shepherdia canadensis phase	-buffaloberry phase
200		PSEUDOTSUGA MENZIESII CLIMAX SERIES	
210	PSME/AGSP h.t.	Pseudotsuga menziesii/Agropyron spicatum h.t.	Douglas-fir/bluebunch wheatgrass
220	PSME/FEID h.t.	Pseudotsuga menziesii/Festuca idahoensis h.t.	Douglas-fir/Idaho fescue
230	PSME/FESC h.t.	Pseudotsuga menziesii/Festuca scabrella h.t.	Douglas-fir/rough fescue
250	PSME/VACA h.t.	Pseudotsuga menziesii/Vaccinium caespitosum h.t.	Douglas-fir/dwarf huckleberry
260	PSME/PHMA h.t.	Pseudotsuga menziesii/Physocarpus malvaceus h.t.	Douglas-fir/ninebark
261	-PHMA phase	-Physocarpus malvaceus phase	-ninebark phase
280	PSME/VAGL h.t.	Pseudotsuga menziesii/Vaccinium globulare h.t.	Douglas-fir/blue huckleberry
281	-VAGL phase	-Vaccinium globulare phase	-blue huckleberry
282	-ARUV phase	-Arctostaphylos uva-ursi phase	-kinnikinnick phase
283	-XETE phase	-Xerophyllum tenax phase	-beargrass phase
290	PSME/LIBO h.t.	Pseudotsuga menziesii/Linnaea borealis h.t.	Douglas-fir/twinflower
291	-SYAL phase	-Symphoricarpos albus phase	-snowberry phase
292	-CARU phase	-Calamagrostis rubescens phase	-pinegrass phase
293	-VAGL phase	-Vaccinium globulare phase	-blue huckleberry phase
310	PSME/SYAL h.t.	Pseudotsuga menziesii/Symphoricarpos albus h.t.	Douglas-fir/snowberry
311	-AGSP phase	-Agropyron spicatum phase	-bluebunch wheatgrass phase
312	-CARU phase	-Calamagrostis rubescens phase	-pinegrass phase
313	-SYAL phase	-Symphoricarpos albus phase	-snowberry phase
320	PSME/CARU h.t.	Pseudotsuga menziesii/Calamagrostis rubescens h.t.	Douglas-fir/pinegrass
321	-AGSP phase	-Agropyron spicatum phase	-bluebunch wheatgrass phase
323	-CARU phase	-Calamagrostis rubescens phase	-pinegrass phase
324	-PIPO phase	-Pinus ponderosa phase	-ponderosa pine phase
330	PSME/CAGE h.t.	Pseudotsuga menziesii/Carex geyeri h.t.	Douglas-fir/elk sedge
340	PSME/SPBE h.t.	Pseudotsuga menziesii/Spiraea betulifolia h.t.	Douglas-fir/white spiraea
350	PSME/ARUV h.t.	Pseudotsuga menziesii/Arctostaphylos uva-ursi h.t.	Douglas-fir/kinnikinnick
360	PSME/JUCO h.t.	Pseudotsuga menziesii/Juniperus communis h.t.	Douglas-fir/common juniper
370	PSME/ARCO h.t.	Pseudotsuga menziesii/Arnica cordifolia h.t.	Douglas-fir/heartleaf arnica
380	PSME/SYOR h.t.[2]	Pseudotsuga menziesii/Symphoricarpos oreophilus h.t.	Douglas-fir/mountain snowberry

(con.)

Appendix A. (con.)

ADP code[1]	Abbreviation	Habitat types and phases: Scientific names	Habitat types and phases: Common names
400		PICEA CLIMAX SERIES	
410	PICEA/EQAR h.t.	Picea/Equisetum arvense h.t.	spruce/common horsetail
430	PICEA/PHMA h.t.	Picea/Physocarpus malvaceus h.t.	spruce/ninebark
440	PICEA/GATR h.t.	Picea/Galium triflorum h.t.	spruce/sweetscented bedstraw
450	PICEA/VACA h.t.	Picea/Vaccinium caespitosum h.t.	spruce/dwarf huckleberry
460	PICEA/SEST h.t.	Picea/Senecio streptanthifolius h.t.	spruce/cleft-leaf groundsel
461	-PSME phase	-Pseudotsuga menziesii phase	-Douglas-fir phase
462	-PICEA phase	-Picea phase	-spruce phase
470	PICEA-LIBO h.t.	Picea/Linnaea borealis h.t.	spruce/twinflower
480	PICEA-SMST h.t.	Picea/Smilacina stellata h.t.	spruce/starry Solomon's seal
600		ABIES LASIOCARPA CLIMAX SERIES	
700		Lower subalpine h.t.'s	
620	ABLA/CLUN h.t.	Abies lasiocarpa/Clintonia uniflora h.t.	subalpine fir/queencup beadlily
621	-CLUN phase	-Clintonia uniflora phase	-queencup beadlily phase
622	-ARNU phase	-Aralia nudicaulis phase	-wild sarsaparilla phase
624	-XETE phase	-Xerophyllum tenax phase	-beargrass phase
625	-MEFE phase	-Menziesia ferruginea phase	-menziesia phase
640	ABLA/VACA h.t.	Abies lasiocarpa/Vaccinium caespitosum h.t.	subalpine fir/dwarf huckleberry
650	ABLA/CACA h.t.	Abies lasiocarpa/Calamagrostis canadensis h.t.	subalpine fir/bluejoint
651	-CACA	-Calamagrostis canadensis phase	-bluejoint
653	-GATR phase	-Galium triflorum phase	-sweetscented bedstraw phase
654	-VACA phase	-Vaccinium caespitosum phase	-dwarf huckleberry phase
660	ABLA/LIBO h.t.	Abies lasiocarpa/Linnaea borealis h.t.	subalpine fir/twinflower
661	-LIBO phase	-Linnaea borealis phase	-twinflower
663	-VASC phase	-Vaccinium scoparium phase	-grouse whortleberry phase
670	ABLA/MEFE h.t.	Abies lasiocarpa/Menziesia ferruginea h.t.	subalpine fir/menziesia
690	ABLA/XETE h.t.	Abies lasiocarpa/Xerophyllum tenax h.t.	subalpine fir/beargrass
691	-VAGL phase	-Vaccinium globulare phase	-blue huckleberry phase
692	-VASC phase	-Vaccinium scoparium phase	-grouse whortleberry phase
720	ABLA/VAGL	Abies lasiocarpa/Vaccinium globulare h.t.	subalpine fir/blue huckleberry
730	ABLA/VASC h.t.	Abies lasiocarpa/Vaccinium scoparium h.t.	subalpine fir/grouse whortleberry
731	-CARU phase	-Calamagrostis rubescens phase	-pinegrass phase
732	-VASC phase	-Vaccinium scoparium phase	-grouse whortleberry phase
733	-THOC phase	-Thalicturm occidentale phase	-western meadowrue phase
740	ABLA/ALSI h.t.	Abies lasiocarpa/Alnus sinuata h.t.	subalpine fir/Sitka alder
750	ABLA/CARU h.t.	Abies lasiocarpa/Calamagrostis rubescens h.t.	subalpine fir/pinegrass
770	ABLA/CLPS h.t.	Abies lasiocarpa/Clematis pseudoalpina h.t.	subalpine fir/virgin's bower
780	ABLA/ARCO h.t.	Abies lasiocarpa/Arnica cordifolia h.t.	subalpine fir/heartleaf arnica
790	ABLA/CAGE h.t.	Abies lasiocarpa/Carex geyeri h.t.	subalpine fir/elk sedge
791	-CAGE phase	-Carex geyeri phase	-elk sedge phase
792	-PSME phase	-Pseudotsuga menziesii phase	-Douglas-fir phase
		Upper subalpine h.t.'s	
810	ABLA/RIMO h.t.	Abies lasiocarpa/Ribes montigenum h.t.	subalpine fir/mountain gooseberry
820	ABLA-PIAL/VASC h.t.	Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium h.t.	subalpine fir-whitebark pine/grouse whortleberry
830	ABLA/LUHI h.t.	Abies lasiocarpa/Luzula hitchcockii h.t.	subalpine fir/smooth wood-rush
831	-VASC	-Vaccinium scoparium phase	-grouse whortleberry phase
832	-MEFE phase	-Menziesia ferruginea phase	-menziesia phase
890		Timberline h.t.'s.	
850	PIAL-ABLA h.t.'s.	Pinus albicaulis-Abies lasiocarpa h.t.'s.	whitebark pine-subalpine fir
860	LALY-ABLA h.t.'s.	Larix lyallii-Abies lasiocarpa h.t.'s.	alpine larch-subalpine fir
870	PIAL h.t.'s.	Pinus albicaulis h.t.'s.	whitebark pine

(con.)

ADP code[1]	Abbreviation	Habitat types and phases: Scientific names	Habitat types and phases: Common names
900		PINUS CONTORTA CLIMAX SERIES	
910	PICO/PUTR h.t.	Pinus contorta/Purshia tridentata h.t.	lodgepole pine/bitterbrush
920	PICO/VACA c.t.	Pinus contorta/Vaccinium caespitosum c.t.	lodgepole pine/twinflower
930	PICO/LIBO c.t.	Pinus contorta/Linnaea borealis c.t.	lodgepole pine/twinflower
940	PICO/VASC c.t.	Pinus contorta/Vaccinium scoparium c.t.	lodgepole pine/grouse whortleberry
950	PICO/CARU c.t.	Pinus contorta/Calamagrostis rubescens c.t.	lodgepole pine/pinegrass
II. BEARPAW MOUNTAINS[3]			
		PINUS PONDEROSA CLIMAX SERIES	
	PIPO/AGSP h.t.	Pinus ponderosa/Agropyron spicatum h.t.	ponderosa pine/bluebunch wheatgrass
	PIPO/FEID h.t.	Pinus ponderosa/Festuca idahoensis h.t.	ponderosa pine/Idaho fescue
	-FESC phase	-Festuca scabrella phase	-rough fescue phase
	PIPO/AMAL h.t.	Pinus ponderosa/Amelanchier alnifolia h.t.	ponderosa pine/serviceberry
		PSEUDOTSUGA MENZIESII CLIMAX SERIES	
	PSME/SYOC h.t.	Pseudotsuga menziesii/Symphoricarpos occidentalis h.t.	Douglas-fir/western snowberry
	-CHVI phase	-Chrysopsis villosa phase	-hairy golden aster phase
	PSME/AMAL h.t.	Pseudotsuga menziesii/Amelanchier alnifolia h.t.	Douglas-fir/serviceberry
	PSME/VICA h.t.	Pseudotsuga menziesii/Viola canadensis h.t.	Douglas-fir/Canadian violet
	PSME/LIBO h.t.	Pseudotsuga menziesii/Linnaea borealis h.t.	Douglas-fir/twinflower
	-CARU phase	-Calamagrostis rubescens phase	-pinegrass phase
	PSME/COCA h.t.	Pseudotsuga menziesii/Cornus canadensis h.t.	Douglas-fir/bunchberry dogwood
	-LIBO phase	-Linnaea borealis phase	-twinflower phase
	-VAMY phase	-Vaccinium myrtillus phase	-Myrtle whortleberry phase
		PICEA CLIMAX SERIES	
	PICEA/JUCO s.t.	Picea/Juniperus communis s.t.	spruce/common juniper
	PICEA/LIBO h.t.	Picea/Linnaea borealis h.t.	spruce/twinflower
		ABIES LASIOCARPA CLIMAX SERIES	
	ABLA/JUCO s.t.	Abies lasiocarpa/Juniperus communis s.t.	subalpine fir/common juniper
	ABLA/LIBO h.t.	Abies lasiocarpa/Linnaea borealis h.t.	subalpine fir/twinflower
III. LITTLE ROCKY MOUNTAINS[3]			
		PONDEROSA PINE CLIMAX SERIES	
	PIPO/JUHO h.t.	Pinus ponderosa/Juniperus horizontalis h.t.	ponderosa pine/horizontal juniper
	PIPO/SYOC h.t.	Pinus ponderosa/Symphoricarpos occidentalis h.t.	ponderosa pine/western snowberry
	PIPO/ARUV h.t.	Pinus ponderosa/Arctostaphylos uva-ursi h.t.	ponderosa pine/kinnikinnick
	PIPO/BERE h.t.	Pinus ponderosa/Berberis repens h.t.	ponderosa pine/creeping holly grape
		PINUS CONTORTA CLIMAX SERIES	
	PICO/JUCO h.t.	Pinus contorta/Juniperus communis h.t.	lodgepole pine/common juniper
	PICO/LIBO h.t.	Pinus contorta/Linnaea borealis h.t.	lodgepole pine/twinflower
		PSEUDOTSUGA MENZIESII CLIMAX SERIES	
	PSME/SYOC h.t.	Pseudotsuga menziesii/Symphoricarpos occidentalis h.t.	Douglas-fir/western snowberry
	-SHCA phase	-Shepherdia canadensis phase	-russet buffaloberry phase
	PSME/ARUV h.t.	Pseudotsuga menziesii/Arctostaphylos uva-ursi h.t.	Douglas-fir/kinnikinnick
	PSME/BERE h.t.	Pseudotsuga menziesii/Berberis repens h.t.	Douglas-fir/creeping holly grape
	-ARUV phase	-Arctostophylos uva-ursi phase	-kinnikinnick phase
	-BERE phase	-Berberis repens phase	-creeping holly grape phase
	PSME/LIBO h.t.	Pseudotsuga menziesii/Linnaea borealis h.t.	Douglas-fir-twinflower
	-ARUV phase	-Arctostaphylos uva-ursi phase	-kinnikinnick phase

(con.)

Appendix A. (con.)

ADP code[1]	Abbreviation	Habitat types and phases: Scientific names	Common names
IV. MISSOURI RIVER BREAKS[4]			
		PINUS PONDEROSA CLIMAX SERIES	
	PIPO/JUSC h.t.	Pinus ponderosa/Juniperus scopulorum h.t.	ponderosa pine/Rocky Mountain juniper
		PSEUDOTSUGA MENZIESII CLIMAX SERIES	
	PSME/JUSC h.t.	Pseudotsuga menziesii/Juniperus scopulorum h.t.	Douglas-fir/Rocky Mountains juniper
	PSME/MUCU h.t.	Pseudotsuga menziesii/Muhlenbergia cuspidata h.t.	Douglas-fir/plins muhly

[1]Automatic data processing codes for National Forest System use.
[2]Pfister and others 1977.
[3]Roberts 1980.
[4]Roberts and Sibbernsen 1979.

APPENDIX B. HABITAT TYPE FIRE GROUPS FOR MONTANA FORESTS

Fire Group 0 – Miscellaneous special habitats:
Scree;
Forested rock;
Meadow;
Grassy bald;
Alder glade;
Aspen grove.

Fire Group 1 – Dry limber pine habitat types:
Pinus flexilis/Agropyron spicatum (PIFL/AGSP; limber pine/bluebunch wheatgrass)
Pinus flexilis/Festuca idahoensis h.t.-*Festuca idahoensis* phase (PIFL/FEID-FEID; limber pine/Idaho fescue-rough fescue phase)
Pinus flexilis/Festuca idahoensis h.t.-*Festuca scabrella* phase (PIFL/FEID-FESC; limber pine/Idaho fescue-rough fescue phase)
Pinus flexilis/Juniperus communis h.t. (PIFL/JUCO; limber pine/common juniper)

Fire Group 2 – Warm, dry ponderosa pine habitat types:
Pinus ponderosa/Andropogon spp. h.t. (PIPO/AND; ponderosa pine/bluestem)
Pinus ponderosa/Agropyron spicatum h.t. (PIPO/AGSP; ponderosa pine/bluebunch wheatgrass)
Pinus ponderosa/Festuca idahoensis h.t.-*Festuca idahoensis* phase (PIPO/FEID-FEID; ponderosa pine/Idaho fescue-Idaho fescue phase)
Pinus ponderosa/Festuca idahoensis h.t.-*Festuca scabrella* phase (PIPO/FEID-FESC; ponderosa pine/Idaho fescue-rough fescue phase)
Pinus ponderosa/Purshia tridentata h.t.-*Agropyron spicatum* phase (PIPO/PUTR-AGSP; ponderosa pine/bitterbrush-bluebunch wheatgrass phase)
Pinus ponderosa/Purshia tridentata h.t.-*Festuca idahoensis* phase (PIPO/PUTR-FEID; ponderosa pine/bitterbrush-Idaho fescue phase)
Pinus ponderosa/Symphoricarpos albus h.t.-*Symphoricarpos albus* phase (PIPO/SYAL-SYAL; ponderosa pine/snowberry-snowberry phase) *Pinus ponderosa/Symphoricarpos occidentalis* h.t. (PIPO/SYOC; ponderosa pine/western snowberry)
Pinus ponderosa/Arctostaphylos uva-ursi h.t. (PIPO/ARUV; ponderosa pine/kinnikinnick)
Pinus ponderosa/Juniperus horizontalis h.t. (PIPO/JUHO; ponderosa pine/horizontal juniper)
Pinus ponderosa/Juniperus scopulorum h.t. (PIPO/JUSC; ponderosa pine/Rocky Mountain juniper)

Fire Group 3 – Warm, moist ponderosa pine habitat types:
Pinus ponderosa/Symphoricarpos albus h.t.-*Berberis repens* phase (PIPO/SYAL-BERE; ponderosa pine/snowberry-creeping Oregon grape phase)
Pinus ponderosa/Berberis repens h.t. (PIPO/BERE; ponderosa pine/creeping holly grape)
Pinus ponderosa/Amelanchier alnifolia h.t. (PIPO/AMAL; ponderosa pine/serviceberry)
Pinus ponderosa/Prunus virginiana h.t.-*Prunus virginiana* phase (PIPO/PRVI-PRVI; ponderosa pine/chokecherry-chokecherry phase)
Pinus ponderosa/Prunus virginiana h.t.-*Shepherdia canadensis* phase (PIPO/PRVI-SHCA; ponderosa pine/chokecherry-buffaloberry phase

Fire Group 4 – Warm, dry Douglas-fir habitat types:
Pseudotsuga menziesii/Agropyron spicatum h.t. (PSME/AGSP; Douglas-fir/bluebunch wheatgrass)
Pseudotsuga menziesii/Festuca scabrella h.t. (PSME/FESC; Douglas-fir/rough fescue)
Pseudotsuga menziesii/Physocarpus malvaceus h.t.-*Calamagrostis rubescens* phase (PSME/PHMA-CARU; Douglas-fir/ninebark-pinegrass phase)
Pseudotsuga menziesii/Symphoricarpos albus h.t.-*Agropyron spicatum* phase (PSME/SYAL-AGSP; Douglas-fir/snowberry-bluebunch wheatgrass phase)
Pseudotsuga menziesii/Symphoricarpos occidentalis h.t.-*Chrysopsis villosa* phase (PSME/SYOC-CHVI; Douglas-fir/western snowberry-hairy golden aster phase)
Pseudotsuga menziesii/Symphoricarpos occidentalis h.t.-*Shepherdia canadensis* phase (PSME/SYOC-SHCA; Douglas-fir/western snowberry-russet buffaloberry phase)
Pseudotsuga menziesii/Calamagrostis rubescens h.t.-*Agropyron spicatum* phase (PSME/CARU-AGSP; Douglas-fir/pinegrass-bluebunch wheatgrass phase)
Pseudotsuga menziesii/Calamagrostis rubescens h.t.-*Pinus ponderosa* phase (PSME/CARU-PIPO; Douglas-fir/pinegrass-ponderosa pine phase)
Pseudotsuga menziesii/Spiraea betulifolia h.t. (PSME/SPBE; Douglas-fir/white spiraea)
Pseudotsuga menziesii/Arctostaphylos uva-ursi h.t. (PSME/ARUV; Douglas-fir/kinnikinnick)
Pseudotsuga menziesii/Berberis repens h.t.-*Arctostaphylos uva-ursi* phase (PSME/BERE-ARUV; Douglas-fir/creeping holly grape- kinnikinnick phase)
*Pseudotsuga menziesii/*Berberis repens h.t.-*Berberis repens* phase (PSME/BERE-BERE; Douglas-fir/creeping holly grape-creeping holly grape phase)
Pseudotsuga menziesii/Juniperus scopularum h.t. (PSME/JUSC; Douglas-fir/Rocky Mountain juniper)
Pseudotsuga menziesii/Muhlenbergia cuspidata h.t. (PSME/MUCU; Douglas-fir/plains muhly)

Fire Group 5 – Cool, dry Douglas-fir habitat types:
Pseudotsuga menziesii/Calamgrostis rubescens h.t.-*Agropyron spicatum* phase (PSME/CARU-AGSP, Douglas-fir/pinegrass-bluebunch wheatgrass phase)
Pseudotsuga menziesii/Festuca idahoensis h.t. (PSME/FEID; Douglas-fir/Idaho fescue)
Pseudotsuga menziesii/Carex geyeri h.t. (PSME/CAGE; Douglas-fir/elk sedge
Pseudotsuga menziesii/Arnica cordifolia h.t. (PSME/ARCO; Douglas-fir/heartleaf arnica)
Pseudotsuga menziesii/Symphoricarpos oreophilus h.t. (PSME/SYOR; Douglas-fir/mountain snowberry)
Picea/Senecio streptanthifolius h.t.-*Pseudotsuga menziesii* phase (PICEA/SEST-PSME; spruce/cleft-leaf groundsel-Douglas-fir phase)

Fire Group 6 – Moist Douglas-fir habitat types:
Pseudotsuga menziesii/Physocarpus malvaceus h.t.-*Physocarpus malvaceus* phase (PSME/PHMA-PHMA; Douglas-fir/ninebark-ninebark phase)
Pseudotsuga menziesii/Viola canadensis h.t. (PSME/VICA; Douglas-fir/Canadian violet)

(con.)

Pseudotsuga menziesii/Vaccinium globulare h.t.-*Vaccinium globulare* phase (PSME/VAGL-VAGL; Douglas-fir/blue huckleberry-blue huckleberry phase)
Pseudotsuga menziesii/Vaccinium globulare h.t.-*Arctostaphylos uva-ursi* phase (PSME/VAGL-ARUV; Douglas-fir/blue huckleberry- kinnikinnick phase)
Pseudotsuga menziesii/Vaccinium globulare h.t.-*Xerophyllum tenax* phase (PSME/VAGL-XETE; Douglas-fir/blue huckleberry-beargrass phase)
Pseudotsuga menziesii/Linnaea borealis h.t.-*Symphoricarpos albus* phase (PSME/LIBO-SYAL; Douglas-fir/twinflower-snowberry phase)
Pseudotsuga menziesii/Linnaea borealis, Arctostaphylos uva-ursi phase (PSME/LIBO-ARUV; Douglas-fir/twinflower-kinnikinnick phase)
Pseudotsuga menziesii/Linnaea borealis h.t.-*Calamagrostis rubescens* phase (PSME/LIBO-CARU; Douglas-fir/twinflower- pinegrass phase)
Pseudotsuga menziesii/Linnaea borealis h.t.-*Vaccinium globulare* phase (PSME/LIBO-VAGL; Douglas-fir/twinflower-blue huckleberry phase)
Pseudotsuga menziesii/Symphoricarpos albus h.t.-*Calamagrostis rubescens* phase (PSME/SYAL-CARU; Douglas-fir/snowberry-pinegrass phase)
Pseudotsuga menziesii/Symphoricarpos albus h.t.-*Symphoricarpos albus* phase (PSME/SYAL-SYAL; Douglas-fir/snowberry-snowberry phase)
Pseudotsuga menziesii/Amelanchier alnifolia h.t. (PSME/AMAL; Douglas-fir/serviceberry)
Pseudotsuga menziesii/Calamagrostis rubescens h.t.-*Arctostaphylos uva-ursi* phase (PSME/CARU-ARUV; Douglas-fir/pinegrass-kinnikinnick phase)
Pseudotsuga menziesii/Calamagrostis rubescens h.t.-*Calamagrostis rubescens* phase (PSME/CARU-CARU; Douglas-fir/pinegrass-pinegrass phase)
Pseudotsuga menziesii/Vaccinium caespitosum h.t. (PSME/VACA; Douglas-fir/dwarf huckleberry)
Pseudotsuga menziesii/Juniperus communis h.t. (PSME/JUCO; Douglas-fir/common juniper)

Fire Group 7 – Cool habitat types usually dominated by lodgepole pine:
Pseudotsuga menziesii/Juniperus communis h.t. (PSME/JUCO; Douglas-fir/common juniper)
Pseudotsuga menziesii/Vaccinium caespitosum h.t. (PSME/VACA; Douglas-fir/dwarf huckleberry)
Pseudotsuga menziesii/Cornus canadensis h.t.-*Linnaea borealis* phase (PSME/COCA-LIBO; Douglas-fir/bunchberry dogwood-twinflower phase)
Pseudotsuga menziesii/Cornus canadensis h.t.-*Vaccinium myrtillus* phase (PSME/COCA-VAMY; Douglas-fir/bunchberry dogwood-myrtle whortleberry phase)
Picea/Vaccinium caespitosum h.t. (PICEA/VACA; spruce/dwarf huckleberry)
Picea/Linnaea borealis h.t. (PICEA/LIBO; spruce/twinflower)
Abies lasiocarpa/Vaccinium caespitosum h.t. (ABLA/VACA; subalpine fir/dwarf huckleberry)
Abies lasiocarpa/Calamagrostis canadensis h.t.-*Vaccinium caespitosum* phase (ABLA/CACA-VACA; subalpine fir/bluejoint-dwarf huckleberry phase)
Abies lasiocarpa/Linnaea borealis h.t.-*Vaccinium scoparium* phase (ABLA/LIBO-VASC; subalpine fir/twinflower-grouse whortleberry phase)
Abies lasiocarpa/Xerophyllum tenax h.t.-*Vaccinium scoparium* phase (ABLA/XETE-VASC; subalpine fir/beargrass-grouse whortleberry phase)
Abies lasiocarpa/Vaccinium globulare h.t. (ABLA/VAGL; subalpine fir/blue huckleberry)
Abies lasiocarpa/Vaccinium scoparium h.t.-*Calamagrostis rubescens* phase (ABLA/VASC-CARU; subalpine fir/grouse whortleberry- pinegrass phase)
Abies lasiocarpa/Vaccinium scoparium h.t.-*Vaccinium scoparium* phase (ABLA/VASC-VASC; subalpine fir/grouse whortleberry-grouse whortleberry phase)
Abies lasiocarpa/Carex geyeri h.t.-*Carex geyeri* phase (ABLA/CAGE-CAGE; subalpine fir/elk sedge-elk sedge phase)
Pinus contorta/Purshia tridentata h.t. (PICO/PUTR; lodgepole pine/bitterbrush)
Pinus contorta/Vaccinium caespitosum h.t. (PICO/VACA; lodgepole pine/dwarf huckleberry)
Pinus contorta/Linnaea borealis h.t. (PICO/LIBO; lodgepole pine/twinflower)
Pinus contorta/Vaccinium scoparium h.t. (PICO/VASC; lodgepole pine/grouse whortleberry)
Pinus contorta/Calamagrostis rubescens h.t. (PICO/CARU; lodgepole pine/pinegrass)
Pinus contorta/Juniperus communis h.t. (PICO/JUCO; lodgepole pine/common juniper)

Fire Group 8 – Dry, lower subalpine habitat types:
Picea/Linnaea borealis h.t. (PICEA/LIBO; spruce/twinflower)
Picea/Physocarpus malvaceus h.t. (PICEA/PHMA; spruce/ninebark)
Picea/Smelacina stellata h.t. (PICEA/SMST spruce/starry Solomon's seal)
Abies lasiocarpa/Xerophyllum tenax h.t.-*Vaccinium globulare* phase (ABLA/XETE-VAGL; subalpine fir/beargrass-blue huckleberry phase)
Tsuga mertensiana/Xerophyllum tenax h.t. (TSME/XETE; mountain hemlock/beargrass)
Abies lasiocarpa/Vaccinium scoparium h.t.-*Thalictrum occidentale* phase (ABLA/VASC-THOC; subalpine fir/grouse whortleberry-western meadowrue phase)
Abies lasiocarpa/Calamagrostis rubescens h.t. (ABLA/CARU; subalpine fir/pinegrass)
Abies lasiocarpa/Clematis pseudoalpina h.t. (ABLA/CLPS; subalpine fir/virgin's bower)
Abies lasiocarpa/Arnica cordifolia h.t. (ABLA/ARCO; subalpine fir/heartleaf arnica)
Abies lasiocarpa/Carex geyeri h.t.-*Pseudotsuga menziesii* phase (ABLA/CAGE-PSME; subalpine fir/elk sedge-Douglas-fir phase)

Fire Group 9 – Moist, lower subalpine habitat types:
Picea/Equisetum arvense h.t. (PICEA/EQAR; spruce/common horsetail)
Picea/Clintonia uniflora h.t.-*Vaccinium caespitosum* phase (PICEA/CLUN-VACA; spruce/queencup beadlily-dwarf huckleberry phase)

(con.)

Picea/Clintonia uniflora h.t.-*Clintonia uniflora* phase (PICEA/CLUN-CLUN; spruce/queencup beadlily-queencup beadlily phase)
Picea/Galium triflorum h.t. (PICEA/GATR; spruce/sweetscented bedstraw)
Abies lasiocarpa/Oplopanox horridus h.t. (ABLA/OPHO; subalpine fir/devil's club)
Abies lasiocarpa/Clintonia uniflora h.t.-*Clintonia uniflora* phase (ALBA/CLUN-CLUN; subalpine fir/queencup beadlily-queencup beadlily phase)
Abies lasiocarpa/Clintonia uniflora h.t.-*Aralia nudicaulis* phase (ABLA/CLUN-ARNU; subalpine fir/queencup beadlily-wild sarsaparilla phase)
Abies lasiocarpa/Clintonia uniflora h.t.-*Vaccinium caespitosum* phase (ABLA/CLUN-VACA; subalpine fir/queencup beadlily-dwarf huckleberry phase)
Abies lasiocarpa/Clintonia uniflora h.t.-*Xerophyllum tenax* phase (ABLA/CLUN-XETE; subalpine fir/queencup beadlily-beargrass phase)
Abies lasiocarpa/Clintonia uniflora h.t.-*Menziesia ferruginea* phase (ABLA/CLUN-MEFE; subalpine fir/queencup beadlily-menziesia phase)
Abies lasiocarpa/Galium triflorum h.t. (ABLA/GATR; subalpine fir/sweetscented bedstraw)
Abies lasiocarpa/Calamagrostis canadensis h.t.-*Calamagrostis canadensis* phase (ABLA/CACA-CACA; subalpine fir/bluejoint-bluejoint phase)
Abies lasiocarpa/Calamagrostis canadensis h.t.-*Galium triflorum* phase (ABLA/CACA-GATR; subalpine fir/bluejoint-sweetscented bedstraw phase)
Abies lasiocarpa/Linnaea borealis h.t. (ABLA/LIBO; subalpine fir/twinflower)
Abies lasiocarpa/Linnaea borealis h.t.-*Linnaea borealis* phase (ABLA/LIBO-LIBO; subalpine fir/twinflower-twinflower phase)
Abies lasiocarpa/Linnaea borealis h.t.-*Xerophyllum tenax* phase (ABLA/LIBO-XETE; subalpine fir/twinflower-beargrass phase)
Abies lasiocarpa/Menziesia ferruginea h.t. (ABLA/MEFE; subalpine fir/menzeisia phase)
Tsuga mertensiana/Menziesia ferruginea h.t. (TSME/MEFE; mountain hemlock/menzieia)
Abies lasiocarpa/Alnus sinuata h.t. (ABLA/ALSI; subalpine fir/Sitka alder)

Fire Group 10 – Cold, moist upper subalpine and timberline habitat types:
Picea/Senecio streptanthifolius h.t.-*Picea* phase (PICEA/SEST-PICEA; spruce/cleft-leaf groundsel-spruce phase)
Picea/Juniperus communis h.t. (PICEA/JUCO; spruce/common juniper)
Abies lasiocarpa/Ribes montigenum h.t. (ABLA/RIMO; subalpine fir/mountain gooseberry)
Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium h.t. (ABLA-PIAL/VASC; subalpine fir-whitebark pine/grouse whortleberry)
Abies lasiocarpa/Luzula hitchcockii h.t.-*Vaccinium scoparium* phase (ABLA/LUHI-VASC; subalpine fir/smooth woodrush-grouse whortleberry phase)
Abies lasiocarpa/Luzula hitchcockii h.t.-*Menziesia ferruginea* phase (ABLA/LUHI-MEFE; subalpine fir/smooth woodrush-menziesia phase)
Abies lasiocarpa/Juniperus communis h.t. (ABLA/JUCO; subalpine fir/common juniper)
Tsuga mertensiana/Luzula hitchcockii h.t.-*Vaccinium scorparium* phase (TSME/LUHI-VASC; mountain hemlock/smooth woodrush-grouse whortleberry phase)
Tsuga mertensiana/Luzula hitchcockii h.t.-*Menziesia ferruginea* phase (TSME/LUHI-MEFE; mountain hemlock/smooth woodrush-menziesia phase)
Pinus albicaulis-Abies lasiocarpa h.t.'s (PIAL-ABLA h.t.'s; whitebark pine-subalpine fir)
Larix lyallii-Abies lasiocarpa h.t.'s (LALY-ABLA h.t.'s; alpine larch-subalpine fir)
Pinus albicaulis h.t.'s (PIAL h.t.'s; whitebark pine)

Fire Group 11 – Warm, moist grand fir, western hemlock, and western redcedar habitat types:
Abies grandis/Xerophyllum tenax h.t. (ABGR/XETE; grand fir/beargrass)
Abies grandis/Clintonia uniflora h.t.-*Clintonia uniflora* phase (ABGR/CLUN-CLUN; grand fir/queencup beadlily-queencup beadlily phase)
Abies grandis/Clintonia uniflora h.t.-*Aralia nudicaulis* phase (ABGR/CLUN-ARNU; grand fir/queencup beadlily-wild sarsaparilla phase)
Abies grandis/Clintonia uniflora h.t.-*Xerophyllum tenax* phase (ABGR/CLUN-XETE; grand fir/queencup beadlily-beargrass phase)
Abies grandis/Linnaea borealis h.t.-*Linnaea borealis* phase (ABRG/LIBO-LIBO; grand fir/twinflower-twinflower phase)
Abies grandis/Linnaea borealis h.t.-*Xerophyllum tenax* phase (ABGR/LIBO-XETE; grand fir/twinflower-beargrass phase)
Thuja plicata/Clintonia uniflora h.t.-*Clintonia uniflora* phase (THPL/CLUN-CLUN; western redcedar/queencup beadlily-queencup beadlily phase)
Thuja plicata/Clintonia uniflora h.t.-*Aralia nudicaulis* phase (THPL/CLUN-ARNU; western redcedar/queencup beadlily-wild sarsaparilla phase)
Thuja plicata/Clintonia uniflora h.t.-*Menziesia ferruginea* phase (THPL/CLUN-MEFE; western redcedar/queencup beadlily-menziesia phase)
Thuja plicata/Oplopanax horridus h.t. (THPL/OPHO; western redcedar/devil's club)
Tsuga heterophylla/Clintonia uniflora h.t.-*Clintonia uniflora* phase (TSHE/CLUN-CLUN; western hemlock/queencup beadlily- queencup beadlily phase)
Tsuga heterophylla/Clintonia uniflora h.t.-*Aralia nudicaulis* phase (TSHE/CLUN-ARNU; western hemlock/queencup beadlily-wild sarsaparilla phase)

APPENDIX C. SCIENTIFIC NAMES OF PLANTS MENTIONED IN TEXT

Common name	Scientific name
Alder	Alnus spp.
Alpine larch	Larix lyallii
Alpine wintergreen	Gaultherea humifusa
Antelope bitterbrush	Balsamorhiza sagittata
Arrowleaf groundsel	Senecio triangularis
Ballhead sandwort	Arenaria congesta
Beargrass	Xerophyllum tenax
Big sagebrush	Artemisia tridentata
Black cottonwood	Populus trichocarpa
Blue huckleberry	Vaccinium globulare
Bluebunch wheatgrass	Agropyron spicatum
Bluejoint	Calamagrostis canadensis
Bluestem	Andropogon spp.
Broadleaf arnica	Arnica latifolia
Bunchberry dogwood	Cornus canadensis
Canadian violet	Viola canadensis
Chokecherry	Prunus virginiana
Cleft-leaf groundsel	Senecio streptanthifolius
Common horsetail	Equisetum arvense
Common juniper	Juniperus communis
Creeping holly grape	Berberis repens
Creeping juniper	Juniperus horizontalis
Creeping Oregon grape	Berberis repens
Douglas-fir	Pseudotsuga menziesii
Dwarf huckleberry	Vaccinium caespitosum
Elk sedge	Carex geyeri
Elkweed	Frasera speciosa
Engelmann spruce	Picea engelmannii
Fairy bells	Disporum trachycarpum
False Solomon's seal	Smilacina racemosa
Grouse whortleberry	Vaccinium scoparium
Hairy goldenaster	Chrysopsis villosa
Heartleaf arnica	Arnica cordifolia
Horizontal juniper	Juniperus horizontalis
Idaho fescue	Festuca idahoensis
Junegrass	Koeleria cristata
Kinnikinnick	Arctostaphylos uva-ursi
Limber pine	Pinus flexilis
Lodgepole pine	Pinus contorta
Mountain arnica	Arnica latifolia
Mountain death camas	Zigadenus elegans
Mountain gooseberry	Ribes montigenum
Mountain lover	Pachistima myrsinites
Mountain snowberry	Symporicarpos oreophilus
Myrtle whortleberry	Vaccinium myrtillus
Ninebark	Physocarpus malvaceus
Northern bedstraw	Galium boreale
Oceanspray	Holodiscus discolor
Paper birch	Betula papyrifera
Parry rush	Juncus parryi
Pinegrass	Calamagrostis rubescens
Plains muhly	Muhlenbergia cuspidata
Ponderosa pine	Pinus ponderosa
Prickly currant	Ribes lacustre
Pussytoes	Antennaria racemosa
Quaking aspen	Populus tremuloides
Queencup beadlily	Clintonia uniflora
Red baneberry	Actaea rubra
Red mountain heath	Phyllodoce empetriformis
Redoiser dogwood	Cornus stolonifera
Richardson's geranium	Geranium richardsonii
Rocky Mountain juniper	Juniperus scopulorum
Ross sedge	Carex rossii
Rough fescue	Festuca scabrella
Russet buffaloberry	Shepherdia canadensis
Serviceberry	Amelanchier alnifolia
Showy aster	Aster conspicuus
Shrubby cinquefoil	Potentilla fruticosa
Sidebells pyrola	Pyrola secunda
Sitka alder	Alnus sinuata
Slender hawkweed	Hieracium gracile
Smooth woodrush	Luzula hitchcockii
Snowberry	Symphoricarpos albus
Spike trisetum	Trisetum spicatum
Spreading dogbane	Apocynum androsaemilifolium
Starry Solomon's seal	Smilacina stellata
Strawberry	Fragaria spp.
Subalpine fir	Abies lasiocarpa
Swamp laurel	Kalmia polifolia
Sweet cicely	Osmorhiza chilensis
Sweetscented bedstraw	Galium triflorum
Thimbleberry	Rubus parviflorus
Timber milkvetch	Astragalus miser
Twinflower	Linnaea borealis
Twisted stalk	Streptopus amplexifolius
Utah honeysuckle	Lonicera utahensis
Valerian	Valeriana dioica
Valerian	Valeriana sitchensis
Virgin's bower	Clematis pseudoalpina
Wax currant	Ribes cereum
Western groundsel	Lithospermum ruderale
Western meadowrue	Thalictrum occidentale
Western snowberry	Symphoricarpos occidentalis
Wheeler bluegrass	Poa nervosa
White rhododendron	Rhododendron albiflorum
White spiraea	Spiraea betulifolia
White spruce	Picea glauca
Whitebark pine	Pinus albicaulis
Wild sarsaparilla	Aralia nudicaulis
Wild strawberry	Fragaria virginiana
Yellow mountain heath	Phyllodoce glandulifolia

Fischer, William C.; Clayton, Bruce D.Fire ecology of Montana forest habitat types east of the Continental Divide. Gen. Tech. Rep. INT-141. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 83 p.

Provides information on fire as an ecological factor for forest habitat types occurring east of the Continental Divide in Montana. Identifies "Fire Groups" of habitat types based on fire's role in forest succession. Describes forest fuels and suggests considerations for fire management.

KEYWORDS: fire ecology, forest ecology, forest fire, fire management, habitat types, forest fuels

☆ U.S. GOVERNMENT PRINTING OFFICE: 1983—676-032/1000 REGION No. 8