United States
Department
of Agriculture

Forest Service

Intermountain
Research Station

General Technical
Report INT-287

June 1992

Fire Ecology of Forests and Woodlands in Utah

Anne F. Bradley
Nonan V. Noste
William C. Fischer

THE AUTHORS

ANNE F. BRADLEY is currently a planning/appeals specialist for the Fisheries and Wildlife Management Staff of the Forest Service Pacific Southwest Region in San Francisco, CA. Her involvement with this report occurred while assigned as an ecologist in the Fire Effects: Prescribed Fire and Wildfire research work unit at the Intermountain Research Station, Intermountain Fire Sciences Laboratory, Missoula, MT. Anne earned a B.A. degree in biology from Colorado College and an M.A. degree in botany from the University of Montana. Early work assignments included that of a naturalist for the National Park Service, and as a biological technician and later as a botanist for the Intermountain Station.

NONAN V. NOSTE (retired) was a forester, Intermountain Research Station, Intermountain Fire Sciences Laboratory, Missoula, MT. During his Forest Service career, Nonan was involved in fire control research in Alaska; silviculture research in Wisconsin, and fire technology and fire effects and use research in Missoula. He earned B.S. and M.F. degrees in forestry from the University of Montana.

WILLIAM C. FISCHER is a research forester and team leader for the Fire Effects work unit at the Intermountain Research Station, Intermountain Fire Sciences Laboratory, Missoula, MT. He is a graduate of Paul Smith's College and the University of Michigan (B.S., B.S.F. 1956). Prior to joining the staff at the Fire Sciences Laboratory, he was employed in a variety of fire and resource management assignments with the Boise National Forest in Idaho.

RESEARCH SUMMARY

This report summarizes available information on fire as an ecological factor for forest habitat types and the unclassified pinyon-juniper and oak-maple woodlands occurring in Utah. Habitat types and the unclassified vegetative communities are assigned to Fire Groups based on fire's potential role in forest succession.

For each Fire Group, the authors discuss (1) the relationships of major tree species to fire, (2) forest fuels, (3) the natural role of fire, (4) fire's hypothetical role in forest succession, and (5) fire management considerations.

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Intermountain Research Station
324 25th Street
Ogden, UT 84401

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INTRODUCTION

This report summarizes the available fire ecology and management information relating to forest habitat types, montane oak-maple woodlands, and pinyon-juniper woodlands of Utah. Specifically, the report covers the Wasatch-Cache, Dixie, Fishlake, Manti-La Sal, Ashley, and Uinta National Forests and the Raft River Mountain portion of the Sawtooth National Forest, but it is also applicable to the forested portions of Zion and Bryce Canyon National Parks and Cedar Breaks National Monument. The primary purpose of this report is to promote the understanding of fire's role, particularly its influence on succession in the forests, pinyon-juniper woodlands, and oak-maple brushlands of Utah.

The habitat types recently described by Mauk and Henderson (1984), Youngblood and Mauk (1985), and to a limited extent the community types described by Padgett and others (1989) and by Mueggler (1989) are assigned to 13 "Fire Groups" based on the response of dominant tree species to fire and similarity of development in postfire succession. In Utah, neither pinyon-juniper woodlands nor montane woodlands dominated by Gambel oak or bigtooth maple have been classified by habitat type. These woodlands therefore have been assigned to Fire Groups on the basis of cover type. Both pinyon-juniper and oak-maple cover large acreages in the State.

The successional path taken by any given site following fire depends on many variables. The preburn vegetation, size and severity of the fire, topography, climate and soil, and chance all contribute to the process. Thus, a single habitat type may be a member of more than one Fire Group. The individual land manager must evaluate conditions on a site by site basis to determine the most likely results of fire. The groups defined in this report are offered as a general guide, not a definitive treatment.

Format

This report is patterned after "Fire Ecology of Montana Forest Habitat Types East of the Continental Divide" (Fischer and Clayton 1983). The major topics presented in this report are organized into sections, described below.

Relationship of Major Tree Species to Fire—This section discusses each principal tree species in Utah 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 summarizes the effect of fire on the response of important grass, forb, and shrub species associated with the major conifer 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.

Wildlife Response to Fire—This section contains brief summaries of the general effects of fire on common Utah mammals, reptiles, amphibians, and birds. Fire response of wildlife is largely inferred from expected changes in habitat as a result of fire.

Fire Use Considerations—This section summarizes cautions that apply to the use of fire for resource management purposes. Emphasis is on effective use of fire, site protection, minimizing damage to residual stand, and wildlife habitat protection.

Fire Groups—The Fire Groups (FG's) are defined with reference to "Coniferous Forest Habitat Types of Northern Utah" (Mauk and Henderson 1984), "Coniferous Forest Habitat Types of Central and Southern Utah" (Youngblood and Mauk 1985), "Aspen Community Types of the Intermountain Region" (Mueggler 1989), and "Riparian Community Types of Utah and Southeastern Idaho" (Padgett and others 1989). Generally, a habitat type or habitat type phase is assigned to only one Fire Group. Where exceptions to this rule occur, the exception is noted and explained. The forest habitat types assigned to the Utah Fire Groups are listed in appendix A and summarized in table 1. General descriptive literature was used to identify pinyon-juniper woodlands (FG 1) and oak-maple woodlands (FG 2), because

Table 1—Summary of Utah habitat type Fire Groups (see appendix A for formal listing of habitat types)

Habitat type
FIRE GROUP ZERO
Misc. special habitats
FIRE GROUP ONE
Pinyon-juniper woodlands
FIRE GROUP TWO
Montane maple-oak
FIRE GROUP THREE
PIPO/ARPA
PIPO/ARNO
PIPO/CAGE
PIPO/CELE
PIPO/FEID-ARPA
PIPO/FEID-ARTR
PIPO/FEID-FEID
PIPO/MUMO
PIPO/PUTR
PIPO/QUGQ-SYOR
PIPO/QUGQ-QUGA
PIPO/SYOR
FIRE GROUP FOUR
PSME/ARPA
PSME/BERE-CAGE
PSME/BERE-PIPO
PSME/CELE
PSME/CEMO
PSME/QUGA
PSME/SYOR
FIRE GROUP FIVE
PSME/ACGL
PSME/BERE-JUCO
PSME/BERE-SYOR
PSME/BERE-BERE
PSME/CARU
PSME/OSCH-PAMY
PSME/PHMA
PSME/PHMA-PAMY
FIRE GROUP SIX
ABCO/ACGL
ABCO/ARPA
ABCO/BERE-JUCO
ABCO/BERE-SYOR
ABCO/BERE-BERE
ABCO/CELE
ABCO/JUCO
ABCO/OSCH
ABCO/PHMA
ABCO/QUGA
ABCO/SYOR
PIPU/AGSP
PIPU/BERE
PIPU/JUCO
FIRE GROUP SEVEN
POTR/AMAL/PTAQ
POTR/AMAL/TALL FORB
POTR/AMAL/THFE
POTR/AMAL/CARU
POTR/AMAL-SYOR/TALL FORB
POTR/ARTR
POTR/CARU
POTR/CARO
POTR/FETH
POTR/TALL FORB
POTR/JUCO/CAGE
POTR/JUCO/LUAR
POTR/PTAQ
POTR/SARA
POTR/STCO
POTR/SYOR/CARO
POTR/SYOR/CARU
POTR/SYOR/THFE
POTR/SYOR/FETH
POTR/SYOR/TALL FORB
POTR/VECA
POTR-ABLA/AMAL
POTR-ABLA/CAGE
POTR-ABLA/CARO
POTR-ABLA/JUCO
POTR-ABLA/SYOR/THFE
POTR-ABLA/SYOR/TALL FORB
POTR-ABLA/TALL FORB
POTR-ABCO/ARPA
POTR-ABCO/POPR
POTR-ABCO/SYOR
POTR-PIPU
POTR-PICO
POTR-PICO/CAGE
POTR-PSME/AMAL
POTR-PSME/JUCO
POTR/ASMI
POTR/BRCA
POTR/JUCO/ASMI
FIRE GROUP EIGHT
ABLA/VACA
ABLA/VASC-VASC
PICO/ARUV
PICO/BERE
PICO/CACA
PICO/CARO
PICO/JUCO
PICO/VACA
PICO/VASC
PIEN/VACA
PIEN/VASC
FIRE GROUP NINE
PIFL/BERE
PIFL/CELE
FIRE GROUP TEN
ABLA/ACGL
ABLA/BERE-CAGE
ABLA/BERE-JUCO
ABLA/BERE-PIEN
ABLA/BERE-PIFL
ABLA/BERE-PSME
ABLA/BERE-RIMO
ABLA/BERE-BERE
ABLA/CAGE
ABLA/CARO
ABLA/CARU
ABLA/JUCO
ABLA/OSCH
ABLA/PERA-PSME
ABLA/PERE-PERA
ABLA/PHMA
ABLA/RIMO-MEAR
ABLA/RIMO-PICO
ABLA/RIMO-THFE
ABLA/RIMO-RIMO
ABLA/VACA
ABLA/VACA-PIEN
ABLA/VAGL
ABLA/VAMY
ABLA/VASC-ARLA
ABLA/VASC-CAGE
ABLA/VASC-VASC
FIRE GROUP ELEVEN
ABLA/ACCO
ABLA/ACRU
ABLA/CACA
ABLA/STAM
PIEN/EQAR
PIEN/CALE
PIPU/EQAR
CONIFER/COSE
CONIFER/ACCO
FIRE GROUP TWELVE
ABLA/RIMO-TRSP
ABLA/VASC-VASC
PIEN/RIMO
PIEN/VACA
PIEN/VASC

classification of these vegetation types in Utah is not complete.

Habitat types and community 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.

Vegetation—Following the list of habitat types that comprise each Fire Group, we describe the characteristic overstory and undergrowth vegetation for that Group. Climax and seral tree species are identified.

Forest Fuels—The fuels likely to occur in each Fire Group are characterized in this section. The emphasis is on downed and dead woody fuels. Live and standing dead fuels are also discussed where they contribute significantly to fire hazard. To date, there are no published summaries of fuel loadings by cover type or habitat type for coniferous forests and woodlands in Utah. Consequently, if applicable, fuel estimates from surrounding States are presented. For each Fire Group, we discuss the kind and amount of dead, woody material likely to be found on the forest floor.

Role of Fire—Information on the ecology of the important trees, fuel characteristics, and the results of fire history studies are integrated to describe the historical (presettlement period, generally prior to the mid-1800's) role of fire in shaping the vegetative composition of a particular Fire Group. This section is mainly a literature review covering succession and fire within the appropriate habitat types or plant communities.

Forest Succession—For each Fire Group, successional pathway flow charts represent a synthesis of both knowledge and speculation about the effects of fire at several points in the life history of a stand. They illustrate the many possible influences fires of varying severities have on stands of differing ages, densities, and species composition. The flow charts follow the method suggested by Kessell and Fischer (1981).

How trees respond to fire often depends on their size. Tree size classes used in our flow charts are: saplings—2 to 4 inches in diameter at breast height (d.b.h.); small poles—trees 4 to 8 inches d.b.h.; large poles—8 to 12 inches d.b.h. (Society of American Foresters, 1958).

The tree species names are symbolized in order to simplify the diagrams and flow charts. The symbols are defined as follows:

Abies concolor, white fir (ABCO)
Abies lasiocarpa, subalpine fir (ABLA)
Acer grandidentatum, bigtooth or canyon maple (ACGR)
Juniperus osteosperma, Utah juniper (JUOS)
Juniperus scopulorum, Rocky Mountain juniper (JUSC)
Picea engelmannii, Engelmann spruce (PIEN)
Picea pungens, blue spruce (PIPU)
Pinus contorta, lodgepole pine (PICO)
Pinus edulis, pinyon pine or two-needle pinyon (PIED)
Pinus flexilis, limber pine (PIFL)
Pinus longaeva, Western bristlecone (PILO)
Pinus monophylla, singleleaf pinyon (PIMO)
Pinus ponderosa, ponderosa pine (PIPO)
Populus tremuloides, aspen (POTR)
Pseudotsuga menziesii, Douglas-fir (PSME)
Quercus gambelii, Gambel oak (QUGA)

Fire Severity—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, or removes the entire duff layer, or both, over much of the area. Heat from the fire impacts the upper soil layer and often consumes the incorporated soil organic matter.

The amount of soil heating is critical to the survival of tree roots and resprouting undergrowth species. Observing soil surface characteristics after fire can help make predictions of postburn plant response more accurate. Ryan and Noste (1985) have presented some easily observable soil and fuel characteristics to determine the relative depth of char in different vegetation types (table 2).

Fire Management Considerations—This section discusses how the preceding information can be used to develop fire management plans that support land and resource management objectives. Suggestions given are offered as an aid to decision making, but for specific situations the manager must rely on personal experience to best determine how to use information presented in this document.

Table 2—Visual character of ground char from observation of depth of burn[1] (Ryan and Noste 1985)

Ground char class	Site		
	Timber/slash	**Shrub fields**	**Grasslands**
Unburned	The fire did not burn on the forest floor. Some damage may occur to vegetation due to radiated or convected heat from adjacent areas. Ten to 20 percent of the area within slash burns is commonly unburned.[2] There is a wide range in the percent of unburned area within fires in natural fuels.	See timber/slash	See timber/slash
Light ground char	Leaf litter is charred or consumed. Upper duff may be charred, but the duff layer is not altered over the entire depth. The surface generally appears black immediately after the fire. Woody debris is partially burned. Some small twigs and much of the branch wood remain. Logs are scorched or blackened but not charred. Crumbled, rotten wood is scorched to partially burned. Light ground char commonly makes up 0-100 percent of burned areas with natural fuels and 45-75 percent of slash areas.	Leaf litter is charred or consumed, and some leaf structure is still discernible. The surface is predominantly black, although some gray ash may be present immediately after the fire. Gray ash soon becomes inconspicuous. Charring may extend slightly into soil surface where leaf litter is sparse, but the mineral soil is not otherwise altered. Some leaves and small twigs remain on the plants. Burns are irregular and spotty. Less than 60 percent of the brush canopy is commonly consumed.	Litter is charred or consumed, but some plant parts are still discernible. Charring may extend slightly into the soil surface, but the mineral soil is not otherwise altered. Some plant parts may still be standing. Bases of plants are not deeply burned and are still recognizable. Surface is predominantly black immediately after the burn, but this soon becomes inconspicuous. Burns may be spotty to uniform, depending on the continuity of the grass.
Moderate ground char	Litter is consumed.[3] Duff is deeply charred or consumed but the underlying mineral soil is not visibly altered. Light-colored ash prevails immediately after the fire. Woody debris is largely consumed. Some branch wood is present, but no foliage or twigs remain. Logs are deeply charred.	Surface leaf litter is consumed. Some charred litter may remain but is sparse. Charring extends up to 0.5 inch into mineral soil but does not otherwise alter the mineral soil. Gray or white ash is conspicuous immediately after the burn, but this quickly disappears.	Litter is consumed, and the surface is covered with gray or white ash immediately after the burn. Ash soon disappears, leaving bare mineral soil. Charring extends slightly into mineral soil, but the plant parts are no longer discernible, no plant parts standing, and the bases of plants are burned to ground level.

(con.)

Table 2 (Con.)

Ground char class	Site: Timber/slash	Shrub fields	Grasslands
	Moderate ground char commonly occurs on 0-100 percent of natural burned areas and 10-75 percent on slash burns. Trees with lateral roots in the duff are often left on pedestals or topple. Burned-out stump holes are common.	Some charred stems remain on the plants, and these are generally greater than 0.25-0.50 inch in diameter. Burns are more uniform than in previous classes. Between 40 and 80 percent of the brush canopy is commonly consumed.	Plant bases are obscured in the ash immediately after burning. Burns tend to be uniform. Moderate ground char is generally limited to backing fires and fires burning during dry conditions.
Deep ground char	Litter and duff are completely consumed, and the top layer of mineral soil is visibly altered, often reddish. Structure of the surface soil may be altered. Below the colored zone 1 inch or more of the mineral soil is blackened from organic material that has been charred or deposited by heat conducted downward. Twigs and small branches are completely consumed. Few large branches may remain, but those are deeply charred. Sound logs are deeply charred, and rotten logs are completely consumed. Deep ground char occurs in scattered patches under slash concentrations or where logs or stumps produced prolonged, intense heat. Deep ground char generally covers less than 10 percent of natural and slash areas. One extreme case of 31 percent was reported in a slash burn. In extreme cases, clinkers or fused soil may be present. These are generally restricted to areas where slash was piled.	Leaf litter is completely consumed, leaving a fluffy white ash surface. All organic matter is consumed in the mineral soil to a depth of 0.5-1.0 inch. This is underlain by a zone of black organic material. Colloidal structure of the surface mineral soil may be altered. Large branches with main stems are burned, and only stubs greater than 0.5 inch in diameter remain.	Deep ground char is uncommon due to short burnout time of grasses. Surface consists of fluffy white ash immediately after the burn. This soon disappears leaving bare mineral soil. Charring extends up to 0.5 inch into soil. Soil structure is slightly altered (for consistency with other fuel types, no citations specifically mention soil alteration). Deep ground char is generally limited to situations where heavy loadings on mesic sites have burned under dry conditions and low wind.

[1]Visual characteristics were developed from the following literature sources and combined for consistency: Bever 1954; Tarrant 1956; Dyrness and Youngberg 1957; Bentley and Fenner 1958; Daubenmire 1968; Morris 1970; Ralston and Hatchell 1971; Vogl 1974; Wells and others 1979.

[2]The area coverage estimates for each of the ground char classes are ranges encountered in the literature and experienced by the authors. Obviously, any combination of depth of char classes is possible. The inclusion of these ranges points out the variability that may be encountered within a given fuel situation.

[3]Some late-season fires have been observed to spread by glowing combustion in the duff, leaving the charred remains of the litter on top of the mineral soil and ash. This should not be confused with light ground char because temperature measurements indicate a considerable heat pulse is received by the mineral soil.

Nomenclature

The common names of trees and the scientific names of shrubs and herbaceous plants are used throughout the text of the report. Corresponding scientific plant names and common names used in the text are listed in appendix B. Nomenclature generally follows "Utah Flora" (Welsh and others 1987) except as otherwise noted. A major exception is the nomenclature for genera of perennial Triticeae, which follows Barkworth and Dewey (1985). Little (1979) is our authority for trees and for classifying woody species as either trees or shrubs. Scientific and common names of habitat types are as presented in the habitat type classification source documents cited in the Introduction of this report.

RELATIONSHIPS OF MAJOR TREE SPECIES TO FIRE

Wildfire has played a major role in forest succession throughout the Western United States, including forests and woodlands in Utah. Lodgepole pine, for example, owes much of its widespread occurrence to past fire. Without fire, Douglas-fir and white fir would dominate many areas where ponderosa pine is now the prevalent overstory species. Periodic fires rejunvenate decadent seral aspen stands. Fire also favors Engelmann spruce at the expense of subalpine fir (Wellner 1970).

Table 3 summarizes the relative fire resistance of some of the principal conifers in Utah forests and woodlands.

Much of the information cited below has been previously reported in other fire ecology reports (Crane 1982; Crane and Fischer 1986; Davis and others 1980; Fischer and Bradley 1987; Fischer and Clayton 1983).

Quaking Aspen (*Populus tremuloides*)

Quaking aspen's response to fire can be examined from two perspectives: (1) the individual stems (or suckers), which are not very resistant to fire, and (2) the clone itself, which is very fire resistant.

Individual stems have thin bark with a green photosynthetic layer. They are heat sensitive and easily killed by fire. If they are not killed outright a fire can cause basal scarring that provides entry for fungal diseases. With or without fire, the stems are rather short-lived. Life span varies with area. In the Intermountain area, aspen maturity appears to take place in 80 to 100 years (Schier 1974), with ages of 180 years or more attained in parts of Wyoming and Utah (Gruell 1990). This compares with a life expectancy of 50 to 70 years in the Colorado Front Range (Mitton and Grant 1980). As individual stems in a stand mature, growth slows and stems become increasingly susceptible to disease and insect attack. The age when this process begins (60 to 100 years) may be related to site quality.

The aspen clone itself is very long lived. It may survive for many centuries, periodically sending up new suckers to replace stems that die. Suckers originate from an extensive lateral root system. Most suckers are produced on roots within 3 to 4 inches (7 to 10 cm) of the soil surface. Following a severe fire where killing heat penetrates into the soil, some suckers may originate from roots down to 12 inches (30.5 cm) below the surface (DeByle 1991).

Table 3—Relative fire resistance of some important conifers occurring in Utah (source: Flint 1925)

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 to medium	Very resistant
Lodgepole pine	Very thin	Deep[1]	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]Lodgepole pine is generally deep rooted in well-drained, medium-textured soils. Root development is restricted by layers of coarse soils, impermeable layers, high water tables, or dense stand conditions (Pfister and Daubenmire 1975).

In the Western United States, sexual reproduction by aspen is rare. Vegetative reproduction is stimulated by killing or the removal of the overstory stems in the clone. When stems are killed or removed by fire, logging, or other disturbance, the source of auxin is removed. Auxin, produced by apical buds, travels down the stem, and represses sucker formation on the roots. Fire in an aspen clone has several effects. It releases sucker primordia on roots from auxin inhibition, removes canopy shade, and blackens the soil surface, which increases heat absorption. Increased soil temperatures aid in sucker production. Some suckers are produced by undisturbed clones; however, most are generally suppressed and die in the shade of the canopy. Suckers will survive around the periphery of the stand and in gaps left by dying stems. Natural thinning is common in young aspen stands because of shade intolerance.

Moderate fires can rejuvenate deteriorating aspen. In the absence of fire, aspen may give way to conifers or break up and revert to shrub- or grass-dominated vegetation. Climax aspen respond to fire similarly, but it is less clear how important fire is in the life of the clone. Climax aspen clones in Utah may have dominated some Utah sites for a thousand years or more (Mueggler 1976). Fire relationships in aspen-dominated communities are described in Fire Group Seven.

Ponderosa Pine (*Pinus ponderosa*)

Ponderosa pine has many fire-resistant characteristics. Even seedlings and saplings are often able to withstand fire. Seedlings and saplings can maintain themselves on sites with fire intervals as short as 6 years if fire severity is low. Development of insulative bark and meristems shielded by enclosing needles and thick bud scales contribute to the heat resistance of pole-sized and larger trees.

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

On moist ponderosa pine sites, Douglas-fir or white fir often form dense understories, which may act as fuel ladders that carry surface fires to the overstory. Crown fires are, consequently, more frequent on moist sites than they are on dry sites. Understory ponderosa pine may be more susceptible to fire damage where crowded conditions result in slower diameter growth. Such trees do not develop their protective layer of insulative bark as early as do faster growing trees. 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 commonly found in this species.

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 generally light fuel quantities. 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 an individual tree susceptible to fire damage and can enlarge existing fire scars.

Ponderosa pine is the most fire-resistant tree growing in Utah. As a result, it has a competitive advantage over most other species when mixed stands burn (Fire Groups Three, Four, and Six).

Douglas-fir (*Pseudotsuga menziesii*)

Mature Douglas-fir is a relatively fire-resistant tree. Saplings, however, are vulnerable to surface fires because of their thin, photosynthetically active bark, resin blisters, closely spaced flammable needles, thin twigs, and bud scales. The moderately low and dense branching habit of saplings enables surface fires to carry 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. Fire-resistant bark takes about 40 years to develop on moist (favorable) sites. This protection is often offset by a tendency to have branches closely spaced along 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 often occurs in open stands, but it also grows in dense 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 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 trees increase the probability of fire injury. Resin deposits often contribute to the enlargement of old fire scars during subsequent fires. The effects of fire on Utah Douglas-fir communities are discussed in Fire Groups Four and Five.

Engelmann Spruce (*Picea engelmannii*)

Engelmann spruce is easily killed by fire. The dead, dry, flammable lower limbs, low-growing canopy, and thin bark contribute to the species' vulnerability. The shallow root system is readily injured by fire burning through the duff. Large old spruce may occasionally survive one or more light fires, but deep accumulations of resinous needle litter around their bases usually make them particularly susceptible to fire damage. Survivors are often subjected to successful attack by wood-destroying fungi that easily enter through fire wounds. The high susceptibility of spruce to fire damage is mitigated in part by the generally cool and moist sites where it grows.

Spruce is not an aggressive pioneer. It is a moderate seeder, but seed viability is rated good and the vitality persistent (Alexander and Sheppard 1984). Seedlings can survive on a wide variety of seedbeds. Initial establishment and early growth of seedlings may be slow, but it is usually good when encouraged by shade and abundant moisture. Spruce seedlings can occur as members of a fire-initiated stand with lodgepole pine. 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 eventually dominates the stand, but it takes a long period without any fire before this can occur.

Restocking takes place more quickly if some spruce trees survive within the burn than if regeneration is dependent on seed from trees at the edge of a burn. 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. One hundred to 150 years after establishment, stand regeneration diminishes due to insufficient sunlight at ground level and to accumulating duff. At this point on most sites, the more tolerant subalpine fir begins to dominate in the understory. Fire Groups Ten, Eleven, and Twelve describe the role of fire in the subalpine environments where Engelmann spruce is a climax species.

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 is unique, 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 pine stands are composed of trees containing both serotinous (closed) and nonserotinous (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. If fire does not occur for a long period of time, even stands that are mostly serotinous will gradually become dominated by open-coned trees as serotinous trees die out.

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 that contribute to lodgepole pine's success in dominating a recently burned site 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 on recently regenerated lodgepole can fill in voids left by the original 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*. Viable seed has been found in 80-year-old serotinous cones.

4. *High survival and rapid growth*. High seedling survival and rapid early growth are characteristic of lodgepole, especially on mineral soil seedbeds exposed to full sunlight.

Lodgepole pine's 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 dead woody fuel on the forest floor. Thus, the stage is set for another stand-destroying wildfire. Lodgepole pine occurs in Fire Groups Three, Five, Eight, Ten, and Eleven.

Subalpine Fir (*Abies lasiocarpa*)

Subalpine fir is the least fire-resistant conifer in Utah 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 relatively cool ground fires can kill 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. But subalpine fir usually remains a slower growing, minor component dominated by less-tolerant species.

Subalpine fir can exist better under low light conditions than most associated species. Engelmann spruce will, however, often grow faster than subalpine fir where light intensity exceeds 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 invade and grow in the understory of lodgepole stands. Given a long enough fire-free period, subalpine fir will overtop lodgepole pine on Fire Group Ten and Eleven sites, where it is the indicated climax, as well dominating timberline Group Twelve sites, where it is the major seral and climax species.

White Fir (*Abies concolor*)

White fir is easily killed or injured by fire when it is young, but it becomes more fire resistant as it grows older. Young trees have thin, smooth bark with resin blisters. As the tree matures, the bark becomes thick (4 to 7 inches; 10 to 18 cm) and deeply furrowed. Counterbalancing the good insulation provided by the bark is a tendency for the tree to retain low branches, providing a fuel ladder into the dense crown. Moderately shallow roots and heavy lichen growth on the branches also contribute to white fir's only moderate fire resistance.

White fir is one of the most shade tolerant species in Utah. Only subalpine fir and Engelmann spruce are more tolerant. At lower elevations, white fir is often the indicated climax on moister sites. Douglas-fir is frequently associated with white fir. Because of its great longevity, it is often a late seral to climax codominant.

White fir may occur in a fire-initiated stand, but environmental extremes and winter kill often hamper its direct establishment in open areas. Its early growth is slow, and it will normally be a minor early seral component on sites in Fire Group Six, where it is the indicated climax. White fir may also occur as a seral species in Fire Group Ten.

Blue Spruce (*Picea pungens*)

Blue spruce is easily killed by fires. Its thin bark (0.75 to 1.5 inches or 2 to 3.8 cm thick at maturity) is evidently insufficient to protect the cambium, even from low-severity fires (Preston 1940). In addition, blue spruce is slow to self-prune lower branches and the foliage is dense, allowing surface fires to crown. Despite its shallow root system, blue spruce is windfirm and may resist wind better than other spruces in fire-opened stands.

Blue spruce is a good to prolific seeder, with full cone crops occurring every 2 or 3 years. Seed production begins at approximately 20 years and peaks between 50 and 150 years. Most seed falls within 300 ft (91 m) of the upwind timber edge. Most natural germination takes place on mineral soil. Overhead light with side shade favors seedling development (Fechner 1985).

Blue spruce is the least shade tolerant and most drought tolerant spruce. It appears to be slightly more tolerant than Douglas-fir in Utah. It is less tolerant than subalpine fir or white fir. On some sites where it is considered the climax dominant, it may share dominance with Engelmann spruce. Sites where blue spruce is the indicated climax are often moist. It is commonly a member of riparian communities and frequently borders wet meadows. It is also climax on dry sites with calcareous parent material. With different soils, these more xeric sites would most likely be dominated by Douglas-fir. On sites between these moisture extremes it acts as a seral species in Utah (Youngblood and Mauk 1985). Blue spruce may be climax or a major seral species in relation to white fir in Fire Group Six, or a climax species on a few sites included in Fire Groups Ten and Eleven.

Western Bristlecone (*Pinus longaeva*)

Fire plays a minor role in the the environments where western bristlecone is the climax dominant. Because fire rarely enters bristlecone stands, little is known about its relative fire resistance. It has thin bark and a low, branching, dense crown, suggesting low fire resistance. Western bristlecone grows on dry ridges and exposed slopes, mainly on dolomitic or limestone soils. It occurs on sites above the elevational ranges of ponderosa pine, Douglas-fir, and subalpine fir, up to timberline. On these harsh sites, the trees grow in scattered or open groves, and there is little undergrowth to carry fire.

Bristlecone is a very slow growing, intolerant species, and reproduction is sparse. Its seeds are often cached by Clark's nutcracker, and its most successful reproduction comes from cached seed. Its smaller size and the presence of a wing allow bristlecone seed to be dispersed by wind for short distances as well (Ahlenslager 1987b).

There is a relatively large number of shrub and herbaceous species that may be associated with bristlecone across its range in Utah. This diversity has made habitat type classification difficult (Youngblood and Mauk 1985). As of yet habitat types have not been identified. Sites where bristlecone is dominant, or codominant with limber pine, are described in Fire Group Nine.

Limber Pine (*Pinus flexilis*)

The degree of stem scorch usually determines the extent of fire injury to limber pines. Young trees are 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.

In many climax Utah limber pine stands, fire plays a relatively minor role. Limber pine is a frequent codominant with bristlecone on extremely dry, unproductive sites. Fuels are scarce and fires infrequent. Where limber pine is seral to other conifers, conditions are more productive, and the effects of fire more important.

Keown (1977) conducted prescribed fire studies in central Montana limber pine stands. Study results indicated 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 only about 20 percent. In similar situations with a dense shrub understory (primarily *Potentilla fruticosa*) fire severity was high and limber pine mortality often reached 80 percent. Fires in grassland- or shrubland-forest transition zones were the most severe. Limber pines in these transition zones were often less than 10 ft (3 m) tall, with lower branches intermingled with ground fuels. Keown's study was conducted in a limber pine/bunchgrass vegetation type having much higher fine fuel loadings than can be expected on climax limber pine sites. The results may apply to more productive sites where limber pine is a seral species.

Limber pine is not dependent on fire to provide favorable seedbed. Seed is distributed mainly by the Clark's nutcracker, which caches the large pine seeds for future consumption. Although nutcrackers often cache seed on recent burns, they may also do so in undisturbed areas.

Limber pine is a climax species in Fire Group Nine and may occur as a seral species in Fire Groups Three, Four, Six, and Ten.

Gambel Oak (*Quercus gambelii*)

Gambel oak acts as an overstory climax dominant or an important understory species associated with ponderosa pine, bigtooth maple, Douglas-fir, white fir, pinyon, or juniper. Gambel oak seedlings are rare. Acorns may be dispersed by birds or small mammals or may be carried away from the parent clone by water or gravity. Most of the acorns that are produced are eaten by birds, mammals, or insects. Vegetative reproduction is the main means of regenerating the species.

Individual stems of Gambel oak are not particularly fire resistant. Stems are often short and small in diameter. Crowns are frequently within the reach of flames carried by understory fuels. Nevertheless, a clone or thicket of Gambel oak is very fire resistant. The majority of the plant's biomass is protected below the ground and comprises a complex of rhizomes and lignotubers with many dormant buds (Tiedemann and others 1987). Because of this, Gambel oak resprouts vigorously following fire. It is capable of sending up multiple shoots from its underground organs soon after fire has removed aboveground stems. Fire temporarily reduces cover and height of oak clones but increases stem density. The most common effect of fire on oak is to stimulate suckering, thicken existing stands, and encourage the merging of scattered clumps (Brown 1958).

Gambel oak occurs as the climax dominant in Fire Group Two, and is an important species in Fire Groups Three, Five, and Six.

Pinyon (*Pinus edulis*) and Singleleaf Pinyon (*Pinus monophylla*)

Pinyon pine trees are most vulnerable to fire when they are small (under 4 ft [1.2 m] tall). Mature trees are short with open crowns, but they do not self-prune their dead branches. The accumulated fuel in the crowns and the relative flammability of the foliage make individual trees susceptible to fire. Stand structure, however, has a greater impact on fire susceptibility than characteristics of the tree itself. Trees may be scattered to dense and have varying amounts of undergrowth. Open stands of trees on sites with large amounts of fine grass fuel are the most flammable.

Seeds of pinyon pines are heavy and wingless. They are not dispersed by wind. Instead, they are collected and cached by pinyon jays, Clark's nutcrackers, and other birds. Seedlings emerge from unrecovered caches. Adult trees are drought tolerant, but seedlings require "nurse plants"—shrubs, Utah junipers, or mature pinyons—to protect them from excessive drying and heating. Because of typically unfavorable site conditions, pinyons are among the slowest growing pines. Pinyon reaches sexual maturity at about 25 years and singleleaf pinyon at 35 years. Peak seed production may not be reached until trees are 160 to 200 years old, and good cone crops occur at infrequent intervals (Evans 1988).

Pinyons are coclimax species with Utah juniper in Fire Group One. They occur as occasional seral associates in Fire Group Three.

Utah Juniper (*Juniperus osteosperma*)

Utah juniper is least fire resistant as a small tree (under 4 ft [1.2 m] in height). Trees become more fire resistant as they get larger. Larger trees have thicker bark, and their foliage is farther above the ground. Mature trees can generally survive low-severity fires. Mortality occurs when 60 percent or more of the crown is scorched (Jameson 1966). The sparse fuels associated with juniper rarely produce enough heat to kill larger trees. The trees themselves contribute to the lack of fuel by producing phenolic compounds that can inhibit grass growth (Jameson 1970).

Utah junipers begin to produce seed when they are about 30 years old. They establish best where nurse shrubs or snags provide some shade. Seed is dispersed mostly by birds and other animals. Seedlings typically form clumps beneath bird-perching trees and along fencelines.

Utah juniper is a climax dominant or codominant in Fire Group One. It may also occur as a minor seral species in Fire Group Three.

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 in Fire Groups Three, Four, Five, and Six.

UNDERGROWTH RESPONSE TO FIRE

Many of the common shrubs and herbaceous plants that grow in Utah forests and woodlands can renew themselves from plant parts that survive fire. Other plants are quite susceptible to fire-kill and often must reestablish or colonize from off-site seed sources in unburned areas within or immediately adjacent to the burned area.

Stickney (1982) described the process of postfire plant succession following fire in Northern Rocky Mountain forests. The processes and management implications are essentially the same for forests in Utah:

> ...the severity of the disturbance treatment directly affects the representation of the survivor component in the postfire vegetation. Since survivors derive from plants already established at the time of disturbance, it is possible, by pretreatment inventory, to determine the potential composition for the survivor component. For this reason it also follows that forest stands with little undergrowth vegetation could be expected to have a sparse or limited survivor component following disturbance. In addition, if the survivor component is composed mostly of shade-tolerant climax-like species the rate of survivor recovery can be expected to be slow. Nearly all of our native forest shrub species are capable of surviving burning, and they can therefore be expected to function as survivors. A majority of the predisturbance forest herb species also demonstrated the ability to survive fire, particularly those species with underground stems (rhizome) or rootcrowns (caudex). As a generalization, the more severe the fire treatment to vegetation, the less the survivor component. In the drier, more open forest types this usually results in a reduction of amount, but not major changes in composition. However, in the moister forest types, where the undergrowth is made up of more mesic shade-tolerant species, marked changes in postfire composition can occur as increasing severity reduces survivor representation.
>
> The severity of disturbance treatment (particularly fire) influences the potential for colonizer presence in two ways: (1) the degree of severity creates the character of the ground surface on which colonizer seedlings germinate, and (2) it activates onsite stored seed. Generalizing, the more severe the disturbance treatment the more favorable the site becomes for colonizers. As the extent of exposed mineral soil increases, the ground surface becomes more favorable as a site for germination and establishment of colonizer plants. Increases in treatment severity also favor germination of ground-stored seeds by increasing their exposure to light or heat.

Predicting the occurrence of colonizers in post-disturbance vegetation is much less certain than predicting for survivors, but knowledge of the previous succession history can provide the potential composition of residual colonizers. Locally this information is often available from an adjacent or nearby clearcut. Least predictable is the offsite colonizer component, for its occurrence is dependent on the timing of the disturbance to the availability and dispersal of offsite airborne seed. Even in this case reference to local clearcuts can provide some idea of the composition for the most common offsite colonizer species likely to occur.

Table 4 summarizes plant response to fire for some species that occur in Utah forests. The fire response information is generalized. Plant response to fire depends on many factors, including soil and duff moisture, plant vigor and phenological state, 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.

Table 4—Summary of postfire survival strategy and fire response information of some plant species occurring in forests in Utah forests and woodlands. (Sources: Ahlenslager 1988, 1986; Armour and others 1984; Bradley 1986a,b,c,d,e,f,g,h, 1984; Britton and others 1983; Crane 1991, 1990a,b, 1989a,b; Crane and others 1983; Daubenmire and Daubenmire 1968; Fischer 1986a,b; Freedman 1983; Fulbright 1987; Hickerson 1986a,b,c; Hironaka and others 1983; Holifield 1987a,b; Keown 1978; Klemmedson and Smith 1964; Kramer 1984; Lotan and others 1981; Lyon 1971, 1966; Lyon and Stickney 1976; McLean 1969; McMurray 1987a,b,c,d,e, 1986a,b,c,d,e; Miller 1977; Morgan and Neuenschwander 1988a,b, 1985; Mueggler 1965; Noste 1985; Noste and Tirmenstein 1990; Rowe 1983; Snyder 1991h; Stickney 1981; Tirmenstein 1990a,b,c, 1989a,b, 1988a,b, 1987a,b,c,d,e,f,g, 1986; Uchytil 1989a,b,c; Viereck and Dyrness 1979; Viereck and Schandelmeir 1980; Volland and Dell 1981; Walkup 1991; Winkler 1987a,b,c,d,e; Woodard 1977; Wright 1980, 1978, 1972; Wright and Bailey 1980; Wright and others 1979; Zager 1980; Zimmerman 1979; Zimmerman 1991)

Species	Fire survival strategy	Comments on fire response
SHRUBS AND SMALL TREES:		
Acer glabrum Rocky Mountain maple	Sprouts from surviving crown or caudex.	Usually increases following fire. Survival and response may be reduced by hot surface fire.
Alnus incana Thinleaf alder	Sprouts from surviving root crown or caudex; off-site seed dispersal by wind and water.	Increased density because multiple stems arise from each burned plant. Late summer burns are immediately colonized by fall seed crop.
Amelanchier alnifolia Serviceberry	Sprouts vigorously from surviving, root crown and rhizomes.	Usually survives even severe fires especially if soil is moist at time of fire. Coverage may decrease and frequency increase following fire.
Arctostaphylos patula Greenleaf manzanita	Sprouts from dormant buds in root burl; or from fire-simulated germination of dormant residual seeds in the soil.	Can withstand repeated burning. New sprouts may appear in 10 days to 3 weeks.
Arctostaphylos uva-ursi Kinnikinnick	May sprout from a root crown or caudex; regeneration from stolons more common. May have somewhat fire resistant seeds stored in soil.	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.
Artemisia arbuscula Low sagebrush	Off-site wind dispersal seed.	Recovery may take within 2 to 5 years on favorable sites.
Artemisia nova Black sagebrush	Wind-dispersed off-site seed.	Recovery hastened by seed from on-site survivors.
Artemisia tridentata Big sagebrush	Wind-dispersed seed. Subspecies *vaseyana* stores seed in the soil, which germinates as a result of fire-induced heating.	Very susceptible to fire-kill. Recovery is hastened when a good crop exists before burning.
Ceanothus greggii Desert ceanothus	Germination of heat stimulated viable on-site seed in soil.	Hot, late growing-season fires produce most effective response.

(con.)

Table 4 (Con.)

Species	Fire survival strategy	Comments on fire response
Ceanothus velutinus Snowbrush ceanothus	Soil-stored seed germinates following heat treatment. Also sprouts from root crowns and roots following a cool fire.	Usually increases rapidly and dramatically. Can dominate site within 2 to 11 years.
Cercocarpus ledifolius Curlleaf mountain-mahogany	Weak sprouter; off-site wind-dispersed seed.	Seriously damaged by severe fires. Seeds need mineral soil to germinate.
Cercocarpus montanus alderleaf mountain-mahogany	Sprouts vigorously from root crown or caudex; wind-dispersed seed.	Resprouts vigorously and rapidly after most fires.
Chrysothamnus nauseosus Rubber rabbitbrush	Resprouts from buds at or near the soil surface; wind-borne seed.	Severe fires may kill plants; prolific wind-borne seed recolonizes burns quickly.
Chrysothamnus viscidiflorus Viscid rabbitbrush	Resprouts from buds just below the surface; numerous wind-borne seeds.	Resprouts vigorously after fire but may be killed by severe fires. Post-fire production low 1-3 years, then large increases in cover. Reduced competition on burned sites stimulates prolific seed production.
Clematis columbiana Columbia clematis	Sprouts from surviving root crowns.	Poorly documented.
Cornus sericea Red-osier dogwood	Sprouts from surviving roots or stolons (runners) and from base of aerial stems.	Generally increases. Will survive all but severe fires that remove duff and cause extended heating of upper soil.
Gutierrezia sarothrae Broom snakeweed	Usually regenerates from off-site wind-dispersed seed; weak sprouter.	Often increases as a result of rapid seedling establishment.
Holodiscus dumosus Mountain spray	Off-site wind-dispersed seed; possibly soil-stored seed or sprouts from surviving root crown. Poorly documented.	Response poorly documented. *H. discolor* increases by prolific sprouting.
Juniperus communis Common juniper	Long viability on-site seed and bird-dispersed off-site seed.	Very susceptible to fire-kill. Seed requires long germination period.
Juniperus horizontalis Creeping juniper	Fire activated on-site seed in soil and off-site animal-carried seed.	Fire response poorly documented.
Linnaea borealis Twin-flower	Sprouts from surviving root crown located just below soil surface. Fibrous roots and (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	Sprouts from surviving root crown.	Often a reduction in cover and frequency following fire.
Mahonia repens Oregon-grape	Sprouts from surviving rhizomes, which grow 0.5 to 2 inches (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.
Pachistima myrsinites Mountain lover	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.

(con.)

Table 4 (Con.)

Species	Fire survival strategy	Comments on fire response
Physocarpus malvaceus Mallow-leaved ninebark	Sprouts from surviving root crown or horizontal rhizomes.	Fire resistant. Resprouts well although spreading may be somewhat delayed.
Potentilla fruticosa Shrubby cinquefoil	Sprouts from surviving root crown.	Susceptible to fire-kill, but may survive low to moderate fires.
Prunus virginiana Chokecherry	Sprouts from surviving root crown; occasionally from rhizomes; also, on-site seed.	Usually increases coverage following fire.
Purshia mexicana var. *stansburiana* Cliffrose	Reported separately as a strong sprouter and as a nonsprouter.	May take decades to reestablish a site after fire.
Purshia tridentata Bitterbrush	A weak sprouter; surviving root crown or caudex. Rodent-dispersed seed and seed caches located on burned areas.	Very susceptible to fire-kill, especially in summer and fall. Decumbent growth form frequently sprouts, columnar form does so only weakly. Spring burns enhance sprouting, fall burns are best for regeneration by seed.
Ribes aureum Golden currant	Sprouts from surviving rhizomes; germination of heat-stimulated on-site seed.	Resprouts best after low- to moderate-severity fires.
Ribes cereum Wax currant	A weak sprouter from root crown. Germination from heat-stimulated on-site seed.	Susceptible to fire-kill. Seldom survives severe fire. Regeneration is favored by short duration low-severity fires.
Ribes lacustre Swamp black gooseberry	Sprouts from surviving root crown and rhizomes. Also on-site fire scarified seed.	Resistant to fire-kill. Usually increases even after a severe fire. Seedlings may establish after low- or moderate-severity fires.
Ribes montigenum Gooseberry currant	Sprouts from surviving root crown or caudex; germination of heat-stimulated on-site seed.	Fire response poorly documented.
Ribes viscosissimum Sticky currant	A weak sprouter, soil-stored seed may require heat treatment.	Susceptible to fire-kill. Relatively shade intolerant. May contribute substantially to postfire revegetation.
Rosa gymnocarpa Baldhip rose	Sprouts from surviving root crowns.	
Rosa woodsii Woods rose	Sprouts from surviving root crowns.	Some ecotypes can spread by root sprouting.
Rubus parviflorus Thimbleberry	Sprouts from surviving rhizomes and root crown; seedlings from soil-stored and possible bird-dispensed seed.	Enhanced by fire. Spreads vigorously from rhizomes; rapid recovery after fire.
Salix scouleriana Scouler willow	Multiple sprouts from root crown. Also off-side wind-dispersed seed.	Resprouts vigorously even after severe fire. Seeds germinate rapidly on moist burned sites.
Sambucus racemosa Red elderberry	Sprouts from rhizomes and root crown. Germination of fire-activated on-site seed in soil.	Seed germination may be extensive; response may decline with repeated burning.

(con.)

Table 4 (Con.)

Species	Fire survival strategy	Comments on fire response
Shepherdia canadensis Soapberry	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.
Sorbus scopulina Rocky Mountain ash	Sprouts from deep-seated rhizomes.	Resprouts vigorously after fire.
Symphoricarpos albus Common snowberry	Sprouts vigorously from underground rhizomes and from root crown or caudex.	Increases; survives low- to moderate-severity fires; may produce fruit first postfire year.
Symphoricarpos longiflorus Long-flower snowberry	Sprouts from on-site surviving root crown and rhizomes.	Response poorly documented.
Symphoricarpos oreophilus mountain snowberry	Sprouts from buds on root crowns and rhizomes; root crown sprouts originate from bud at 1 inch below the soil surface.	Has been described as a weak sprouter. May take several years to achieve preburn cover.
Vaccinium caespitosum Dwarf huckleberry	Sprouts from shallow rhizomes; off-site animal-transported seed.	Sprouts may quickly reoccupy a site after low- to moderate-severity fire.
Vaccinium globulare Dampwoods blueberry	Sprouts from dense network of shallow and deep rhizomes.	Moderately resistant to fire-kill. Will usually survive cool to moderately severe fires. Preburn cover may be attained within 3 to 5 years.
Vaccinium myrtillus Dwarf bilberry	Sprouts from root crown of caudex and from extended network of underground rhizomes.	May be virtually eliminated from a site by severe fire.
Vaccinium scoparium Grouseberry	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.
GRASSES:		
Agropyron cristatum Fairway or crested wheatgrass	Low flammability growth habit; deep underground stems.	Varies with season and fire severity; growth may be favored by late summer fire. Spring fires can cause decreased yields for several years.
Bouteloua gracilis Blue grama	On-site surviving rhizomes which may be stimulated by fire.	Variable response.
Bromus tectorum Cheatgrass	Large soil seed reserves; variable germination seasons; relatively high heat resistance of seed.	Individual plants susceptible to heat-kill. Surviving seeds germinate at various times during the year—fall, late winter, spring. Early summer burns before seed falls are more effective for controlling cheatgrass than midsummer and fall burns.
Calamagrostis canadensis Bluejoint reedgrass	Invader, wind-disseminated seed; also an enduring sprouter.	Increases on wet to moist postfire sites.
Calamagrostis rubescens Pinegrass	Sprouts from surviving rhizomes which grow within the top 2 inches (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.

(con.)

Table 4 (Con.)

Species	Fire survival strategy	Comments on fire response
Carex geyeri Elk sedge	Sprouts from surviving rhizomes.	Invades burned areas and forms dense stands. Often increases following fire.
Carex rossii Ross sedge	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.
Elymus elymoides Squirreltail	Sprouts from surviving growing points. Animal-dispersed seed.	Resprouts after most fires.
Elymus glauca Blue wildrye	On-site surviving root crown or caudex; on-site seed may survive some fires.	Seedlings establish and develop rapidly on burned sites.
Festuca ovina var. *ingrata* Idaho fescue	Seed germination and survival of residual plant.	Susceptible to fire-kill. Response will vary with severity of fire and physiological 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 thurberii Thurber fescue	On-site surviving root crown; off-site wind-dispersed seed.	Response may be poor where accumulated litter results in severe soil heating.
Hilaria jamesii Galleta	On-site surviving rhizomes.	Can reestablish within 2 years.
Koeleria cristata Prairie junegrass	Seed germination and residual plant survival.	Susceptible to fire-kill. Response will vary according to fire severity and physiological state of plant.
Leucopoa kingii Spike fescue	On-site surviving rhizomes; off-site wind-dispersed seed.	Often increases following fire.
Leymus salinus Salina wildrye	On-site surviving root crown and rhizomes.	Poorly documented.
Pascopyrum smithii Western wheatgrass	On-site surviving rhizomes; growth habit discourages adverse surface heating.	Increases in abundance and density.
Poa fendleriana Muttongrass	On-site surviving root crown or caudex, and underground rhizomes.	Generally recover from most fires in 1 to 3 years. Can be damaged by spring fires after growth has started. Produces heavy seed crop following fire.
Poa secunda Sandberg bluegrass	On-site surviving root crown or caudex; growth habit discourages adverse surface heating.	Cover may increase; older, pedastaled plants may be susceptible to damage.
Pseudoroegneria spicata Bluebunch wheatgrass	Seed germination and some sprouts from surviving growing points.	Usually not seriously damaged by fire. Response depends on severity of fire and physiological state of plant. Damage will be greatest following dry year.
Stipa comata Needle and thread	Animal-dispersed seed. Some resprouting.	Susceptible to fire-kill. If above-eground stems consumed, plant usually dies.

(con.)

Table 4 (Con.)

Species	Fire survival strategy	Comments on fire response
Stipa hymenoides Indian ricegrass	Off-site seed; growth habit discourages surface heating.	Secondary colonizer; recovery seed dependent. Slow to increase; 2 to 4 years for recovery. Can survive early spring fires.
Stipa lettermanii Letterman needlegrass	Off-side seed.	Recovery of surviving plants slow. Efficient seedling establishment speeds recovery.
FORBS:		
Achillea millefolium Milfoil yarrow	Sprouts from extensive rhizomes.	Survives most fires, can increase cover rapidly.
Actaea rubra baneberry	Sprouts from thick underground caudex; off-site animal-transported seed.	Vigorous growing sprouts may occur the first year after fire.
Arnica cordifolia Heartleaf arnica	Sprouts from surviving rhizomes, which creep laterally from 0.4 to 0.8 inch (1 to 2 cm) below soil.	Susceptible to fire-kill. Shoots produce small crowns within the duff. These are easily killed by all but cool fires, which occur when duff is moist. May rapidly invade burned area via wind-borne seed.
Arnica latifolia Broadleaf arnica	Sprouts from laterally creeping rhizomes.	Susceptible to fire-kill. Will usually survive cool to moderately severe fires. May exhibit rapid initial regrowth accompanied by heavy flowering and seedling establishment.
Astragalus miser Weedy milkvetch	Sprouts from buds along surviving taproot, which may be 2 to 8 inches (5 to 20 cm) below 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. Poisonous to sheep and cattle.
Balsamorhiza sagittata Arrowlead balsamroot	Regrowth from surviving thick caudex.	Will survive even the most severe fire. Increases in frequency and density after fire.
Disporum trachycarpum Fairybell	Rhizomes.	*Disporum hookeri* is initially decreased by fire but recovers to preburn levels relatively rapidly.
Dracocephalum parviflorum American dragon head	Residual seed in duff.	Dramatic increase following fire. Decreases after second year.
Epilobium angustifolium Fireweed	Wind-blown seed and sprouts from rhizomes.	Needs mineral soil to establish, can persist vegetatively and flower the first summer following a fire. Large increase following fire.
Equisetum arvense Meadow horsetail	Spreading rhizomes and wind-dispersed propagules.	Frequency unchanged or increased after fire. Especially favored by moist mineral soil exposure.
Fragaria virginiana Mountain strawberry	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.

(con.)

Table 4 (Con.)

Species	Fire survival strategy	Comments on fire response
Galium triflorum Sweet-scented bedstraw	Sprouts from surviving rhizomes.	Susceptible to fire-kill. Usually a sharp decrease following severe fire. Can increase following spring and fall fires.
Osmorhiza chilensis Mountain sweetroot	Short shallow roots; barbed, animal-dispersed seeds.	Moderately fire-resistant; temporary increase after fire.
Pteridium aquilinum Bracken fern	Well adapted; profusely sprouts from surviving rhizomes; off-site wind carried spores.	New sprouts are more vigorous and produce more spores in fire created openings. Sprouting slower following summer fire.
Pyrola secunda Secund wintergreen	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.
Senecio streptanthifolius Manyface groundsel	Nonrhizomatous, regenerates from off-site seed.	
Smilacina racemosa False Solomon-seal	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.
Smilacina stellata Starry false-Solomon seal	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.
Streptopus amplexifolius Clasping twisted-stalk	Extensively rhizomatous.	Decreased by fire.

WILDLIFE RESPONSE TO FIRE

The effects of fire on wildlife are mainly secondary effects. Fire creates, destroys, enhances, or degrades wildlife habitat (food supply, cover, shelter, physical environment), thereby causing changes in the subsequent occurrence and abundance of animal species on a burned area (fig. 1). Table 5 lists the probable effects of fire on some mammals, reptiles, and amphibians in Utah forests and woodlands. The indicated fire effects are inferred either from habitat requirements or from studies conducted on specific wildfire or prescribed fire areas. A major problem in attempting any generalization about the effects of fire on wildlife is the variation in fire intensity, duration, frequency, location, shape, extent, season, fuels, site, and soils (Lyon and others 1978).

Bird species' response to fire has been hypothesized by Kramp and others (1983) using a classification suggested by Walter (1977).

Four fire response categories are recognized in this classification: fire-intolerant, fire-impervious, fire-adapted, and fire-dependent. These classes are described as follows (Kramp and other 1983).

Fire-intolerant species decrease in abundance after fire and are present only in areas characterized by very low fire frequency and severity. Characteristic Utah species include the hermit thrush, red-breasted nuthatch, and brown creeper, which are closely associated with closed canopy forests. These birds prefer a dense nesting and foraging cover but do not use fire-opened habitat.

Fire-impervious bird species are unaffected by fire; they neither increase nor decrease because of fire. Bird species whose niche incorporates successional and climax community types may be expected to show the highest flexibility in response to fire.

Fire-adapted species are associated with habitat that is characterized by recurring fires of various severity. These species, however, are not dependent on fire-influenced habitat. Fire-adapted species may also occupy areas with the same frequency-severity ratio as fire-intolerant species. Fire-adapted birds include those that use both dense canopy areas and

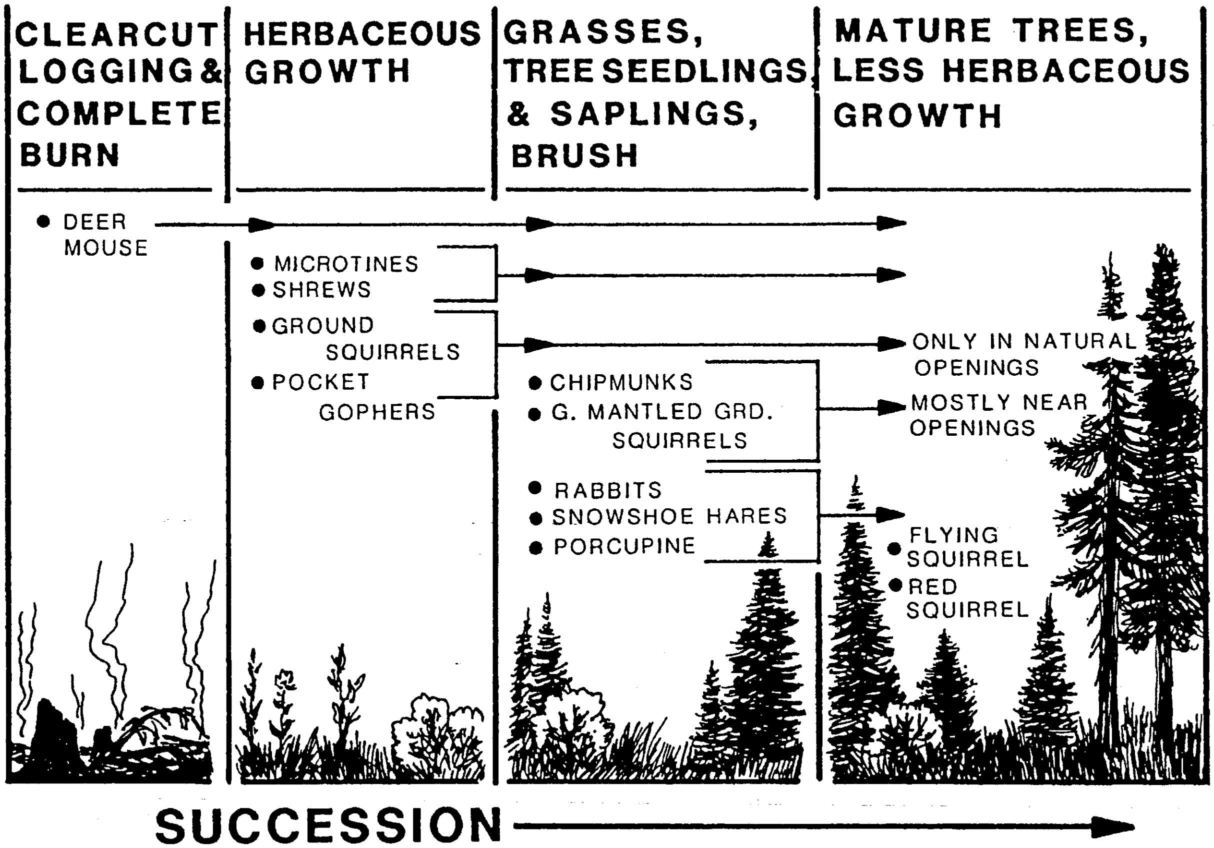


Figure 1—Small mammals found in the successional stages after clearcut logging and burning (Ream and Gruell 1980).

Table 5—Probable effects of fire on some Utah mammals, reptiles, and amphibians (major sources: Bernard and Brown 1977; Crane and Fischer 1986; Fischer and Bradley 1987; Snyder 1991a,b,c,d,e,f,g,h,i; Thomas 1979; Verner and Bass 1980)

Species	Habitat considerations	Fire effects
INSECTIVORA (insect eaters):		
Masked shrew *Sorex cinereus*	Prefers moist situations in forest or open. Requires a mat of ground vegetation for cover; stumps, logs, slash piles for nest sites.	May be temporarily eliminated from severe burns where duff and ground cover are absent. Some direct mortality of nestlings possible.
Merriam's shrew *Sorex merriami*	Prefers arid regions, mostly in bunchgrass, sagebrush, and open woodland. Eats insects and small animals.	May be temporarily reduced or eliminated where ground vegetation and debris are consumed by fire.
Vagrant shrew *Sorex vagrans*	Prefers streamsides, marshes and bogs, but also occurs in moist soil; mat of ground vegetation or debris for cover. Stumps, rotten logs for feeding and nesting.	May be temporarily eliminated from severe burns where duff, ground cover, and debris are absent. Some direct mortality of nestlings possible.
Dusky shrew *Sorex obscurus*	Habitats include coniferous forest, marsh, and dry hillsides. Nests in stumps, bogs, and debris.	Adversely impacted by fires that consume surface debris.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Water shrew *Sorex palustris*	Prefers riparian areas at middle and high elevations. Requires small, cold streams, and wet areas with protected banks and ground cover.	May be eliminated from severely burned areas where duff and stream-side cover have been removed.
CHIROPTERA (bats):		
Little brown myotis *Myotis lucifugus*	Common in forest and at the forest edge. Requires snags and tree holes for roosting and for maternity colony sites.	Severe fires may destroy roosting and breeding sites. Relatively impervious to cool and moderate fires.
Long-eared myotis *Myotis evotis*	Occurs in coniferous woodland as well as in spruce-fir zone. Uses snags and tree holes for roosting and for breeding colonies.	Severe fires may destroy roosting and breeding sites; otherwise relatively impervious to fire.
Fringe-tailed myotis *Myotis thysanodes*	Prefers open coniferous woodlands, desert scrub, and grassy meadows; near streams or ponds. Roosts in crevices, caves, tunnels, and buildings.	Relatively unaffected by most fires.
Small-footed myotis *Myotis subulatus*	Most common in ponderosa pine zone. May use hollow trees and snags for roosting and breeding.	Severe fires may destroy roosting and breeding sites but have little impact on populations.
Long-legged myotis *Myotis volans*	Prefers open coniferous forests. May use tree cavities for roosting and breeding.	Severe fires may destroy roosting and breeding sites but have little impact on populations.
Silver-haired bat *Lasionycteris noctivagrans*	Feeds in openings and adjacent to mature forest. Roosts in tree foliage; uses hollow trees and snags for breeding.	Severe fires may destroy roosting and breeding sites. Relatively impervious to fire.
Big brown bat *Eptesicus fucus*	Common over grassy meadows surrounded by ponderosa pine. Roosts and breeds in hollow trees and snags.	Severe fires may reduce breeding and roosting sites. Relatively impervious to fire.
Hoary bat *Lasiurus cinereus*	Prefers wooded areas and trees with dense foliage for roosting and breeding.	Severe fires can destroy roosting and breeding sites. Cool fires have little effect on populations.
Red bat *Lasiurus borealis*	Roosts in trees or shrubs near or on the ground. Hunts in evening along water courses or among trees.	Fire may destroy roosting sites and some feeding areas.
Townsend's big-eared bat *Plecotus townsendi*	May be found in forests up through spruce-fir zone. Not a tree user.	Relatively impervious to fire.
Pallid bat *Antrozous pallidus*	Occasionally frequents ponderosa pine forests; mostly deserts and grasslands. Roosts in caves, rocks, and trees. Eats insects.	Roost trees may be damaged by fire.
Brazilian free-tailed bat *Tadarida braziliensis*	Common in pinyon-juniper (P-J) woodland. Feeds on moths. Roosts in caves, buildings.	Relatively unaffected by most fires.
LAGOMORPHA (pikas, hares, and rabbits):		
Pika *Ochotona princeps*	Prefers high-altitude talus slopes adjacent to forest openings containing grasses and forbs.	Relatively impervious to fire. Severe fire may create favorable forest openings with abundant grass-forb food supply.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Pygmy rabbit *Sylvilagus idahoensis*	Habitat includes dense rabbitbrush and sagebrush. Burrows beneath large dense sagebrush.	Minimal chance of adverse impact from fire since animal is in burrow during daylight.
Mountain cottontail *Sylvilagus nuttalli*	Prefers dense, shrubby undergrowth and pole-sized trees for cover. Uses downed logs for cover and nest sites.	Temporarily eliminated from severe burns but reoccupies as shrub cover increases. Will continue to use less than severe burns.
Desert cottontail *Sylvilagus audubonii*	Habitat includes P-J forest edge. Nest for young built in ground depression. May use abandoned burrows of other animals.	Young may be susceptible to fire kill if in nest when fire occurs. Fire in dense trees may create preferred habitat.
Snowshoe hare *Lepus americanus*	Prefers dense shrubs in forest openings or under pole-sized trees for food and cover. Uses downed logs for cover and nest sites.	Temporarily eliminated from severe burns. Populations may increase dramatically as shrubs resprout and dominate the area. Will continue to use many less than severe burns.
White-tailed jackrabbit *Lepus townsendi*	Prefers early grass-forb successional stages.	May increase where fire removes overstory and creates meadow-type habitat.
Black-tailed jackrabbit *Lepus californicus*	Common in grassland, sagebrush, and ponderosa pine forest edge. Prefers open areas with scattered shrubs. Eats succulent green vegetation.	Fire can create a preferred food supply.
RODENTIA (gnawing mammals):		
Least chipmunk *Eutamias minimus*	Present in high mountain coniferous forests. Requires open areas with stumps, downed logs, and shrubs or other high vegetation for cover.	Temporarily decreases following severe fire that reduces cover. Returns first season after fire and usually abundant by third postfire year.
Yellowpine chipmunk *Eutamias amoenus*	Prefers shrub, seedling, and sapling stages of forest succession. Usually abundant in open ponderosa pine forests and edges. Needs shelter of downed logs, debris, or shrubs. Often burrows under downed logs and stumps.	Recent burns with stumps and shrubs are favored habitat, especially as seed and fruit producing annuals become available.
Cliff chipmunk *Eutamias dorsalis*	Range includes P-J and conifer woodlands. Occupies sparsely vegetated rocky slopes.	Relatively impervious to fire.
Colorado chipmunk *Eutamias quadrivittatus*	Occupies areas of rock within open conifer forests such as ponderosa pine; P-J; mixed conifer.	Relatively impervious to fire.
Uinta chipmunk *Eutamias umbrinus*	Frequents ponderosa pine forest and up through the subalpine. Nests in burrows, hollow logs, and in rock crevices.	Hot surface fire may consume desirable ground debris.
Yellow-bellied marmot *Marmota flaviventris*	Prefers rocky outcrops or talus slopes; forest openings up through spruce-fir zone. Uses downed logs for cover; burrows under tree roots. Feeds on green grass and forbs.	Relatively impervious to fire. Benefits from fire-created openings dominated by grass and forbs.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
White-tailed antelope ground squirrel *Ammospermophilus leucurus*	P-J, woodlands included in preferred habitats. Burrows beneath large shrub, tree, or rock. Eats insects, small animals, and seeds.	Relatively impervious to fire. Fire may result in immediate reduction of food supply but then an increase.
Uinta ground squirrel *Citellus armatus*	Prefers moist habitats with lush vegetation and soft soil; subalpine meadows; forest edges.	May increase dramatically on areas where fire has killed overstory; may be favored by increased light and temperature as well as increase in herbaceous growth.
Belding ground squirrel *Citellus beldingi*	Generally restricted to mountain meadows and early successional stages in ponderosa pine, lodgepole pine, and Douglas-fir forests. Nests underground; requires friable soil. Feeds on grasses, forbs, seeds, bulbs, etc.	Benefits from fire-created openings that produce abundant herbaceous undergrowth.
Thirteen-lined ground squirrel *Citellus tridecemlineatus*	Prefers grassland, brushy edges and some ponderosa pine woodlands on friable soil. Conceals burrow with grass or shrubs. Eats seeds, weeds, and insects.	Relatively impervious to most fires except for loss of cover.
Spotted ground squirrel *Citellus spilosoma*	Habitat includes open pine forest with dry sandy soil. Burrows under shrubs or rocks. Feeds on seed, green vegetation, and insects.	Relatively impervious to most fires except for loss of cover.
Rock squirrel *Citellus variegatus*	Frequents broken terrain, rocky canyons, and slopes. Dens under rocks or in hollow trees. Eats mites, seeds, fruit, eggs, and insects.	Hot fires that consume den trees or down logs and surface cover have adverse effect.
Golden-mantled ground squirrel *Citellus lateralis*	Widespread from ponderosa pine forest to alpine meadows. Most abundant in open forests lacking a dense undergrowth or understory. Needs downed logs, stumps, or rocks for cover. Burrows for shelter.	Generally increases on recently burned areas due to increased abundance of forbs, providing adequate escape cover exists.
Abert's squirrel *Sciurus aberti*	Resides in ponderosa pine forest. Nests in tree crown and eats pine cones, pine cambium, mushrooms, berries, roots, and green vegetation.	Hot fires that scorch tree crowns or kill trees remove nesting habitat and food supply.
Red (pine) squirrel *Tamiasciurus hudsonicus*	Found in late successional forests. Nests in tree cavities and branches. Feeds on conifer seeds, nuts, bird eggs, and fungi. Uses downed logs for cover.	Essentially eliminated following stand-replacing fires. Cavities in fire-killed trees may be used for dens but only if surrounded by live trees.
Northern flying squirrel *Glaucomys sabrinus*	Prefers a mature forest. Requires snags and trees with nest cavities. Also requires an abundance of downed logs. Feeds on conifer seed, serviceberries, and mushrooms.	Same as for red squirrel except may forage for fungi in recent burns.
Southern picket gopher *Thomomys unbrinus*	Frequents pine (and oak) forests with shallow, rocky soil.	Relatively impervious to most fires except as it affects availability of roots, tubers, surface herbs, and other preferred foods.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Northern pocket gopher *Thomomys talpoides*	Prefers disturbed areas of secondary vegetative growth; also pine forests, alpine parks, and meadows. Occurs mostly in deep sandy soils but also in clay and gravelly soils. Requires an herbaceous food source, especially annual forbs.	Population densities usually increase on areas burned by fires that open canopy and disturb the soil resulting in undergrowth of early successional forbs and grasses.
Silky pocket mouse *Perognathus flavus*	Preferred habitats include loose sandy soils in open P-J woodlands. Burrows under yucca, cactus, or low shrubs. Eats seed.	Impervious to most fires except for temporary reduction in food supply. Fire creates preferred open habitat.
Apache pocket mouse *Perognathus apache*	Preferred habitats include loose sandy soils in open P-J woodlands. Burrows under yucca, cactus, or low shrubs. Eats seed.	Impervious to most fires except for temporary reduction in food supply. Fire creates preferred open habitat.
Little pocket mouse *Perognathus longimembris*	Habitat includes P-J woodlands containing medium to large openings. Seed eater.	Relatively impervious to fire. Fire may create habitat by opening canopy of dense stands of P-J.
Great Basin pocket mouse *Perognathus parvus*	Habitat includes P-J woodlands and chaparral with friable soils. Prefers grass-forb stage of succession. Burrows under shrubs. Seed and insect eater.	Fires that kill trees and tall shrubs create favorable habitat.
Great Basin kangaroo rat *Dipodomys ordii*	Prefers low, hot valleys and rocky slopes including P-J woodlands. Eats green vegetation and seed.	Moderate to severe fires can create preferred grass-forb successional stage.
Beaver *Castor canadensis*	Requires streams or lakes bordered by stands of aspen, alder, birch, poplars, or willow for food and building materials.	Usually increases following fires that initiate a successional sequence that includes aspen as an intermediate stage.
Western harvest mouse *Reithrodontomys megalotis*	Generally restricted to grass-forb stages on all habitat types. Usually nests on ground but sometimes in woodpecker holes. Eats seeds and fruit of grass and shrubs.	Generally favored by fires that result in establishment of seed-producing annual plants.
Canyon mouse *Peromyscus crinitus*	Generally restricted to rocky habitats; arid conditions, warm, dry canyons, or the base of cliff faces in P-J zone. Nests among rocks or in a burrow beneath rocks.	Relatively impervious to most fires.
Deer mouse *Peromyscus maniculatus*	Ubiquitous. Occurs in most successional stages of most habitat types. Nests in burrows, trees, and stumps. Uses downed logs for nesting sites and cover.	Populations reduce immediately following fire but significantly increase as soon as rain settles the ash. Most abundant small mammal on severely burned areas.
Brush mouse *Peromyscus boylii*	Prefers arid and semiarid rough, rocky plateaus, mesas, and canyons primarily in P-J stands or rocky hillsides with stands of evergreen oak and other shrubs; likes dense undergrowth. Nests under rocks and other debris. Eats pine nuts, acorns, seeds, and berries.	Moderate to severe fires that consume undergrowth and forest floor debris destroy habitat. Fires that scorch or kill crowns adversely impact food supply.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Pinyon mouse *Peromyscus truei*	Occupies P-J woodland in rocky areas and brushy places. Nests in hollow branches of junipers or among rocks. Eats seeds and nuts.	Fires that kill trees and remove surface cover destroy habitat and food source.
Rock mouse *Peromyscus difficilis*	Occupies areas of broken rock, on cliffs, canyon walls, and on foothills; usually in P-J and oak woodlands and sometimes ponderosa pine.	Stand-destroying fires adversely affect food supply.
White-throated woodrat *Meotoma albigula*	Habitat includes mixed conifers and P-J woodlands. Burrows at base of shrub or cactus or under rocks. Diet includes cactus.	Relatively impervious to most fires. Severe fire can destroy habitat and food supply.
Desert woodrat *Neotoma lepida*	Habitat includes P-J woodlands and chaparral. Den is under rocks, on ground, or along cliffs. Eats seeds, acorns, cactus, or fruit.	Relatively impervious to fire except as it affects food supply.
Stephen's woodrat *Neotoma stephensi*	Occupies rocky areas in the P-J zone. Nest often made from juniper branches.	Relatively impervious to fire except as it affects occupied nests and food supply.
Mexican woodrat *Neotoma mexicana*	Habitat is mixed conifer forest, P-J woodlands, and rocky sites with scrub oak or mountain mahogany. Constructs nest of sticks and debris, in crevices, under logs or tree roots, and in deserted buildings. Eats acorns, nuts, seeds, fruits, mushrooms, or cactus.	Severe fire destroys habitat and food supply. Hot surface fire destroys nest and nest sites.
Bushy-tailed woodrat *Neotoma cinerea*	Prefers rocky situations. Dens in rock crevices; sometimes in hollow logs. Gathers conifer seed, berries, fungi, twigs, shoots, and green vegetation.	Relatively impervious to fires that occur in high-elevation rocky habitat. Usually not abundant on recent burns.
Southern red-backed mouse (boreal red-backed vole) *Clethrionomys gapperi*	Prefers mesic areas within coniferous forests that contain abundance of large debris on forest floor and undergrowth of shrubs and herbs. Feeds on conifer seed, bark, fungi, and green vegetation. A coniferous overhead tree canopy is preferred.	Usually eliminated from severely burned areas within 1 year after fire. If overstory trees are present and survive, favorable habitat may return in 7 or more years after the fire.
Heather vole *Phenacomys intermedius*	Prefers open grassy areas and forest openings, but also riparian zones. Nests under rocks, stumps, or other debris on forest floor. Often found in association with huckleberry.	Benefits from forest openings and early successional undergrowth that result from moderate to severe fires. Severe surface fires may destroy nesting habitat.
Meadow vole *Microtus pennsylvanicus*	Requires a mat of ground cover for runways, palatable herbs, conifer seed, and moisture. Uses downed logs for cover and nest sites. Usually found near streamside.	Usually eliminated from severe burns where surface organic layer is absent. The wet nature of preferred habitat tends to resist fire.
Montane vole *Microtus montanus*	Habitat includes wet areas and mountain meadows within a relatively broad elevational range. Forages on ground for succulent stems and leaves of grasses and forbs. Constructs underground burrows.	Benefits from fire-created openings that support an undergrowth of grasses, sedges, and other wet site forbs.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Longtail vole *Microtus longicaudus*	Widespread in wet mountain meadows and forest edge, often near streams. Requires a grass-sedge-forb food source. Less restricted to runways and dense grass than other *Microtus*.	Use increases with removal of tree canopy especially on moist north slopes.
Mexican vole *Microtus mexicanus*	Herb-filled openings in ponderosa pine and mixed conifer forests. Nests underground in summer and probably above ground in winter. Creates runways and burrows through the grass cover.	Generally impervious to most fires unless caught out of burrow during fire.
Water vole *Arvicola richardsoni*	Restricted to alpine marshes, willow-lined streambanks, and grass and sedge areas of the alpine and subalpine forests. Nests under roots, stumps, and logs.	Relatively impervious to fire. Severe fire that removes streamside cover may result in temporary loss of habitat.
Muskrat *Ondatra zibethicus*	Occupies cattail marshes, banks of ponds, lakes, or slow-moving streams. Requires a source of succulent grasses or sedges, or other aquatic vegetation.	Periodic fire retains marshes in a subclimax state and removes unfavorable vegetation that crowds out useful plants.
Western jumping mouse *Zapus princeps*	Requires a well-developed extensive herbaceous layer along edge of rivers, streams, lakes, or other wet areas and moist soil. Uses downed logs for cover and nest sites. Eats seed, grass, and forbs.	Generally eliminated from severe burns that lack the required vegetative cover.
Porcupine *Erethizon dorsatum*	Prefers medium and old-age conifer stands of less than 70 percent crown closure and containing shrubs and herbs. Uses hollow logs and tree cavities for dens.	Use of severely burned areas curtailed especially if overstory is killed. May continue to use light and moderate burns.
CARNIVORA (flesh-eaters):		
Coyote *Canis latrans*	Widespread occurrence in most habitats and most successional stages. Uses hollow logs or stumps for dens. Preys on mice.	Increased use of burned areas that support abundant small mammal populations.
Gray wolf *Canis lupus*	Highly adaptable but probably restricted to wilderness forests. Preys on other mammals.	Probable increased use of burned areas that support an abundant population of prey species.
Red fox *Vulpes vulpes*	Prefers open areas in or near forest. Uses hollow stumps and logs for dens. Food includes berries, insects, birds, rodents, squirrels, rabbits, and other small mammals.	Benefits from fires that create favorable habitat for small mammal prey species, especially those that enhance snowshoe hare populations.
Black bear *Ursus americanus*	Prefers mature forests mixed with shrub-fields and meadows. Omnivorous. Requires windfalls, excavated holes, or uprooted or hollow trees for den sites.	Benefits from abundant regeneration of berry-producing shrubs following fire. Severe fires may destroy favorable den sites.
Ringtail *Bassariscus astutus*	Prefers open forest, riparian deciduous forest, and woodlands. Dens in hollow trees, under rocks, in caves, or rock crevices. Feeds primarily on rodents; some birds, reptiles, fruit, and insects.	Fire may remove den trees and forest floor habitat for prey animals.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Raccoon *Procyon lotor*	Very adaptable to environmental change; in riparian situations; along marshes, streams, and lakes. Uses hollow trees and downed logs for dens. Omnivorous.	Relatively impervious to fire because of mobility and wide ecological amplitude.
Marten *Martes americana*	A forest dweller; requires relatively dense climax or near-climax situation. Uses tree or snag cavities and hollow stumps for nest sites. Food includes tree squirrels, chipmunks, mice, berries, and insects.	Eliminated from severely burned stands. Benefits from vegetative mosaics resulting from periodic small fires because of increased food supply. Burns containing adequate cover may be used for feeding during summer and fall.
Fisher *Martes pennanti*	Prefers forest of large trees with many windfalls and downed logs. Nests in tree holes, hollow logs, and snags. Eats squirrels, porcupines, woodrats, mice, rabbits, insects, and berries.	Preferred habitat is adversely affected by severe fire. Benefits from increase in prey species on burns adjacent to favorable habitat. Adapts better to early successional stages than marten.
Ermine (shorttail weasel) *Mustela erminea*	Prefers mature dense forest for breeding and resting; meadows or other forest openings for hunting. Dens often located in hollow logs and snags. Voles are an important prey; also mice, shrews, and chipmunks.	Adversely affected by severe fire that removes ground debris or kills overstory trees. Benefits from increased biomass of prey species that usually results on fire-created grass-forb successional stages.
Longtailed weasel *Mustela frenata*	Ubiquitous—common in most habitats. Prefers open areas and young pole stands. Den sites include logs, stumps, and snags. A major predator of voles and mice. Also feeds on gophers, birds, insects, and vegetation.	Benefits from increased biomass of prey species that usually results on recently burned areas.
Mink *Mustela vison*	May occur in any habitat containing fish-supporting marshes, lakes, and streams. Hollow logs and tree stumps along streams may be used for den sites.	Relatively impervious to most fires. May be adversely affected where fire removes streamside cover and debris.
Badger *Taxidea taxus*	Grass-forb stages of conifer forest succession is a preferred habitat. Likes deep, friable soil for burrowing and rodent capturing.	Benefits from fires that result in grass-forb successional stages because of the abundant rodent populations that are often present.
Western spotted skunk *Spilogale gracilis*	Habitat includes rocky and brushy areas in woodlands and chaparral. Prefers seedling-sapling stage. Den sites include rock outcrops, ground burrows, hollow logs, stumps, snags, or brush piles. Eats mostly insects and small rodents, also reptiles, amphibians, birds, eggs, and plant matter.	Moderate to severe fires may temporarily impact den sites and food supply.
Striped skunk *Mephitis mephitis*	Prefers early successional stages of forest but may be found in all stages and cover types. Uses hollow logs, stumps, and snags for den sites. Food includes large insects and small rodents.	Relatively impervious to fire. Benefits from increased biomass of prey species that usually occur on severe burns.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
River otter *Lutra canadensis*	Occurs along streams, marshes, and lakes. Dens in bank. Aquatic.	Essentially impervious to fire. Severe fires may destroy essential escape cover along streams, thereby adversely affecting use.
Mountain lion (cougar, puma) *Felis concolor*	Found throughout all habitat types and successional stages. Highly mobile. Hunts deer, hares, rodents, and porcupines.	Often flourishes on recently burned areas due to increased prey availability.
Lynx *Felis lynx*	Primarily in dense coniferous forests at higher elevations. May den in hollow logs. Snowshoe hare is an important prey species.	Benefits from fire-initiated shrub stages of succession that support large populations of snowshoe hare.
Bobcat *Lynx rufus*	Found in most habitats and successional stages; shrub-sapling stages being especially desirable. May establish den under large logs or in hollow logs. Preys on rodents, reptiles, and invertebrates.	Relatively impervious to fire. Benefits from any fire-induced increase in availability of prey species.
ARTIODACTYLA (even-hoofed mammals):		
Elk *Cervus canadensis*	Prefers semiopen forest but with areas of dense cover for shelter. Requires food supply of grass, forbs, and shrubs, especially Scouler willow, maple, serviceberry, redstem, and chokecherry.	Severe burns usually experience a decline in first-year use; then an increase as preferred browse species become available. Moderate fires in forest may remove ground debris and other obstructions to movement.
Mule deer *Odocoileus hemionus*	Occupies a wide range of habitats including open montane and subalpine coniferous forest; forest edges, woodlands, and shrubfields. Shrub-seedling sapling stage of succession preferred. Needs trees and shrubs for winter range. Preferred food includes tender new growth of palatable shrubs—ceanothus, cherry, mountain-mahogany, bitterbrush; many forbs and some grasses.	Fire may improve winter nutrition in grassland and mountain shrub communities by increasing the amount of green grasses. Often a decline in use during the first postburn year and then an increase in subsequent years. Where antelope bitterbrush is an important winter range species, moderate to severe fires may be detrimental.
Whitetail deer *Odocoileus virginianus*	Prefers dense forest; rough, open shrublands; thickets along streams and woodlands. Diet includes shrubs, twigs, fungi, grasses, and forbs.	Fire-initiated early successional stages supporting new growth of grasses, forbs, and shrubs provide a preferred food source.
Moose *Alces alces*	Prefers subclimax forests with lakes and swamps. Ideal habitat includes a mosaic of numerous age classes and distribution of aspen and associated trees and shrubs within the wintering range.	Fires that result in abundant aspen and willow regeneration create a preferred habitat. Optimal successional stage occurs from 11 to 30 years following a severe fire.
Bighorn sheep (mountain sheep) *Ovis canadensis*	Preferred habitat characterized by rugged rocky mountain slopes with sparse trees and adjacent to alpine meadows. Feeds on alpine shrubs and forbs in summer; shrubs and perennial grasses in winter.	Canopy removal by fire may yield increased productivity of undergrowth and makes available more open habitat, thereby dispersing populations and reducing incidence of lungworm infections. Fire may retard successional advance of alpine grasslands and

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Bighorn sheep (Con.)		improve productivity and palatability of important forage species. Fire can improve nutrition in mountain shrublands by increasing availability of green grass.
CAUDATA (salamanders):		
Tiger salamander *Abystoma tigrinum*	Found in and near pools, ponds, lakes, and streams. Adults sometimes burrow in decayed logs in damp forest situations.	Impervious to fire except for minor direct mortality in severe fire situations.
SALIENTIA (frogs and toads):		
Bullfrog *Rana catesbeiana*	Inhabits lakes, marshes, pools, ponds, reservoirs, and streams. Hides under debris at water's edge.	Relatively impervious to fire.
Spotted frog *Rana pretiosa*	Highly aquatic.	Impervious to fire.
Leopard frog *Rana pipiens*	Stays around water. In summer it inhabits swamps, grassy woodland, or short-grass meadows.	Generally impervious to fire. Some direct mortality possible from fast-spreading surface fire.
Canyon tree frog *Hyla arenicolor*	Found near streams in ponderosa pine and riparian forest zones.	Relatively impervious to most fires although severe fire can destroy favorable forest floor habitat.
Chorus frog *Pseudacris triseriata*	Occupies high grasslands and mountain forests. Inhabits marshes, meadows, lake margins, and grassy pools. Usually found on the ground or in low plants.	Relatively impervious to fire because of wet habitat.
Great Basin spadefoot *Scaphiopus intermontanus*	Favorable habitat extends from P-J woodlands into spruce-fir forest in Utah. Lives in underground burrow during dry weather. Feeds on insects near open water. Breeds in open water.	Relatively unaffected by fire.
Boreal toad (western toad) *Bufo boreas*	Found in or near water. Burrows in loose soil. Breeds in open water. Feeds on insects.	Relatively impervious to fire.
CHELONIA (turtles):		
Painted turtle *Chrysemys picta*	Highly aquatic. Basks near the water on mudbanks, rocks, and logs.	Impervious to fire.
SQUAMATA (snakes and lizards):		
Collared lizard *Crotaphytus collaris*	May inhabit evergreen woodland with scattered rock and sparse undergrowth.	
Leopard lizard *Gambelia wislizeni*	Habitat includes densely covered forest stands. Feeds on lizards, insects, spiders, rodents, seeds, and blossoms.	
Eastern fence lizard *Sceloporus undulatus*	Its many habitats include woodland and conifer forest. Finds refuge in trees, shrubs, logs, rodent burrows, and rocks. Diet includes insects, spiders, snails, and other small animals.	Fires that consume forest floor vegetation and debris can destroy favorable habitat conditions.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Sagebrush lizard *Sceloporus graciosus*	Favors sagebrush but also occurs in P-J woodland and ponderosa pine forest. Likes scattered low shrubs on fine, gravelly soil. Eats insects, spiders, ticks, snails, and other small animals.	Fires that consume forest floor vegetation and debris can destroy favorable habitat conditions.
Northern tree lizard *Urosaurus ornatus*	Generally restricted to boulders, canyon walls, and cliffs in oak, pine, P-J. Also alder and cottonwood in riparian areas. Usually on boulders, shrubs, and trees, rarely on ground. Eats insects and arthropods.	Unfavorable impacted by stand-destroying fires.
Western skink *Eumeves skiltonianus*	Found in woodland and forest with dense vegetation. Inhabits rocky streamsides, dry grassy hillsides, forest openings, and meadows. Hides under logs and bark. Diet includes moths, beetles, crickets, grasshoppers, and spiders.	Severe surface fires will reduce cover and food supply.
Plateau whiptail *Cnemidophorus velos*	Common in P-J, oak, and ponderosa pine. Prefer lower mountain elevations near streams. Diet includes insects and other small animals.	Severe fire may result in some direct mortality. Generally benefits from fire-created openings.
Western whiptail *Cnemidophoru tigris*	Found in openings; avoids dense vegetation. Prefers open woodlands and warmer parts of the forest. Eats insects and other small animals on the ground.	Severe fire may result in some direct mortality. Generally benefits from fire-created openings within its range.
Rubber boa (Rocky Mountain boa) *Charins bottae*	Found near streams and meadows in all forest types; prefers pole to mature stands. Uses rotting logs, and bark of fallen and standing dead trees for hiding. Feeds on rodents, insects, and lizards on forest floor.	Severe surface fire can remove cover and temporarily reduce abundance of prey species.
Racer (western yellow-bellied racer) *Coluber constrictor*	Inhabits open woodlands, wooded ravines, and thickets. Diet includes lizards, frogs, small rodents, snakes, and insects.	Surface fire may adversely affect food supply. Severe fire can create preferred early successional habitat.
Striped whipsnake *Masticophis taeniatus*	Habitat includes P-J, pine-oak, fir, and willows especially along streams. Forages in rocks, rodent burrows, and in trees and shrubs. Eats lizards, rodents, birds, and insects.	Severe surface fire may temporarily remove prey species.
Corn snake *Elaphe guttata*	Found along stream and river bottoms, on rocky wooded hillsides, and in conifer forest. Forages on ground and hides in rodent burrows, under logs, rocks, and other debris. Eats rodents, lizards, birds, and frogs.	Direct mortality can result from fast-moving fires. Severe surface fire also remove prey species and cover.
Gopher snake (bullsnake) *Pituophis melanoleucus*	Highly adaptable species; occupies a variety of habitats. Mainly hunts on surface for small mammals.	Relatively impervious to fire because of wide ecological amplitude.

(con.)

Table 5 (Con.)

Species	Habitat considerations	Fire effects
Common kingsnake *Lampropeltis getulus*	Varied habitats include conifer forest, woodland, and chaparral. Highly adapted ground dweller and burrow hunter, but also forages in trees and shrubs. Diet includes snakes (rattlers), lizards, frogs, birds, eggs, and small animals. Inhabits areas with rock outcrops and clumps of vegetation, under rotting logs, debris, and rocks.	Severe, fast-spreading fire can cause direct mortality. Surface fires result in removal of hiding and foraging cover and temporarily reduce prey species.
Common garter snake (red-sided garter snake; valley garter snake) *Thamnophis sirtalis*	Widely distributed in many different habitats which include a water source. Diet largely aquatic but includes small mammals.	Impervious to fire.
Western terrestrial garter snake *Thamnophis elegans*	Found in all successional stages of all habitat types near permanent or intermittent streams and ponds.	Relatively impervious to fire because of its tendency to be close to water.
Western rattlesnake *Crotalus viridis*	Highly variable habitats, including open woodlands to mountain forests. Often found in rock outcrops. Hunts on surface for rodents, ground squirrels, and mice.	Relatively impervious to fire except for possible direct mortality in severe surface fire situations. Such fires may also cause a temporary reduction in prey species.

openings; a predator such as the sharp-shinned hawk is an example. Such birds benefit by increased hunting success in recent burns, but generally depend on unburned habitat for nesting sites.

Fire-dependent species are associated with fire-dependent and fire-adapted plant communities. When fire frequency decreases, these plant communities shift to fire-neutral or fire-intolerant types, and fire-dependent species are unable to persist. The blue grouse may be a Utah example. The bird depends on medium to large fire-created forest openings with shrub-grass-forb vegetation for breeding adjacent to dense foliage conifers for roosting and hooting.

Table 6 presents the hypothesized fire tolerance of some Utah bird species.

FIRE USE CONSIDERATIONS

Applications of fire ecology information are described at the end of each Fire Group discussion. The possible use of fire to accomplish certain resource management objectives is suggested. The following fire use considerations apply generally to all Fire Groups.

Fuels

Estimates of surface fuel loadings are required to accurately predict fire behavior. This information serves as input to mathematical models of fire spread and intensity such as FIREMOD (Albini 1976) and BEHAVE (Burgan 1987; Burgan and Rothermel 1984). Uses of fuel loading information include fire danger rating and fire behavior prediction for fire dispatching, presuppression planning, and fuel management (Brown and Bevins 1986).

Published fuel data for Utah forests and woodlands are scant. Brown and Bevins (1986) describe fuel loadings for fire groups similar to those presented herein. Figure 2 shows the range of loading by fuel category for fire groups described for Montana (Fischer and Bradley 1987; Fischer and Clayton 1983). As indicated in figure 2, the variation of fuel loading and associated potential fire behavior within a group is probably large when compared to measurements between groups. When knowledge of potential fire behavior for a particular site is needed, site-specific fuel estimates or measurements must be made.

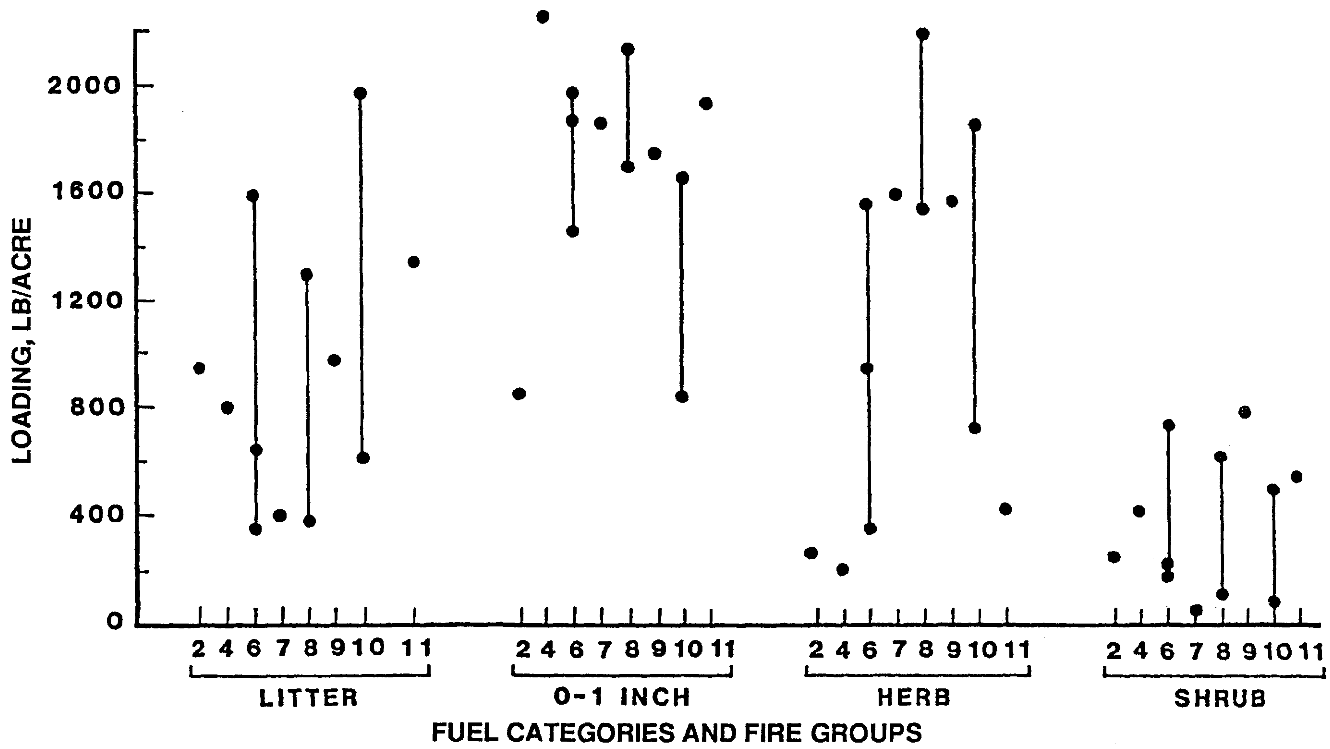
Table 6—Hypothesized fire tolerance in some Utah birds (adapted from Kramp and others 1983)[1]

Fire intolerant	Fire impervious	Fire adapted	Fire dependent
Ash-throated flycatcher	American crow	American kestrel	Blue grouse
Bewick's wren	American robin	American robin	House wren
Black-capped chickadee[2]	Black-billed magpie	Black-headed grosbeak	Mourning dove
Black-throated gray warbler	Black vulture	Blue grosbeak	Sandhill crane
Blue-gray gnatcatcher	Blue-winged teal	Blue-winged teal	Wild turkey
Brewer's sparrow	Brown-headed cowbird	Brewer's sparrow	
Brown creeper	Canada goose	Canada goose	
Burrowing owl	Cedar waxwing	Cassin's kingbird	
Bushtit	Clark's nutcracker	Clark's nutcracker	
Cassin's finch[2]	Cliff swallow	Cliff swallow	
Chipping sparrow	Common raven	Common nighthawk	
Golden-crowned kinglet	Common snipe	Cooper's hawk	
Grasshopper sparrow	Eastern kingbird	Dark-eyed junco	
Great horned owl	European starling	Downy woodpecker	
Hammond's flycatcher	Gadwall	Fox sparrow	
Hermit thrush	Great blue heron	Gambel's quail	
Mountain chickadee[2]	Greater roadrunner	Hairy woodpecker	
Goshawk	Green-tailed towhee	House wren	
Horned lark	Lark bunting	Killdeer	
Northern harrier	Loggerhead shrike	Lark sparrow	
Pine siskin	MacGillivray's warbler	Lazuli bunting	
Pygmy nuthatch	Mallard	Mallard	
Red-breasted nuthatch[2]	Mourning dove	Mountain bluebird	
Red crossbill	Northern flicker	Northern flicker	
Ruby-crowned kinglet	Northern pintail	Northern harrier	
Rufous-sided towhee[2]	Red-winged blackbird	Northern pintail	
Sharp-shinned hawk	Snowy egret	Poor-will	
Solitary vireo	Song sparrow	Purple martin	
Western flycatcher	Steller's jay	Rufous-sided towhee	
Western tanager[2]	Townsend's solitaire	Savanah sparrow	
White-crowned sparrow[2]	Turkey vulture	Snowy egret	
White-throated sparrow		Three-toed woodpecker	
Yellow-rumped warbler[2]		Tree swallow	
Yellow warbler		Vesper sparrow	
		Violet-green swallow	
		Western bluebird	
		Western kingbird	
		Western meadowlark	
		Western screech owl	
		Western wood pewee	
		Wild turkey	
		Williamson's sapsucker	
		Yellow-bellied sapsucker	

[1]Assignment of a species to one or more categories is based, in most cases, on limited data and opinion. Definitions in the text of each category should be read carefully.
[2]Breeding cover negatively impacted by fire, foraging use made of burned areas.

For broad-scale applications, physical properties such as loading may not be as important as fuel moisture and the condition of live vegetation to predict fire behavior. These are largely related to elevation, aspect, and season (Brown and Bevins 1986). Habitat types, and therefore fire groups, reflect elevation, aspect, and length of fire season on a site. To this extent they may be useful for fire behavior prediction efforts.

Fire may be relatively infrequent in a number of Utah Fire Groups because of sparse fuel or high moisture content. Fine fuels are frequently light in pinyon-juniper (FG 1), oak-maple brush (FG 2), and limber pine-bristlecone (FG 9) stands. In other types, fine fuels may be sufficient but rarely be dry enough to burn. This may be true of aspen (FG 7) and all the Fire Groups dominated by subalpine fir or Engelmann spruce (FG's 10, 11, and 12).



Key to numbers representing Montana Fire Groups. Utah Fire Groups roughly equivalent to these groups are in parentheses.

2 = Warm, dry ponderosa pine habitat types (Utah FG3)
4 = Warm, dry Douglas-fir habitat types (Utah FG4)
6 = Moist Douglas-fir habitat types (Utah FG5)
7 = Cool habitat types usually dominated by lodgepole pine (Utah FG8)
8 = Dry, lower subalpine habitat types (Utah FG10)
9 = Moist, lower subalpine habitat types (Utah FG11)
10 = Cold, moist upper subalpine and timberline habitat types (Utah FG12)
11 = Moist grand fir, western redcedar, and western hemlock habitat types (equivalent does not occur in Utah)

Figure 2—Fuel loading estimates for Montana Fire Groups. Plotted points represent mean fuel loading of selected fuel categories for fire ecology groups and locations. Variation within fire groups is shown by lines connecting different locations. Fire Groups are represented by one to three locations.

Lodgepole pine-dominated stands (FG 8) may suffer from both a lack of fine fuels and year-round high fuel moistures. Fine fuels can be significantly reduced by grazing or increased greatly by the presence of highly flammable annual grasses, such as *Bromus tectorum*. Overall fire hazard in many Utah forest and woodland types may be relatively low. Nevertheless, prolonged dry, windy weather can create very hazardous conditions in most fire groups. More flammable types often spread fire to stands that would not ordinarily ignite easily.

Predicting Fire Mortality

Fire can damage trees in several ways: crown damage, including bud kill and foliage mortality, bole damage, cambial damage, and root damage (especially in shallow-rooted species). Mortality often results from the effects of a combination of fire-induced injuries. Trees of different species and sizes vary in their resistance to fire damage. Tall trees are likely to have a large proportion of their foliage above scorch height and often have thicker bark, as well.

Reinhardt and Ryan (1988) have combined the factors that affect tree mortality and developed a series of nomograms to relate tree characteristics and types of potential fire damage to help managers estimate tree mortality after prescribed underburning. They give the following example for use of the nomograms (refer to figure 3):

> To use the mortality nomogram, choose an acceptable level of mortality (e.g. 20 percent or a 0.2 probability of mortality). Acceptable mortality will depend on the value of the trees and the objectives of the fire. Successful underburning involves choosing and staying

within a reasonable level of mortality... . Once an acceptable level of mortality has been chosen for a particular species, the nomogram can be used to develop a burning prescription... . Consider a shelterwood harvest with Douglas-fir leave trees averaging 17 inches (43.2 cm) in diameter, 100 ft (13.1 m) tall, with a crown ratio of 0.5. Entering the nomogram at the lower left at observed tree diameter, draw a horizontal line until you intersect the correct species line. Then turn a right angle and draw a line straight up. When the line crosses the edge of the lower left box, bark thickness can be read, if desired, but it is not necessary to do so. In this example, bark thickness of a 17-inch (43.2-cm) Douglas-fir is seen to be about 1.1 inches (2.8 cm). Continue the line straight up until it intersects the target mortality rate curve (0.2). At this point, turn a right angle again, to the right. This time, when passing from the upper left to the upper right quadrant, it is possible to read off crown volume scorched (percent). This example shows that a little more than 40 percent of the crown volume of these trees may be scorched without exceeding the target mortality of 20 percent.

Refer to the original document for further instruction.

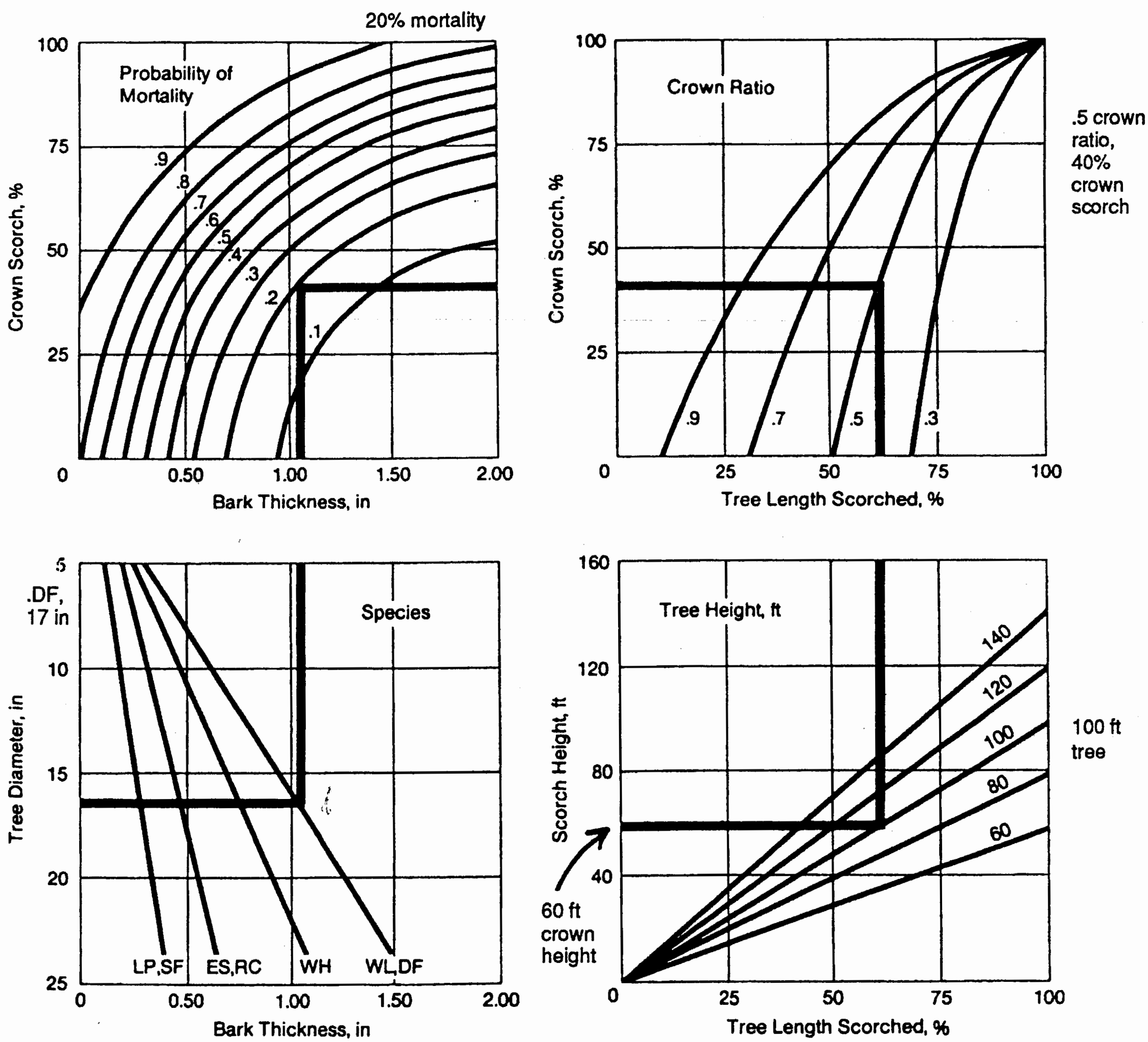


Figure 3—Nomogram to estimate tree mortality after prescribed underburning (Reinhardt and Ryan 1988). For a description of its use, see text.

Crown Damage and Insect Attack

Care must be taken when burning in forest stands to prevent or minimize scorching the crowns of residual overstory trees. Heavy fuel accumulations or slash concentrated near the base of overstory trees may require scattering or other treatment to avoid lethal cambium heating. Reduced vigor resulting from excessive crown scorch, cambium damage, or both can increase susceptibility to bark beetle attack and tree mortality. For example, the relationships between crown defoliation and mortality caused by the western pine beetle in ponderosa pine have been generalized as follows (Stevens and Hall 1960):

Percentage defoliation	Percentage of trees killed by beetles
0 - 25	0 - 15
25 - 50	13 - 14
50 - 75	19 - 42
75 - 100	45 - 87

The season in which a fire occurs is an important factor influencing tree mortality and the occurrence, duration, and severity of a potential beetle attack on fire-weakened trees. The result of crown scorching is usually more severe during the active growth period early in the summer than later when growth has slowed, terminal buds have formed, and a food reserve is being accumulated (Wagener 1955, 1961). Likewise, crown scorching that occurs in early spring, before or immediately after bud burst, often results in minimum damage to the tree.

Prescribed burning of understory vegetation and dead surface fuels can be carried out without serious threat of subsequent damage by bark beetles provided the overstory trees are not severely scorched (Fischer 1980). If accidental scorching does occur, and bark beetle activity is detected, prompt removal of the severely scorched trees will reduce the probability of subsequent damage to healthy green trees. If scorching occurs outside the active growth period, scorched trees may recover and regain lost vigor. This may take 3 years, but signs of recovery should be visible during the first growing season that follows scorching.

Frequency of Burning

The consequences of too frequent fire on forest sites may include loss of seed source or regenerating roots and rhizomes, loss of nutrients, invasion by noxious weed species, and a decline in site fertility. Suppression of fire can result in hazardous fuel loadings, lack of regeneration, lowered understory and overstory diversity, and stand decadence. Plant communities have evolved under differing fire regimes. If the management objective is to retain or restore a particular mix of species or age classes, investigation of the historic fire frequency is a good starting point. In some cases, enhancement of valuable plant species rather than reproduction of the historic landscape is the goal. Here, individual species' response to various fire frequencies should be considered. For example, burning semiarid foothill sites at the historic intervals of 5 to 20 years may be excessive on mule deer winter ranges because shrub production is a major objective (Gruell 1990).

Large Woody Debris

Fire is frequently used to reduce woody fuel buildup on forest sites. Fire plays an important role in recycling nutrients locked up in dead plant materials, especially in cold, dry environments where decay takes place very slowly. But a fire prescription should never be written so as to remove all woody debris from a site. Organic matter in the soil releases nutrients and enhances aeration and water retention. Material that results from decaying large logs acts as a reservoir for mycorrhizae and nitrogen-fixing bacteria, which can then reinoculate the site after fire or other disturbance. The importance of woody debris increases on droughty or otherwise harsh sites. Harvey and others (1987) recommend leaving between 11 and 16 tons/acre (24 and 36 metric tons/hectare) to retain productivity on forest sites.

Scattered large logs left on a site also retard soil movement and provide shade for seedlings. The more tolerant tree species such as subalpine fir or Engelmann spruce will not successfully regenerate without at least partial shade. In addition, only as much mineral soil should be bared as is necessary to obtain desired stocking. Quantities of organic matter in excess of the above requirements can be considered undesirable, especially on dry sites. Excess buildup of fuels can set the stage for severe wildfires that may result in an extreme reduction of the soil's organic reserves.

A final reason for leaving moderate amounts of large-diameter woody debris scattered on the site following logging and burning is to supply food and cover for wildlife. Many small mammals that reside in Utah forests rely on forest floor debris for cover and nesting sites. Rotten logs are often important foraging sites for both mammals and birds. Logs, for example, are important feeding sites for pileated woodpeckers.

Woodpeckers and other cavity-nesting birds (and mammals) also require snags, preferably scattered patches of snags, for nesting sites (McClelland and Frissell 1975; McClelland and others 1979).

The need to retain moderate amounts of scattered, large-diameter woody debris should not preclude slash disposal. Untreated logging slash represents a significant fire hazard on most sites; usually dead wood greatly exceeds that of the pretreatment situation. This increased hazard will exist for at least 3 to 5 years, even with a maximum compaction effect from winter snows.

Logging slash, as well as large accumulations of deadfall in untreated stands, can affect elk behavior and movement. Elk use may be diminished when slash inside a treatment unit exceeds 1.5 ft (0.5 m) in depth and dead and down material outside the opening exceeds 1.5 ft (0.5 m) (Boss and others 1983).

Heat Effects on Soil

Properly applied, prescribed fire has a low risk of causing long-term adverse effects on the fertility of the most common Utah soils. The effect on naturally infertile soils is, however, unclear and should be monitored. The intense heat and ashes resulting from burning bulldozer-piled slash can affect regeneration success on the area occupied by the piles. Size of piles should be kept small, and burning should be deferred to periods of relatively high fuel and soil moisture (Holdorf 1982).

Prescribed Fire Planning

From a fire management perspective, a successful prescribed fire is one that is executed safely, burns under control, accomplishes the prescribed treatment, and attains the land and resource management objectives for the area involved. Successful prescribed burning requires planning. Such planning should be based on the following factors (Fischer 1978):

1. Physical and biological characteristics of the site to be treated.
2. Land and resource management objectives for the site to be treated.
3. Known relationships between preburn environmental factors, expected fire behavior, and probable fire effects.
4. The existing art and science of applying fire to a site.
5. Previous experience from similar treatments on similar sites.

FIRE GROUP ZERO: MISCELLANEOUS SPECIAL HABITATS

Fire Group Zero is a miscellaneous collection of habitats that neither form a widespread vegtative zone nor fit into the Utah habitat type classifications.

Scree

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

The discontinuous fuel often makes scree slopes unburnable. Individual trees or islands of vegetation may ignite, but fire spread is limited. A severe wind-driven 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.

Forested Rock

Forested rock is usually a very steep canyon wall or mountainside composed of rock outcrops, cliffs, and occasional clumps of trees clinging to ledges and crevices. Forested rock is especially prominent along canyons 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, 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.

Wet Meadow

A meadow is an opening in the forest that is characterized by herbaceous vegetation and abundant moisture. Subirrigation is common during at least some part of the growing season. Mountain meadows are frequently too wet to burn during the fire season. In midsummer, larger wet meadows often act as natural firebreaks, but during the late summer and early fall they may carry grass fires. In some situations, especially when meadows are dominated by grass, they may burn early in the spring following snowmelt and prior to greenup.

Streamside meadows may gradually become drier in the course of succession from a hydric to a 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 wet meadow and grassland. In some such sites the meadow becomes bordered by fire-maintained grassland. The absence of fire has allowed conifers to invade meadows where they would not normally be found.

Mountain Grassland

A mountain grassland (or grassy bald) is a grass-covered opening within an otherwise continuous coniferous forest. Mountain grasslands may act as firebreaks and can be maintained as grassland by light fires, but usually their fire ecology is less obvious. In the Bighorn Mountains of Wyoming, Despain (1973) found boundaries between grassland and forest that he attributed to topography and soils. Daubenmire (1943) suggested that soil factors might cause permanent mountain grasslands. It is also possible that these are natural grasslands that have little potential for forest development. Caution is indicated in management of stands adjacent to mountain grasslands until conditions responsible for their perpetuation are determined.

Deciduous Riparian Communities

Deciduous riparian communities are composed of sites dominated by deciduous trees, shrubs, or herbaceous vegetation adjacent to seasonal or perennial free-flowing streams or open bodies of water. They are often found in a narrow strip along drainage bottoms or between streambeds and upland forest vegetation. Overstory dominants include cottonwoods, aspen, willows, maples (including boxelder), and alders. The understory may be lush and includes a diverse assemblage of forb and graminoid species (Padgett and others 1989).

The effects of fire in these communities have been little studied. Although riparian communities are productive and frequently have large amounts of live and dead woody fuels, moist conditions generally inhibit fire spread. Leaf litter decomposes more rapidly than conifer needles, and dry fine fuels may be relatively scarce. Wind-driven fires originating in surrounding forests can carry in riparian communities during extended droughty weather. Such severe fires destroy trees and top-kill shrubs. Reinvasion of burned areas should take place soon after fire because of the moist soil conditions. Many species, such as willow, are able to resprout after top removal. Cottonwood, willow, alder, and maple have airborne seeds that can invade from some distance. Some upland species, particularly blue spruce and aspen, may intermingle with strictly riparian vegetation. The fire ecology of moist-site conifers is described in Fire Group Eleven. Aspen is discussed in Fire Group Seven.

FIRE GROUP ONE: PINYON-JUNIPER WOODLANDS

Vegetation

Habitat types for juniper or pinyon climax sites have not yet been identified for Utah. Fire Group One consists of all stands dominated by pinyon, juniper, or both at climax. Further refinement may be possible when habitat typing is completed.

The pinyon-juniper type extends over an area of more than 24,000 square miles (62,400 km^2) in the mountain foothills and plateaus of Utah. Pinyon, or two-needle pinyon (Welch and others 1987), dominates in the central and eastern region. Singleleaf pinyon, a typical Great Basin species, is the dominant in the mountains west of the Wasatch Range and the central plateaus. Occurring alone or as a codominant with both pinyons is Utah juniper. Scattered individuals of Rocky Mountain juniper are widespread but do not form extensive stands. Pinyon-juniper woodlands commonly lie immediately below the montane forest zone. Most often, this is dominated by ponderosa pine. Douglas-fir, limber pine, or lodgepole pine stands may also occasionally be found adjacent to woodlands. Along the Wasatch Front and in some southern mountains, pinyon-juniper woodlands are bordered at their upper limit by mountain shrub communities that replace the usual ponderosa pine belt (see Fire Group 2). In mountains adjacent to desert, like the Abajos, grasslands may form a zone above the pygmy conifer woodlands where hot, desiccating winds prevent the establishment of trees. At their lower boundaries, pinyon-juniper woodlands most often grade into shrublands or grasslands. Sagebrush communities are particularly common (fig. 4).

Stand composition varies with climatic and topographic location. Juniper has a wider ecological amplitude than pinyon and dominates lower or more xeric sites. More moderate higher elevation sites favor pinyon in climax communities. Because of the wide distribution of the type, the mix of species making up the undergrowth is not constant. In general, the trend is for shrubs and cool season grasses to prevail in the northern and western parts of the State. Stands to the south and east have increasingly

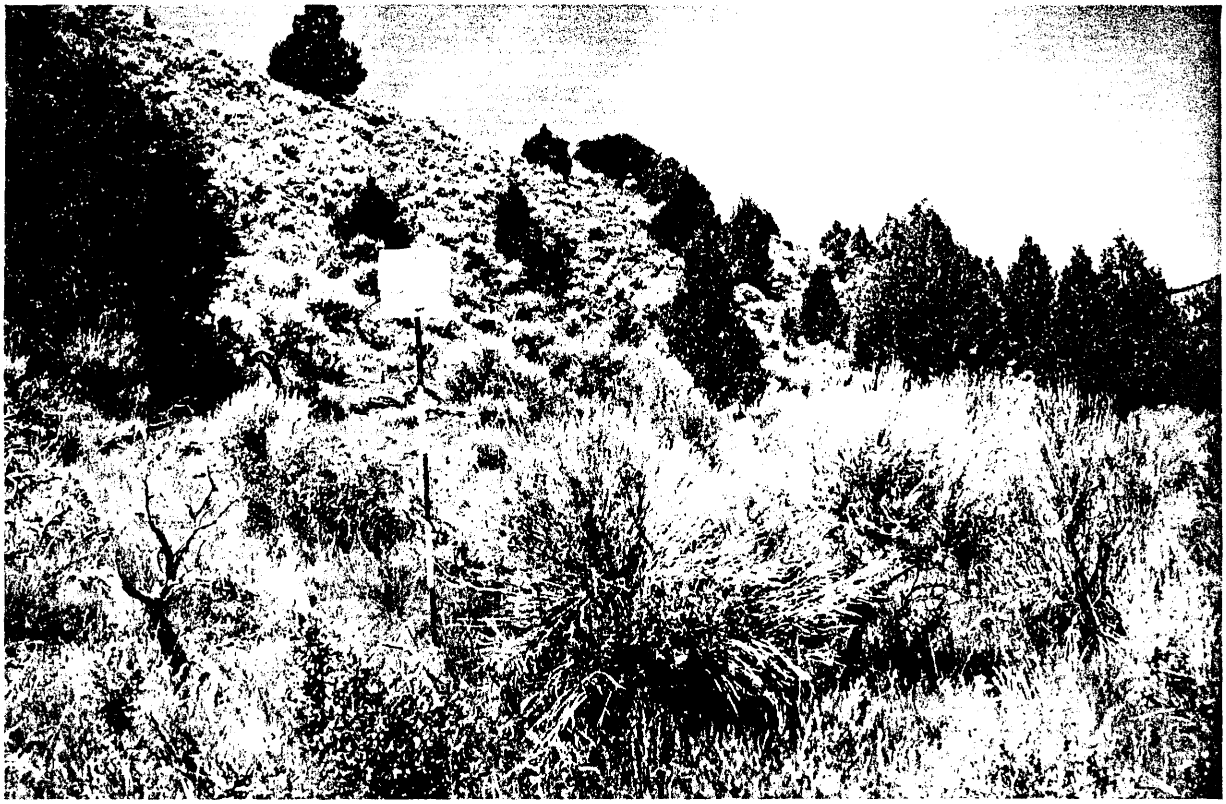


Figure 4—Utah juniper encroaching into a sagebrush grassland on the Paunsaugunt Plateau. Fire can set back plant succession in grass or shrublands with adequate fuels.

greater amounts of warm season grasses. This change results from the larger proportion of annual precipitation that falls during the growing season as one moves to the southeast (West 1984).

Pinyon-juniper woodlands in Utah have a variety of shrub species associated with them, including *Amelanchier alnifolia, Artemisia arbuscula, A. nova, A. tridentata, Ceanothus greggii, Cercocarpus ledifolius, C. montanus, Chrysothamnus viscidiflorus, Purshia mexicana* var. *stansburiana, P. tridentata,* and *Symphoricarpos longiflorus.* Widespread graminoids in the type are *Bouteloua gracilis, Bromus tectorum, Elymus elymoides, Festuca ovina* var. *arizonica, F. ovina* var. *ingrata, Hilaria jamesii, Koeleria macrantha, Oryzopsis hymenoides, Pascopyrum smithii, Poa secunda* (including *P. nevadensis*), *Pseudoroegneria spicata,* and *Stipa comata.* Forbs are less abundant in this type. *Balsamorhiza sagittata* and several species of *Phlox, Cryptantha, Aster,* and *Solidago* may be found scattered in stands (Isaacson 1966).

Forest Fuels

Fine surface fuels in many open pinyon-juniper stands range from 600 to 1,000 lb/acre (0.7 to 1.1 metric tons/ha) (Wright and others 1979). Approximately 600 to 700 lb/acre (0.7 to 0.8 metric tons/ha) of fine surface fuels are required to sustain surface fires (Jameson 1987). The productivity of understory vegetation is reduced as stands mature and the canopy closes. Pinyon-juniper stands most likely to burn by wildfire have small scattered trees with abundant herbaceous fuel between the trees, or have dense, mature trees capable of carrying crown fire during dry, windy conditions. Such stands are often located just below the ponderosa pine type. Stands of moderate tree density where overstory competition reduces the herbaceous fuel, and the trees themselves are more widely spaced, are very unlikely to burn (Jameson 1987).

Closed pinyon-juniper stands do not have understory shrubs to carry a surface fire, and do not burn until conditions are met to carry a crown fire. Central Texas sites with greater than 5.46 tons/acre (12.24 metric tons/ha) of fine fuel were found to develop a heat sufficient to kill Ashe juniper trees greater than 12.1 ft (3.7 m) tall. Many pinyon-juniper sites in the Great Basin are not productive enough to produce this amount of fine fuel (fig. 5), particularly if they have an overstory of trees (Bunting 1987). Trees taller than 4 ft (1.2 m) in

Figure 5—Mature pinyon-juniper stands often have scant fine fuels. Such stands do not carry fire except during periods of severe fire weather, particularly high winds (Abajo Mountains, southern Utah).

open pinyon-juniper are difficult to kill unless there are heavy accumulations of fine fuel beneath the trees.

Pinyon pine burns more readily than juniper. This may be due to inherent flammability of the foliage, or the tendency of pinyon to inhabit more mesic sites, so that understory fuels and tree density are greater and fire spreads more rapidly. Stands burn better as the proportion of pinyon to juniper increases. Even-aged, healthy pinyon-juniper stands less than 100 years old are less apt to spread fire compared to old or otherwise decadent stands that open up and permit an increase in fine surface fuels.

Sites with good growth of cheatgrass (*Bromus tectorum*) are at higher risk for large fires. Barber and Josephson (1987) reported greater fire spread after several years of good precipitation had increased cheatgrass yields. Tumbleweeds accumulated at the base of trees can significantly increase fire intensity around individual trees (Wright and others 1979). Livestock grazing reduces fine herbaceous fuels and lowers fire probability and fire severity.

Role of Fire

In the pinyon-juniper type, fire opens stands, increases diversity and productivity in understory species, and creates a mosaic of stands of different sizes and ages across the landscape. It also maintains the boundary between woodlands and adjacent shrub or grasslands. In the presettlement era, fire was a relatively common event. Specific fire history studies are few, but some estimates are available. Leopold (1924) suggested that fire occurred at intervals of 10 to 30 years in Arizona. Evidence of past fire was common in climax western juniper stands of southwestern Idaho. On four study sites, fire-free intervals were 23, 18, 8, and 11 years between the years 1840 and 1910—the decades with the most reliable fire history information (Burkhardt and Tisdale 1976). Moir (1982) believed that Mexican pinyon stands in the Chisos Mountains of Texas could be maintained in a "natural" condition by fires occurring every 50 years or so. Because pygmy conifer woodlands inhabit areas that frequently experience drought, climate, as well as fire, affects the successional development of stands. Pinyon pines and juniper bear good seed crops only every 2 to 5 years and require exceptional moisture conditions after germination for large numbers of seedlings to establish. On xeric sites, fire may never have been as important an influence as climatic fluctuations in governing the rate of tree invasion of shrubland or grassland because of the lack of undergrowth to act as fuel. Moister, more productive sites probably had more extensive and frequent fires when droughty periods occurred (Jameson 1987).

Grazing also has interacted with fire and climate to shape the woodlands. Great Basin pinyon-juniper stands have been used for grazing livestock for over 100 years. Southwestern sites may have been grazed for as long as 400 years. Grazing has reduced herbaceous cover significantly on most sites. Fire occurrence and extent has been severely limited by the removal of the fine fuels. This and past fire control policies have contributed to the current pattern of juniper and pinyon encroachment into formerly treeless areas. It has been estimated that up to 50 percent of the area now occupied by pinyon or juniper stands in the Great Basin is of relatively recent origin, the oldest trees being 125 years old (Tausch and others 1981).

Woodland Succession

Where juniper and pinyon occur together, juniper generally establishes first on the site because of its greater drought and insolation tolerance. But juniper, as well as pinyon, is generally dependent on shrubs and residual trees to act as "nurse plants" to protect vulnerable seedlings from excessive heat and drying. Factors that influence the pattern of succession after fire include past use history (particularly grazing), site factors, moisture regime, stand age when disturbed, fire severity, presence of residual trees, and the presence of animal dispersal agents. The seeds of pinyon and juniper are heavy and do not disperse by wind. Birds such as Clark's nutcracker, pinyon jay, and Steller's jay cache pinyon seeds and thus distribute it from its site of origin. A variety of other birds disseminate juniper seed along fencelines or in clumps beneath perches. Mammals also carry seed. Without animal dispersal, it is difficult for trees to expand into new areas.

The general successional pattern followed after fire in pygmy woodlands is illustrated in figure 6 (from Evans 1988). Erdman (1970) suggested a time sequence for successional events on the Mesa Verde in southwestern Colorado (fig. 7).

The hypothetical role of fire in succession is illustrated in figure 8 (subsequent letters in this section refer to fig. 8). The initial stand (A) following a crown fire may be dominated by annuals or residual

FIRE SUCCESSION IN SOUTHWESTERN COLORADO

Climax pinyon-juniper forest
↓
Fire
↓
Skeleton forest and bare soil
↓
Annual stage
↓
Perennial grass/forb stage
↓
Shrub stage
↓
Shrub/open tree stage
↓
Climax pinyon-juniper forest

FIRE SUCCESSION IN WESTERN UTAH

Juniper woodland
↓
Fire
↓
Skeleton forest (dead trees) and bare soil
↓
Annual stage
↓
Perennial grass/forb stage
↓
Perennial grass/forb/shrub stage
↓
Perennial grass/forb/shrub/young juniper stage
↓
Shrub/juniper stage
↓
Juniper woodland

Figure 6—General postfire successional patterns in pinyon-juniper woodlands (Evans 1988).

herbaceous perennial plants. In many stands herbs are succeeded by shrubs (B). Whether perennials are still present depends on site conditions and preburn stand age. Older, closed stands may be devoid of undergrowth and residual rhizomes and rootcrowns needed to regenerate shrubs and herbs. Regrowth success of perennial species will then depend on outside seed sources. Some on-site seed may be stored in the soil, but the seedbank declines with stand age (Koniak and Everett 1982). Stands dominated by annuals may experience a slow rate of succession back to woodland condition because of the

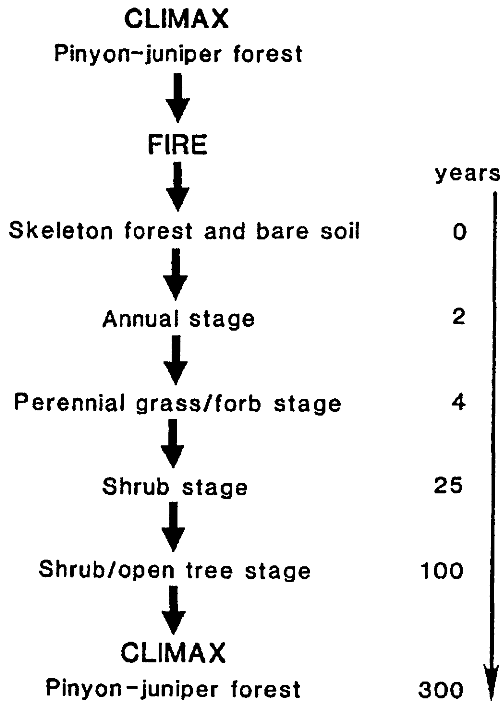


Figure 7—A suggested timeline of successional stages for pinyon-juniper woodlands on Mesa Verde, CO (Erdman 1970).

lack of nurse plants. Because of their greater drought tolerance, junipers are generally the first trees to reinvade a burned area (C). Pinyon seedlings follow, using the junipers as nurse plants (D). It takes about 30 years for seedlings and saplings to be evident on a site. Seedlings and saplings of both species can be eliminated by fire of any severity. In 70 or 80 years, the site is dominated by pole-sized trees (E). Stands are typically multiaged in appearance. If a good seedcrop is followed by several years of especially favorable moisture and temperature conditions, a dense, more or less even-aged stand may develop. Pole-sized stands are susceptible to fire. At this stage of development, however, the stand structure is usually open. Low-severity fires should leave at least scattered individuals (F1). A mature stand (F) consists of juniper and variable amounts of pinyon. On drier sites, stands may be pure juniper. More favorable locations support a mixture of the two species. Pinyon pines begin bearing good seedcrops at approximately 75 to 100 years of age, but do not reach maximum production until trees are about 160 to 200 years old. Where both juniper and pine are present, pinyon begins to dominate the overstory in the mature stand. Most of the understory trees will also be pinyon. Low-severity fires in a mature stand will remove trees in the

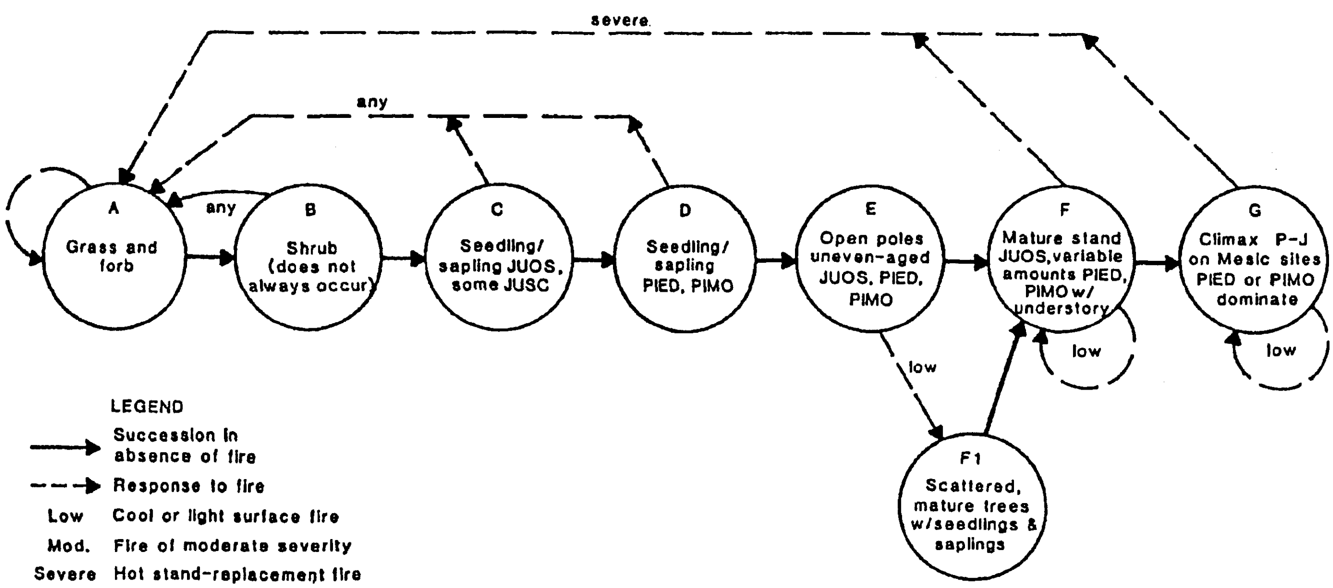


Figure 8—Hypothetical fire-related successional pathways for Fire Group One.

understory and a few overstory trees. Moderate fires remove more of the overstory, particularly pinyon. Where stands are closed or dense, the undergrowth declines significantly by the mature state. Fires become less and less common as the fuels needed to sustain their spread become more scarce. Where pinyon occurs, it tends to dominate climax stands (G), sharing the overstory with a few old juniper. Stand-replacement fires are possible when fire invades from adjacent sites under the influence of wind and flammable vegetation, such as big sagebrush.

Fire Management Considerations

Pinyon-juniper woodlands provide fuelwood, posts and poles, pinyon nuts, browse and forage for livestock and wildlife, and recreational opportunities. As the population of the Intermountain region continues to grow, the value of these commodities will also increase.

Many pinyon and juniper stands have been under "custodial" management, that is, little or no effort has been made to manipulate vegetation to preserve or enhance resource values because of inaccessibility or cost. The future productivity of these stands is at risk as they become more dense and important browse or forage species die out (Doughty 1987). Fire can be used as a relatively inexpensive tool to maintain or renew site productivity and to create a diversity of stand ages and densities across the landscape to optimize resource values.

Specific guidelines for burning pinyon-juniper-shrub sites were presented by Bruner and Klebenow (1979). They found that the success of a burn could be predicted accurately by adding together the maximum windspeed in miles per hour, the air temperature in degrees Fahrenheit, and the percentage of vegetation cover. If the number obtained was less than 110, fires would not burn. If it was greater than 130, fires were too hazardous to light. Scores between 110 and 125 produced fires that needed continual retorching, and numbers between 126 and 130 produced fires that spread unaided and burned clean. In general, burning success varied with cover class as follows (Blackburn and Tueller 1970):

Percent canopy cover	Cover class
0 - 2	open
2 - 9	dispersed
9 - 23	scattered
23 - 35	dense
35+	closed

Scattered and dense stands burned best in the nonfire season. Open and dispersed stands were not chosen as good candidates because trees exerted little influence on the undergrowth. Closed stands had few live shrubs and were extremely difficult to burn out of fire season.

Sparse ground fuels make burning into closed stands of pinyon and juniper relatively safe (Barber and Josephson 1987). In Nevada, observed fuel consumption by prescribed fires was similar whether fires carried well or only the immediate ignition area burned, suggesting that mostly fine fuel was being consumed. Closed pinyon-juniper stands are extremely difficult to burn out of the fire season, while many successful prescribed fires are conducted in scattered pinyon-juniper communities, which often include sagebrush as a major fuel (Bunting 1987).

Burning at intervals of 30 years or less can prevent tree invasion into neighboring shrubland. The earlier in the invasion process burning is done the more successful it is likely to be. But burning early in succession also means burning more frequently. An interval must be chosen that will effectively reduce tree cover but will maintain desirable undergrowth species (Bunting 1987). Table 7 shows the potential response of some common undergrowth species to different fire intervals.

Many degraded woodland stands are dominated by cheatgrass. Fires hot enough to remove litter and the seed stored in it can give managers a window of opportunity the first year after burning to plant more desirable perennial species (Evans 1988).

In a study of two species of mistletoe that infest pinyon and juniper in Grand Canyon National Park, AZ, fire was the most limiting factor on the mistletoe, and mistletoes and their hosts appeared to be in equilibrium (Kilgore 1981). Removal by burning of all pinyon slash larger than 3 inches (8 cm) during harvest will usually prevent pinyon ips (*Ips confusus*) populations from reaching epidemic proportions (Meeuwig and Bassett 1983).

FIRE GROUP TWO: MONTANE MAPLE-OAK WOODLAND

Vegetation

Fire Group Two is made up of montane communities where Gambel oak or bigtooth maple is considered the climax or long-term seral dominant or codominant species. Habitat type classifications are not available for these sites. Preliminary classification of Gambel oak-dominated communities of southwestern Colorado has been attempted (Steinhoff 1978, 1979). Steinhoff suggests that many pure oak stands are "temporary climax" stands, that is, they may have the potential to support ponderosa pine but are unlikely to do so for at least 500 years. These stands could be managed like "true" climax Gambel oak. A *Quercus gambelii*/

Table 7—Scenario of plant response to varying fire intervals relative to current conditions in western juniper communities in the Owyhee Mountains of southwestern Idaho[1] (Bunting 1987)

	Average fire recurrence (years)			
	<10	25	50	100
Shrubs:				
Artemisia tridentata ssp. *vaseyana*	–[2]	0	0	–
Chrysothamnus viscidiflorus	+	+	0	–
Juniperus occidentalis	–	–	0	+
Purshia tridentata	–	–	0 to +	–
Grasses:				
Agropyron spicatum[3]	0	+	+	–
Festuca idahoensis	0 to –	+	+	–
Sitanion hystrix[3]	+	+	0	–
Stipa occidentalis	+	+	0	–
Stipa thurberiana	–	0	0	–
Forbs:				
Agoseris spp.	+	0	–	–
Balsamorhiza sagittata	+	+	0	–
Crepis spp.	+	0	–	–
Lupinus spp.	+	+	0	–

[1]This region receives greater than 8.9 inches (350 mm) annual precipitation and is over 5,850 ft (1,500 m) in elevation.
[2]Symbols indicate that in the long term this species will: – = decrease, 0 = not change, or + = increase in abundance under this fire interval as compared to the current status.
[3]Nomenclature as originally published.

Symphoricarpos oreophilus (Gambel oak/mountain snowberry) habitat type has been identified in central Colorado (Hoffman and Alexander 1980, 1983). There has been some initial characterization of shrub communities in central Utah (Hayward 1948; Kunzler and others 1981; Ream 1964). The fire ecology described here is necessarily general and awaits further refinement based on completed habitat type classification. A description of the fire ecology of sites where Gambel oak is codominant with ponderosa pine can be found in Fire Group Three.

Maple-oak woodlands usually occur between 5,500 and 7,800 ft (1,676 and 2,377 m) in Utah. They form a belt between the warmer and drier pinyon-juniper or sagebrush types and more mesic stands dominated by Douglas-fir, aspen, or white fir. They occur in southern mountains, such as the La Sals (fig. 9), but reach their greatest development in central Utah, especially in the Wasatch Range. On most sites from the southern border northward to approximately the latitude of Brigham City, Gambel oak appears to be the climax dominant. In the Wasatch Range from north-central Utah to southeastern Idaho, Gambel oak drops out and bigtooth maple becomes the dominant species at climax. On at least some sites in central Utah, Gambel oak appears to be seral to bigtooth maple (Eastmond 1968; Harper and others 1985).

Small trees and shrubs that commonly inhabit the montane zone with oak and maple include: *Amelanchier alnifolia*, *Artemisia tridentata*, *Cercocarpus ledifolius*, *C. montanus*, *Chrysothamnus viscidiflorus*, *Mahonia repens*, *Pachystima myrsinities*, *Physocarpus malvaceous*, *Prunus virginiana*, *Purshia tridentata*, *Rosa woodsii*, and *Symphoricarpos oreophilus*. Herbaceous vegetation is often depauperate, especially in dense stands. Graminoids that commonly occur in more open stands are *Agropyron cristatum*, *Bromus tectorum*, *Carex hoodii*, *Elymus glaucus*, *Poa pratensis*, *Pseudoroegneria spicata*, and *Thinopyrum intermedium* ssp. *intermedium*. Typical forbs are *Allium acuminatum*, *Balsamorhiza sagittata*, *Galium aparine*, *Lathyrus pauciflorus*, *Lupinus* spp., *Solidago sparsiflora*, *Stellaria jamesiana*, *Vicia americana*, and *Viguieria multiflora*.

Montane shrub communities grow at elevations typically dominated by ponderosa pine in similar habitats to the north, south, and east. Spring and summer drought conditions may be responsible for the lack of pine regeneration in much of Utah's oak-maple zone (Baker and Korstian 1931).

Fuels

Specific fuel-loading information for this fire group is scant. A biomass inventory of eight Gambel oak stands near Ephraim, UT, gives an estimate of fuel loadings. Branches and boles on the ground weighed 2.64 tons/acre (5.92 metric tons/ha). Litter, primarily

Figure 9—Gambel oak clones interspersed with ponderosa pine and aspen, La Sal mountains, Manti-La Sal National Forest.

dropped foliage, weighed 16.66 tons/acre (37.35 metric tons/ha) (Clary and Tiedemann 1986).

Generally the oak zone is not considered to be highly combustible (fig. 10). In fact, it sometimes is treated as a "green belt" among other more flammable types. Occasionally, however, fuel conditions in this type develop into a severe wildfire hazard. For example, a potentially dangerous situation occurs when a late spring freeze kills the sprouting oak leaves, which remain as dried tinder during the summer or early fall (Winward 1985). As maple cover increases, stand fire susceptibility lessens. Rapidly decomposing leaf litter and a reduced understory make it difficult for fires to spread. Where conifers are accidental or are encroaching, flammability of the stand will increase because of their resinous foliage and persistent litter (Harper and others 1985). Dense understory oak increases fire risk to ponderosa pine. Oak can serve as a ladder fuel that carries fire to overstory tree crowns during both prescribed and wild fires.

Role of Fire

Many factors have affected the fire regime in the oak-maple zone since settlement. Fires started by Native Americans have been eliminated, heavy grazing has removed fine fuels in which fires started and spread, and wildfires have been actively suppressed in the latter part of the 20th century. Vegetation associated with Gambel oak and bigtooth maple has also been altered by logging and the spread of exotic weedy plants. Paired historic and modern photographs of central Utah foothill sites indicate that oak and maple stands are now more extensive than they were 75 to 150 years ago (Gruell 1990; Rogers 1982). In the past, the more extensive grass cover likely permitted relatively frequent fires during the dry season. Such fires would have inhibited the establishment of oak and maple seedlings and killed smaller stems on the margins of existing clones. In many places in central Utah older oak clones contain residual charcoal as evidence of past fires (Gruell 1990). On moist sites, fire may have maintained oak as a seral species where other more shade tolerant species such as bigtooth maple or white fir had the potential to dominate at climax. Because of the drastic change in the balance between grass-dominated and deciduous tree and shrub-dominated vegetation, fire's role has also changed. The relatively low fire frequency in this type at present may be the result of clone development over the last

Figure 10—Gambel oak may grow in relatively short or tall forms. Taller forms, such as this specimen, may be less flammable because their crowns are farther above potential fine fuels and they commonly occur on moist sites.

century and a half. The opportunities for fire have been reduced, especially where maple has become the dominant species, due to a depauperate understory and relatively nonflammable litter.

Gambel oak is known to be a vigorous resprouter after fire. Fire temporarily reduces cover and height of oak clones but increases stem density. In central Utah, stands have recovered their preburn height in 6 to 35 years, with most stands recovering in about 15 years (Kunzler and Harper 1980). Higher elevation stands recover more slowly than those at lower elevations. The most common effect of fire on oak is to stimulate sprouting, thicken existing stands, and encourage the merging of scattered clumps (Brown 1958). Composition of burned oak stands in Utah was found to resemble unburned stands within 20 years following fire (McKell 1950).

Brushland Succession

The successional pathway illustrated in figure 11 assumes a mesic productive site where Gambel oak can attain small-tree stature and where bigtooth maple is the potential climax species. (Subsequent letters in this section refer to fig. 11). Where Gambel oak occurs alone, the response of the associated plant species is much more variable than that of the oak itself. Single applications of fire have little long-term impact on oak clones. Bigtooth maple sprouts, but perhaps not as strongly as oak. Different fire severities may not elicit the same responses. More research is needed on maple response.

Residual perennial herbs and invading annuals dominate the initial stage of succession after a stand-replacement fire (A). Within a few weeks or months, depending on the season of burning, vigorous sprouts of Gambel oak and possibly some bigtooth maple appear (B). The shrub clones grow in a low, dense thicket. Over several years, a few stems in the clones gain dominance and increase in diameter (C). Self-thinning leaves the shrub clones more open, and undergrowth productivity often increases. Maple seedlings and sprouts from stem layering begin to dominate the oak understory. Oak and maple make up the overstory of the mature stand. By this phase, oak reproduction is completely shaded out and maple alone makes up the understory (D). As maple increases in the overstory, oak stems and the undergrowth decline, reducing fuel loadings. At climax, maple is the dominant (E). Oak remains only as residual stems around the fringes of maple clones. Mature maple clones burn much less readily than oak. In some stands, white fir or Douglas-fir seedlings and saplings may occur in the understory, although it is often unclear whether or not they will become significant members of the overstory. Their presence may make the shrub stand more flammable.

Fire Management Considerations

Periodic removal or reduction of stems in Gambel oak stands can improve quality of wildlife browse, enhance livestock movement, and increase productivity of the undergrowth. Reducing the number of stems by fire or any other means is only a temporary measure because of oak's ability to resprout quickly and prolifically. True control or elimination of Gambel oak with fire is not possible or even desirable. Gambel oak provides wildlife cover and browse, stabilizes soil, and retards snowmelt. Maintaining a diversity of stand ages can provide a good balance of forage and cover for wildlife.

Gambel oak and bigtooth maple are valuble as fuelwood because of their high heat output and

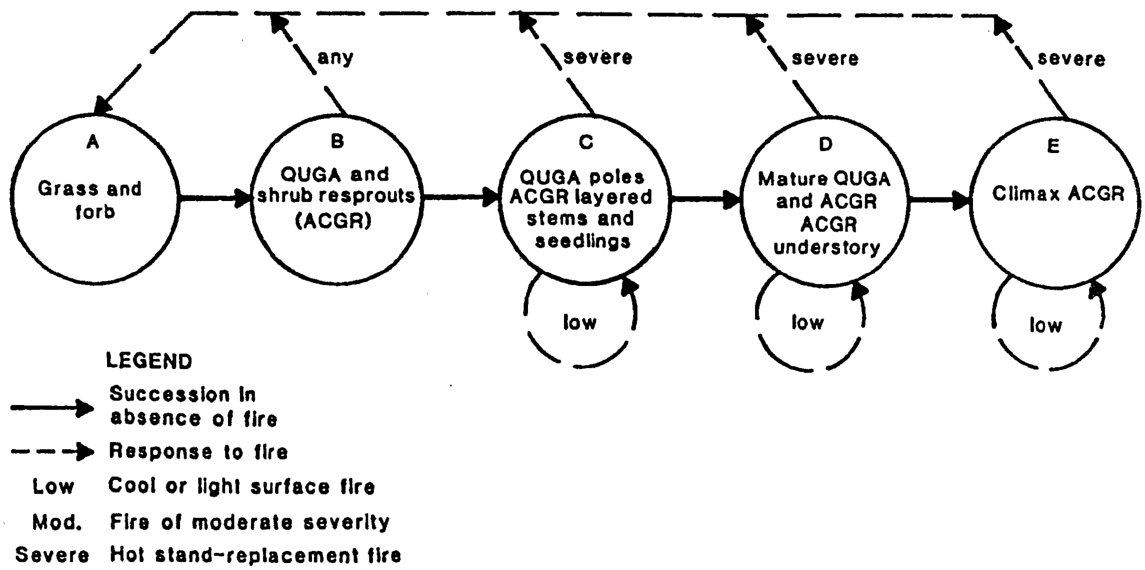


Figure 11—Hypothetical fire-related successional pathways for Fire Group Two habitat types.

speed of regeneration after cutting. Demand for quality fuelwood is increasing (Clary and Tiedemann 1986, 1987). Burning or cutting may be used as a tool to rejuvenate stands. There may be potential to use prescribed fire on sites following fuelwood cutting to reduce Gambel oak or bigtooth maple competition. Removal of the canopy and subsequent drying of fuels will aid fire spread through the recently emerged sprouts (Gruell 1990).

Managers in southwestern Colorado found that pure oak stands burned best between October 1 and snowfall when the National Fire Danger Rating System (NFDR) burning index (BI) is between 40 and 75 and dead leaves remain on the branches. Oak stands also burn well during very dry summer conditions, particularly on steep south aspects (Harrington 1990; Steinhoff 1979). A potentially dangerous fire situation can develop when sprouting oak leaves freeze in the spring and remain as dry fuel on the shrubs during the hot summer season. Disease may also create large amounts of fine dry fuel when leaves die. Flames can spread readily through oak and maple crowns during dry, windy weather, especially on steep terrain. Some fuel management is advisable for property owners in the oak-maple zone, particularly on steep slopes. Radtke (1983) offers suggestions for homeowners in chaparral-type vegetation including removing and pruning shrubs adjacent to buildings to reduce fuel load and continuity.

Oak clones vary in height, density, and size, depending on a combination of age, environment, and genetic factors. Fire susceptibility varies with community structure. For example, treelike forms of Gambel oak are less likely to be top killed than oak shrubs in a low-severity fire because their branches are farther above the burning surface fuels. Oak clones tend to be taller on moist sites where fine fuels are more abundant, but the period of high flammability is short. Likewise, stems in more mature clones are less easily damaged than those in denser, younger clones because of the generally larger stem diameters.

Bigtooth maple clones are typically less flammable than Gambel oak. Fuelwood cutting is probably the best method available for reducing density in mature stands. Managers who wish to prevent the spread of either oak or maple should consider burning before trees become large and the potential undergrowth fuel is severely reduced by shading.

FIRE GROUP THREE: PONDEROSA PINE HABITAT TYPES

Habitat Type, Phase

Pinus ponderosa/Arctostaphylos patula h.t. (PIPO/ARPA), ponderosa pine/greenleaf manzanita

Pinus ponderosa/Artemisia nova h.t. (PIPO/ARNO), ponderosa pine/black sagebrush

Pinus ponderosa/Carex geyeri h.t. (PIPO/CAGE), ponderosa pine/elk sedge

Pinus ponderosa/Cercocarpus ledifolius h.t. (PIPO/CELE), ponderosa pine/mountain-mahogany

Pinus ponderosa/Festuca idahoensis h.t.-*Arctostaphylos patula* phase (PIPO/FEID-ARPA), ponderosa pine/Idaho fescue-greenleaf manzanita phase

Pinus ponderosa/Festuca idahoensis h.t.-*Artemisia tridentata* phase (PIPO/FEID-ARTR), ponderosa pine/Idaho fescue-big sagebrush phase
Pinus ponderosa/Festuca idahoensis h.t.-*Festuca idahoensis* phase (PIPO/FEID-FEID), ponderosa pine/Idaho fescue-Idaho fescue phase
Pinus ponderosa/Muhlenbergia montana h.t. (PIPO/MUMO), ponderosa pine/mountain muhly
Pinus ponderosa/Purshia tridentata h.t. (PIPO/PUTR), ponderosa pine/antelope bitterbrush
Pinus ponderosa/Quercus gambelii h.t.-*Symphoricarpos oreophilus* phase (PIPO/QUGA-SYOR), ponderosa pine/Gambel oak-mountain strawberry phase
Pinus ponderosa/Quercus gambelii h.t.-*Quercus gambelii* phase (PIPO/QUGA-QUGA), ponderosa pine/Gambel oak-Gambel oak phase
Pinus ponderosa/Symphoricarpos oreophilus h.t. (PIPO/SYOR), ponderosa pine/mountain snowberry

Vegetation

Fire Group Three is made up of relatively warm, dry sites where ponderosa pine is the climax dominant. In northern Utah, these habitats are mostly restricted to the southern and eastern Uinta Mountains. They cover extensive areas of the plateaus and mountains in the central and southern portions of the State. In the north, the geographic distribution of ponderosa pine appears to be limited to areas with adequate moisture in the early growing season. Ponderosa pine generally occupies the lowest elevation of any of the coniferous forest types. At its lower elevational boundary, it borders shrub and woodland communities, and its understory often resembles these vegetation types. At its upper limits, aspen or conifers typical of cooler or moister sites are found.

Important seral tree species associated with ponderosa pine habitat types include lodgepole pine, aspen, and Gambel oak (fig. 12). Ponderosa pine may be the dominant tree during seral and climax stages on some sites. Minor seral species may also include pinyon pines, limber pine, Rocky Mountain juniper, or Utah juniper. Many Utah stands have shrub-dominated understories, unlike the common ponderosa pine/bunchgrass habitat types found in neighboring Arizona. Exceptions to this are the *Pinus ponderosa/Muhlenbergia montana* habitat type in southern and central Utah and the *Pinus ponderosa/Festuca idahoensis-Festuca idahoensis* habitat type found in the eastern Uinta Mountains. Shrub-dominated habitat types may be the result of historic grazing practices, an absence of fire, or better moisture conditions than those in grassland types. In similar Colorado stands, pine reproduction on these sites is more dependable than in drier savanna habitat types. Adequate and timely moisture (particularly in the spring) is a critical factor for successful reproduction.

Figure 12—Ponderosa pine with seral aspen, Dixie National Forest.

Typical shrub species in Utah ponderosa pine forests are *Amelanchier alnifolia, Arctostaphylos patula, Artemisia nova, A. tridentata, Ceanothus fendleri, Cercocarpus ledifolius, C. montanus, Juniperus communis, Purshia tridentata, Quercus gambelii,* and *Symphoricarpos oreophilus. Bouteloua gracilis, Elymus elymoides, Festuca ovina* var. *ingrata, Muhlenbergia montana, Oryzopsis hymenoides, Poa fendleriana,* and *Stipa comata* are common graminoids throughout the Fire Group. Although forbs contribute less cover than grass or shrubs, several species do occur in many of the habitat types, including *Achillea millefolium, Antennaria microphylla, Eriogonum racemosum, Hymenoxys richardsonii, Lathyrus lanzwertii,* and *Sedum lanceolatum.*

Forest Fuels

Although fires were frequent in most presettlement ponderosa pine stands, severity remained relatively low (fig. 13). Many decades of fire exclusion have altered the fire regime in most stands. Without fire, unnatural accumulations of litter and downed woody fuels and overstocking have become more common. Stands with heavy dead or live fuel loads are susceptible to severe fire.

Average fuel loadings for Utah ponderosa pine habitat types are not available. Historically, frequent low-severity fires probably restricted the accumulation of large down woody fuels. Dieterich (1980) described the historical fuels and their role in fire spread in an interior ponderosa pine forest in Arizona. In the 19th century, fine fuels (grass and needles) were the medium through which historical fires spread since most large fuels (boles and branches) would have been consumed by the frequent fires. Low-severity fires must have been common, and severe fires rare, because of the lower fuel volumes. Small-diameter fuels would respond to slight changes in fuel moisture, limiting fire when conditions were moist or facilitating surface fire spread over large areas during dry spells.

Harrington (1982) contrasted fuels and fire behavior characteristics of stands of different ages in Arizona (ponderosa) pine forests in southeastern Arizona. Widely spaced old growth and dense sapling thickets were compared. Total fuel loads were nearly equal, although the open forests had greater forest floor weights and the sapling stands had more large woody fuels. The openness of the old-growth stands created a warm, dry microclimate, which in turn dried fuels, creating a high ignition potential. When these stands were adjacent to sapling thickets there was a greater risk of severe fire behavior when fires moved from open to dense stands with their higher woody fuel loading. Open stands had approximately 24 percent more humus by weight than the dense stands. This type of fuel has little effect on maximum fireline intensity, but when dry enough for combustion the heavier loadings lead to extended burning time, greater total energy release, and more difficult suppression. Where small trees are crowded under the overstory of larger trees, they

Figure 13—Forest floor litter and duff are important for sustaining low-severity and moderate-severity fires in ponderosa pine stands. This is especially true where relatively frequent fires have prevented the accumulation of downed woody fuels (Bryce Canyon National Park).

add to the fuels and crown fire potential (Kallander 1969; Weaver 1943).

High flammability results from the typically abundant annual needle-fall of ponderosa pine. In dense stands, needle drop may exceed 1.75 tons/acre (3.9 metric tons/ha)/year. Without periodic low-intensity ground fire, litter and woody fuels build up to levels that promote high burning intensities (USDA 1982). Muhley grasses (*Muhlenbergia* spp.), or other grass species, can form dense stands in drier ponderosa pine habitat types (*Pinus ponderosa/Muhlenbergia montana* and *Pinus ponderosa/Festuca idahoensis*), also increasing flammability. Livestock grazing has decreased fine fuels. Sackett (1975) has characterized fuel loads for southwestern ponderosa pine forests. His results are presented in table 8.

Role of Fire

Fire has historically played an important role in Utah's ponderosa pine forests, maintaining open stand conditions by periodically thinning the understory and removing patches of seedlings. 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. Nutrients trapped in woody debris, litter, and duff are

Table 8—Calculated averages of dead fuel loadings in 62 ponderosa pine stands in the Southwest (Arizona, New Mexico, southern Colorado) locations (Sackett 1979)

Fuel component	Mean	Standard deviation	Proportion of 0- to 1-inch diameter dead fuel	Proportion of all dead fuel
	Tons per acre		*Percent*	
L layer (surface fuel) needle material	1.0	0.5	8	5
F layer (ground fuel) needle material	3.8	1.3	30	17
H layer (ground fuel) humus (needle origin)	6.1	2.5	48	28
0 to ¼-inch-diameter woody material	.2	.1	2	1
¼- to 1-inch-diameter woody material	1.0	.5	8	4
Other material	1.0	.5	8	4
Total dead fuel 0- to 1-inch diameter	12.7	3.0	100	58
	Mean	**Standard deviation**	**Proportion of >1-inch diameter dead fuel**	**Proportion of all dead fuel**
	Tons per acre		*Percent*	
Fuel >1-inch diameter 1- to 3-inch material	1.4	0.7	15	6
>3-inch rotten material	5.0	4.3	54	23
>3-inch sound material	2.8	4.4	31	13
Total dead fuel >1-inch diameter	9.2	6.1	100	42
All dead fuel	21.9	7.6		100

released by burning. This process helps to maintain forest health in these relatively dry stands, where decay takes place slowly.

Weaver (1951) described fire's role in the development of forest patterns in neighboring Arizona:

> ...larger trees are constantly being killed by lightning, insects, disease, or windthrow. Fires inevitably attacked and burned the dead snag and windfelled remains of these trees and gradually reduced them to mere beds of ashes, admirably suited for seedbeds. Where such hot fires burned, clearings were made... and groups of seedlings became established in the ashes. This accounts for the even-aged groups of pines in various stages of maturity.

In presettlement times, fire probably occurred with relatively high frequency in habitat types throughout the fire group, with a possible exception of *Pinus ponderosa/Artemisia nova* and *Pinus ponderosa/Purshia tridentata* habitat types, where discontinuous ground fuels may have inhibited fire spread (Youngblood and Mauk 1985). Fire frequencies of 4 to 7 years have been estimated for ponderosa and mixed conifer forests in Bryce Canyon National Park (Buchanan and Tolman 1983). Stein (1988) reported composite fire intervals of 15.2 and 18.4 years in three canyons also on the Paunsaugunt Plateau. The difference in intervals may reflect actual variability in site conditions, or may be a result of sampling areas of different sizes. More limited sampling areas generally give longer fire intervals (Arno and Peterson 1983). Fires were estimated to occur at an average of every 2 years in northern Arizona prior to 1876 (Dieterich 1980). In southwestern Colorado ponderosa pine/Gambel oak stands, Harrington (1985) calculated average fire frequencies of approximately 6 years. Some areas are reported to have longer fire-free intervals. On the Front Range of Colorado, Laven and others (1980) calculated a mean fire interval of 48.6 years.

Although fires were frequent in most presettlement ponderosa pine stands, severity remained relatively low. Stand replacement fires were a rare event. Many decades of fire exclusion have altered the fire regime. Without fire, unnatural accumulations of litter and downed woody fuels, and overstocking have become more common. Stands with heavy dead or live fuel loads are susceptible to severe fire.

Historical grazing practices have contributed, along with fire exclusion, to create stand conditions that were rare or nonexistent in primeval ponderosa pine forests. Madany and West (1983) studied the interaction of grazing and fire in Zion National Park. They compared the vegetation on a formerly heavily grazed plateau and that on an isolated ungrazed mesa. The grazed plateau had a much higher density of pine, juniper, and Gambel oak saplings. This was despite a much higher fire frequency (4 to 7 years vs. 69 years) as evidenced by the fire-scarred trees examined on both sites. They attributed this condition to removal of herbaceous vegetation by livestock grazing and trampling, and subsequent establishment by pine seedlings and shrub saplings.

Forest Succession

There are four major successional pathways commonly found in Utah ponderosa pine habitat types. Aspen, lodgepole pine, Gambel oak, or ponderosa pine itself can be major seral species. The letters in the following section refer to letters in figures 14 through 16.

Succession With Lodgepole Pine (fig. 14)—An herb/shrub stage (A) is the result of a stand-destroying fire. Given an available seed source, both ponderosa pine and lodgepole pine soon establish in the newly exposed mineral soil. If the area burned is quite large, lodgepole pine may have an initial advantage because of its lighter, more easily dispersed seeds. Seedling trees may be killed by fire of any severity (B), but by the sapling stage, ponderosa pine has already developed resistance to low-severity fires and to some moderate fires. Lodgepole pine is more easily killed. Low to moderate fires result in a scattered stand of ponderosa pine saplings (C1). If low or moderate fires occur frequently, lodgepole pine cannot reinvade. A pure ponderosa pine overstory and understory develops (E1). In the absence of fire, the sapling mixed pines mature into pole-sized trees (D). Moderate fires in this size class open the stand. Many ponderosa pine and some scattered lodgepole pine survive (D1). Pole-sized stands unaffected by fire continue to mature (E). If the stand is dense, there may be little regeneration beneath the canopy. Fire opens these stands and creates new mineral seedbed for another generation of pines to develop (E2). Eventually, an undisturbed stand of lodgepole pine begins to break up under the influence of wind damage, pathogens, insects, or senescence (F). The long-lived ponderosa pine is maintained, and its regeneration fills the gaps left by the dying lodgepole pine. If there is deadfall created by the lodgepole pine breakup, there is an increased risk of moderate to severe fires at this stage. If severe fires do not occur, a ponderosa pine climax stand develops. It is basically unaffected by low to moderate fire. Severe fires at climax cause a return to the shrub/herb state (A).

Succession With Aspen (fig. 15)—Following a severe fire, the site is dominated by herbs (A). This is quickly succeeded by a stand of aspen and shrub resprouts (B). Some ponderosa pine seedlings may also be present in openings. Aspen grows quickly

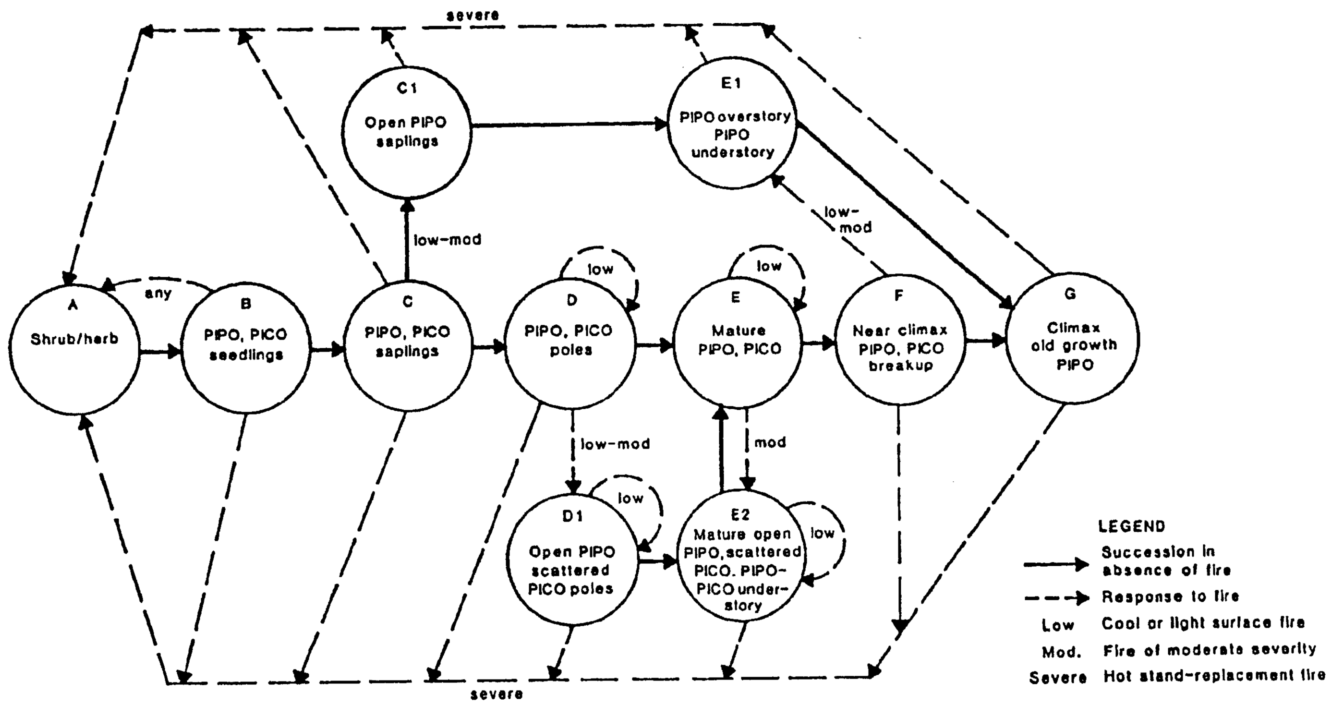


Figure 14—Hypothetical fire-related successional pathways for Fire Group Three habitat types where lodgepole pine is seral.

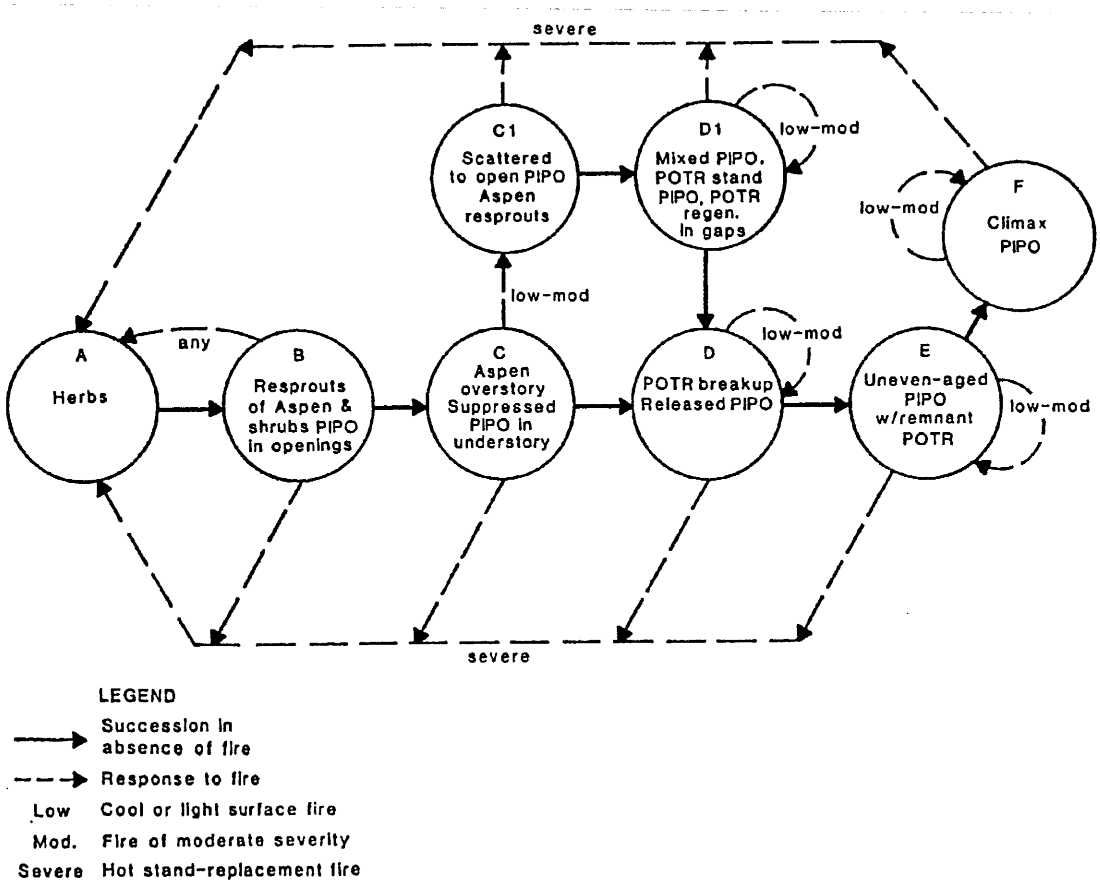


Figure 15—Hypothetical fire-related successional pathways for Fire Group Three habitat types where aspen is seral.

and, without the influence of fire, forms a canopy above the slower growing pine. Ponderosa pine can survive in a suppressed state in the understory for many years. If a low or moderate fire does occur, aspen suckers are killed, and the released pine may take over more of the site by shading some of the new aspen resprouts (C1). Aspen response is rapid, however, and it can subsequently become a codominant with ponderosa pine (D1). Without the rejuvenating stimulus of fire or other disturbance, seral aspen clones in Fire Group Three eventually senesce (D). When the aspen overstory breaks up, understory pine are released and new seedlings can establish in gaps. Low or moderate fires do not significantly alter this state because senescent aspen resprouts poorly. An uneven-aged stand of ponderosa pine with only remnant aspen stems makes up the next successional stage (E). Most low and moderate fires retain this condition. Climax ponderosa stands (F) are very similar, except that by this stage the last vestiges of aspen have died out. Climax stands are maintained by low to moderate fire and destroyed by severe fire. In the event of a severe fire at climax, ponderosa pine will be the sole seral species unless aspen reinvades by roots from adjacent unburned clones.

Succession With Ponderosa Pine Only (no diagram)—As in other Utah climax ponderosa pine stands, succession in this pathway begins with a stand of resprouting shrubs and herbs. Given the right moisture conditions and an adequate seed crop, ponderosa pine is able to establish seedlings in the mineral soil. Seedlings are fire intolerant, and the stand will probably be destroyed by even light surface fires. From the sapling stage on, the main role of fires of low to moderate severity is to thin stands and provide mineral seedbed for regeneration. Underburns or stands where fire removes relatively small groups of trees may have more successful regeneration because of the partial shade provided by the remaining overstory. Shading may keep down undergrowth competition and prevent the soil from drying out as thoroughly while seedlings are developing root systems. In stands with a shrubby understory fire frequencies are probably lower than in pine/bunchgrass habitat types. Because of the potential for shrub competition with seedlings, regeneration success after fire varies with habitat type.

Moir and Dieterich (1988) have presented a detailed successional pathway for *Pinus ponderosa/* bunchgrass types in northern Arizona (fig. 16). It is probably applicable to the *Pinus ponderosa/ Muhlenbergia montana* habitat type in Utah.

Succession With Gambel Oak (fig. 17)—Gambel oak can occur with ponderosa pine as a minor part of the understory or as a major seral species. Where it acts as a seral dominant, Gambel oak can be a strong competitor with ponderosa pine.

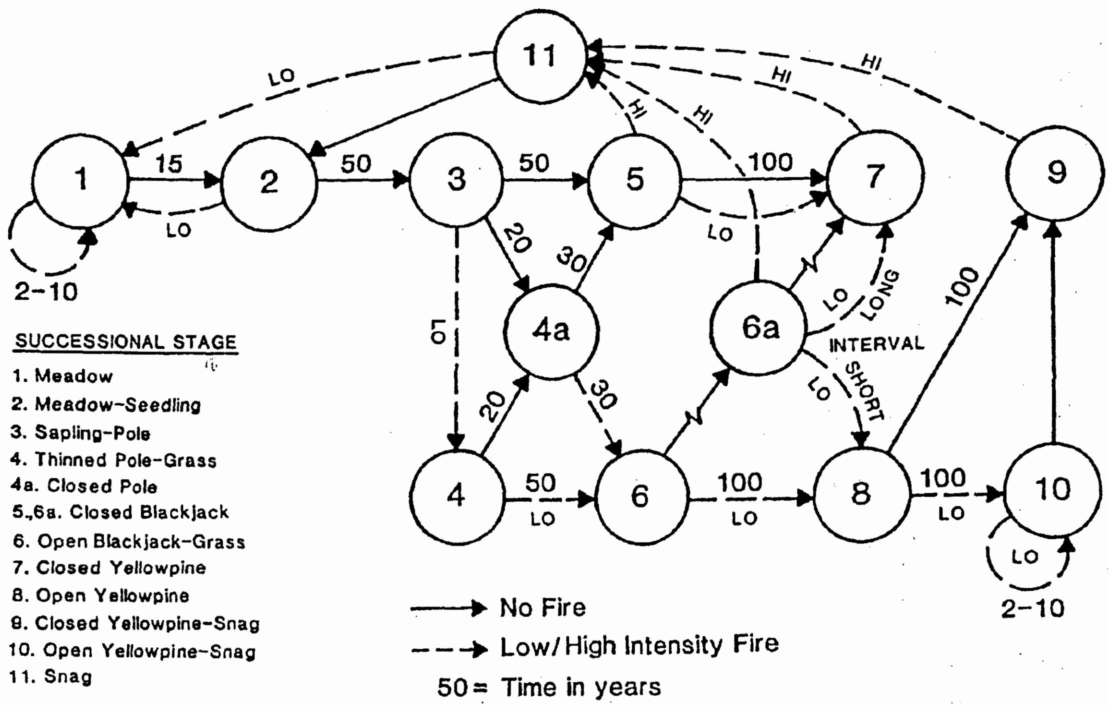


Figure 16—Hypothetical fire-related successional pathway for northern Arizona ponderosa pine/bunchgrass types (from Moir and Dieterich 1988).

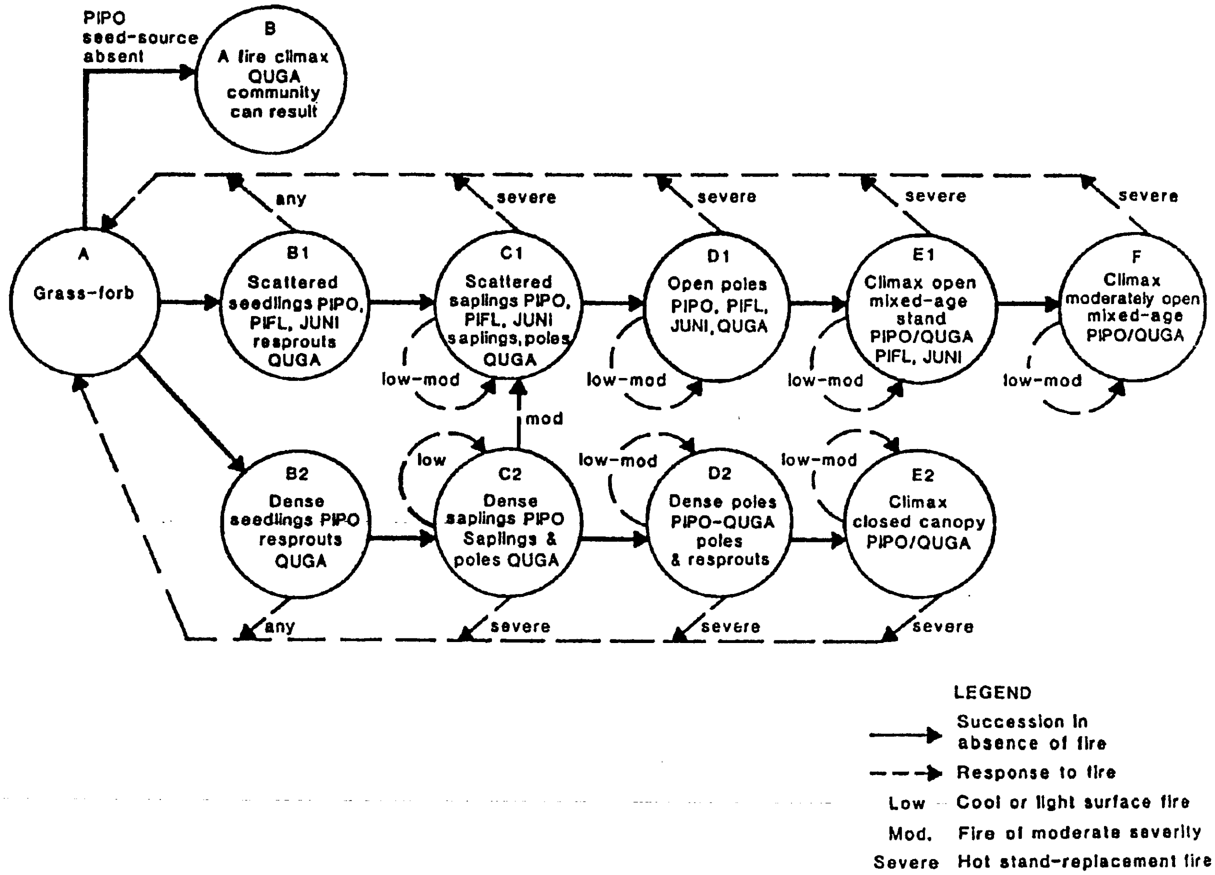


Figure 17—Hypothetical fire-related successional pathways for Fire Group Three habitat types where Gambel oak is seral.

Fire creates good seedbed conditions for pine, but it also stimulates oak resprouting. The result of burning in ponderosa pine/Gambel oak stands depends on available seed source, postfire site conditions, site disturbance history, and fire frequency, season, and severity. Fire severity and the degree of overstory removal determine the potential for oak to dominate subsequent vegetation development. Where fire has been severe, even the fire-resistant older ponderosa pine are removed from the stand (A). Where oak is vigorous, its immediate resprouting response and the lack of available pine seed give it dominance of the site for a long time (B). In southwestern Colorado, such stands are believed to remain stable without the encroachment of pine for 500 years or more (Steinhoff 1979). The role of fire in Gambel oak brush stands is described in Fire Group Two. Where seed is more available and oak somewhat less competitive, pine seedlings may establish in openings in the oak brush. Seedlings may be scattered to dense (B1, B2). Fires of any severity remove all or most of them. Sapling pines (C1, C2) are able to withstand low-severity fires and some moderate-severity fires. Oak saplings and poles do not, and the stand after such fires is characterized by more open pine and new, more dense resprouts of oak. The results of fire in the pole stage are similar (D1, D2). With continued periodic low to moderate fires, a mixed-age stand of pine and oak develops (E1). Fire continues to create patches of seedbed and to regenerate oak. Shading by the expanding ponderosa pine canopy helps to suppress oak to some degree. Climax stands may be open to dense, with oak cover less in dense pine stands (F).

Fire Management Considerations

In their guide to understory burning in ponderosa pine-larch-fir forests, Kilgore and Curtis (1987) cited objectives listed by expert fire practioners in Forest Service Regions 1 and 6:

PRIMARY USES OF FIRE:

1. Fuel reduction; both natural fuels and slash
2. Site preparation
3. Range and wildlife habitat improvement

OTHER USES OF FIRE:

1. Timber stand improvement by thinning and mistletoe control
2. Insect and disease abatement
3. Species manipulation (herb, shrub, and tree)
4. Esthetics
5. Recreation (campground) maintenance

Fire can be used as a tool to achieve the same objectives in Utah ponderosa pine forests.

Many Utah ponderosa pine habitat types have understories dominated by Gambel oak or shrubs. The composition of the preburn community and the desired postburn composition should be evaluated before fire is applied to a site. Understory Gambel oak and some shrubs, such as *Arctostaphylos patula*, *Symphoricarpos oreophilus*, *Ceanothus fendleri*, and *Amelanchier alnifolia* resprout successfully after fire. They may compete with pine seedlings for light and moisture (Shainsky and Radosevich 1986). Some shrubs commonly associated with ponderosa pine, like *Purshia tridentata* (bitterbrush), are killed by fire. Even bitterbrush, however, can be considered fire-dependent because it requires open stands to survive. It often establishes well from seed on sites with fire-exposed mineral soil. Increased shrub cover may be considered a detriment or an improvement, depending on the management objectives.

One of the most problematic shrubby habitat types for managers in the Southwest has been *Pinus ponderosa/Quercus gambelii*. Many stands that were once pine-oak are today dominated by the oak alone. Clearcut logging, grazing, and fire exclusion have all favored oak regeneration over pine. Historical fire-free intervals in the type probably ranged from 3 to 20 years (Youngblood and Mauk 1985). Fire suppression prevented the creation of mineral seedbed for pine. Wildfires that occurred despite suppression efforts were often more severe because of high fuel loads, and oak was favored over the more fire-sensitive pine. Logging and grazing removed competitive vegetation and stimulated further expansion of oak clones. At present, it is not economically feasible to convert dense oak groves to pine on many sites. There is some evidence that repeated fire, timed correctly, may reduce cover and density of Gambel oak. In southwestern Colorado, Harrington (1985) experimented with biennial burning at different seasons and phenological stages. He found that a moderate initial burn and a low-severity maintenance burn in August (summer) applied on a biennial basis reduced oak cover in a ponderosa pine understory. Biennial spring and fall burning were not effective.

Partial burning of forest floor fuels helps retain site productivity in ponderosa pine stands. Preburn site characteristics can be used to predict the amount of fuel consumed under given fire conditions. One important factor is the moisture level in the lower duff (Brown and others 1985; Norum 1977). Harrington (1987) found measurements of H-layer moisture and forest floor depth to be the most useful predictor of litter and duff consumption in a southeastern Arizona ponderosa pine forest. Percent consumption increased with decreasing H-layer moistures and increasing forest floor depth. Another important factor was stand density. There was less consumption in more dense stands, probably due to reduced air movement, lower fuel temperatures, and higher relative humidities beneath the canopy. Measurements were made under the following fire conditions: downslope backing fires, upslope winds of 1 to 5 mi/h, air temperatures between 55 and 75 °F, relative humidity 25 to 50 percent, and surface L-layer fuels with 5 to 9 percent moisture.

Postfire rehabilitation efforts after severe fires in dense ponderosa pine stands have become more common in the southwestern United States. Seeding with exotic grasses may be included in these efforts. Some caution should be exercised on drier ponderosa pine sites where pine regeneration is a concern. Elliot and White (1987) found that the commonly seeded exotic grasses, *Agropyron desertorum* and *Dactylis glomerata*, may compete successfully with pine seedlings for soil moisture. The impact of these deep-rooted grasses appears to be greater than for seeded native species such as *Bouteloua gracilis* and *Elymus elymoides*. *Melilotus officinalis*, *Sanguisorba minor*, and other seeded exotic forbs also competed for moisture, although the effect was not as great as that for the exotic grasses. *Agropyron desertorum* may also compete with pine seedlings for available nitrogen.

In the past, frequent low-severity fires probably helped control dwarf mistletoe (*Arceuthobium campylopodum* and *A. vaginatum*) infestations by pruning back infected branches in the lower crowns. Heavily infected trees were likely consumed by fire because of their greater flammability. Mistletoe-infected trees develop witches' brooms whose dense branching and tendency to catch dead needles provide a source of easily ignited fuel into the crown. Infected trees also have more dead woody fuel at the base of the bole as a result of branch shedding. Fire exclusion has permitted more heavily infested overstory trees to remain in stands where they serve as a source of infection for regeneration. Fire exclusion has also led to the development of extensive two-aged stands, which provide optimum conditions for mistletoe spread (Alexander and Hawksworth 1975; Koonce 1981). Drier, less-productive habitat types have more frequent and more severe dwarf mistletoe infections. In Colorado, the *Pinus ponderosa/*

Muhlenbergia montana habitat type was most affected (Merrill and others 1987).

Prescribed fires can mitigate the effects of subsequent wildfire by reducing hazardous fuels. Controlled burning was found to give almost complete protection to trees above about 8 inches (20 cm) d.b.h. in a southwestern ponderosa pine forest when it occurred 1 year before a wildfire. The effects of this hazard reduction should last at least 5 years (Wagle and Eakle 1979).

Prescribed fire can reduce understory and surface fuels appreciably. In a southeastern Arizona experiment, three relatively moist ponderosa pine stands were burned in September and three drier sites were burned in October to reduce the fuel hazard. Almost all trees less than 4 ft (1.2 m) tall growing under larger trees were killed, and there was some thinning of pole-size saplings on plots burned in October. Overall tree stem density was reduced from 5,470 to 2,154 on the September-burned plots, and on those burned in October from 4,365 to 989. The large reduction in stems per acre increased the amount of dead wood on the October-burn plots, but this did not create any particular wildfire hazard because the fire removed most of the previously accumulated dead woody fuels. In this case, the dry needle fall the following year did not appreciably increase the fire hazard (Biswell and others 1973). Nevertheless, needle fall has the potential to create a real hazard because it is all fine fuel. Harrington (1990) recommends a maintenance burn after the initial treatment. Such burns are easy to conduct and highly effective.

FIRE GROUP FOUR: DRIER DOUGLAS-FIR HABITAT TYPES

Habitat Types, Phases

Pseudotsuga menziesii/Arctostaphylos patula h.t. (PSME/ARPA), Douglas-fir/greenleaf manzanita

Pseudotsuga menziesii/Berberis repens h.t.-*Carex geyeri* phase (PSME/BERE-CAGE), Douglas-fir/creeping Oregon-grape-elksedge phase

Pseudotsuga menziesii/Berberis repens h.t.-*Pinus ponderosa* phase (PSME/BERE-PIPO), Douglas-fir/creeping Oregon grape-ponderosa pine phase

Pseudotsuga menziesii/Cercocarpus ledifolius h.t. (PSME/CELE), Douglas-fir/curlleaf mountain-mahogany

Pseudotsuga menziesii/Cercocarpus montanus h.t. (PSME/CEMO), Douglas-fir/mountain-mahogany

Pseudotsuga menziesii/Quercus gambelii h.t. (PSME/QUGA), Douglas-fir/Gambel oak

Pseudotsuga menziesii/Symphoricarpos oreophilus h.t. (PSME/SYOR), Douglas-fir/mountain snowberry

Vegetation

Fire Group Four consists of warm, dry Douglas-fir habitat types often dominated by seral ponderosa pine and dry types where Douglas-fir is the major seral species as well as the climax dominant. Other minor seral associates may include limber pine, aspen, Rocky Mountain juniper, or pinyon pine.

The overstory in these stands tends to be open, with the cool dry sites having only scattered Douglas-fir intermingled with shrubs, juniper, or pinyon pine (fig. 18). Associated shrubs (and small trees) include *Amelanchier alnifolia*, *Arctostaphylos patula*, *Artemisia tridentata*, *Cercocarpus ledifolius*, *Chrysothamnus nauseosus*, *Gutierrezia sarothrae*, *Mahonia repens*, *Purshia tridentata*, *Quercus gambelii*, and *Rosa woodsii*. Common graminoids are *Carex geyeri*, *C. rossii*, *Elymus elymoides*, *Festuca ovina*, *Leucopoa kingii*, and *Poa secunda*. Forb cover is less than in Fire Group Five, and species found include *Achillea millefolium*, *Eriogonum racemosum*, *Hymenoxys richardsonii*, *Lathyrus lanzwertii*, *Lupinus* spp., and *Thalictrum fendleri*.

Forest Fuels

In similar dry sites with low productivity in central Idaho, the amount of downed dead fuel less than 3 inches (7.6 cm) rarely exceeded 5 tons/acre (11.2 metric tons/ha). Material greater than 3 inches varied by stand age and condition and accounted for 70 percent or more of the total woody fuel load (Crane and Fischer 1986). Ground fuels are discontinuous with deep needle mats possible in stands dominated by ponderosa pine (fig. 19). Open ponderosa pine stands have a dry, warm ground surface microclimate conducive to fire ignitions (Harrington 1982). The dense shrub understories present in some types may be significant live fuel during dry, windy weather. On the other hand, the typically sparse herbaceous layer is not likely to carry fire. Dwarf mistletoe (*Arceuthobium douglasii*) is a management problem in many of these stands (Youngblood and Mauk 1985). The presence of witches' brooms increases crown flammability. Mistletoe-infested branches may break during snowstorms and add to the fuel around the bases of trees. Such fuel accumulations increase the likelihood of surface fires killing trees by cooking the cambium or by providing a means for fire to reach the crown (Crane and Fischer 1986). Poor stocking rates and the resulting open stands make Fire Group Four habitat types less likely to experience widespread fire than more productive sites.

Figure 18—Open Douglas-fir/curlleaf mountain-mahogany stand, Wasatch-Cache National Forest.

Figure 19—Ponderosa pine needle mats are a significant ground fuel in Fire Group Four habitat types where pine is seral (Ashley National Forest).

Role of Fire

In general, the role of fire in Group Four is to open stands, promote the establishment and dominance of seral ponderosa pine, and prepare seedbeds for Douglas-fir and pine.

Frequent fires of low or moderate severity favor the development of ponderosa pine stands in those habitat types where pine is normally seral. Longer fire-free intervals (50+ years) favor instead Douglas-fir, which may form multistoried stands. Fires in ponderosa pine stands generally remain low in severity, thinning saplings and seedlings, reducing smaller woody fuels, and consuming shrubs and herbaceous vegetation. Where Douglas-fir regeneration has become dense under a canopy of ponderosa pine, fire behavior is more variable. Low- to moderate-severity fires may creep through the duff and act as a thinning agent. Under more severe dry, windy conditions, fire may reach the overstory crowns through the understory fuel ladder and kill all or part of the ponderosa pine stand. In the new stand, stand-replacement fires favor Douglas-fir because its seeds are lighter and more easily dispersed. On dry sites where Douglas-fir is both the seral and climax species, scattered stands generally sustain low-severity thinning fires, and only in dry, windy weather can fire be driven through the crowns.

Historically, fire was a frequent occurrence in many of these stands, particularly those dominated by ponderosa pine. In Bryce Canyon National Park, fire frequencies of 4 to 7 years have been estimated for ponderosa and mixed conifer forests that include Douglas-fir (Buchanan and Tolman 1983). Stein (1988) reported composite fire intervals of 15.2 to 18.4 years for three canyons on the Paunsaugunt Plateau. Steele and others (1986) reported fire frequencies for ponderosa pine-dominated Douglas-fir habitat types in the Boise Basin of central Idaho (table 9). Utah stands in the *Pseudotsuga menziesii/ Physocarpus malvaceus* habitat type generally do not have ponderosa pine as a major seral species, and so are included in Fire Group Five.

In the open, dry, shrubby habitat types such as *Pseudotsuga menziesii/Cercocarpus ledifolius* or *Pseudotsuga menziesii/Cercocarpus montanus*, fire was probably less common because of fine fuel discontinuity. On these severe sites, droughty soils or otherwise poor stocking conditions may have slowed the influx of conifers during fire-free intervals. Today, however, many formerly open stands are dominated by conifers and decadent shrubs. When fires do occur on these sites they are more likely to be severe. In presettlement times, fire opened stands and rejuvenated sprouting shrubs. It also favored vigorous resprouting species over those that resprout poorly, such as curlleaf mountain-mahogany and antelope bitterbrush (Gruell 1986). Arno and Wilson (1986) found that in their Idaho study sites

> ...frequent wildfires prior to 1900 kept mountain mahogany largely confined to extremely rocky sites where fuel was sparse. Absence of fire during the past century on many sites allowed the species to increase in abundance. However, mountain-mahogany is becoming decadent on many sites and seems unable to compete with associated conifers.

Despite their sensitivity to fire damage, *Cercocarpus ledifolius* and *Purshia tridentata* are still dependent on fire to reduce conifer competition and to produce favorable soil conditions for seedling establishment.

Forest Succession

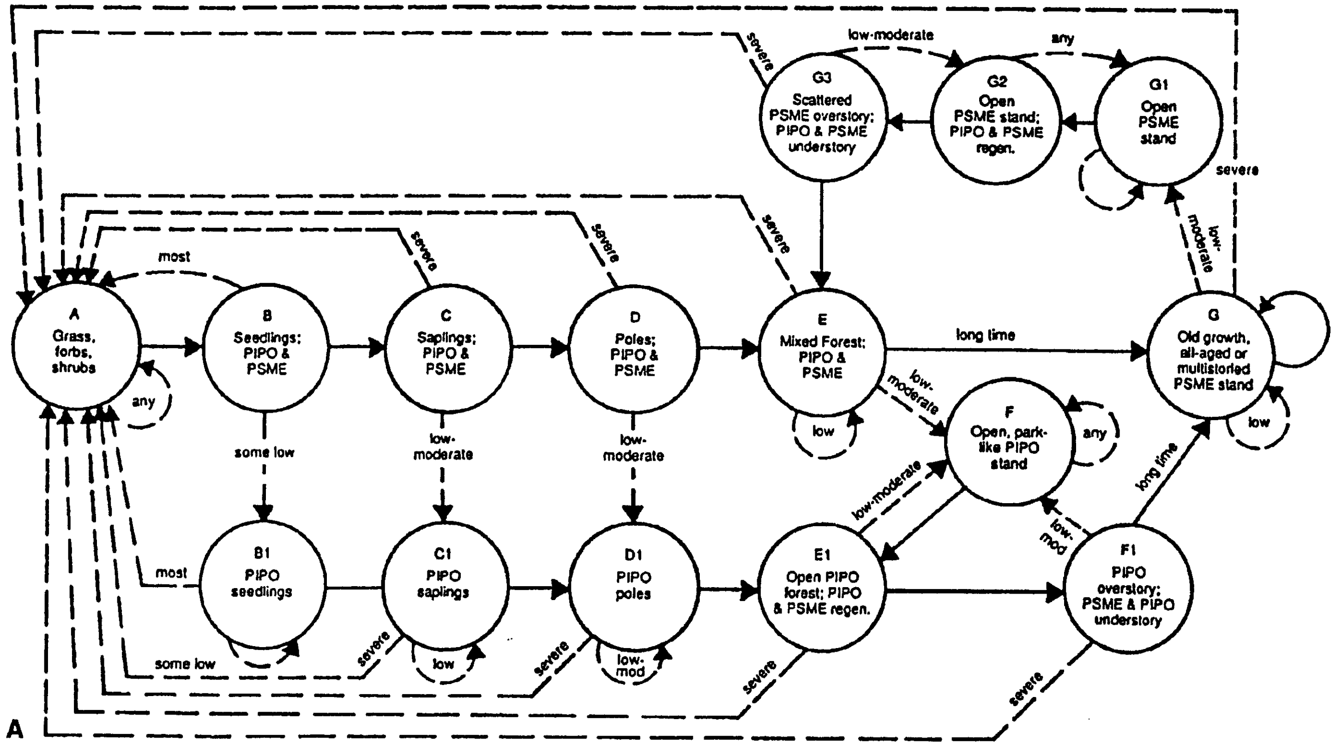
Ponderosa pine or Douglas-fir may dominate seral stands in Fire Group Four. Figure 20 illustrates the role of fire in succession with these species. (Subsequent letters in this section refer to figure 20).

Succession With Ponderosa Pine—Following a stand-replacement fire, herbs and resprouting shrubs dominate the site. Any additional fires at this stage will maintain the treeless condition. Both ponderosa pine and Douglas-fir regeneration are favored by exposed mineral soil. Sites that have experienced large stand-replacement fires may have Douglas-fir as the dominant seral species because its light seeds are more easily dispersed than the heavy seeds of ponderosa pine. Smaller burns, or parts of a larger burn adjacent to surviving ponderosa pine will have more pine in the initial seedling mix (B). Any fire in the seedling state kills the young trees and causes a reversion to the initial shrub/herb condition. Unlike smaller diameter Douglas-fir, sapling- and pole-sized ponderosa pine are able to survive many low to moderate fires because of their thicker bark, less dense foliage, and large, protected buds. Open stands of pine result from fires in these stages (C1, D1). Pine dominance is perpetuated by further fire occurrence. A mixed species overstory develops without fire (E). Douglas-fir regeneration is favored in the understory and, in the continued absence of fire, it will eventually dominate. Low-severity fires maintain both species in a mixed stand, but moderate fires remove most or all Douglas-fir and thin the pine. The result is an open, ponderosa pine park (F). Frequent fires perpetuate this condition. The theoretical climax stand is all-aged Douglas-fir (G). This state was rarely reached in primeval times because of relatively frequent fires and the long life span of ponderosa pine. Fire exclusion and the selective removal of pine has made the condition more common today. If pine has been eliminated from the stand, open to scattered large diameter-Douglas-fir are probably the only survivors after moderate fire. In the openings, Douglas-fir and possibly ponderosa pine establish in the exposed mineral soil (G2, G3) and provide another pathway for a mixed stand to

Table 9—Reported fire frequencies for ponderosa pine-dominated Douglas-fir habitat types[1] in the Boise Basin of central Idaho (Steele and others 1986)

Stand No.	Elevation	Habitat type	Mean fire interval (1700 to 1895)
	Feet		
3	5,625	PSME/CAGE	9.8
1	4,600	PSME/SPBE	10.3
4	4,975	PSME/SPBE	18.1
6	4,850	PSME/PHMA (dry extreme)	12.8
2	5,820	PSME/PHMA (typical)	15.9
7	5,600	PSME/PHMA (moist extreme)	21.7

[1]Utah stands of PSME/PHMA do not generally have ponderosa pine as a major seral species. They are included in Fire Group 5.



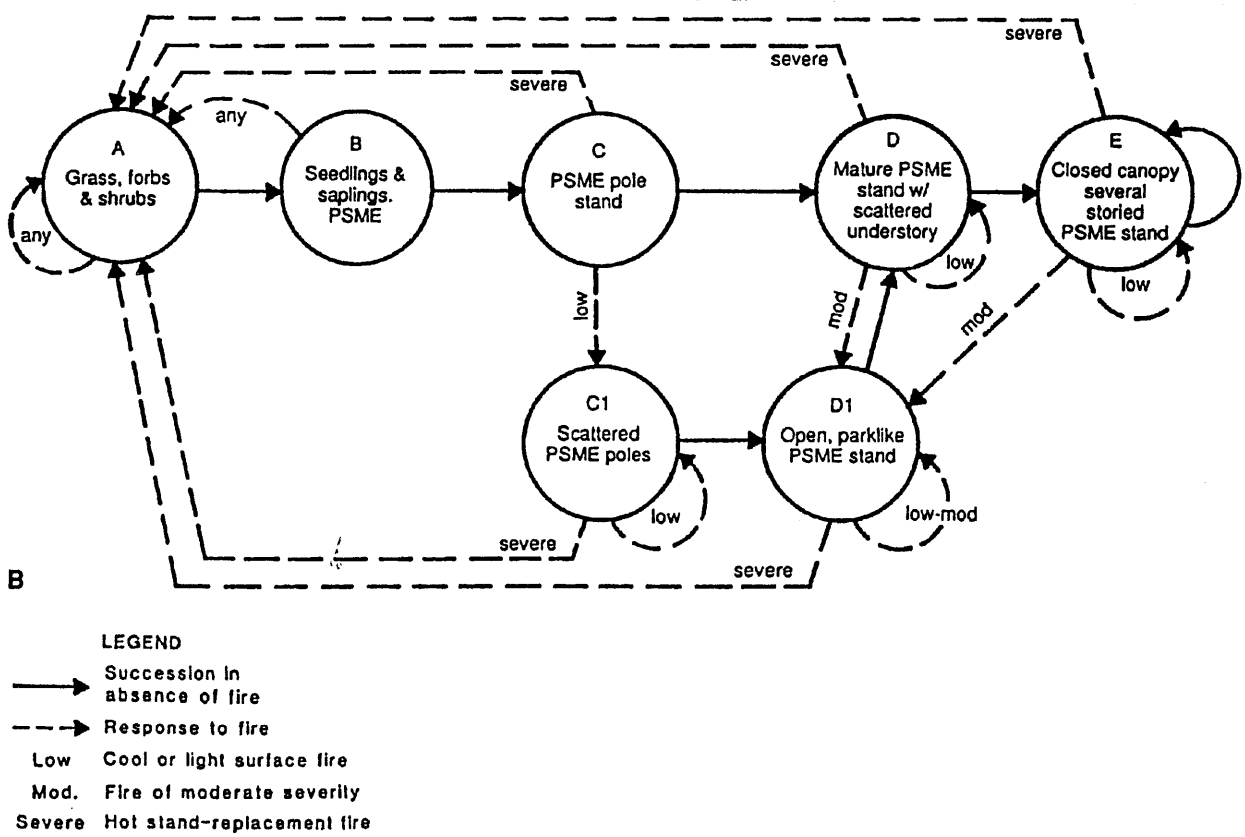


Figure 20—Hypothetical fire-related successional pathways for habitat types in Fire Group Four (A) where ponderosa pine is seral; (B) where Douglas-fir alone is seral.

develop (E). Low to moderate fires keep the stand as open Douglas-fir. Severe fire at any stage of development will remove both tree species from the site (A).

Succession With Douglas-fir Alone—Sites where Douglas-fir is the only seral species are generally open, with discontinuous fuels. Severe fires are infrequent unless they originate in neighboring, more productive stands. Following a stand-replacing fire, resprouting shrubs and herbaceous vegetation dominate the site. Given an adequate seed source, Douglas-fir seedlings soon follow (B). Any fire from this state until the pole stage will cause the stand to revert to shrub and herb vegetation. Pole-sized trees may tolerate low to possibly low-moderate fires. Stands are further opened by these fires, and in the canopy openings, shrubs, herbs, and more Douglas-fir seedlings will establish (C1). Without fire, a mature stand of Douglas-fir develops, with young Douglas-fir in the understory (D). Low-severity fires thin smaller trees and create mineral seedbed. Moderate fires may remove the understory but are unlikely to kill large overstory trees. The result of a moderate fire is a more open, parklike stand of mature trees (D1). A climax stand may contain several age classes of trees and is maintained by low and moderate fires. In the unlikely event of a severe fire, the stand will return to the initial treeless condition (A).

Fire Management Considerations

Fire uses in Group Four stands include hazard reduction, seedbed preparation, control of species composition, safeguarding recreation sites, improving wildlife habitat, and enhancing esthetic values.

In the absence of fire, hazardous fuel situations can develop in some stands in Fire Group Four. A 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.

Fire may be used to reduce the susceptibility of Douglas-fir stands to western spruce budworm. In Montana, the increased duration and severity of western spruce budworm outbreaks in the last several decades appears to be associated with the decrease in fire extent, which began with the advent of effective fire suppression. Where Douglas-fir makes up the understory beneath ponderosa pine, or where it forms multistoried stands, the potential for an intensive budworm attack is much greater. A high density of Douglas-fir increases the chance that budworms migrating downward from the canopy will land in other suitable host trees. Where stands are open, or where there are significant amounts of nonhost ponderosa pine, migrating budworms will land instead on the unpalatable pine or on the ground where they may desiccate, starve, or be eaten by various predators (Anderson and others 1987; Fellin and others 1983).

Habitat types in this fire group have generally low potential for timber production. Low site index, stocking limitations, and steep slopes make these sites more valuable for other uses. Where regeneration of Douglas-fir or ponderosa pine is a concern, some shading will protect seedlings and reduce the cover of competitive shrubs. Low-severity fires that do not top-kill tall shrubs and scarification without burning are better options where shrub competition is a problem (Steele 1988). Scarification treatment may encourage pocket gophers more than burning, and compaction may be a problem.

Big-game winter range and spring range can be rejuvenated with properly applied prescribed fire. Such fires can reduce encroachment of Douglas-fir, remove accumulated dead plant materials, recycle nutrients, regenerate mature shrubs and decadent shrubs, and increase distribution and production of nutrient-rich grasses and forbs. 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).

The shrubby understory of Group Four stands provides seasonal browse and cover for wild ungulates. *Pseudotsuga menziesii/Cercocarpus ledifolius* sites are important nesting sites for blue grouse and American kestrel. The complex vertical structure of *Pseudotsuga menziesii/Quercus gambelii* stands is also valuable habitat for birds. Fire may be used to thin the overstory and rejuvenate sprouting shrubs or provide good seedbed for shrubs that spread by seed. Cattle use Fire Group Four sites mainly for resting when they are grazing on adjacent shrub or grasslands.

Grazing has accelerated succession to conifers in Douglas-fir stands by reducing the cover of competing understory plants, exposing favorable seedbed, and eliminating fine fuels that carry thinning fires.

Armour and others (1984) observed the effect of different fire intensities on understory recovery in an Idaho *Pseudotsuga menziesii/Physocarpus malvaceus* habitat type. They found that reduction in graminoid abundance depended more on the amount of duff and large woody fuel consumed than fire line intensity or flame length. Heat transferred into the soil when heavier fuels are consumed causes mortality. Flame length is dependent on fine fuel amount and moisture content, whereas duff and large fuels are consumed after the flame front passes. Greater fire line intensity significantly impacted graminoid response only when both fine surface fuels and duff were dry. Careful fuel measurements, pre- and postfire, can help managers predict the effects of fire on important forage species.

A guide to prescribed fire opportunities in grasslands invaded by Douglas-fir has been prepared by Gruell and others (1986). Although the specific study location was in Montana, the basic principles and guidelines presented are generally applicable to other dry Douglas-fir sites as well. Managers who are interested in using fire to enhance productivity of grassland or shrubland where Douglas-fir encroachment is a problem may wish to refer to this publication.

FIRE GROUP FIVE: COOL OR MOIST DOUGLAS-FIR HABITAT TYPES

Habitat Types, Phases

Pseudotsuga menziesii/Acer glabrum h.t. (PSME/ACGL), Douglas-fir/Rocky Mountain maple

Pseudotsuga menziesii/Berberis repens h.t.-*Juniperus communis* phase (PSME/BERE-JUCO), Douglas-fir/creeping Oregon grape-common juniper phase

Pseudotsuga menziesii/Berberis repens h.t.-*Symphoricarpos oreophilus* phase (PSME/BERE-SYOR), Douglas-fir/creeping Oregon grape-mountain snowberry phase

Pseudotsuga menziesii/Berberis repens h.t.-*Berberis repens* phase (PSME/BERE-BERE), Douglas-fir/creeping Oregon grape-creeping Oregon grape phase (Uintas)

Pseudotsuga menziesii/Calamagrostis rubescens h.t. (PSME/CARU), Douglas-fir/pinegrass

Pseudotsuga menziesii/Osmorhiza chilensis h.t.-*Pachistims myrsinites* phase PSME/OSCH-PAMY), Douglas-fir/mountain sweetroot-myrtle pachistima phase

Pseudotsuga menziesii/Physocarpus malvaceus h.t. (PSME/PHMA), Douglas-fir/ninebark

Pseudotsuga menziesii/Physocarpus malvaceus h.t.-*Pachistima myrsinites* phase (PSME/PHMA-PAMY), Douglas-fir/ninebark-myrtle pachistima phase

Pseudotsuga menziesii/Symphoricarpos oreophilus h.t. (PSME/SYOR), Douglas-fir/mountain snowberry

Vegetation

Fire Group Five consists of relatively moist Douglas-fir habitat types, or phases of habitat types, where lodgepole pine, aspen, bigtooth maple, or Douglas-fir may be major seral species (fig. 21). These types occur on cooler or more moist exposures between 5,000 and 9,000 ft (1,524 and 2,743 m) in the northern portion of the State, and they dominate midelevation forests on calcareous soils in the Uinta Mountains. In central and southern Utah, the elevational range of Group Five habitat types is between 8,000 and 9,700 ft (2,438 and 2,957 m), generally above the range of ponderosa pine. Unlike the majority of drier types in Fire Group Four, Fire Group Five habitat types may be capable of forming dense overstories made up of Douglas-fir or lodgepole pine. Dominant associated small trees and shrubs include *Acer glabrum*, *Juniperus communis*, *Pachystima myrsinites*, *Physocarpus malvaceus*, *Prunus virginiana*, *Ribes montigenum*, and *Symphoricarpos oreophilus*. *Bromus carinatus*, *Calamagrostis rubescens*, *Carex geyeri*, *Elymus glaucus*, and *Poa secunda* are graminoids that are often present. Forbs occurring in these stands include species such as *Achillea millefolium*, *Arnica cordifolia*, *Lathyrus lanzwertii*, *Osmorhiza chilensis*, *Smilacina racemosa*, and *Thalictrum fendleri*.

Forest Fuels

In comparable Montana Douglas-fir stands, downed fuel loads averaged about 13 tons/acre (29 metric tons/ha) but may be considerably heavier. Closed stands with dense Douglas-fir understories present the highest fire hazard. Stands may have large amounts of downed twigs and small branchwood (fig. 22). Downed as well as standing dead trees resulting from dwarf mistletoe mortality and associated witches' brooms may add greatly to fuel loads and corresponding fire hazard. If dense understories are absent, fire hazard is reduced accordingly; however, the dense overstory trees and the presence of dead branches near the ground create a crown fire potential under severe burning conditions. Fuel conditions in stands dominated by either lodgepole pine or aspen are less hazardous than in those dominated by Douglas-fir. Ladder fuels are less prevalent, and there is less probability of fire moving from the forest floor to the crown (Crane and Fischer 1986; Fischer and Clayton 1983).

Role of Fire

Forests dominated by Douglas-fir and lodgepole pine have variable fire regimes (Kilgore 1981). Topography, weather, stand structure, and fuel loading all contribute to different patterns of fire intensity and frequency in these stands. A range of fire behavior, from light surface to stand replacement, can occur. As a result, a mosaic of fire treatments probably existed across the historical landscape, with much variability within a single fire treatment (Arno 1980). Stands were thinned or replaced, and species relationships were altered. Low or thinning

Figure 21—Douglas-fir/mountain snowberry stand with dense Douglas-fir understory beneath seral aspen and ponderosa pine. Fallen aspen are evident in the foreground (Dixie National Forest).

Figure 22—In Fire Group Five, Douglas-fir stands downed woody fuel accumulations vary with habitat type and dominant seral species. Fire hazard increases as Douglas-fir replaces seral aspen and lodgepole pine.

fires favored Douglas-fir because mature trees are fairly fire resistant, and the relatively shade-tolerant seedlings were able to establish in moderate amounts of residual duff. Stand-replacement fires favored seral lodgepole pine or aspen on sites where seeds or suckering roots were available. The success of aspen regeneration depended partly on severity of the fire. A high-severity burn reduced or eliminated suckering if shallow roots were exposed to lethal heating. Habitat types in this fire group are more moist and provide better stocking conditions than habitat types in Fire Group Four, and succession may proceed more quickly. Aspect affects the rate of tree seedling establishment. On moist Douglas-fir and subalpine habitat types in northwestern Montana, Shearer (1976) found that natural regeneration was best on north-facing aspects.

Fire histories for moist or cool Douglas-fir types in Utah are lacking. Douglas-fir in the Uinta Mountains have multiple fire scars and stands contain much scattered charcoal, indicating fire has occurred at relatively frequent intervals in the past. In northwestern Utah, most stands are second growth, having become established after extensive cutting and burning during settlement of the area at the end of the last century (Mauk and Henderson 1984). Older stumps with multiple fire scars are more widely distributed than present tree spacing, indicating that fire may have occurred at relatively close intervals. Native Americans were likely responsible for at least some of these fires (Gruell 1990). Large coverages of aspen, lodgepole pine, or *Calamagrastis rubescens* (pinegrass) on the landscape may indicate the occurrence of severe fires in the past.

Arno (1980) reported a mean fire-free interval of 15 to 30 years for the Douglas-fir habitat types in the Northern Rocky Mountains. In southwestern mixed conifer stands, mean intervals of 13.8 and 11.8 years were obtained (Ahlstrand 1980). *Pseudotsuga menziesii/Physocarpus malvaceus* and *Pseudotsuga menziesii/Vaccinium globulare* stands in western Montana had mean fire-free intervals of 15.8 years (Crane and others 1983). In southwestern Montana, Douglas-fir/bunchgrass and *Pseudotsuga menziesii/Calamagrostis rubescens* stands had a historic mean fire-free interval of 26 years (Arno and Gruell 1986).

Forest Succession

Lodgepole pine, Douglas-fir, aspen, or bigtooth maple are the major seral species in Fire Group Five. Figures 23 through 25 illustrate the role of fire with each of these species (letters in this section refer to these figures).

Succession With Lodgepole Pine and Douglas-fir (fig. 23)—Where lodgepole pine and Douglas-fir are seral, a stand of herbs and shrubs follows stand-replacement fires (A). Repeated fires maintain the treeless condition. Conifer seedlings and saplings soon dominate the site without subsequent fires (B). Seed availability and site conditions help determine the relative proportions of each species in the stand. Where serotinous lodgepole pine was present in the preburn stand or where open-coned seedtrees are nearby, lodgepole pine may be quite dense. Fires of all severities can remove seedlings and saplings, and the stand reverts to the herbaceous state. A dense to open stand of poles develops in the absence of fire (C). Low to moderate fires thin the stand and open areas for further conifer regeneration (C1). Moderate to severe fires remove most or all of the trees.

As Douglas-fir and lodgepole pine increase in diameter, they develop greater fire resistance. Low-severity fires have little effect on older stands (D,F). Moderate fires can cause extensive mortality of lodgepole pine even in larger size classes. Douglas-fir is considerably more fire resistant and can survive most moderate-severity fires. An open stand of Douglas-fir results from fire in a mixed species stand (E). As the overstory canopy closes, the more tolerant Douglas-fir is favored over lodgepole pine in the understory. Low-severity fires may provide microsites where some lodgepole pine can establish and maintain its presence in the stand (F). In the absence of fire, the result is a climax stand in which lodgepole pine is replaced by Douglas-fir (G). The thick-barked old-growth trees can survive low and moderate fires. Small openings created by fire are quickly repopulated with Douglas-fir seedlings. Only severe fires threaten the climax stand, and then even the largest trees are destroyed. The stand then reverts to herbs and shrubs (A).

Succession With Aspen (fig. 24)—The initial postfire herb community will rapidly give way to a stand of aspen resprouts (B). Some Douglas-fir may establish in openings. Any fire in this stage will destroy the stand. In the absence of fire, a pole-sized stand of aspen develops, with an understory of slower growing Douglas-fir (C). Low-severity fires open the stand, providing microsites where aspen suckers and Douglas-fir seedlings can establish. Moderate fires probably eliminate Douglas-fir and aspen stems, and new aspen suckers again dominate the postfire site. If fire does not occur in this stage, a mixed stand develops (D). Douglas-fir shares the overstory with aspen, and Douglas-fir dominates the understory. Moderate fires remove the understory and kill aspen stems, creating an open Douglas-fir stand with resprouting aspen (D1). Low-severity

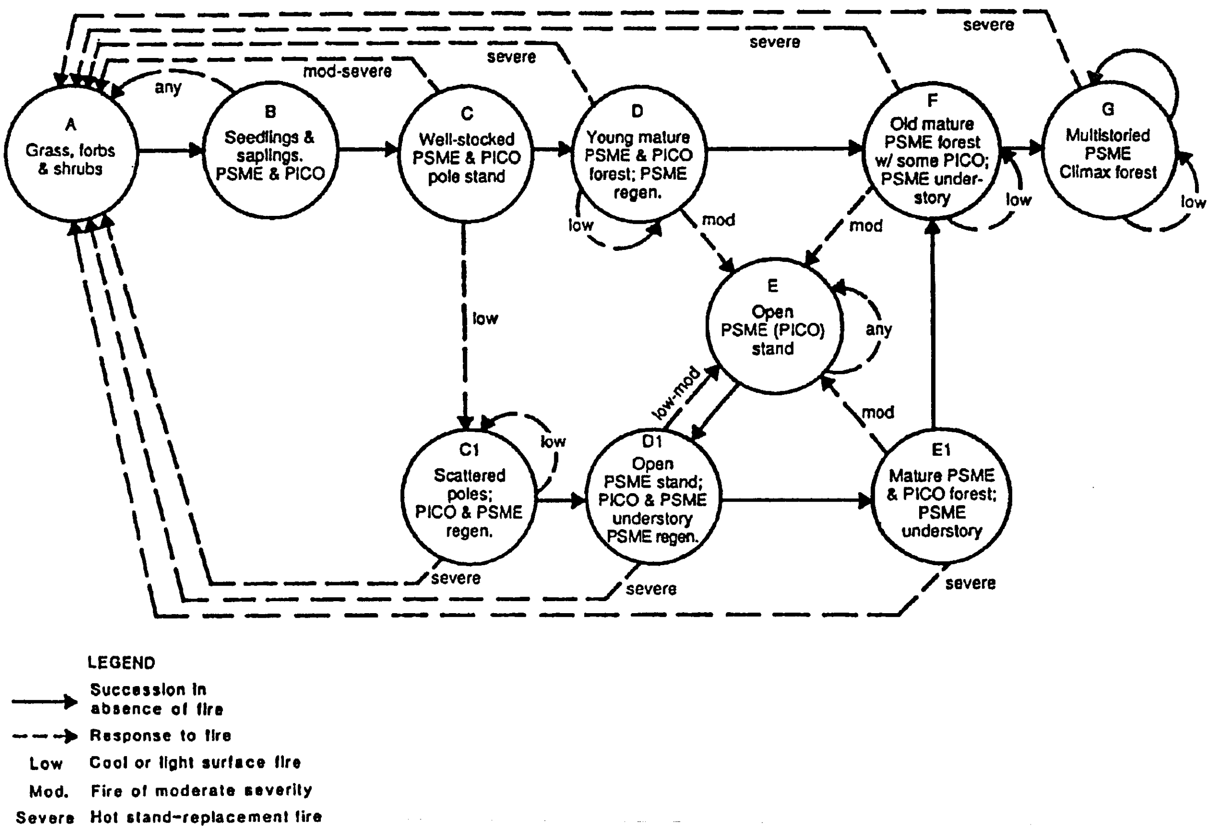


Figure 23—Hypothetical fire-related successional pathways for habitat types in Fire Group Five where lodgepole pine and Douglas-fir share dominance as seral species.

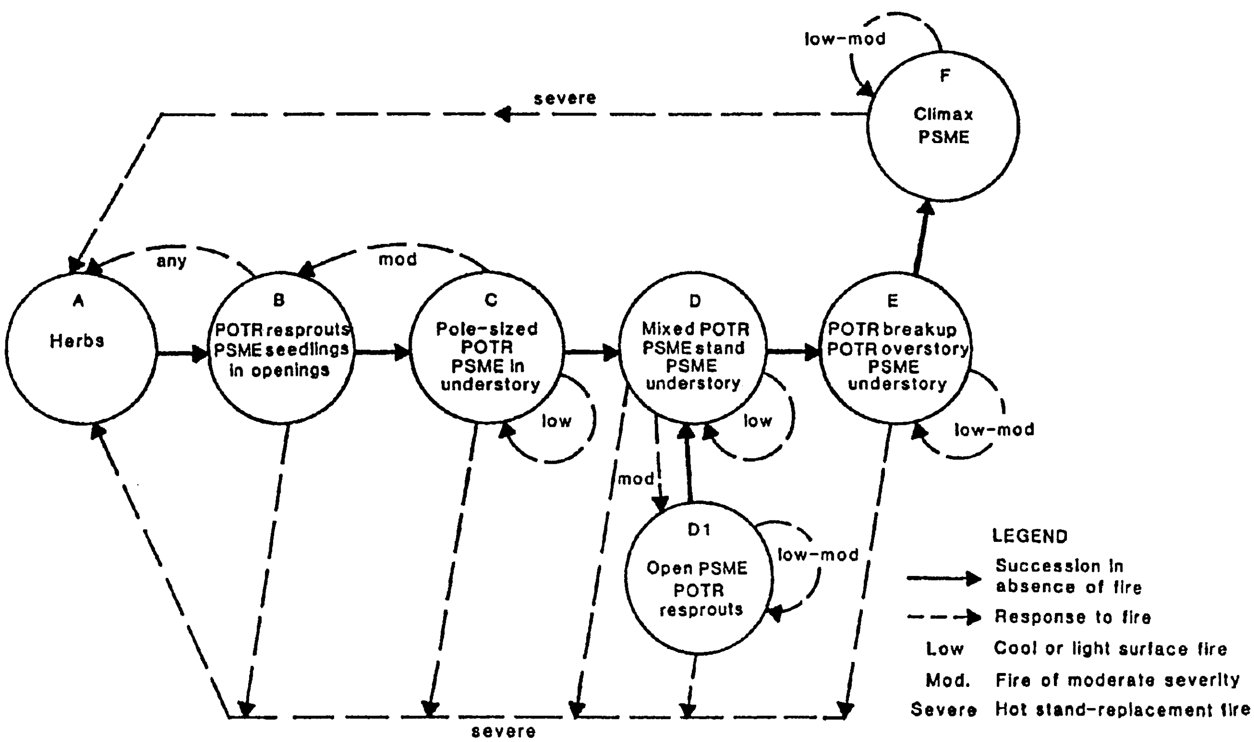


Figure 24—Hypothetical fire-related successional pathways for habitat types in Fire Group Five where aspen is the dominant seral species.

fires maintain the stand, opening gaps for regeneration of either species. If no fires occur, aspen becomes less prominent (E). Once Douglas-fir makes up a significant part of the overstory, it continues to be favored by low to moderate fire. Older trees are fire-resistant, and the overstory remains intact. This environment is too shady to sustain aspen resprouts. Moderate fires result in a more open stand, with Douglas-fir and some residual aspen in canopy openings. The climax stand is a multiaged Douglas-fir forest (F). If there is a severe fire after the remaining aspen roots have died, the successional sequence resembles that where Douglas-fir is the only seral and climax species (Fire Group Four).

Succession With Bigtooth Maple (fig. 25)—Although bigtooth maple has been observed to resprout following top removal, little is known about its successional role in Utah Douglas-fir habitat types. As a result the successional pathway here is mostly supposition based on knowledge of the general ecology of Douglas-fir and bigtooth maple.

After a stand-destroying fire, bigtooth maple resprouts will replace the initial postfire herb stage. Douglas-fir seedlings may also occur where there is an adequate seed source (B). Douglas-fir is probably restricted to openings in the maple cover at this stage of development (B). Because young maple clones can form a dense canopy, conifer invasion may be slow. Douglas-firs that gain a foothold in openings early in stand development continue to grow, however, and a mixed stand may result by the pole stage (C). Low-severity fires thin trees and kill smaller diameter maple stems, clearing areas for tree seedlings and new resprouts. Moderate fires remove much of the Douglas-fir and top-kill most of the maple, initiating a new cycle of resprouting (C1). Without fire, conifers begin to dominate more of the stand, forming an overstory of varying density above the maple (D). There may be both Douglas-fir and maple regeneration beneath the canopy. Bigtooth maple plants can establish from both seedlings and layered stems. If fire does not occur, Douglas-fir eventually dominates both the overstory and the understory. Remnant maple may survive in the understory for a long time (E). In some habitat types, especially the *Pseudotsuga menziesii/Acer grandidentatum* type, bigtooth maple is a normal understory component at climax. In other types climax

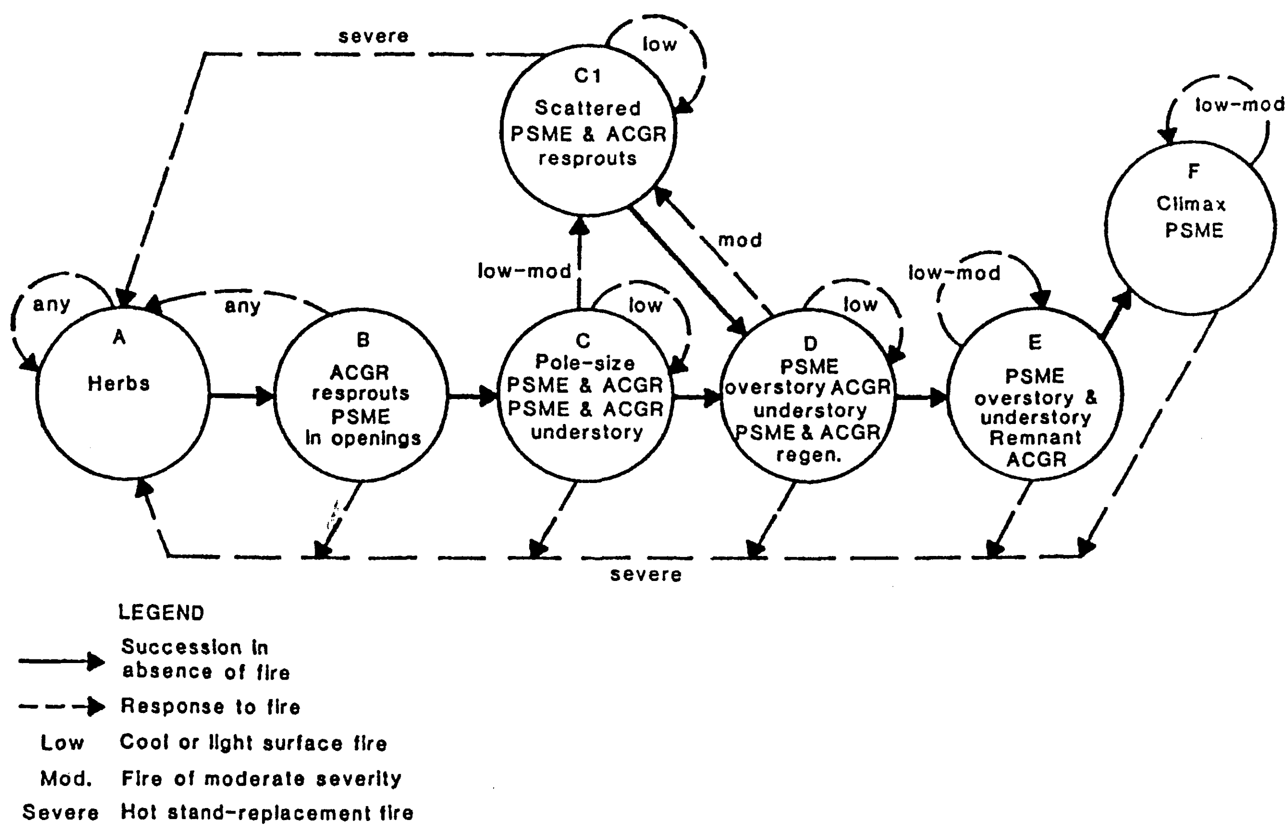


Figure 25—Hypothetical fire-related successional pathways for habitat types in Fire Group Five where bigtooth maple is the dominant seral species.

consists of multiaged Douglas-fir little affected by low to moderate fire (F). The potential for severe fire increases with stand age as young and suppressed understory conifers form fuel ladders. Severe fires remove Douglas-fir, and maple may again dominate early succession where its resprouting roots or rhizomes have survived in the stand. Where Douglas-fir persists, subsequent succession is dominated by Douglas-fir until maple is able to invade the stand from off-site sources.

Fire Management Considerations

Management opportunities in Fire Group Five habitat types are limited by steep slopes, brush control problems, and, on many sites, harsh conditions for regeneration. Fire may serve as a means of thinning otherwise inaccessible stands. Fire can also be used to sanitize postlogging stands by removing residual trees infested with dwarf mistletoe (*Arceuthobium douglasii*) (Alexander and Hawksworth 1975). Low-severity fires may be the best for stand regeneration. They can thin understory trees but leave mature Douglas-fir to provide wind and sun protection for seedlings. Moderate shading may also slow the regrowth of competing shrubs.

Fire can reduce fuels, recycle nutrients, and provide mineral seedbed. Where aspen is a seral species, fire can stimulate suckering and rejuvenate stands. Fire top-kills decadent shrubs, which often respond by resprouting prolifically. Resprouts are more succulent and nutritious to wildlife and livestock than the old, woody stems.

Grazing can impact conifer succession by reducing the cover of competing undergrowth plants, exposing favorable seedbed, and reducing the fine fuels needed to carry low-severity fires. In central Idaho, grazing favored Douglas-fir regeneration in a *Pseudotsuga menziesii/Physocarpus malvaceus* habitat type where a relatively closed canopy and duff conditions prevented good establishment of ponderosa pine (Zimmerman and Neuenschwander 1983).

FIRE GROUP SIX: WHITE FIR AND BLUE SPRUCE HABITAT TYPES (MIXED CONIFER TYPES)

Habitat Types, Phases

Abies concolor/Acer glabrum h.t. (ABCO/ACGL), white fir/Rocky Mountain maple

Abies concolor/Arctostaphylos patula h.t. (ABCO/ARPA), white fir/greenleaf manzanita

Abies concolor/Berberis repens h.t.-*Juniperus communis* phase (ABCO/BERE-JUCO), white fir/creeping Oregon grape-common juniper phase

Abies concolor/Berberis repens h.t.-*Symphoricarpos oreophilus* phase (ABCO/BERE-SYOR), white fir/creeping Oregon grape-mountain snowberry phase

Abies concolor/Berberis repens h.t.-*Berberis repens* phase (ABCO/BERE-BERE), white fir/creeping Oregon grape-creeping Oregon grape phase

Abies concolor/Cercocarpus ledifolius h.t. (ABCO/CELE), white fir/curlleaf mountain-mahogany

Abies concolor/Juniperus communis h.t. (ABCO/JUCO), white fir/common juniper

Abies concolor/Osmorhiza chilensis h.t. (ABCO/OSCH), white fir/mountain sweetroot

Abies concolor/Physocarpus malvaceus h.t. (ABCO/PHMA), white fir/ninebark

Abies concolor/Quercus gambelii h.t. (ABCO/QUGQ), white fir/Gambel oak

Abies concolor/Symphoricarpos oreophilus h.t. (ABCO/SYOR), white fir/mountain snowberry

Picea pungens/Agropyron spicatum h.t. (PIPU/AGSP), blue spruce/bluebunch wheatgrass

Picea pungens/Berberis repens h.t. (PIPU/BERE), blue spruce/creeping Oregon grape (central and southern Utah)

Picea pungens/Juniperus communis h.t. (PIPU/JUCO), blue spruce/common juniper

Vegetation

Fire Group Six consists of nonriparian white fir climax habitat types and three upland types where blue spruce is the potential climax dominant. White fir habitat types occur throughout Utah, but are more important in the central and southern portions of the State. They are particularly common on the southern plateaus (fig. 26). White fir is climax where conditions are too droughty or warm for dominance by subalpine fir or Engelmann spruce, but are often moister than those on Douglas-fir climax sites. The northerly distribution of white fir may be limited by cold winter temperatures. Its northern limit in the Rocky Mountains is Cottonwood Creek, east of Logan, UT. This limit may correspond to a mean maximum January temperature of 32 °F (0 °C), within the lower altitudinal limits of white fir. Predation by rodents may also affect success of white fir. Porcupines appear to prefer white fir over other conifers, and mice often browse terminal buds and branches (Hayward 1946; Mauk and Henderson 1984). Predation by rodents combined with unfavorable weather conditions probably prevent white fir from dominating on lower montane sites at the higher latitudes. It is replaced by Douglas-fir as a climax dominant on these sites (Mauk and Henderson 1984).

White fir stands vary in their density and composition. Drier habitat types may support only scattered trees and have predominantly shrubby

Figure 26—Typical white fir or mixed conifer stand on the Paunsaugunt Plateau. Snags of early seral ponderosa and limber pine are evident.

vegetation. Where conditions are more favorable, there may be a dense canopy of conifers, often a mixture of white fir and Douglas-fir (fig. 27). Some habitat types appear to be dominated for very long periods of time by Douglas-fir or ponderosa pine. On these sites white fir is restricted to the understory, the apparent climax dominant, but it rarely achieves that state.

Blue spruce grows in a range of conditions from warm, dry, steep slopes to mesic stream bottoms. In northern Utah, it is able to outcompete Douglas-fir on warm dry sites with calcareous substrates. On more moderate sites, it may be difficult to discern a single climax dominant. The relationship between the species may be similar to that between Engelmann spruce and subalpine fir. Because of its longevity, Douglas-fir, like Engelmann spruce, can remain as a long-term dominant on a site where blue spruce may be the recognized climax species because of its dominance in the understory. Blue spruce is less tolerant than white fir, and where these species grow together, it is considered seral. As one moves south or east through Utah into Arizona, New Mexico, and Colorado, blue spruce, Douglas-fir, and white fir are often found together in "southwestern mixed conifer" forests. The dominance of one species over another is rarely complete over a wide area, and successful regeneration and establishment in a given stand may depend on local topoedaphic conditions and disturbance history more than on relative shade tolerance or climate.

Common seral associates in this Fire Group in the northern mountains are Douglas-fir and aspen. Gambel oak or bigtooth maple may achieve treelike stature on some sites and may be important seral species. In the central and southern region, ponderosa pine becomes increasingly important and blue spruce, limber pine, or Rocky Mountain juniper may also be more minor associates.

White fir and blue spruce also grow in riparian situations where they may be associated with boxelder or one or more cottonwood species. Rarely, Engelmann spruce or subalpine fir may be part of the species mix on these very moist sites. The general fire response of moist-site subalpine conifers is described in Fire Group Eleven, and the basic successional patterns probably apply to white fir-dominated riparian sites as well. The PIPU/EQAR h.t., which occurs on lower subirrigated slopes and riparian areas in southern Utah, is assigned to Fire Group Eleven.

Shrubs and small trees characterize the understory of Fire Group Six stands. Important shrub

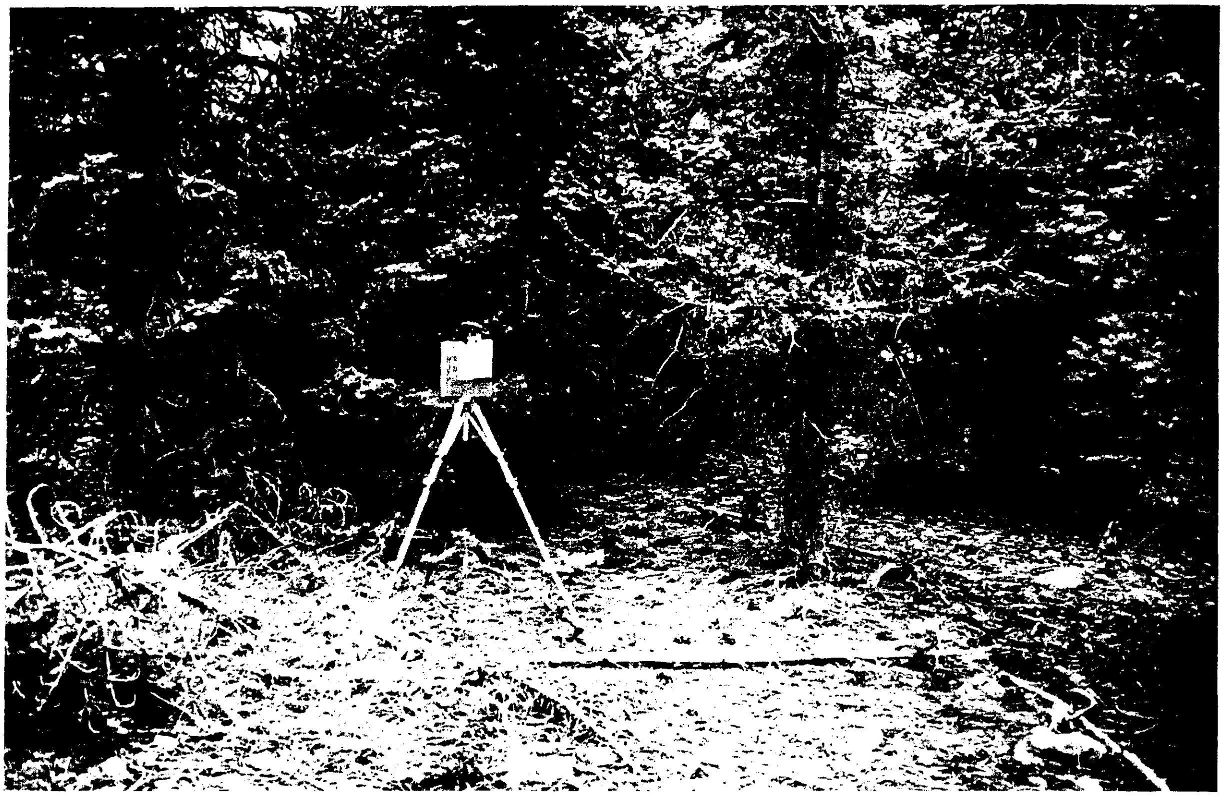


Figure 27—Dense white fir/creeping Oregon-grape stand near Beaver, UT. Seral species are ponderosa pine, aspen, and Rocky Mountain juniper. Downed woody fuel is scant, but there are plenty of live ladder fuels. Note needle draping on understory conifers.

species are: *Acer glabrum*, *A. grandidentatum*, *Amelanchier alnifolia*, *Arctostaphylos patula*, *Cercocarpus ledifolius*, *Juniperus communis*, *Mahonia repens*, *Pachystima myrsinites*, *Purshia tridentata*, *Quercus gambelii*, *Ribes cereum*, *Rosa woodsii*, and *Symphoricarpos oreophilus*. Graminoids include *Bromus cinereus*, *Carex geyeri*, *C. rossii*, *Elymus elymoides*, *Poa fendleriana*, *P. secunda*, *Pseudoroegneria spicata*, and *Stipa lettermanii*. *Achillea millefolium*, *Arnica cordifolia*, *Astragalus miser*, *Balsamorhiza sagittata*, *Erigeron peregrinus*, *Geranium viscosissimum*, *Lathyrus lanzwertii*, *L. pauciflorus*, *Solidago parryi*, and *Thalictrum fendleri* are dominant forbs.

Forest Fuels

Summarized fuel loading information for Utah white fir and blue spruce habitat types is not available. Fuel estimates for mixed conifer stands in neighboring Arizona should be comparable to Utah stands. The absence of fire since the latter 19th century has made white fir habitat types more susceptible to severe fires than was the case historically. Fuel loadings have increased significantly during the long fire-free interval. Historical loadings in the mixed conifer type were probably no more than one-fourth to one-third of present-day loadings, or 12.14 to 18.20 tons/acre (27.21 to 40.80 metric tons/ha). Under a natural fire regime, rates of fuel accumulation would have accelerated for 3 to 5 years following area-wide fires until the material that was killed was deposited on the ground. Sufficient fuel to support another fire accumulated within a relatively short time (Dieterich 1983).

Forest floor and downed woody fuel loadings were inventoried on the Apache-Sitgreaves National Forest in Arizona. Litter, fermentation, and humus layers averaged 22.25 tons/acre (55 metric tons/ha), of which 15.37 tons/acre (38 metric tons/ha) was in the humus layer. Combined woody forest fuel and forest floor material was 53.8 tons/acre (133 metric tons/ha) (Dieterich 1983). Averaged loadings for 16 mixed conifer stands in Arizona and New Mexico are shown in table 10.

The mean depth and weight of the mixed conifer forest floor measured in three Arizona watersheds were 1.6 inches (4 cm) and 13.0 tons/acre (29 metric tons/ha) respectively, with the greatest accumulations in the fermentation and humus layers (Ffolliott and others 1977).

Table 10—Averaged loadings for 16 mixed conifer stands in Arizona and New Mexico (Sackett 1979)

Fuel type	Tons/acre
L layer needle material	1.1
F layer needle material	3.9
H layer needle material	12.3
¼-inch diameter woody material	1.4
¼- to 1-inch woody material	2.2
Other material	1.3
Total dead fuel 0- to 1-inch diameter	22.2
1- to 3-inch woody material	3.3
>3-inch rotten woody material	10.3
3-inch sound woody material	8.3
Total dead fuel >1-inch diameter	21.9
All dead fuel	44.1

Role of Fire

Little is known about presettlement fire history in Utah white fir or blue spruce stands. Logging operations during the period of European settlement altered natural stand composition. The species that provide the best fire record (ponderosa pine and Douglas-fir) were much sought after for lumber and often selectively removed. Accidental fires caused by logging, mining, or agricultural activity altered the fire regime by burning areas at seasons or frequencies different than those prevalent in the presettlement period. As a result, the information we do have must be supplemented by studies done in other similar, but less impacted areas. The fire ecology of white fir appears similar to drier grand fir habitat types described for central Idaho (Crane and Fischer 1986; Steele and others 1981). Proximity, similar precipitation patterns, and lightning frequencies suggest that southern Utah white fir and blue spruce forests are comparable to the mixed conifer type in Colorado, Arizona, and New Mexico. Hypothesized fire response of southwestern mixed conifer stands (Jones 1974) as well as those for montane white fir forests in the Sierra Nevada of California (Parsons and DeBenedetti 1979) provide relevant information.

The presettlement fire interval in Fire Group Six was probably relatively short (Youngblood and Mauk 1985). Tree species that require open stands and mineral soil for regeneration are commonly found in white fir stands. Jones (1974) summarized what he thought to be the historical role of fire in mixed conifer forests of Arizona and New Mexico:

> Primeval wildfires were important to the composition and structure of mixed conifer forests. Most fires were light, and therefore killed many seedlings and saplings but generally spared larger trees, especially of resistant species. Patches in less flammable situations were often spared. Some patches burned intensely, especially where insects or disease left local concentrations of fuel. In such hot spots even large trees, especially of susceptible species, were scarred or killed. Partly as a consequence, irregular structures are the rule in mixed conifer stands... .

Dieterich (1980, 1983) reported an average fire interval of 22 years for mixed conifer stands in the White Mountains of Arizona. Kilgore and Taylor (1979) estimated the fire frequency of white fir in the southern Sierra Nevada to be between 8 and 18 years. White fir has low fire resistance as a young tree because of its relatively thin bark and low branching habit. Its resistance increases as its bark thickens with age. Fire carried by shrubby undergrowth tree species such as Gambel oak or common juniper can torch out understory conifer trees. More fire-resistant seral species, such as ponderosa pine or Douglas-fir, are favored by frequent fires of low to moderate severity. White fir is favored and becomes dominant where fire is excluded.

Forest Succession

Generalized patterns of succession in southwestern mixed conifer and subalpine fir forests have been proposed (Jones 1974; fig. 28). Utah white fir and blue spruce habitat types are similar. There are a number of potential seral species, and patterns of postfire succession are variable. Aspen, Douglas-fir, and ponderosa pine are important seral trees. On some sites, bigtooth maple or Gambel oak dominate seral stands. The relationship of seral species to white fir is similar to that of Douglas-fir, and on some sites Douglas-fir is codominant with white fir. Figure 29 illustrates the hypothetical role of fire in Utah white fir or blue spruce stands (letters in the following section refer to fig. 29).

A severe fire results in state A, the herb condition. If the roots of Gambel oak, bigtooth maple, or aspen are present, this stage is short-lived. A stand of resprouts made up of one or more species will develop quickly. Seedlings and saplings of ponderosa pine, Douglas-fir, and possibly blue spruce or white fir may also be found (B). A dense shrub cover can restrict ponderosa pine to openings or even exclude it from the site. The more tolerant Douglas-fir, blue spruce, and white fir are able to establish beneath the shrub canopy. A fire in this state kills the conifers and aboveground portions of the aspen and shrubs, returning the stand to the herb state. Aspen grows rapidly and will be the first tree to dominate the stand in the absence of fire (C). Pole-sized trees of conifer species are also present, but may suffer slower growth rates if they are beneath the aspen canopy. Low or moderate fires thin the stand and

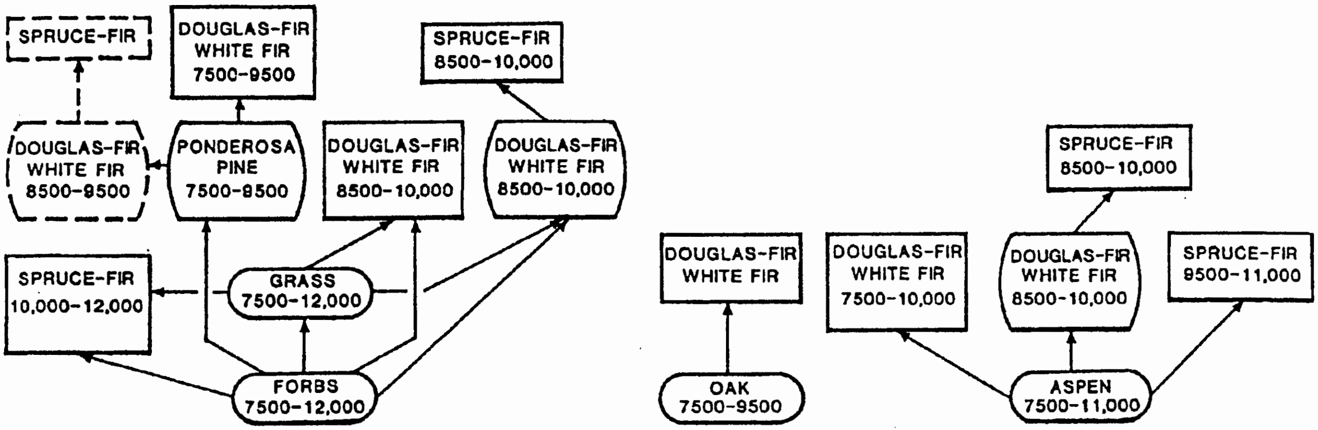


Figure 28—Generalized successional pathway for southwestern mixed conifer and subalpine forests (Jones 1974). Fire Group Six white fir and blue spruce habitat types resemble mixed conifer stands in their successional patterns.

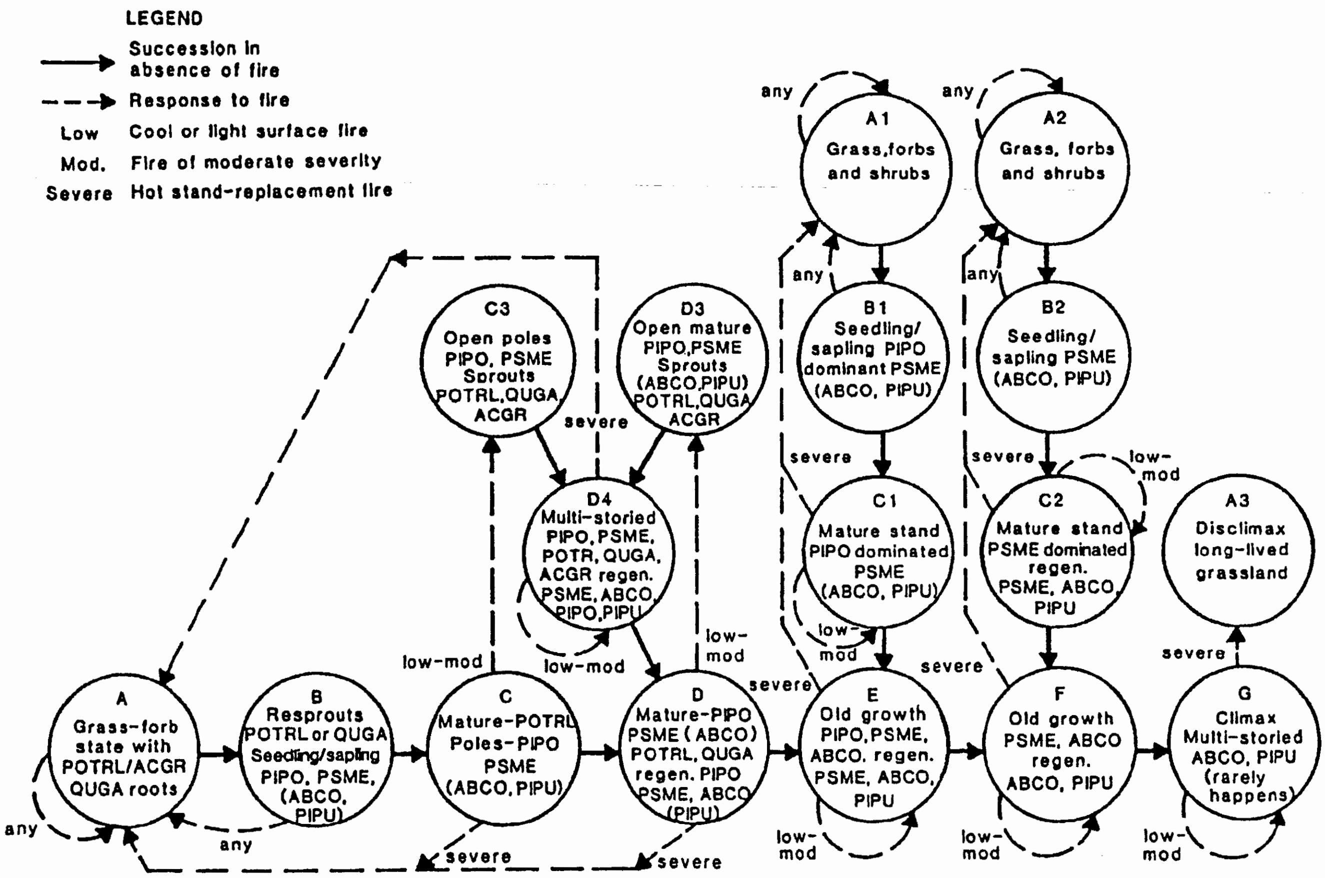


Figure 29—Hypothetical fire-related successional pathways for habitat types in Fire Group Six.

top-kill the resprouting species. White fir and blue spruce are the least fire-resistant conifers present and are probably eliminated by all but coolest fires (C3). The open pole stand is succeeded by a multistoried mixed forest made up of two or more species. The condition is maintained by low to moderate fires, with the species mix changing, depending on the fire severity and the relative fire resistance of the species present. Without fire, a mature stand of conifers develops and begins to shade out aspen and the sprouting shrubs (D). Again, low to moderate fires serve to open these stands and reduce the coverage of white fir (D3). A long fire-free period results in an old-growth conifer stand of pine, Douglas-fir, and white fir or blue spruce (E). The effects of fire in this state resemble those described for drier Douglas-fir habitat types (Fire Group Four). Older white fir may survive low-severity fires, but in general, ponderosa pine and Douglas-fir will dominate after disturbance. Douglas-fir will dominate succession in stands where ponderosa pine has become senescent or where pine is not normally a seral species (F). In either case, fire serves to prevent white fir or blue spruce from dominating because of their fire intolerance. It may be possible to achieve a climax state of multistoried white fir (G), but this very rarely happens. The fire frequency and longevity of ponderosa pine and Douglas-fir assure that stands will retain a more diverse species composition under a natural fire regime.

As the stand ages, the chance of a crown or stand-replacement fire increases. An understory of young fir and Douglas-fir may form a fuel ladder to the overstory. Severe fires in any successional stage will cause the site to revert to an herbaceous condition and encourage aspen, oak, or maple resprouting where viable roots or rhizomes are still present. Frequent low-severity fires and less frequent moderate fires maintain open stands of ponderosa pine or Douglas-fir and provide favorable microsites for the establishment of other seral species.

Fire Management Considerations

The timber potential of white fir and blue spruce stands in Utah varies widely. Timber potential in central and southern parts of the State is usually low. *Abies concolor/Osmorhiza chilensis* in the northern portion of the State has some of the highest observed sample site index values of the montane zone of northwestern Utah (Mauk and Henderson 1984). Because of the overriding importance of other resource values, however, timber harvesting is usually limited. Watershed protection, wildlife habitat, range, and recreation are all important considerations throughout this fire group.

Fire may be applied to enhance multiple resource values in the right circumstances. Replacing conifer cover with aspen, shrub, or herbaceous vegetation will improve water yield (DeByle 1985; Jaynes 1978). Fire can enhance range and wildlife habitat by rejuvenating decadent forage plants and by improving the overall vegetative composition on a site. The patchy pattern of vegetation typically left by fire in these stands provides a good mix of cover and open grazing and browsing areas. Frequent low-severity fires open closed stands for viewing and stimulates the regeneration of aspen stands, enhancing esthetics. On timber sites where shrub competition is a concern, fire may be used to improve tree establishment. Preharvest burns can reduce shrub seed reserves in the soil. "Prescribed fires kill many seeds and stimulate others to germinate. The resulting seedlings can be eliminated by natural mortality in the closed stands or by logging and postharvest site preparation activities" (Pearce 1988).

Kilgore and Curtis (1987) have provided an excellent guide for understory burning beneath canopies of ponderosa pine, larch, Douglas-fir, and grand fir for Forest Service Regions 1 and 6. They describe how to define objectives, produce successful burning prescriptions, use different burning techniques, and monitor and evaluate burn results. These objectives and techniques are applicable to many Utah conifer stands dominated by ponderosa pine, Douglas-fir, or white fir. Managers interested in burning in mixed conifer stands should consult this guide.

Human intervention in many white fir and blue spruce stands has affected their composition and density dramatically. Historic heavy grazing in open stands of white fir, blue spruce, Douglas-fir, and ponderosa pine severely reduced the available fine fuel and thus the frequency of light surface fires. Reduction in ground cover and fires permitted large numbers of conifer seedlings to establish in years when the spring moisture was greater than average. As stands became more dense, the less tolerant ponderosa pine seedlings were outcompeted by Douglas-fir and white fir. White fir, the most tolerant species, formed a dense understory beneath seral conifers or aspen. Mixed-species stands and the vegetative mosaic of interspersed forest and grassy areas gave way to dense, multilayered forests of tolerant conifers with a depauperate herb and shrub component. Today, wildfires on these sites are often severe, killing overstory trees, including relatively fire-resistant ponderosa pine and Douglas-fir. A careful program of prescribed burning may be used to reduce fuel hazards and return the stand to a more natural fire regime.

FIRE GROUP SEVEN: ASPEN DOMINATED HABITAT AND COMMUNITY TYPES

Stable Community Types (Probably Climax Habitat Types)

Populus tremuloides/Amelanchier alnifolia/Pteridium aquilinum c.t. (POTR/AMAL/PTAQ), aspen/serviceberry/bracken fern

Populus tremuloides/Amelanchier alnifolia/Tall Forb c.t. (POTR/AMAL/TALL FORB), aspen/serviceberry/tall forb

Populus tremuloides/Amelanchier alnifolia/Thalictrum fendleri c.t. (POTR/AMAL/THFE), aspen/serviceberry/Fendler meadowrue

Populus tremuloides/Amelanchier alnifolia-Symphoricarpos oreophilus/Calamagrostis rubescens c.t. (POTR/AMAL-SYOR/CARU), aspen/serviceberry-mountain snowberry/pinegrass

Populus tremuloides/Amelanchier alnifolia-Symphoricarpos oreophilus/Tall Forb c.t. (POTR/AMAL-SYOR/TALL FORB), aspen/serviceberry-mountain snowberry/tall forb

Populus tremuloides/Artemisia tridentata c.t. (POTR/ARTR), aspen/big sagebrush

Populus tremuloides/Calamagrostis rubescens c.t. (POTR/CARU), aspen/pinegrass

Populus tremuloides/Carex rossii c.t. (POTR/CARO), aspen/Ross sedge

Populus tremuloides/Festuca thurberi c.t. (POTR/FETH), aspen/thurber fescue

Populus tremuloides/Tall Forb c.t. (POTR/TALL FORB), aspen/tall forb

Populus tremuloides/Juniperus communis/Carex geyeri c.t. (POTR/JUCO/CAGE), aspen/common juniper/elk sedge

Populus tremuloides/Juniperus communis/Lupinus argenteus c.t.(POTR/JUCO/LUAR), aspen/common juniper/silvery lupine

Populus tremuloides/Pteridium aquilinum c.t. (POTR/PTAQ), aspen/bracken fern

Populus tremuloides/Sambucus racemosa c.t. (POTR/SARA), aspen/red elderberry

Populus tremuloides/Stipa comata c.t. (POTR/STCO), aspen/needle-and-thread

Populus tremuloides/Symphoricarpos oreophilus/Carex rossii c.t. (POTR/SYOR/CARO), aspen/mountain snowberry/Ross sedge

Populus tremuloides/Symphoricarpos oreophilus/Calamagrostis rubescens c.t. (POTR/SYOR/CARU), aspen/mountain snowberry/pinegrass

Populus tremuloides/Symphoricarpos oreophilus/Thalictrum fendleri c.t. (POTR/SYOR/THFE), aspen/mountain snowberry/Fendler meadowrue

Populus tremuloides/Symphoricarpos oreophilus/Festuca thurberi c.t. (POTR/SYOR/FETH), aspen/mountain snowberry/Thurber fescue

Populus tremuloides/Symphoricarpos oreophilus/Tall Forb c.t. (POTR/SYOR/TALL FORB), aspen/mountain snowberry/tall forb

Populus tremuloides/Veratrum californicum c.t. (POTR/VECA), aspen/western false-hellebore

Community Types (and Cover Types) Probably Seral to Coniferous Habitat Types

Populus tremuloides-Abies lasiocarpa/Amelanchier alnifolia c.t. (POTR-ABLA/AMAL), aspen-subalpine fir/serviceberry

Populus tremuloides-Abies lasiocarpa/Carex geyeri c.t. (POTR-ABLA/CAGE), aspen-subalpine fir/elk sedge

Populus tremuloides-Abies lasiocarpa/Carex rossii c.t. (POTR-ABLA/CARO) aspen-subalpine fir/Ross sedge

Populus tremuloides-Abies lasiocarpa/Juniperus communis c.t. (POTR-ABLA/JUCO), aspen-subalpine fir/common juniper

Populus tremuloides-Abies lasiocarpa/Symphoricarpos oreophilus/Thalictrum fendleri c.t. (POTR-ABLA/SYOR/THFE), aspen-subalpinefir/mountain snowberry/Fendler meadowrue

Populus tremuloides-Abies lasiocarpa/Symphoricarpos oreophilus/Tall Forb c.t. (POTR-ABLA/SYOR/TALL FORB), aspen-subalpine fir/mountain snowberry/tall forb

Populus tremuloides-Abies lasiocarpa/Tall Forb c.t. (POTR-ABLA/TALL FORB) aspen-subalpine fir/tall forb

Populus tremuloides-Abies concolor/Arctostaphylos patula c.t. (POTR-ABCO/ARPA), aspen-white fir/greenleaf manzanita

Populus tremuloides-Abies concolor/Poa pratensis c.t. (POTR-ABCO/POPR), aspen-white fir/Kentucky bluegrass

Populus tremuloides-Abies concolor/Symphoricarpos oreophilus c.t. (POTR-ABCO/SYOR), aspen-white fir/mountain snowberry

Populus tremuloides-Picea pungens cover type (POTR-PIPU cover type), aspen-blue spruce

Populus tremuloides-Pinus flexilis cover type (POTR-PIFL cover type), aspen-limber pine

Populus tremuloides-Pinus ponderosa cover type (POTR-PIPO COVER TYPE), aspen-ponderosa pine

Populus tremuloides-Pinus contorta/Carex geyeri c.t. (POTR-PICO/CAGE), aspen-lodgepole pine/elk sedge

Populus tremuloides-Pseudotsuga menziesii/ Amelanchier alnifolia c.t. (POTR-PSME/AMAL), aspen-Douglas-fir/serviceberry
Populus tremuloides-Pseudotsuga menziesii/ Juniperus communis c.t. (POTR-PSME/JUCO) c.t. aspen-Douglas-fir/common juniper

Community Types Probably Grazing Disclimaxes

Populus tremuloides/Astragalus miser c.t. (POTR/ ASMI), aspen/timber milkvetch
Populus tremuloides/Bromus carinatus c.t. (POTR/ BRCA), aspen/mountain brome
Populus tremuloides/Poa pratensis c.t. (POTR/ POPR), aspen/Kentucky bluegrass
Populus tremuloides/Juniperus communis/ Astragalus miser c.t. (POTR/JUCO/ASMI), aspen/ common juniper/timber milkvetch

Vegetation

Fire Group Seven includes community types where aspen appears to be climax or a long-term seral dominant. The basic ecology and fire management of these types are also applicable to the seral conditions in other fire groups in which aspen is the dominant species or the primary focus of management activities.

Aspen is a widespread species throughout the Rocky Mountains and the Intermountain West. Utah alone has over 1.6 million acres (648,000 ha) of aspen-dominated forest (Mueggler and Campbell 1986). Aspen is able to tolerate a wide range of environmental conditions and, as a consequence, is associated with a diverse number of understory shrub and herbaceous species. A few species occur in a relatively large number of stands. Small tree and shrub species common to a number of community types include *Amelanchier alnifolia, Mahonia repens, Prunus virginiana, Rosa* spp., and *Symphoricarpos oreophilus*. Aspen stands have a particularly rich forb component with *Achillea millefolium, Agastache urticifolia, Aquilegia caerulea, Aster engelmannii, Corallorhiza maculata, Delphinium* spp., *Descurania richardsonii, Fragaria virginiana, Geranium viscosissimum, Lathyrus* spp., *Lupinus* spp., *Mertensia arizonica, Osmorhiza* spp., *Potentilla gracilis, Smilacina stellata, Stellaria jamesiana, Thalictrum fendleri*, and *Viola* spp. common. The number of graminoid species is considerably less, but *Calamagrostis rubescens, Carex geyeri, Elymus glaucus, E. trachycaulus* ssp. *trachycaulus, Festuca thurberi, Poa pratensis, P. secunda*, and *Stipa nelsonii*, may all be significant members of the community.

Forest Fuels

Brown and Simmerman (1986) classified aspen stands in relation to fuels into five types: aspen-dominated stands with shrubs, tall forbs, or low forbs (aspen/shrub, aspen/tall forb, aspen/low forb), and mixed conifer and aspen stands with shrubs and forbs (mixed/shrubs, mixed/forbs) (see table 11). Although this classification is based on community types found in southeastern Idaho and western Wyoming, fuel type classification should be applicable in Utah stands where understory vegetation is similar.

Brown and Simmerman generalized their findings:

1. Shrubs contributed significantly to fine fuel loadings.
2. Fine fuel loadings differed substantially between the shrub and forb understory types and between the aspen/tall forb and aspen/low forb types.
3. Herbaceous vegetation in the aspen/tall forb class averaged two to four times greater than in the other classes.
4. Litter loadings differed greatly among individual stands within types, but the average difference among types was small and not meaningful.
5. Loadings of downed woody fuel 0 to 1 inches (0 to 2.54 cm) and 0 to 3 inches (0 to 7.62 cm) in diameter also varied substantially from stand to stand. The mixed types appear to have slightly more downed woody fuel than the other types, because conifer crowns shed more small dead twigs and branches than aspen. Considering the variation among stands, however, the differences among types appear insignificant. This emphasizes the need to appraise downed woody fuels on an individual stand basis.
6. Differences in dead fuel loadings between the aspen/shrub and mixed/shrub types are small. Nevertheless, these types should be regarded separately because conifers in the mixed types are likely to torch, thus creating a more severe fire. (The same relationship exists between the aspen/low forb and mixed/low forb types.)

Brown and Simmerman (1986) further found that heavy grazing can reduce fine fuels so that fireline intensity and rates of spread may be as low as one-tenth that of ungrazed stands. Fire in aspen stands will not spread unless flame lengths are 1 to 1.5 ft (2.54 to 3.81 cm), which requires at least 50 percent cured herbaceous vegetation in the aspen/shrub and aspen/tall forb types (fig. 30). Surface fuels in pure aspen stands are not typically conducive to prolonged flaming or burnout owing to a lack of intermediate fuels 0.4 to 3 inches (1 to 8 cm) in diameter. In all cases, the presence of conifers increases stand

Table 11—Average fuel loadings and shrub cover from sampled stands representing the aspen fuel types sampled in southeastern Idaho and western Wyoming (Brown and Simmerman 1986)

Fuel	Aspen-shrub	Aspen-tall forb	Aspen-low forb	Mixed-shrub	Mixed-forb
			Lb/acre		
Herbaceous	670 (230-1,000)	1,330 (1,030-2,020)	300 (180-460)	90 (80-90)	290 (10-550)
Shrubs[1]	3,170 (980-6,150)	110 (0-440)	260 (0-630)	3,040 (2,480-3,610)	630 (100-1,350)
Litter	1,810 (420-2,810)	1,600 (790-2,240)	1,350 (170-2,740)	1,980 (1,920-2,040)	1,680 (740-2,560)
Fines[2]	6,140 (4,030-9,390)	3,170 (1,970-3,990)	2,430 (1,640-3,330)	6,050 (5,850-6,250)	3,070 (2,150-2,560)
Downed woody 0- to 1-inch	2,440 (710-4,220)	1,080 (620-1,440)	2,600 (1,460-3,690)	4,240 (3,400-5,080)	2,710 (1,440-3,900)
Downed woody 0- to 3-inch	7,020 (3,580-12,510)	7,340 (1,520-16,210)	5,720 (3,290-7,600)	6,970 (5,550-8,390)	7,810 (4,090-12,250)
			Percent		
Shrub cover	40 (30-60)	10 (0-20)	10 (0-30)	60 (60-70)	20 (10-30)

[1]Shrubs include foliage and stemwood.
[2]Fines include live and dead herbaceous plants and shrubs, litter, and 0 to 1-inch downed woody fuel.

flammability significantly (fig. 31). Further discussion of this useful report may be found in the Fire Management Considerations section of Fire Group Seven.

Role of Fire

Many aspen stands in the West are even-aged seral stages of coniferous habitat types and result from rapid suckering after disturbance such as fire. In the Intermountain region, however, perhaps a third of the aspen stands are believed to be relatively stable and occur on sites unsuited to conifers (Mueggler 1989). Uneven-aged stands often occur where aspen is the apparent climax dominant. Here, regeneration takes place as a gradual process, with new suckers establishing as older stems die from age or disease. Uneven-aged structure also occurs where aspen clones invade adjacent grasslands or shrublands. The frequency of fire and its importance to community development may differ between even-aged and uneven-aged stands. Uneven-aged stands may be able to perpetuate themselves without periodic disturbance by fire or cutting. On some sites, even-aged stands may become uneven aged over time as individual stems die and new sprouts take their place (Baker 1925). On many others though, conifers will suppress aspen regeneration, or the stand loses reproductive vigor as stems die and new sprouts are not initiated. Fire plays a significant role in maintaining and regenerating aspen on such sites.

Fire frequencies of 100 to 300 years appear to be appropriate for maintaining most seral aspen stands (DeByle and others 1987). Fires in aspen and aspen-conifer stands before and during the mid-19th century were apparently larger and more frequent than has been true since. In Ephraim Canyon, Baker (1925) believed fire may have occurred as often as every 7 to 10 years, based on aspen bole scars he attributed to heat injury. DeByle and others (1987) list several factors possibly contributing to the reduction in fire occurrence in modern times:

1. Direct control of wildfires during the past 50 years has been especially effective, particularly in the aspen type.
2. For the past century, most aspen stands in the West have been grazed by domestic livestock. Thus, fine fuels have been reduced each summer before they cure and contribute to fire spread in the autumn.
3. During the 19th century, Native Americans were removed from most of their former homeland. Their deliberate use of fire on wildlands prior to Caucasian settlement is well documented.
4. Perhaps most of the flammable aspen-conifer mixed stands were burned during the late 1800's. Succession to flammable conifers in this type may just now be reaching a critical fuel condition that, in the next drought period, may result in uncontrollable

Figure 30—The lush undergrowth typical of many aspen stands frequently limits fire spread. Successful prescribed burning is generally restricted to times when the vegetation is in a cured condition.

Figure 31—Mixed stands of conifer and aspen have more downed and dead fuel. Young conifers in the understory and a shrubby undergrowth increase flammability.

fires and another pulse of extensive, more or less pure, aspen stands.

Regardless of the cause, the lack of fire or other mechanisms of regeneration has precipitated the decline of seral aspen on many thousands of acres throughout the West.

Although aspen often depends on fire for successful regeneration, it is extremely fire-sensitive. Even low-severity fires can cause mortality because of aspen's thin bark. Trees not killed outright by the heat of the fire often suffer mortality by the second or third growing season, succumbing to disease or other stress. Surviving fire-scarred trees are especially susceptible to heart rot (Jones and DeByle 1985). The relationship between fire severity, mortality, and suckering is discussed by Brown and DeByle (1987). Suckering is a highly variable process. The auxin and other hormones produced by aboveground stems suppress sucker growth. Killing most or all of the clonal stems helps to stimulate good resprouting. Suckering ability is governed by clonal genetics, stand vigor, and postfire site factors as well as hormonal balance. Thus it is difficult to predict the amount of resprouting that will take place in a particular stand after a specific fire treatment. Moderately severe fire may be more likely to produce good suckering when compared with low-severity fires, which may not kill enough stems, or high-severity fires, which may kill shallow aspen roots (Brown 1990).

Forest Succession

The hypothetical pathway presented in figure 32 describes succession in climax or persistent aspen stands (letters in this section refer to fig. 32). Long-term effects of fire exclusion on these stands is not understood. The biological response of seral aspen is similar, and its relationship to conifer species is described in Fire Groups Three, Five, Six, and Ten.

A short-lived herb stage follows a stand-replacement fire. Resprouting generally begins within the first growing season following fire, although suckering after a severe burn may be delayed because the resprouts must come from deeper roots (B). Any fire at this stage will recycle the stand. Repeated fires may maintain aspen in a shrublike form. Low-severity fire in an immature or mature stand (C and D) opens the stand and may stimulate some suckering. This results in a two-storied aspen stand (E1). Succeeding fires are more likely to be moderate to highly severe because of the downed stems left by low-severity fire. Moderate to highly severe fires return the stand to the herb state.

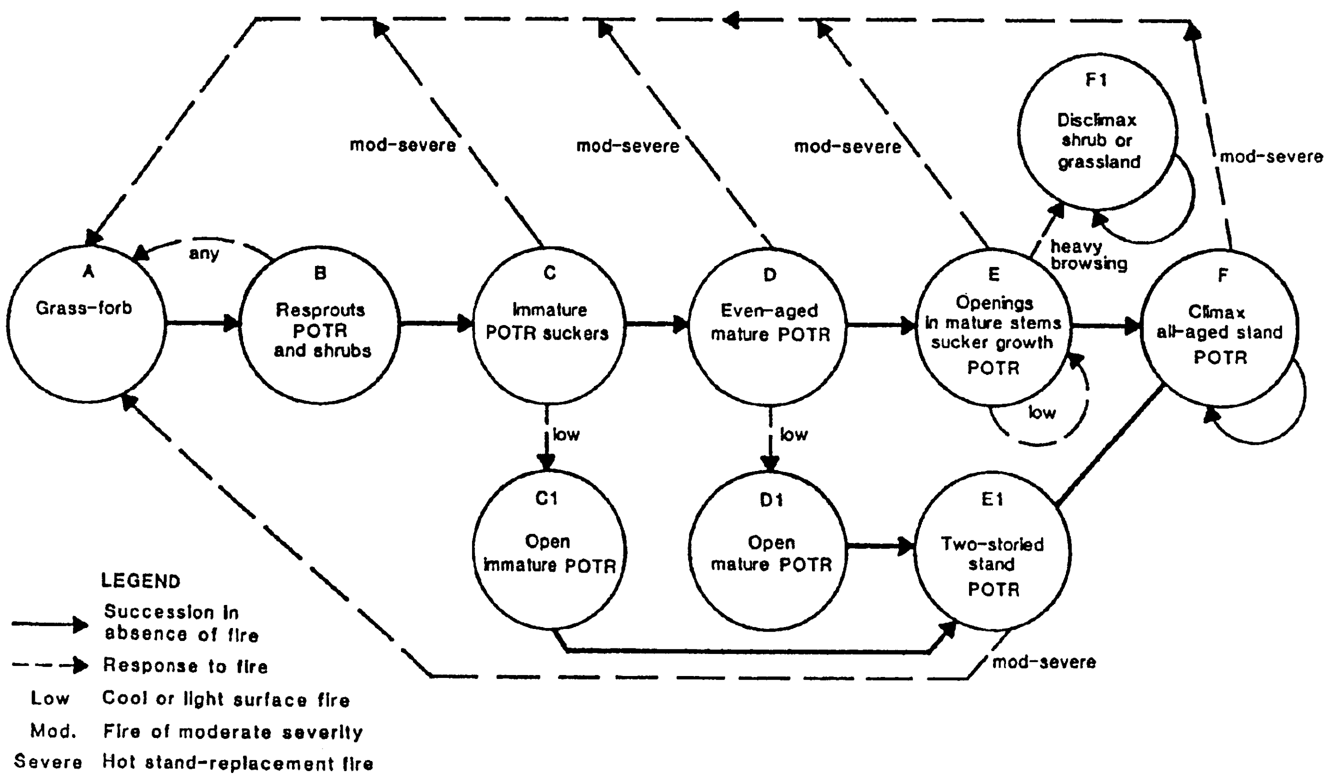


Figure 32—Hypothetical fire-related successional pathways for habitat types and communities in Fire Group Seven.

Climax all-aged aspen is the result of a prolonged period without fire (F). Mature stems continue to degenerate and are replaced by suckers in the openings. Although low-severity fires may not kill aspen outright, injured stems are very susceptible to invasion by fungal pathogens. Where the vigor of the clone is reduced by disease, there is less suckering. This may slow succession or, in extreme cases, may return dominance to shrubs and herbaceous vegetation. Heavy browsing on aspen suckers may also lower clone vigor to the point that suckering no longer takes place. A shrub or herb disclimax results (F1). Browsing pressure may allow aspen to regenerate, but prevent the development of trees. Aspen will grow instead as a dense shrub.

Fire Management Considerations

Approximately a third of Utah's commercial forest land is occupied by aspen (DeByle and others 1987). Aspen stands provide excellent forage for livestock and wildlife, with production values of up to 1.5 tons/acre (3.4 metric tons/ha) recorded for some stands (Mueggler 1988). Aspen provides quality browse and cover for many wildlife species. Rapid development of urban and agricultural areas in the Mountain States is increasing the utilization of aspen stands as a source of fuel, fiber, and water. Aspen stands have a water-yielding capacity superior to conifer-dominated stands (DeByle 1985; Jaynes 1978), a critical feature in the coming decades, especially in arid Utah. Population growth has also increased the demand for recreational opportunities, and aspen forests are popular for picnicking, hiking, or viewing.

In the Intermountain region as a whole, two-thirds of aspen stands are at least 96 years old and 90 percent are at least 75 years old. Western aspen usually matures between 60 and 80 years of age and deteriorates rapidly after 120 years. Relatively few trees live to be over 200 years old. Approximately 94 percent of aspen stands appear to be mature or overmature (Mueggler 1989). Whether or not some kind of treatment is needed to assure the continued presence of aspen in these stands depends on the degree of conifer invasion and the relative success of regeneration. Mueggler (1989) has developed a decision tree as an aid in determining the need for treatment (fig. 33).

It may be difficult to decide whether aspen regeneration in a stand is adequate. The number of sprouts needed for rapid stand replacement is not well understood. Mueggler does suggest that mature or overmature stands with less than 500 suckers per acre (1,235/ha) may have regeneration problems, and that those with over 1,000 suckers per acre (2,470/ha) appear to be reproducing successfully.

Regeneration of seral aspen stands requires killing most of the aboveground stems in a clone. This may be achieved by clearcutting, top-killing with herbicides, or using prescribed fire. Where clearcutting is not feasible, fire is the most acceptable management tool (DeByle and others 1987).

Before planning any manipulation of aspen, the manager will want to consider carefully what successional stage, or pattern of successional stages, best satisfies management objectives. Cattle prefer grazing in relatively open stands, free of dense reproduction. Early successional stages provide optimum habitat for ruffed grouse (Stauffer and Peterson 1985). Elk may use young, sapling aspen as a source of winter browse. Where hunting pressure is intense, later successional stands with a higher density of young conifers may be desirable to provide adequate hiding cover and prevent overharvesting of game. Water yield is greatest in the earliest stages of succession. A mosaic of different developmental stages over the landscape maximizes the value of these stands for a variety of uses.

Fire can be used to enhance many of the values associated with aspen. But not all stands are equally suited to fire use. Aspen forests are often called "asbestos forests" because they are considered difficult to burn compared with most conifer stands. Aspen stands have been used as firebreaks when managers burn other vegetation types. Brown and Simmerman (1986) have characterized aspen fuels to determine potential flammability of aspen stands for prescribed burning.

In addition to the limits imposed by specific fuel types, managers need to be aware of other flammability factors:

> Grazing can greatly reduce flammability where herbaceous vegetation is a significant fuel. Our sampling showed a two-thirds reduction of herbaceous vegetation due to grazing in aspen/shrub and aspen/tall forb types... . Heavy grazing, with few exceptions, negates the opportunity to use prescribed fire in aspen forests. Light grazing prior to burning may be possible, depending on other factors influencing flammability (Brown and Simmerman 1986).

Aids to flammability in aspen stands include the presence of large downed woody fuel, small conifers, and an open canopy. Autumn leaf fall does not aid flammability to any great extent, but leaf litter may help sustain a fire in marginal conditions. Determining when fuels are ready to burn is more complicated in aspen forests than in most other vegetation types. Curing is probably the most important variable to monitor. Successful fire application requires waiting until live fuels are adequately cured and windspeed and dead fuel moistures enhance fire spread. Adequate curing is particularly important where herbaceous vegetation is the primary fine fuel.

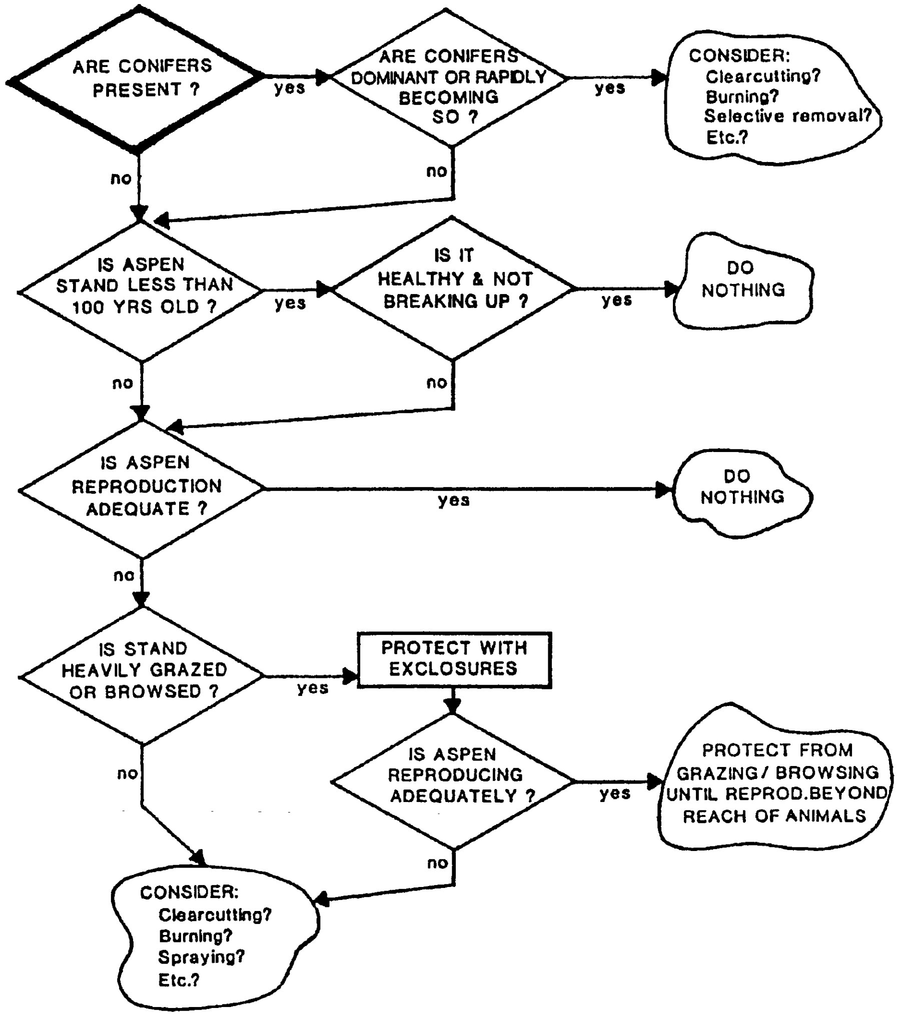


Figure 33—General decision-making tree for maintaining aspen stands in the Intermountain Region (Mueggler 1989).

Burning operations in these situations should not be delayed. Cured herbaceous vegetation is more flammable, but the chance of snow or rain increases over time as curing continues. The time a stand remains in prescription is usually brief (Brown and Simmerman 1986). Figure 34 illustrates the fluctuation of live fuel moisture with season and precipitation for fine fuels collected in a western Wyoming aspen stand.

Brown and Simmerman classified western Wyoming and southeastern Idaho aspen stands into five fuel types (table 12). This classification may also be applied to Utah aspen communities.

In mixed-shrub and mixed-forb fuel types, conifers codominate with aspen in the overstory. Mixed stands are probably seral stages of climax coniferous habitat types. These stands have a higher potential for successful prescribed fire because of the more flammable conifers. Although community classification requires only 5 to 15 percent conifer coverage for conifers to be considered codominant, for fuel purposes conifer coverage must be at least 50 percent before a stand falls into the mixed category.

Flammability is altered by many factors. The influence of grazing and downed woody fuel loading is reflected in the probability of burning success ratings given in table 13. Fire potential ratings for the fine aspen fuel types and several combinations of grazing intensity and downed woody fuel accumulations are given in table 14. Brown and Simmerman (1986) identify the following general trends from table 14:

1. The mixed-forb class has higher fire potential than the aspen-low forb class due to differences in downed woody fuel loadings and torching potentials.
2. Grazing reduces fire intensity and rate of spread by at least one rating level.
3. Heavy fuel loadings result in increased intensities except where substantial grazing is expected.

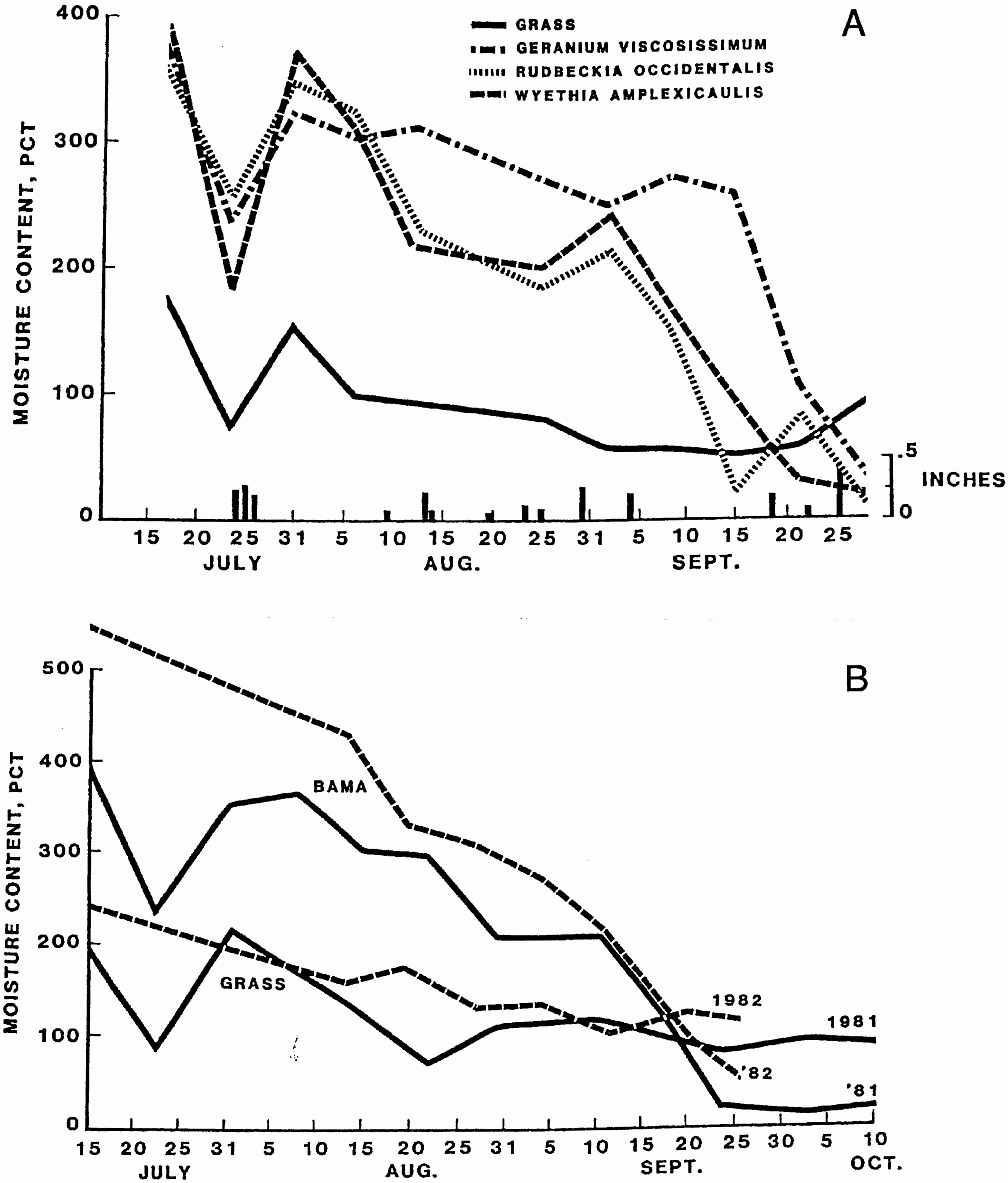


Figure 34—Live moisture contents of fine fuels collected at different dates and different precipitation levels in a western Wyoming aspen stand. (A) Moisture content of grasses (*Elymus* and *Bromus* spp.) from an aspen stand in the Kemmerer Ranger District, Bridger-Teton National Forest, WY, 1981. The bars along the horizontal axis show precipitation. (B) Moisture content of *Balsamorhiza macrophylla* (BAMA) and grass (*Elymus* and *Bromus* spp.) from an aspen stand in the Kemmerer Ranger District, Bridger-Teton National Forest, WY. Precipitation during August and September was 1.58 inches in 1981 and 4.66 inches in 1982.

Table 12—A vegetation classification of aspen fuels and flammability (Brown and Simmerman 1986)

Characteristics	Vegetation-fuel types: Aspen-shrub	Aspen-tall forb	Aspen-low forb	Mixed-shrub	Mixed-forb
Overstory species occupying 50 percent or more of canopy	Aspen	Aspen	Aspen	Conifers	Conifers
Shrub coverage, percent	Greater than 30	Less than 30	Less than 30	Greater than 30	Less than 30
Community type understory indicator species that may be present	*Prunus* *Bromus* *Amelanchier* *Shepherdia* *Symphoricarpos* *Artemisia* *Juniperus* *Pachistima*	*Ranunculus* *Heracleum* *Ligusticum* *Spiraea* *Calamagrostis* *Rudbeckia* *Wyethia*	*Prunus* *Berberis* *Arnica* *Astragalus* *Thalictrum* *Geranium* *Poa*	*Ligusticum* *Shepherdia* *Spiraea* *Amelanchier* *Symphoricarpos*	*Pedicularis* *Berberis* *Arnica* *Calamagrostis* *Thalictrum*

Table 13—Probabilities of successfully applying prescribed fire in aspen forests according to fuel types and the influence of grazing and quantities of downed woody material (Brown and Simmerman 1986)

		Fuel types				
Grazing	**Woody fuel**	**Aspen-shrub**	**Aspen-tall forb**	**Aspen-low forb**	**Mixed-shrub**	**Mixed-forb**
Ungrazed	Light	high	moderate	low	high	moderate
Ungrazed	Heavy	high	moderate	low	high	high
Grazed	Light	moderate	low	low	moderate	low
Grazed	Heavy	high	low	low	high	moderate

Table 14—Fire intensity and rate-of-spread adjective rating according to fuel types, grazing intensity, and downed woody fuel quantities (Brown and Simmerman 1986). The first rating is for intensity and the second for rate-of-spread. H, M, L, N mean high, moderate, low, and nil, respectively

		Fuel types				
Grazing	**Woody fuel**	**Aspen-shrub**	**Aspen-tall forb**	**Aspen-low forb**	**Mixed-shrub**	**Mixed-forb**
Ungrazed	Light	M-M	L-L	N-N	M-M	L-L
Ungrazed	Heavy	H-M	M-L	L-L	H-H	M-M
Grazed	Light	L-L	N-N	N-N	L-L	N-N
Grazed	Heavy	M-L	N-N	N-N	M-L	L-L

4. Heavy fuel loadings increase rate of spread in stands with mixed overstories, but not aspen overstories.

The method of ignition is an important consideration in prescribed burning of aspen.

Method of ignition should be carefully considered in planning prescribed fire in aspen because it affects the conditions chosen for burning and chances of success. Both hand-held and aerial ignition methods can be used successfully; however, aerial ignition with jelled gasoline permits burning at higher fine fuel moisture contents than possible using hand ignition, because more heat can be generated for preheating adjacent fuels, particularly where fuels are abundant and continuous. Aerial ignition can create larger flames to kill unwanted vegetation and get the fire to spread in marginal fuels, particularly where fuels are abundant and continuous (Brown and Simmerman 1986).

On the Fishlake National Forest, successful mixed conifer-aspen burns have been ignited in the late summer and fall using a helitorch (Gruell 1990).

If simply retaining the aspen type is desired, any fire severity will probably suffice. To obtain the greatest sucker densities, moderate burns are advised. High-severity fires may be useful in limited conditions, for example where ceanothus stimulation is desirable or in upper elevation spruce-fir types where only a high-severity fire is sustainable because of the scant fuel loading.

Where commercial development of aspen is the objective, clearcutting may produce more consistent stand regeneration than fire. On sites where Douglas-fir or ponderosa pine are undesirable competing conifers, low-severity fires may actually enhance their reproduction over aspen if the conifers survive. They will quickly establish in the newly exposed mineral soil (Brown and Simmerman 1986).

Postfire conditions will influence stand reestablishment. Heavy sucker utilization by wildlife may be one limitation. On Breakneck Ridge in the Gros Ventre drainage, Wyoming, postburn sucker numbers doubled the second year after fire. By the third year, though, there were 37,000 to 50,000 per acre (15,000 to 20,000 per hectare), similar to the numbers that existed before the fire. Because of heavy winter elk use, these densities have not been enough to regenerate the stand (Bartos and Mueggler 1981). Nevertheless, aspen can be remarkably persistent. Where browsing is heavy, aspen may exist for long periods of time as an inconspicuous shrub. If grazing pressure is removed, it may be capable of developing into a viable stand (Mueggler 1990). Treatment areas that are too small (<40 acre; <16 ha), are isolated, or that are in areas more available or attractive to ungulates may suffer overuse (Bartos and Mueggler 1979; Gruell and Loope 1974). Where wild ungulate use is not heavily concentrated, browsing is less of a problem (Spillett n.d.). Domestic animal use, especially that of sheep, can also impact regeneration success (Smith and others 1972).

FIRE GROUP EIGHT: HABITAT TYPES WITH PERSISTENT LODGEPOLE PINE

Habitat Types, Phases

Abies lasiocarpa/Vaccinium caepitosum h.t. (ABLA/VACA), subalpine fir/dwarf huckleberry

Abies lasiocarpa/Vaccinium scoparium h.t.-*Vaccinium scoparium* phase (ABLA/VASC-VASC), subalpine fir/grouse whortleberry-grouse whortleberry phase

Pinus contorta/Arctostaphylos uva-ursi c.t. (PICO/ARUV), lodgepole pine/bearberry

Pinus contorta/Berberis repens c.t. (PICO/BERE), lodgepole pine/creeping Oregon grape

Pinus contorta/Calamagrostis canadensis c.t. (PICO/CACA), lodgepole pine/bluejoint

Pinus contorta/Carex rossii c.t. (PICO/CARO), lodgepole pine/Ross sedge

Pinus contorta/Juniperus communis c.t. (PICO/JUCO), lodgepole pine/common juniper

Pinus contorta/Vaccinium caespitosum c.t. (PICO/VACA), lodgepole pine/dwarf huckleberry

Pinus contorta/Vaccinium scoparium c.t. (PICO/VASC), lodgepole pine/grouse whortleberry

Picea engelmannii/Vaccinium caespitosum h.t. (PIEN/VACA), Engelmann spruce/dwarf huckleberry

Picea engelmannii/Vaccinium scoparium h.t. (PIEN/VASC), Engelmann spruce/grouse whortleberry

Vegetation

Habitat types where lodgepole pine can be a persistent seral species or where it forms an apparent climax make up Fire Group Eight. Lodgepole pine is restricted to northern Utah, and occurs in a belt from about 7,500 to 10,300 ft (2,286 to 3,139 m) on granitic soils that are often droughty and nutrient poor. True climax lodgepole pine stands occur only in the Uinta Mountains. Stands of persistent lodgepole in the Wasatch Mountains are considered seral phases of subalpine fir habitat types (Mauk and Henderson 1984). PIEN/VACA, PIEN/VASC, and ABLA/VASC-VASC sites located above the cold limits of lodgepole pine are assigned to Fire Group Twelve. Other lower elevation ABLA/VASC-VASC sites where lodgepole is not persistent are assigned to Fire Group Ten.

According to Pfister and others (1977), lodgepole pine becomes a climax species where (1) repeated conflagration or light underburning has eliminated the seed source of potential competitors, (2) the absence of catastrophic disturbance permits the development of dense lodgepole stands that prevent any conifer regeneration until the stand deteriorates, and (3) sites are too harsh for the establishment of other species.

The undergrowth of climax or persistent lodgepole pine stands is not usually diverse or dense. Harsh growing conditions and/or a dense canopy permit relatively few species to flourish (fig. 35). Shrubs may include *Juniperus communis*, *Mahonia repens*, *Shepherdia canadensis*, *Vaccinium caespitosum*, and *V. scoparium*. Graminoids include *Carex geyeri*, *Poa secunda*, *Trisetum spicatum*, and on moist sites, *Calamagrostis canadensis* and *Elymus glaucus*. Forbs with higher constancy include *Antennaria microphylla*, *Epilobium angustifolium*, *Geranium viscosissimum*, *Lupinus argenteus*, and *Pyrola secunda*.

Forest Fuels

Published fuel summaries are unavailable for persistent lodgepole pine stands in Utah. Measurements of downed woody loadings have been made in

Figure 35—A dense even-aged lodgepole pine stand in the Uinta Mountains. These stands support little other vegetation.

similar Montana stands. Average fuel loads are 15 to 18 tons/acre (33.6 to 40.3 metric tons/ha) although maximum loads were found to be much higher. Typically, most of this loading is in the large-fuel (greater than 3 inches or 7.6 cm) category. The nature of fuels changes over time in lodgepole pine stands, although the amount of fuel produced over time appears to be quite variable (Brown and See 1981). A classification that relates lodgepole pine stand age and flammability has been developed for Yellowstone National Park (Romme and Despain 1989; Despain n.d.):

LP-0 (Young Stands)

The earliest stage of post-fire succession is LP-0. Initially the vegetation is dominated by herbs and small shrubs, most of which resprouted from root stocks that survived the fire. Within a few years, these plants may become larger and more productive than they were before the fire because they are no longer competing with trees for light, water, and nutrients. Fire-killed trees, both standing and fallen, are conspicuous in this stage. Over the first 10 to 20 years after the fire, lodgepole pine seedlings establish themselves and slowly grow to overtop the herbs and shrubs.... The LP-0 stage lasts until this pioneer generation of lodgepole pine growth is large enough to form a closed canopy and begins to shade the forest floor, a span of about 40 years on most sites. (Romme and Despain 1989.)

Fuels in this type consist mainly of forbs, grasses, and rotten logs. Sound logs begin to rot and seeds germinate immediately after a fire. As time goes on, the number of rotten logs, tress seedlings, and saplings increases. Under normal moisture conditions only the rotten logs burn, predrying and burning some of the herbaceous growth next to them. Occasional small trees or clumps of small trees burn if fuel conditions at their base are just right. If the fire brand rain is heavy enough, most of the rotten logs will burn. Under very dry conditions (drought) right wind and moisture conditions fire spread through this type is possible though rare. Fire starts are moderately common in this type because of the rotten wood. (Despain n.d.)

LP-1 (Immature Stands)

The next successional stage is called LP-1 and is characterized by a dense stand of small lodgepole. Competition for nutrients, water and light may be intense among these young trees and many of the weaker trees die, producing a natural thinning of the stand. The herbs and shrubs on the forest floor become more sparse than they were in the previous stage, apparently because they are suppressed by the maturing trees. Almost all of the fire-killed trees have fallen and are now large decomposing logs on the forest floor. This stage usually lasts until the trees reach their full size and the natural thinning process is completed, generally from 40 to 150 years. (Romme and Despain 1989.)

Fuels here are nearly all in the crowns of the doghair lodgepole. The compact needle litter is difficult to burn. Under normal fire season moisture this type is nearly unburnable. Fire brands may find an occasional rotten log and burn out a small spot. Under very dry crowning fire reaches the stand. Fire spread, however, will stop when the wind ceases. There are no fuels to get the fire back into the canopy even if the wind should return. Fire starts in this type are very rare to nonexistent. (Despain n.d.)

LP-2 (Mature Stands)

Stands in the next stage, LP-2, still have a closed canopy, but they are usually less dense than the previous stage. Most of the dead trees, both those killed by the previous fire and those that died in the thinning process, have decomposed. The forest floor is now open and easy to walk through. The herbs and low shrubs become more abundant and tree sapling more prominent toward the end of this stage. These saplings may have been present for many years but were suppressed by the larger trees, or they may represent a second generation of trees that is just now becoming established. The species may be subalpine fir and Engelmann spruce on moist fertile sites, lodgepole pine on dry infertile sites or Douglas-fir at lower elevations. This stage usually lasts from 150 to 300 years after the fire. (Romme and Despain 1989.)

Fuels in this type are largely herbaceous or low shrubs like grouse whortleberry (*Vaccinium scoparium*). Under normal conditions this type is very difficult to burn. The understory vegetation stays moist enough to retard fire spread. Very few rotten logs are available. Under very dry conditions the herbaceous growth may carry the fire. Fire spread, however, is very slow because the canopy keeps wind from reaching the flames. If a good understory of globe huckleberry (*V. globulare*) develops and trees killed by bark beetles begin to fall and contribute to understory fuels, crowning is possible. In the older stands sufficient young trees may be on hand to allow crowning. Bark beetle kill is common in this type; however, experience had shown that it affects fire behavior very little. The red crowns are much drier than the green crowns but crowning is still dependent on the ladder fuels or understory fuels. Fire starts are rare in this type. (Despain n.d.)

LP-3 (Overmature Stands)

LP-3...is an old-growth forest...containing trees of many sizes and ages, as well as a variety of low shrubs and herbaceous plants. The LP-3 stage generally is reached after about 300 years [probably sooner in stands off the Yellowstone Plateau] of post-fire succession, and it slowly develops into the climax forest as the pioneer lodgepole die. The climax consists entirely of second-generation trees, and it persists until the next hot fire, which then initiates a new successional cycle. True climax is uncommon in Yellowstone, suggesting that fire usually recurs before the successional process is complete. (Romme and Despain 1989.)

Fuels in this type are right for burning. Young trees contribute to understory fuels and fuels continuous with the overstory. Spruce and fir trees are scattered among the overstory and may contribute to the dead and down fuels in the understory. On the better growing sites, globe huckleberry may also contribute significantly to the fuels. Lichen accumulations in older trees contribute to the fuel load and flashability of the trees. Lightning strikes and other fire brands find an easily burnable substrate in these crowns. The bulk of the extreme fire behavior takes place in this type. Under normal moisture conditions this type burns. If winds are present, crowning and spotting are nearly inevitable. Without winds, torching occurs. Under dry conditions local crowning and smoke column development is possible even without wind. Spotting is very common and is the largest contributor to fire spread. Under wet conditions, these stands allow severity fires to smolder and persist, although spread is minimal. Deep litter and duff accumulations and rotten logs protected from precipitation by overstory trees provide sites where fires can persist even for several weeks. Most fires start in this type. (Despain n.d.)

...the post-fire succession brings with it an important change in the flammability of the forests...the early stages (LP-0, LP-1 and at least the initial period of LP-2) do not carry a crown fire as readily as the older stages, except during strong winds... . In late LP-2 and especially in the LP-3 and climax stages, flammability increases substantially, both because of the dead trees and other dead woody fuels that begin to accumulate on the forest floor and because of the small trees that are growing into the forest canopy. These small trees are flammable themselves, especially fir and spruce, and they also create continuity between the dead fuels on the ground and the live tree crown.

An analysis of 235 lightning-caused fires allowed to burn between 1976 and 1987 revealed that most fire starts occurred in LP-3 and climax forest stands...[in 1988] strong winds drove [fires] through extensive areas of young forest in the extremely dry conditions of late August and early September... there are significant differences in flammability among the various stages of forest succession except in unusual (and infrequent) dry windy years (Romme and Despain 1989).

Brown (1975) characterized fuel cycles and fire hazard in lodgepole pine stands, as shown in figure 36. Curve A of that figure corresponds to what Muraro (1971) describes as typical fire hazard in lodgepole pine where young, especially dense

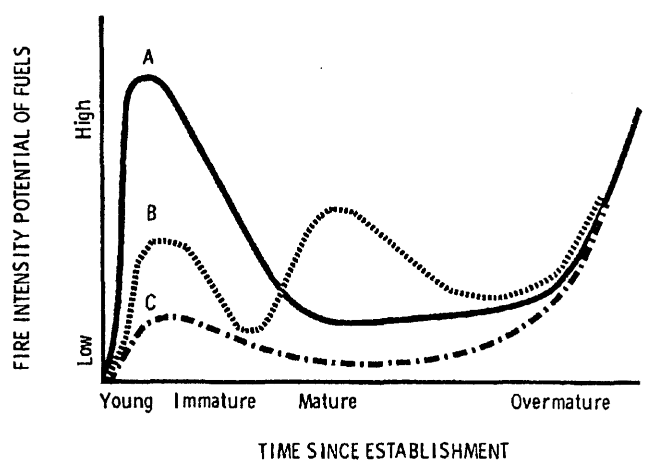


Figure 36—Fuel cycles and fire intensity potential in lodgepole pine (Brown 1975). See text for description and discussion of curves A, B, and C.

stands are most hazardous. Least hazardous are moderately dense to open, advanced, immature, and mature stands. Hazard increases as stands become overmature and as 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).

In a young lodgepole stand the snags created by the previous fire provide an immediate source of downfall. Lyon (1977, 1984) 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. 37). Overall, an average of 497 snags per acre was reduced to an average of 75 snags per acre after 15 years (table 15). After 21 years, nearly 93 percent of all snags had fallen.

Role of Fire

In lodgepole pine stands, fire perpetuates or renews the species. Where pine is a seral species, shade-tolerant species will replace it without fire or other disturbance because of its intolerance and mineral seedbed requirement. Lodgepole pine establishes readily on disturbed areas. Bare mineral soil, whether caused by logging or fire, provides the best seedbed (Lotan 1975).

Lodgepole pine often has serotinous, or closed, cones, but even in populations with a high degree of serotiny there will be open-coned individuals. Serotiny can affect the age distribution in a stand. Seed from open-coned trees produces uneven-aged stands, where seedlings establish over a period of years. Closed-cone trees generally produce even-aged stands. They develop from the flush of seedlings that arises following the fire-induced release of large numbers of seeds on the freshly prepared mineral seedbed. Rocky Mountain lodgepole pine stands vary in their degree of serotiny. Proportions of serotinous trees range from zero to 80 percent (Lotan 1975). Double burns or successive burns within a 50-year span favor serotiny. A mix of serotinous and nonserotinous trees usually results after low or moderate fires. A higher proportion of regeneration from serotinous trees follows severe crown fires. Over time, without fire, even stands with a very high proportion of closed cones can become predominantly open-coned as regeneration replaces the original trees (Muir 1984). In mixed species stands, fire interrupts the course of succession and increases the proportion of lodgepole with each burn.

Reported fire frequencies for lodgepole pine stands vary from 22 years in the Bitterroot Valley of western Montana (Arno 1976) to 300 plus years in

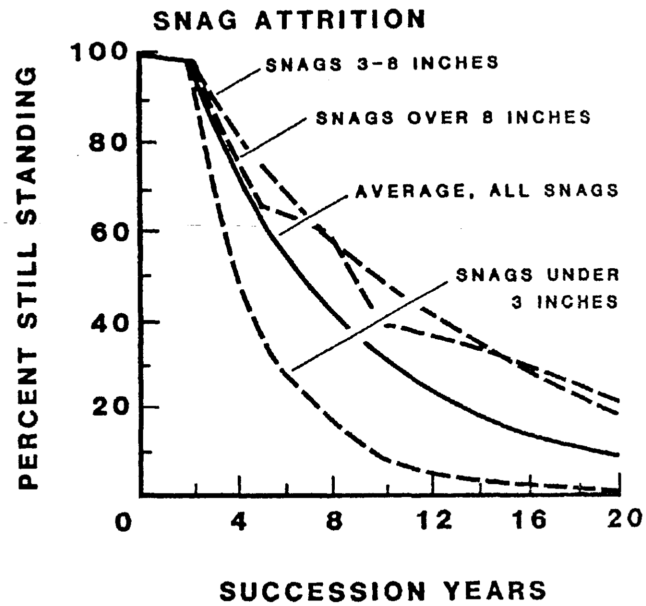


Figure 37—Percentage of lodgepole pine snags still standing, by year and diameter class, Sleeping Child Burn, Bitterroot National Forest, MT, 1962 to 1982 (Lyon 1984).

Table 15—Average number of snags per acre by size class and year count, Sleeping Child Burn, Bitterroot National Forest, MT (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

Yellowstone National Park (Romme 1982). The interval between any two fires in an area may only be a few years. Regional fire frequency varies with summer dryness and lightning occurrence. Locally it depends on slope, aspect, elevation, and natural fire barriers. Fire size is also weather dependent. Large fires may occur during droughty conditions in most lodgepole stands regardless of stand age (Brown 1975). The overriding effect of weather was demonstrated in the fires that occurred in Yellowstone Park in 1988.

Fires in lodgepole pine-dominated stands tend toward one of two extremes. They may smolder and creep slowly on the soil surface consuming litter and duff, or act as severe, stand-replacing crown fires. Most are low-intensity fires due to the generally sparse undergrowth and stand growth habit. Cool, moist conditions prevail under a dense, closed canopy, and fires that start here usually remain on the ground, smoldering for days or even weeks before extinguishing (Lotan and others 1985). Such fires have been observed in Yellowstone National Park (Despain and Sellers 1977). Severe fires are most likely to occur where dead fuels have accumulated. Where there are concentrations of dead or mixed dead and live fuels, individual trees or groups of trees may torch, and fire can continue to travel through the crowns aided by steep slopes and high winds. Though much less common, severe crown fires account for most of the timber consumed. Summer wildfires may exhibit both types of fire behavior, depending on the diurnal weather fluctuations. The chance of crown fire occurring in lodgepole stands is governed by the amount of heat released from surface fuel, the height of tree crowns above the ground, and fire weather conditions. Stand conditions determine the fire potential, and this, in turn, is the result of stand disturbance history (Brown 1975). The kind of fire that occurs will determine stand density and the rate of succession. If open stands result, there will be a faster rate of succession (Brown 1975).

Stand development, vegetation mortality, and fuel accumulation interact dynamically with fire in the lodgepole pine forest (Brown 1975). The type and degree of vegetation mortality affects the fuel buildup, which in turn determines the severity of later fires and subsequent stand regeneration. Historically, fire probably generated the most surface fuel in lodgepole pine stands. Competition between dense seedlings and saplings often results in further fuel buildup from suppression mortality.

Two biotic factors that have a great impact on the fire dynamics of lodgepole pine are dwarf mistletoe and the mountain pine beetle (fig. 38). Dwarf mistletoe reduces tree vigor and may increase mortality. Conversely, the type of fire affects the potential for mistletoe infection. A stand thinned by fire may become more susceptible to mistletoe, because mistletoe is most successful in otherwise unstressed trees, such as those in a well-spaced stand (Parmeter 1978). Mountain pine beetle-lodgepole pine interaction differs with habitat type. McGregor and Cole (1985) found that in southeastern Idaho and northwestern Wyoming habitat types, 44 percent of stands in the *Abies lasiocarpa / Vaccinium scoparium* habitat type were infested between 6,500 and 8,500 ft (1,981 and 2,591 m), 92 percent were infested in the *Abies lasiocarpa/Pachistima myrsinites* habitat type between 6,500 and 7,800 ft (1,981 and 2,377 m), and 64 percent were infested in the *Pseudotsuga menziesii/Calamagrostis rubescens* habitat type between 6,000 and 7,800 ft (1,829 and 2,377 m).

Figure 38—Bug-killed lodgepole pine with aspen. The mountain pine beetle is an integral part of the fire fuel cycle in many lodgepole pine stands.

The relationships between fire, lodgepole pine, and the mountain pine beetle have been well summarized by Amman (1977):

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.

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 1965). Fires tend to eliminate competitive tree species such as Douglas-fir, the true firs, and spruces. Following fire, lodgepole pine usually seeds in abundantly.

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, thick-barked 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 over-mature 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.

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 lodepole 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 beetle's 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] 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.

Fire severity plays an important and variable role in lodgepole pine stand establishment (Lotan and others 1985):

HIGH-INTENSITY FIRE

1. Creates good seedbed conditions on mesic and wet sites, and when seed is abundant, dense stands are established. On dry sites, however, low stocking can result because of poor moisture conditions.

2. Crown fires usually cause maximum release of stored seed. In surface fires with considerable crowning, mineral soil is exposed, serotinous cones open, and if seed is abundant, a dense stand results. Occasionally, severe crown fires consume up to ½-inch diameter fuel, destroying much of the seed supply, and a lower density stand results.

3. When seedbed conditions, seed supply, soil moisture, and other factors are favorable for stand establishment, extremely high stocking (leading to stagnated stands) frequently results.

4. Competition from understory vegetation, particularly grass, can decrease stand density even if other factors influencing establishment are favorable.

LOW-INTENSITY FIRES

1. Moisture content of duff is an important factor in determining level of stocking. When duff is dry, a low-intensity fire will expose mineral soil, resulting in a high level of stocking. When duff is moist, fire will expose less mineral soil, resulting in poor seedbed conditions and low stocking.

2. Mortality may be minimal or sporadic. Sometimes widely spaced stands result. In time, two-aged or three-aged stands can develop.

3. In stands of mixed species, the survival of lodgepole pine depends on its fire resistance relative to other species as well as the seed potential of all species. Post-fire species composition, age structure, and density of mixed stands vary considerably depending on fire characteristics and many other interrelated factors.

Forest Succession

Fire Group Eight stands where lodgepole pine appears to be climax are dominated during succession by either lodgepole pine alone or by a mixture of pine and aspen. Figure 39 illustrates the role of fire in Group Eight stands. Letters in this section refer to letters in figure 39.

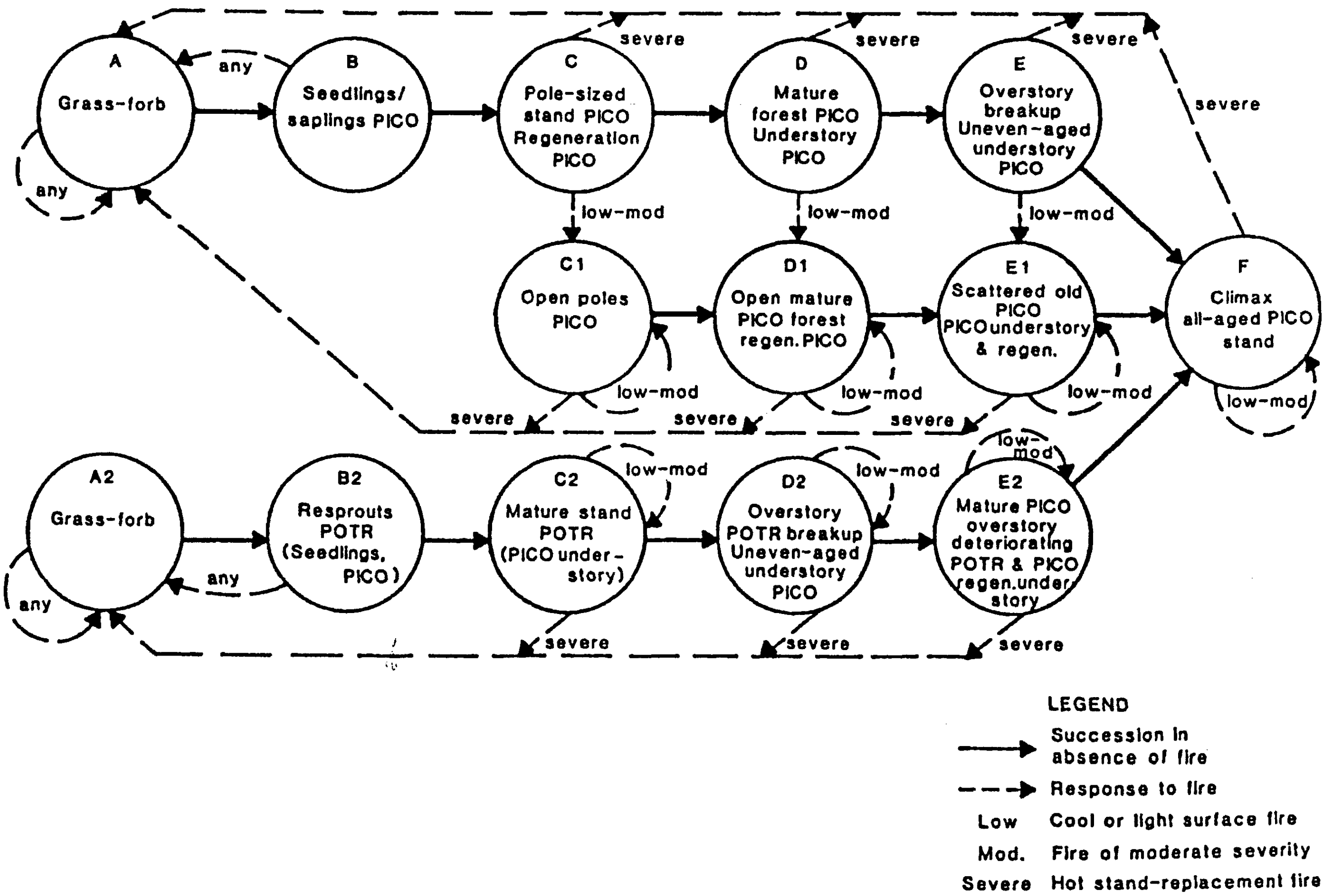


Figure 39—Hypothetical fire-related successional pathways for habitat types and communities in Fire Group Eight where lodgepole pine alone is the major seral and climax species and where aspen is an important seral species with lodgepole pine.

Lodgepole Pine Climax—Lodgepole pine is essentially the only tree present on the site. Consequently, succession is dominated by lodgepole pine at all stages of development, and even several centuries without fire may not change species composition.

After a stand-replacing fire, an initial herb/shrub community will establish on the site (A). Fires of any severity maintain this state. In stands where lodgepole pine is serotinous, this stage is quickly followed by a dense stand of even-aged lodgepole pine seedlings and saplings. Lodgepole pine with nonserotinous cones may also reestablish rapidly where there is an adequate nearby seed source (B). Where conditions are somewhat less favorable for lodgepole pine, a more open stand, possibly with a few fir and spruce, may result. Any fire returns this site to an herb/shrub state. In a serotinous stand, the initial flush of seedlings from heat-opened cones on site may be consumed by subsequent fire. In this case, the formerly serotinous stand becomes dependent on off-site seed and further patterns of regeneration resemble those of the nonserotinous stand. If potential off-site seed trees are predominantly serotinous, pine reestablishment takes considerably longer.

Without fire, in both serotinous and nonserotinous stands a pole-sized stand of lodgepole pine results (C). Young stands are often densely overcrowded. Such stands may have little or no understory. Stand-replacement fires are a possibility in either the pole or mature stages during droughty weather with high winds. Lodgepole pine often produces cones at a young age, and after a crown fire a pole-sized serotinous stand could revert quickly to a seedling-sapling stage. Nonserotinous stands will return again to a shrub/herb condition in the event of a severe fire. A low to moderate fire may open pole or mature stands (C1, D1). In the exposed mineral soil of these openings, seedlings of lodgepole pine can establish. If no fires occur for 60 years or more, the mature, dense overstory begins to open up as a result of beetle-kill, disease, or windthrow (E, E1). New openings are created that enhance seed establishment or the release of suppressed understory trees. Moderate fires are unlikely at this stage. Instead, severe fires can occur, fed by the accumulated downed woody fuels that result from tree mortality and the presence of dense, young lodgepole in the understory. In contrast, the other type of burn commonly encountered is that produced by low, creeping surface fires. They burn with greater frequency but affect smaller areas and cause considerably less mortality, removing patches of variously aged trees rather than whole stands. Sufficiently large openings encourage the establishment of more lodgepole seedlings. Climax stands are all-aged, with old, decadent stems continually replaced by new seedlings (F). Low to moderate fires maintain this age structure, and severe fires recycle the stand to the herbaceous state.

Succession With Aspen—Aspen may be an important seral species with lodgepole pine. Where this is true, the initial herb stage (A2) will be short lived. Any fire in this or the subsequent aspen and shrub resprout stage returns the stand to herbs. Lodgepole pine seedlings may appear about the time the resprouts develop, in the first growing season or two (B2). Fast-growing aspen can overtop the pine seedlings, suppressing them. The pine may die from shading where aspen is vigorous. Seedlings that establish in openings between clones may continue to grow and eventually overtop the aspen. Either species can be favored by fire if it occurs in the mature state (C2). Moderately severe fire would probably kill most aspen and lodgepole pine overstory trees. Pine seed availability and the extent and vigor of aspen roots would determine which species regenerates the site. Low-severity fires should spare at least some lodgepole pine, possibly giving its regeneration the ability to dominate an area more quickly and outcompete the aspen suckers. Low-severity fires can kill aspen stems but may not remove enough of them to stimulate adequate suckering. Severe fire would kill the entire stand, resulting in the herb stage.

If no fires occur in the mature stage, the aspen overstory begins to deteriorate (D2), creating openings as stems die. The gaps may be filled by either aspen or lodgepole pine. As the time without fire lengthens, lodgepole pine begins to dominate the stand (E2). Low to moderate severity fires continue to maintain a mixed species stand while aspen and pine are both viable on the site. Severe fires return the stand to herbs. A climax, all-aged lodgepole pine stand develops after a prolonged period without fire. Subsequent succession after severe fire will involve only lodgepole pine where living aspen roots are no longer on the site.

Spruce and Subalpine Fir Climax Types—Succession in these habitat types differs only slightly from that in lodgepole pine climax types. Lodgepole pine dominates succession regardless of the indicated climax. The only difference in most successional stages is that tolerant climax species may be present in the understory. The successional process is similar to that diagrammed in Fire Group Ten, lower subalpine fir forests. But in stands where lodgepole pine is persistent, the time it takes until spruce and fir dominate may be very long, or may not occur before the next fire. If a stand does attain true climax status, and lodgepole pine has died out of the stand, succession follows the pathway described for Fire Group Twelve (high-elevation spruce-fir forests).

Fire Management Considerations

Perhaps the most important fire management consideration in this group is protection from unwanted fire during periods of drought and severe fire weather. Fires at such times can become holocausts if the lodgepole stand physiognomy and fuel moistures are prime for burning.

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. But low to medium surface fires do occur. Thus there may be opportunities to use prescribed fires to accomplish specific management objectives.

The primary use of prescribed fire in lodgepole pine is hazard reduction and site preparation in conjunction with tree harvesting and subsequent regeneration. Broadcast burning and pile and windrow burning have been the methods most often used to accomplish these tasks. Successful broadcast slash burning usually yields increased forage production for big game. Slash disposal of any kind aids big game movement through these stands. Harvest schedules should be developed and implemented to create age-class mosaics of lodgepole pine. This minimizes 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, house logs, wood chips, and sawlogs may provide opportunities for fuel management-related harvesting.

Prescribed fire has been suggested as a management tool for controlling dwarf mistletoe. 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. Not all fires reduce stand infection. A severe, stand-destroying fire will eliminate dwarf mistletoe. Burns that are sporadic or less severe will leave infected trees on the site to quickly spread the parasite to the developing understory. Where an infested stand has been eliminated, but surrounding mistletoe stands remain, infestation will occur but at a less rapid rate (Zimmerman and Laven 1984). To successfully reduce mistletoe in the Grand Mesa, Uncompahgre, and Gunnison National Forests, managers wrote fire prescriptions to remove between 85 percent and 97 percent of the infected lodgepole pine canopy (Chonka 1988).

Lotan and Perry (1983) have summarized the various considerations that determine the appropriate use of fire for site preparation and regeneration of lodgepole pine forests. Silviculturists and fire managers should consult this guide before developing fire prescriptions to regenerate lodgepole pine.

Competition with herbaceous vegetation affects lodgepole pine success. Lodgepole pine is a poor competitor, and seedlings compete least well against grass. On the Sleeping Child Burn (Bitterroot National Forest, MT) where exotic grass species were seeded following fire, tree seedling attrition on plots where grass cover was less than 1 percent averaged 4 percent annually on north slopes and 5 percent annually on south slopes. On plots where grass cover averaged 29 percent, the comparable rates of mortality were 21 and 29 percent (Schmautz and Williams 1967). Evidence suggests that as growing conditions become less favorable, grass competition becomes less important (Clark and McLean 1974; Stahelin 1943).

Habitat type may help predict the success of tree seedling establishment. In southern Montana and southeastern Idaho, significant differences were found in the lodgepole pine seed:seedling ratios between three habitat types. Ratios were lowest (fewest seeds to establish one seedling) on an *Abies lasiocarpa/Vaccinium scoparium* (subalpine fir/grouse whortleberry) habitat type when compared with those in the *Pseudotsuga menziesii/Calamagrostis rubescens* (Douglas-fir/pinegrass) and *Pinus contorta/Purshia tridentata* (lodgepole pine/antelope bitterbrush) habitat types. The presence of lodgepole pine in a habitat type is a function of the ease of establishment, the fire (or other disturbance) history, and the rate of succession in the type. The presence of the species only partially reflects where it is most easily established. Lodgepole pine is generally a seral species. Where lodgepole cover is low and that of other seral species is high, lodgepole pine is probably less suited to these sites. Conversely, where lodgepole pine cover is high, as in the *Abies lasiocarpa/Vaccinium scoparium* habitat type, lodgepole pine is the best suited seral species, and easier to regenerate. But *Pinus contorta* habitat types may present special regeneration problems. They are too harsh for other conifer species to establish, and seed:seedling ratios for lodgepole pine are often high. Also, trees on these sites tend to be open-coned, and so do not have a large store of seeds reserved to restock the site if the stand is removed. In a study of a *Pinus contorta/Purshia tridentata* habitat type in southwestern Montana, seed:seedling ratios ranged from 621:1 to 2,160:1 on scarified clearcuts and 1,876:1 to 6,480:1 on unscarified clearcuts. Seed crops were good, but only 3 of 15 years had significant seedling establishment (Lotan and Perry 1983).

Table 16 presents estimates of seed:seedling ratio under different site conditions. They are guidelines and should not be used to substitute knowledge gained in a specific area. The estimates are conservative, and favorable sites may have considerably lower ratios. Data from the Medicine Bow Mountains and Alberta suggest ratios on the order of 100:1 on well-scarified sites.

In some wildernesses, 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. In many areas where natural fires have been suppressed, forest residues resulting from mountain pine beetle epidemics accumulate until hot fires occur. "...such fires are normally more destructive than one that would have otherwise occurred if fires had not been suppressed, and they tend to perpetuate future extremes in the mountain pine beetle/ lodgepole pine/fire interactions" (D. Cole 1978). Several opinions have been expressed that the bark beetle epidemics now rampant in the Rockies and Intermountain West may be a product of fire exclusion (Schwennesen 1979). In Glacier National Park, the mountain pine beetle epidemic took such a strong hold because fire suppression programs were so successful and trees that ordinarily might have been burned are now mature and ripe for the beetle (Kuglin 1980).

D. Cole (1978) suggested that a deliberate program of fire management and prescribed fire can be instituted to moderate the mountain pine beetle-lodgepole pine-fire interaction cycle. His premise was that both wildfire and prescribed fire management plans can be developed to use fire to "create a mosaic of regenerated stands within extensive areas of timber that have developed." He believed that prescribed fires can create these ecosystem mosaics more effectively than wildfires. With the recent change from fire control to fire management, managed wildfires will be, in fact, prescribed fires.

Guidelines have been developed by McGregor and Cole (1985) to assist forest managers in integrating pest management techniques for the mountain pine beetle with other resource considerations in the process of planning and executing balanced resource management of lodgepole pine forest. The guidelines present visual and classification criteria and methods for recognizing and summarizing occurrence and susceptibility status of lodgepole pine stands according to habitat types and successional roles and important resource considerations associated with them. McGregor and Cole reviewed appropriate silvicultural systems and practices, including use of fire, for commercial and noncommercial forest land designations, including parks, wilderness, and other reserved areas.

Schmidt (1987) listed some pros and cons of using fire to treat overstocked small-diameter lodgepole pine stands:

SOME ADVANTAGES

– Low-cost method for stand conversion

Table 16—Estimates of lodgepole pine:seedling ratios for different site conditions in southwestern Montana (Perry and Lotan 1977)

Representative habitats	Site preparation: None or slight[1]	Broadcast burning	Bulldozer scarification
Cool, moist, low to moderate competition (for example, *Abies lasiocarpa/Vaccinium scoparium)*	1,000:1	1,000:1	300:1
Moderate moisture and temperature, heavy competition (for example, *Pseudotsuga menziesii/Calamagrostis rubescens* to *Abies lasiocarpa/ Calamagrostis rubescens)*	10,000:1	3,000:1	300:1
Cool and droughty (for example, *Pinus contorta/Purshia tridentata*	10,000:1	3,000:1	1,000:1
Hot and droughty (south slopes) without excessive competition	2,500:1	3,000:1	10,000:1
Hot and droughty with heavy competition	15,000:1	4,000:1	10,000:1

[1]Including lop and scatter.

- Can regenerate new stand with manageable composition and density
- Closely resembles "nature's method"
- By regulating fire intensity, may be able to reduce seed supply and subsequent overstocking
- Usually leaves some shade to enhance seedling survival
- Reduces insect and disease problems
- Usually increases other resource values such as forage
- Can increase availability of nutrients

SOME DISADVANTAGES

- An up-front expense
- With poor fire regulation, may just perpetuate the problem by producing another overstocked stand, or it may require the expense of planting or seeding if all seed is burned under the wrong prescription
- Very limited season for prescribed burning on most lodgepole pine sites
- Requires good fire management skills
- If burned too hot on some sites, nutrient capitals, particularly of nitrogen, can be depleted
- May have a temporary loss in esthetic values

FIRE GROUP NINE: CLIMAX STANDS DOMINATED BY LIMBER PINE OR WESTERN BRISTLECONE

Habitat Types

Pinus flexilis/Berberis repens h.t. (PIFL/BERE), limber pine/creeping Oregon grape
Pinus flexilis/Cercocarpus ledifolius h.t. (PIFL/CELE), limber pine/curlleaf mountain-mahogany

Vegetation

Fire Group Nine consists of sites where limber pine and/or bristlecone pine are the climax dominants (figs. 40, 41). Stands may form a lower timberline adjacent to juniper or mountain mahogany woodlands or, more commonly, represent a topo-edaphic climax in the Douglas-fir and subalpine zones between 7,000 and 9,000 ft (2,134 and 2,743 m). They are rarely extensive, being restricted to particular

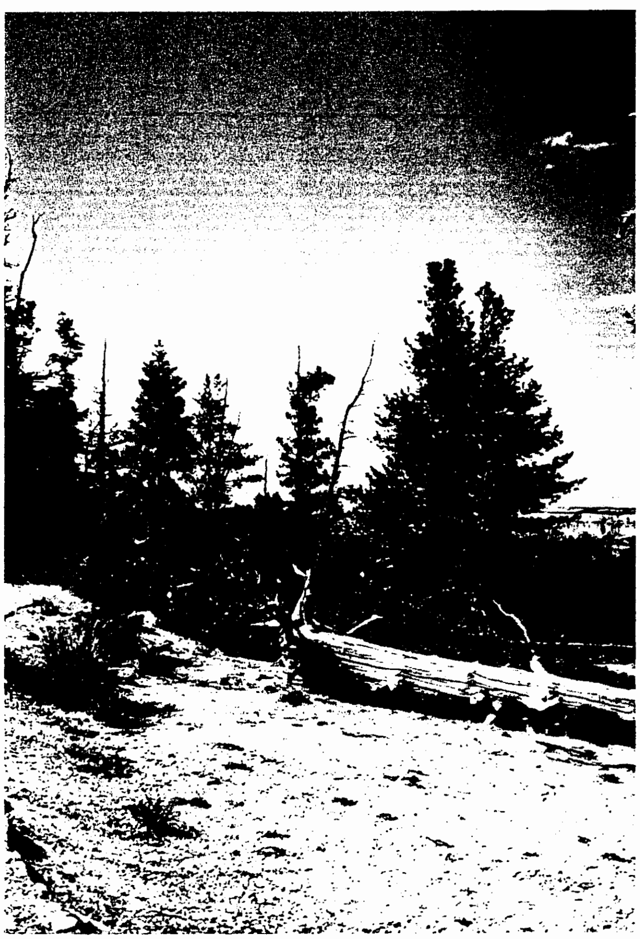


Figure 40—Bristlecone pines, Bryce Canyon National Park.

Figure 41—Limber pine stand, Wasatch-Cache National Forest.

slopes or rocky outcrops. In northern Utah, two limber pine habitat types, *Pinus flexilis/Cercocarpus ledifolius* and *Pinus flexilis/Berberis repens,* have been identified (Mauk and Henderson 1984). Bristlecone pine is restricted to southern and central Utah. Habitat types in this region have not been described. Distinctions between potential habitat types are not clear because of understory diversity (Youngblood and Mauk 1985).

The presence of limber pine or bristlecone pine as climax species indicates special edaphic or topographic conditions. Extreme drought usually prevails on these sites because of rapid soil drainage or excessive evapotranspiration rates induced by intense insolation and constant wind. The two pines are often the only trees able to survive in such severe environments, although in northwestern Utah and the northern Wasatch Range, Douglas-fir may share dominance with limber pine on less harsh sites (Mauk and Henderson 1984).

Representative stands within this fire group are easily seen on the spectacular eroded limestone rims of the Paunsaugunt and Markagunt Plateaus. Utah limber pine and bristlecone pine stands are most common on slopes with southwesterly exposures, although they may occur within the forested zone on any direction slope with droughty soils.

The undergrowth in limber pine-bristlecone pine stands is usually diverse. Most sites are shrubby. Common shrub species that may be scattered through the stands include *Cercocarpus ledifolius, C. montanus, Haplopappus suffruticosus, Juniperus communis, Mahonia repens, Ribes cereum,* and *Rosa woodsii. Cercocarpus ledifolius* may form dense thickets on *Pinus flexilis/Cercocarpus ledifolius* sites in northern Utah. Elsewhere, shrubs may not be conspicuous and graminoid species such as *Carex rossii, Elymus trachycaulus* ssp. *trachycaulus, Leucopoa kingii, Leymus salinus, Muhlenbergia montana,* or *Pseudoroegneria spicata* are more important. On more mesic sites, forb diversity may be better developed. Common species are *Achillea millefolium, Astragalus miser, Hymenoxys richardsonii,* and *Lathyrus lanzwertii.* Various other members of the sunflower family may also be present. On the moistest sites in the series, *Thalictrum fendleri* may occur.

Forest Fuels

For the most part, limber pine and bristlecone pine climax stands occur on sites where fire-sustaining fuels are light to nearly nonexistent. Where dense shrubs occur, such as the *Pinus flexilis/Cercocarpus ledifolius* type, or where graminoids are able to attain good cover in the understory, the fire hazard may be somewhat higher. Otherwise, fuels are sparse and discontinuous.

The greatest hazard to these habitat types is due to their generally small area and proximity to more flammable stands. Severe, fast-spreading fires may burn through nearby tree crowns and extend into pockets of limber pine or bristlecone pine. Group Nine stands otherwise act as a firebreak during less severe fires. Greater flammability may result where limber pine and Douglas-fir share a site. Higher site productivity makes fuel accumulation more likely. Douglas-fir with its denser, longer crown is also more flammable than the sparsely branched limber pine.

Downed woody fuel loadings in Montana limber pine stands range between 5 tons/acre (11.2 metric tons/ha) and 15 tons/acre (33.6 metric tons/ha) with about 80 percent of the loading accounted for by material greater than 3 inches (7.62 cm) in diameter (Fischer and Clayton 1983). Average loadings in Utah Group Nine limber pine sites are probably similar. Lower loadings may occur where bristlecone pine dominates a site.

Role of Fire

There is little evidence of past fires in Utah limber pine or bristlecone pine stands (Mauk and Henderson 1984; Youngblood and Mauk 1985). Stand dynamics appear to be more affected by climate and soil factors and by special animal relations than fire. Seed collection and caching by Clark's nutcrackers is essentially the only means of distribution for limber pine and is the major means of bristlecone pine dispersal (Lanner 1980, 1985, 1988).

Fire potential remains low, and flames are extremely unlikely to enter tree crowns on those sites where there is enough fine fuel available to carry a fire. The scattered distribution of the trees themselves inhibits fire spread. In Yellowstone National Park, Cooper (1975) believed that limber pine—Douglas-fir stands had "variable" fire frequencies. He noted six fire scars on old (>300 years) Douglas-fir associated with limber pine. Arno and Gruell (1983) reported a mean fire interval of 74 years for a southwestern Montana limber pine/bluebunch wheatgrass habitat type at a grassland ecotone. Keown (1977) also reported fairly lengthy fire-free intervals (about 100 years) in a similar Montana limber pine stand with grass and shrub understory. The frequency of spreading fires in Utah limber pine stands where grass dominates the undergrowth may be comparable. But the frequency of extensive burns in bristlecone pine stands, or stands of limber pine with shrubby undergrowth, is undoubtedly less because of scant fine fuels. Trees on exposed slopes or plateau rims are susceptible to lightning, but most fires are restricted to a single tree or group of trees. There is some potential for fire to spread into these stands from surrounding Douglas-fir or subalpine forests. In extremely dry, windy weather, a fire theoretically could spread through the crowns of smaller, relatively dense limber pine or bristlecone pine trees.

Frequent low-severity fires may favor limber pine by keeping fuel loadings to a minimum. Where Douglas-fir is a codominant with limber pine, fire maintains a mosaic of the two species. Fire may favor pine over Douglas-fir in the smaller age classes (Keown 1977). As trees increase in diameter, susceptibility to fire changes. Mature specimens of Douglas-fir are probably more fire-resistant than limber pine trees of similar diameter. Cooper (1975) noted that, unlike Douglas-fir, limber pine does not appear to accumulate multiple fire scars, indicating it is unable to survive as many fires. Bristlecone pine occupies such harsh sites that competition from other trees is minimal. Fire occurrence probably has little impact on these stands beyond changing the age structure. Specific fire frequencies for bristlecone pine have not been reported.

Forest Succession

In southern and central Utah, bristlecone pine and limber pine are often codominants. The range of bristlecone pine does not extend into northern Utah. Douglas-fir is an important associate on many sites throughout the State. Limber pine or bristlecone pine climax stands often grade into the drier Douglas-fir habitat types such as *Pseudotsuga menziesii/Cercocarpus ledifolius*, *Pseudotsuga menziesii/Cercocarpus montanus*, or *Pseudotsuga menziesii/Symphoricarpos oreophilus*. Stands with a large proportion of Douglas-fir may have a fire ecology more like that described for Fire Group Four habitat types. The hypothetical role of fire in Fire Group Nine stands is illustrated in figure 42 (subsequent letters in the text refer to this figure).

Limber pine and bristlecone pine stands are generally multi-aged because of the continual seed-caching by Clark's nutcracker. The exception is where a stand is removed by fire or other disturbance. A low-severity fire of limited extent is the most common type of burn in limber pine and bristlecone pine stands regardless of their age structure. The successional pathway here describes the developmental sequences after a stand replacement fire. Any fire in trees in the youngest age class will return the site to shrubs or herbs (A). Low-severity fires in any of the older age classes will thin the trees and produce open patches of ground (B,C,D,E). Open areas are often attractive seed caching sites for the Clark's nutcracker, and limber pine regeneration results (Lanner and Vander Wall 1980). Stands are typically open with sufficient gaps where intolerant seedlings can establish from seeds that germinate from caches forgotten by nutcrackers. Exposed mineral soil can also make good seedbed for Douglas-fir on more moderate sites. The relative success of the pines or Douglas-fir depends on seedling microsite conditions. Limber pine and bristlecone pine are better able to survive cold and desiccation. Douglas-fir may have a competitive advantage on less harsh sites because of its more rapid growth rate.

Achieving the mature or climax state takes several centuries. Climax, once attained, persists because of the low rate of disturbance and the longevity of the pines. Limber pine may reach 2,500 years of age and bristlecone pine can achieve ages well over 4,000 years (Ahlenslager 1987a, b). Severe fires are very unlikely, but possible, in the mature or climax stages. They will recycle the stand to a shrub or herb condition (A).

Fire Management Considerations

Limber pine and bristlecone pine stands have little commercial timber value. They do provide important wildlife range. In southern Utah, the windy conditions and open stand structure prevent snow from accumulating, leaving forage plants exposed. Available forage is utilized heavily on these sites even in years of relatively low snowpack (Youngblood and Mauk 1985). Limber pine stands are used by deer as summering grounds in the mountains of northern Utah. Limber pine and bristlecone pine also offer watershed protection on slopes too harsh for other vegetation (Mauk and Henderson 1984).

Limber pine and bristlecone pine are extremely long-lived. Bristlecone pine is generally believed to be the world's longest-lived organism. Specimens from the Great Basin have provided overlapping tree-ring chronologies that date back 9,000 years. These records have contributed to studies in climatology, archaeology, and geology (Ahlenslager 1987b). Their gnarled, graceful forms give great pleasure to recreationists.

Although fire does not appear necessary to maintain most limber pine and bristlecone pine stands, important understory forage species may benefit from periodic burning to remove decadent growth and stimulate resprouting (Steele and others 1983). The postfire regeneration of limber pine depends on seed-caching by Clark's nutcracker. Factors that affect the population size or distribution of nutcrackers will impact limber pine regeneration.

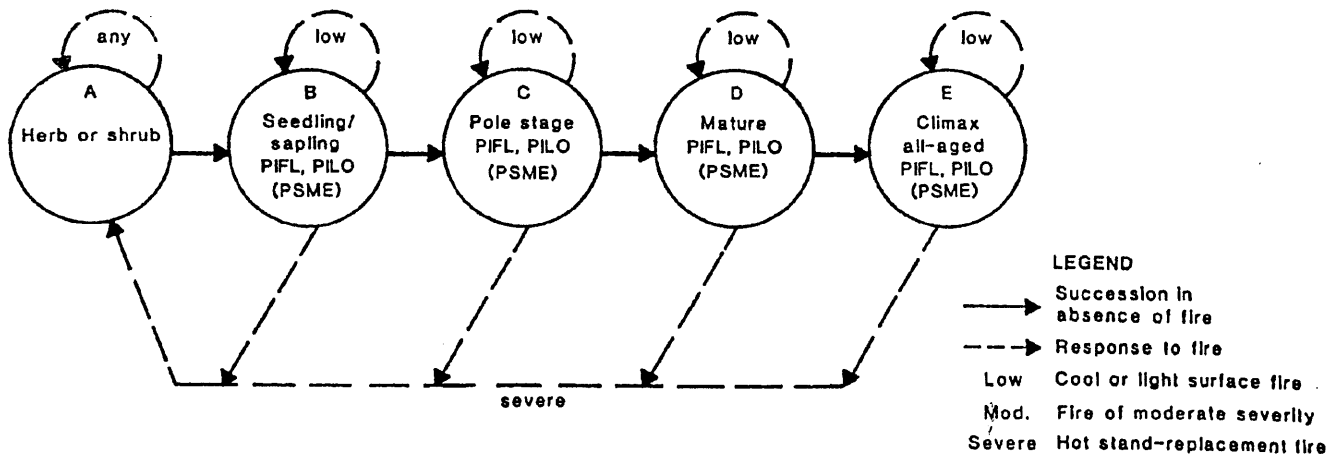


Figure 42—Hypothetical fire-related successional pathways for habitat types and communities in Fire Group Nine.

FIRE GROUP TEN: DRY, LOWER SUBALPINE HABITAT TYPES

Habitat Types, Phases

Abies lasiocarpa/Acer glabrum h.t. (ABLA/ACGL), subalpine fir/Rocky Mountain maple

Abies lasiocarpa/Berberis repens h.t.-*Carex geyeri* phase (ABLA/BERE-CAGE), subalpine fir/creeping Oregon grape-elk sedge phase

Abies lasiocarpa/Berberis repens h.t.-*Berberis repens* phase (ABLA/BERE-BERE), subalpine fir/creeping Oregon grape-creeping Oregon grape phase

Abies lasiocarpa/Berberis repens h.t.-*Juniperus communis* phase (ABLA/BERE-JUCO), subalpine fir/creeping Oregon grape-common juniper phase

Abies lasiocarpa/Berberis repens h.t.-*Picea engelmannii* phase (ABLA/BERE-PIEN), subalpine fir/creeping Oregon grape-Engelmann spruce phase

Abies lasiocarpa/Berberis repens h.t.-*Pinus flexilis* phase (ABLA/BERE-PIFL), subalpine fir/creeping Oregon grape-limber pine phase

Abies lasiocarpa/Berberis repens h.t.-*Pseudotsuga menziesii* phase (ABLA/BERE-PSME), subalpine fir/creeping Oregon grape-Douglas-fir phase

Abies lasiocarpa/Berberis repens h.t.-*Ribes montigenum* phase (ABLA/BERE-RIMO), subalpine fir/creeping Oregon grape-mountain gooseberry phase

Abies lasiocarpa/Calamagrostis rubescens h.t. (ABLA/CARU), subalpine fir/pinegrass

Abies lasiocarpa/Carex geyeri h.t. (ABLA/CAGE), subalpine fir/elk sedge

Abies lasiocarpa/Carex rossii h.t. (ABLA/CARO), subalpine fir/Ross sedge

Abies lasiocarpa/Juniperus communis h.t. (ABLA/JUCO), subalpine fir/common juniper

Abies lasiocarpa/Osmorhiza chilensis h.t. (ABLA/OSCH), subalpine fir/mountain sweetroot

Abies lasiocarpa/Pedicularis racemosa h.t.-*Pseudotsuga menziesii* phase (ABLA/PERA-PSME), subalpine fir/sickletop pedicularis-Douglas-fir phase

Abies lasiocarpa/Pedicularis racemosa h.t.-*Pedicularis racemosa* phase (ABLA/PERA-PERA), subalpine fir/sickletop pedicularis-sickletop pedicularis phase

Abies lasiocarpa/Physocarpus malvaceus h.t. (ABLA/PHMA), subalpine fir/ninebark

Abies lasiocarpa/Ribes montigenum h.t.-*Mertensiana arizonica* phase (ABLA/RIMO-MEAR), subalpine fir/mountain gooseberry-Arizona bluebells phase

Abies lasiocarpa/Ribes montigenum h.t.-*Pinus contorta* phase (ABLA/RIMO-PICO), subalpine fir/mountain gooseberry-lodgepole pine phase

Abies lasiocarpa/Ribes montigenum h.t.-*Thalictrum fendleri* phase (ABLA/RIMO-THFE), subalpine fir/mountain gooseberry-Fendler meadowrue phase

Abies lasiocarpa/Ribes montigenum h.t.-*Ribes montigenum* phase (ABLA/RIMO-RIMO), subalpine fir/mountain gooseberry-mountain gooseberry phase

Abies lasiocarpa/Vaccinium caepitosum h.t. (ABLA/VACA), subalpine fir/dwarf huckleberry

Abies lasiocarpa/Vaccinium caepitosum h.t.-*Picea engelmannii* phase (ABLA/VACA-PIEN)), subalpine fir/dwarf huckleberry-Engelmann spruce phase

Abies lasiocarpa/Vaccinium globulare h.t. (ABLA/VAGL), subalpine fir/blue huckleberry

Abies lasiocarpa/Vaccinium myrtillus h.t. (ABLA/VAMY), subalpine fir/myrtle whortleberry

Abies lasiocarpa/Vaccinium scoparium h.t.-*Arnica latifolia* phase (ABLA/VASC-ARLA), subalpine fir/grouse whortleberry-broadleaf arnica phase

Abies lasiocarpa/Vaccinium scoparium h.t.-*Carex geyeri* phase (ABLA/VASC-CAGE), subalpine fir/ grouse whortleberry-elk sedge phase

Abies lasiocarpa/Vaccinium scoparium h.t.- *Vaccinium scoparium* phase (ABLA/VASC-VASC), subalpine fir/grouse whortleberry-grouse whortleberry phase

Vegetation

Fire Group Ten contains the bulk of subalpine habitat types, those that are neither very moist nor very cold (these habitat types are discussed in Fire Groups Eleven and Twelve, respectively). Climax species are subalpine fir and Engelmann spruce. Forest composition in subalpine forests varies with elevation, exposure, and latitude (Wright and Bailey 1982). Seral species include most of the conifer species represented in the State, as well as aspen. Douglas-fir is most important in northwestern Utah, while lodgepole pine is the dominant species on many sites in the Uintas. White fir, blue spruce, and limber pine may be common in stands in the central and southern mountains and high plateaus, and aspen is widespread throughout the State. Subalpine fir and Engelmann spruce may be the important, or even the only, seral species on some sites. See Fire Group Eight for ABLA/VASC-VASC sites where lodgepole pine is a persistent seral or an apparent climax species.

Undergrowth cover is often sparse in near-climax or climax stands beneath a dense overstory of spruce and fir. Seral stands, particularly those dominated by aspen, may be relatively rich in herbaceous cover. Commonly occurring shrubs include *Acer glabrum*, *Amelanchier alnifolia*, *Juniperus communis*, *Lonicera utahensis*, *Mahonia repens*, *Pachistima myrsinites*, *Rosa nutkana*, *R. woodsii*, *Symphoricarpos oreophilus*, and *Vaccinium scoparium*. Graminoids are *Bromus ciliatus*, *Calamagrostis rubescens*, *Carex geyeri*, *C. rossii*, *Poa secunda*, *Stipa lettermannii*, and *Trisetum spicatum*. *Achillea millefolium*, *Aquilegia caerulea*, *Arnica cordifolia*, *Aster engelmannii*, *Fragaria* spp., *Geranium richardsonii*, *G. viscosissimum*, *Lathyrus lanzwertii*, *Pedicularis racemosa*, *Pyrola secunda*, *Swertia radiata*, *Thalictrum fendleri*, and *Viola adunca*.

Forest Fuels

The most applicable fuels information available comes from studies carried out in neighboring States. Downed and dead woody fuel loadings on lower subalpine habitat types in Montana and northern Idaho averaged between 20 and 25 tons/ acre (56 metric tons/ha) (Brown and See 1981). Loads ranging between 1 to 80 tons per acre (2 to 179 metric tons/ha) were inventoried by Fischer (1981) in Engelmann spruce-subalpine fir cover types in Montana. The heaviest downed woody fuel loads in Utah forests can be expected in Fire Group Ten, particularly on sites where lodgepole pine is the seral species. Live and standing dead fuel can contribute significantly to overall fire hazard. Dense spruce and fir understory trees along with low-hanging moss-covered live and dead branches of overstory trees form effective fuel ladders to the overstory crowns. Dead subalpine fir and Engelmann spruce trees have significant amounts of fine fuels in lateral twigs, which often curl against the larger branches or trunk, frequently along the entire length of the tree. Dead trees are often closely intermingled with live vegetation and easily spread fire to overstory crowns during dry weather.

Clagg (1975) looked at fuels in subalpine forests of Rocky Mountain National Park and the Roosevelt National Forest in Colorado. The number of standing snags left after a fire declined through stand age 74. The number subsequently rose as the canopy closed and competition mortality occurred. Larger snags (greater than 6 inches or 15 cm d.b.h.) dominated in stands aged 8 to 74 years. A second peak at around stand age 200 was dominated by small snags (less than 6 inches d.b.h. or 15 cm). These probably resulted from competition. By age 250, large snags again dominated until the next fire. Fuel moisture was kept high by typical wet summer conditions. Clagg concluded that fuels in these subalpine stands could be considered hazardous only during extended drought or periods of strong winds.

In the same Colorado study, 99 percent of the total downed woody fuel loading was accounted for by 1,000-hour time lag fuels (greater than 3 inches or 7.62 cm diameter). Fuels ranged from 10 to 37 tons per acre (22.4 to 82.9 metric tons/ha). Immediately after a fire fuels measured 19 tons per acre (43 metric tons/ha). Stands 400 years old had fuel loadings of 33 tons per acre (74 metric tons/ha). Sound 1,000-hour fuels remained fairly constant or exhibited a slight downward trend over time. In contrast, the importance of rotten 1,000-hour fuels increased as stands matured. An observed increase in total loading was mostly accounted for by this increase in rotten fuels. Smaller diameter fuels appeared to change little over time. Fine fuels, important for fire spread, were discontinuous and not very abundant.

A combination of deep duff and large amounts of dead, rotten fuel can result in hot, smoldering surface fires during unusually dry conditions. When a dense understory exists, fire can easily spread to the tree crowns and destroy the stand. Even if surface fires do not crown, there is a good chance the overstory spruce and subalpine fir will be killed by cambium heating. Roots of shallow-rooted spruce or fir may be killed or injured by duff fires, leaving them susceptible to insects, disease, or windthrow.

Because of the predominantly cold, moist conditions in subalpine forests, even those stands having relatively heavy fuel loads may not experience fires for many decades or centuries.

Role of Fire

A fire history study in the Engelmann spruce-subalpine fir zone of the Utah State University Experimental Forest showed a decreased fire interval during settlement and a greatly increased interval during the fire suppression era (table 17) (Wadleigh-Anhold 1988). The difference was attributed to logging, livestock, and other activity by settlers of the Cache Valley. The vegetal mosaic created by these settlement fires persists today. These earlier fires, according to Wadleigh-Anhold (1988) favored lodgepole pine and aspen but the less frequent fires of the suppression era are favoring the more tolerant subalpine fir which is regenerating in all types. She predicts that the continued lack of fire will allow the fir and spruce to overtop the lodgepole and aspen.

Specific fire history information for other Utah subalpine forests is lacking. Historically, lightning fires in lower subalpine habitat types were probably less frequent than those in other, drier fire groups. In the Northern Rocky Mountains, fire intervals of 50 to 130 years have been estimated for subalpine fir habitat types (Arno 1980). In Central and Southern Rocky Mountain subalpine forests, relatively few acres appear to have burned during the last 300 to 400 years (Alexander 1987).

In subalpine fir forests, fire led to dominance by one or more of the potential seral species, opened otherwise dense stands, and created a mosaic of different ages and species compositions as in the Utah State University Experimental Forest case cited above. Where lodgepole pine or aspen occurred, higher frequency of fires favored long-term dominance by these species. As conifers replaced aspen, stands became increasingly susceptible to fire as succulent forbs were succeeded by woody fuel and litter (Pfister 1972).

Subalpine forests in the Uintas are typically dominated by lodgepole pine rather than aspen. Here, the conifer-to-conifer succession shortens the period of fuel buildup and the interval between fires (Pfister 1972).

Forest Succession

Which seral species are involved in succession on subalpine fir-spruce dominated sites depends on habitat type, geographic location, and availability of seed or other reproductive means (for example, aspen roots). Pfister (1972) described the structural and successional characteristics of Utah subalpine forests. In general, succession after fire or other disturbance proceeds more slowly on less favorable sites, and seral species retain dominance for long periods. Where spruce is a major component of early seral stands, it tends to dominate late successional and climax stands. It is long-lived (300+ years) and often of large stature (40 inches [100 cm] d.b.h. and 100 ft [30 m] tall) in old-growth stands. Some consider it a co-climax, rather than a persistent seral species, although it appears to be unable to regenerate in its own litter (Mauk and Henderson 1984). On harsh sites, aspen acts as a nurse tree for conifer regeneration. In the *Abies lasiocarpa/Ribes montigenum* habitat type, postfire aspen clones are invaded first by subalpine fir regeneration. Engelmann spruce encroachment may be much slower and restricted to areas of disturbed soil (Youngblood and Mauk 1985). Where livestock or wild ungulates remove aspen, conifer establishment may be hindered.

A generalized model of succession in southern Rocky Mountain subalpine forests was offered by Stahelin (1943) (fig. 43). Schimpf and others (1980) described the basic successional pathways for the *Abies lasiocarpa/Pedicularis racemosa* habitat type in the Wasatch Mountains near Logan Utah:

Table 17—Mean fire interval (MFI)[1] by cover type and fire frequency period for the Utah State University Experimental Forest (Wadleigh-Anhold 1988)

	Historic (1700-1855)	Settlement (1856-1909)	Suppression (1910-1988)	Total (189 years)
Study area	39	4.9	79	18.1
Cover types				
ES/AF	—[2]	9	79	41.3
LP	39	6	—[2]	22.2
AS	156	18	—[2]	72.3

[1]MFI is an arithmetic average in years of the number of years in a period divided by the number of fires occurring in that period.

[2]Denotes no evidence of fire occurring in that period was found.

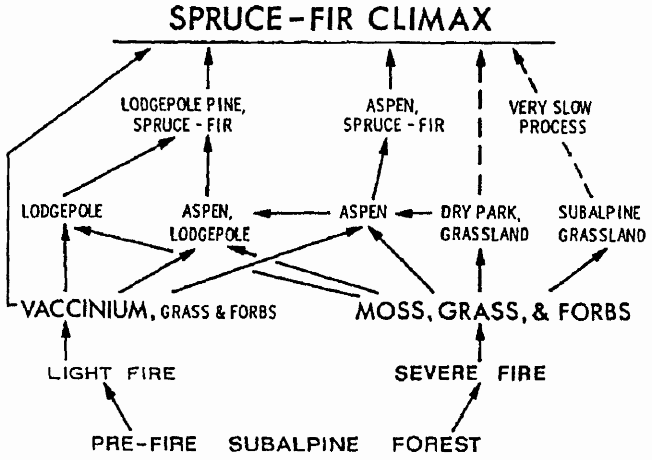


Figure 43—Generalized model of succession in southern Rocky Mountain subalpine forests (Alexander 1974).

> ...there are probably four major pathways of succession leading to spruce-fir forests. Pathway "1" represents succession following the destruction by fire of a forest containing significant aspen root biomass. The aspens sucker within a short period of time to produce an aspen-dominated stand. Spruce and fir subsequently invade, and eventually outlive and replace the aspen.
>
> Pathway "2" occurs in the lower elevational range of the habitat type... . If aspen is not locally abundant then lodgepole is the postfire pioneer, provided that a local seed source exists. Lodgepole cones are not serotinous in this area so seeding is from adjacent stands. Spruce and fir establish and grow more slowly than lodgepole; thus, a pine-dominated ecosystem exists for some time prior to spruce-fir stand recovery. Spruce and fir may establish soon after fire, without site amelioration by aspen or lodgepole, if a significant quantity of unburned woody material remains as protection...pathway "3", [is] where the climax species establish without preclimax tree species. The climax stand structure typically takes less time to develop than through pathways "1" and "2". Pathway "4"...begins with long-persistent meadows, probably not of fire origin... .

These pathways apply for spruce-fir habitat types where nonserotinous lodgepole pine or aspen are the major seral species. Other successional pathways are possible where the seral species mix differs. The three most important seral species are lodgegpole pine, aspen, and Douglas-fir. Aspen can occur on all but the *Abies lasiocarpa/Vaccinium myrtillus*, *Abies lasiocarpa/Vaccinium scoparium-Vaccinium scoparium*, and *Abies lasiocarpa/Vaccinium scoparium-Carex geyeri* habitat types within this fire group. Without aspen, dominance by Douglas-fir is accelerated on sites where it occurs. Figures 44 through 46 illustrate the hypothetical role of fire on sites with different seral species present. Blue spruce is the climax dominant in the *Picea pungens/Berberis repens* habitat type. Although it does not appear in the pathways illustrated, blue spruce (PIPU) can be susbstituted for Engelmann spruce (PIEN) in any of the diagrams. Letters in this section refer to figures 44-46.

Succession With Lodgepole Pine (fig. 44a)—On sites where lodgepole pine is the sole or dominant seral species, after a stand replacing fire an initial herb/shrub community establishes on the site (A). Fires of any severity maintain this state. Where lodgepole pine is serotinous, this stage is quickly followed by a dense stand of evenaged seedlings and saplings (B). Lodgepole pine with nonserotinous cones may also reestablish relatively rapidly when there is an adequate outside seed source. Nonserotinous stands are often less dense, and the seedlings may invade over a period of several years, giving the stand an uneven-aged character. A more open stand (B1) may include Engelmann spruce. Subalpine fir is not usually present at this stage. If pine regeneration is dense, other conifer seedlings are probably crowded out (C). Low to moderate fire may open the stand and permit regeneration of fir and spruce as well as more pine (C1). Without fire, a dense pole stand becomes a crowded mature stand of pine (D). Stem density is somewhat reduced by competition-induced mortality. The understory in the pole or mature state is sparse. Low to moderate fire in the mature state can open the stand and permit further development of a mixed species understory. The stand eventually breaks up due to disease, decadence, or beetle kill (E). Fir and spruce are able to invade openings. Stands with a dying lodgepole pine overstory and fir-spruce understory are susceptible to severe fire because of their typically heavy live and dead fuel loads. Severe fires recycle the stand. If no fire occurs during breakup, the stand is dominated by climax fir and spruce (G).

Moderate fires in mixed stands (E1) kill most of the tolerant conifers but may spare some of the lodgepole pine. The overstory is then again made up of scattered lodgepole pine (D1). At near-climax or climax (F,G), a severe fire returns the stand to an herb/shrub state. Low-severity surface fires reduce fuels and expose mineral soil for regeneration. If a lodgepole pine seed source is not available, a severe fire initiates a successional process in which spruce and fir alone dominate seral stands (see Fire Group Twelve). Fire ordinarily occurs before this condition is reached. On the *Picea pungens/Berberis repens* h.t., blue spruce may dominate at climax, replacing Engelmann spruce shown in the diagram.

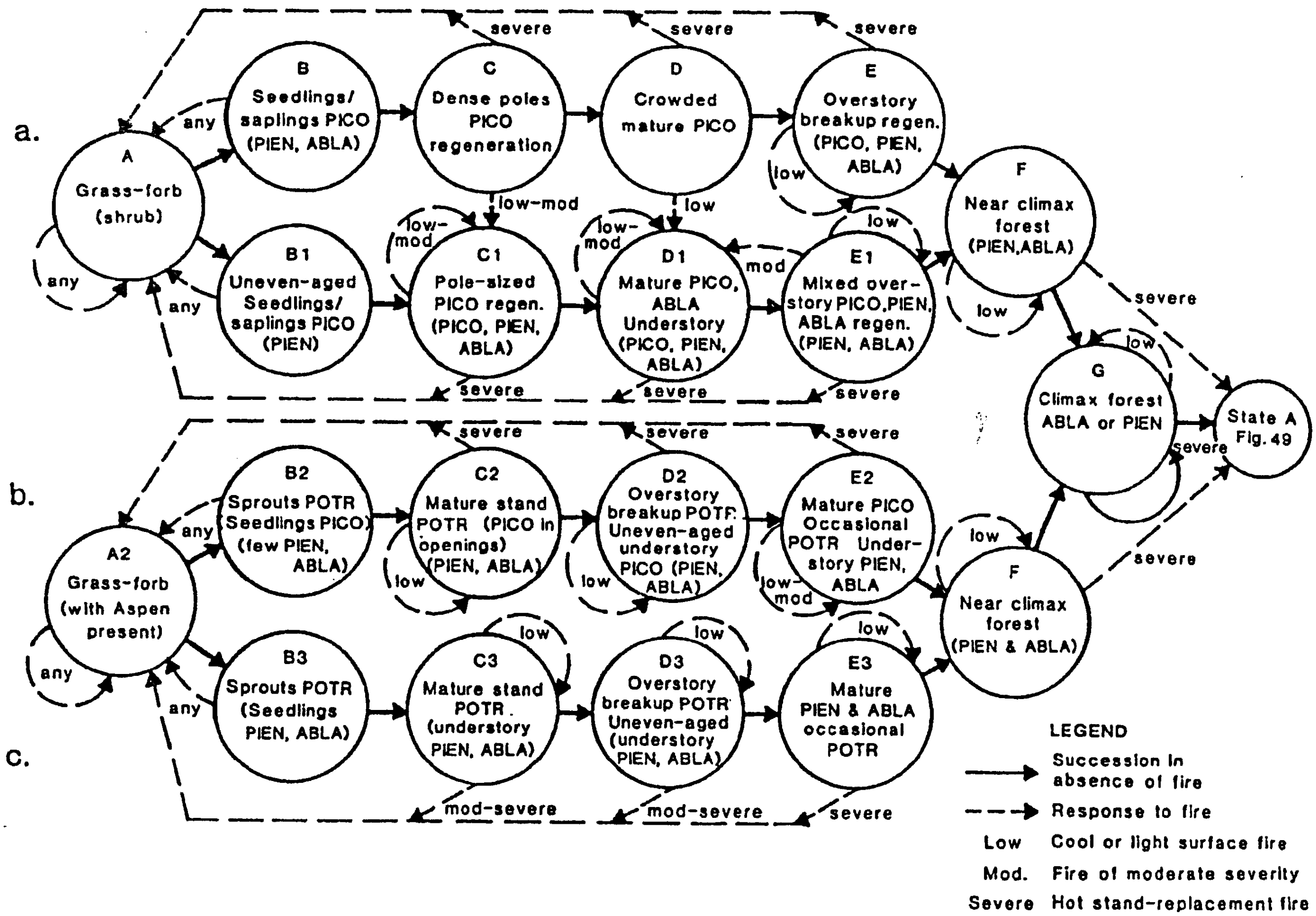


Figure 44—Hypothetical fire-related successional pathways for habitat types in Fire Group Ten, (a) where lodgepole pine is seral, (b) where lodgepole pine and aspen are seral, (c) where aspen alone is seral.

Succession With Lodgepole Pine and Aspen (fig. 44b)—Where aspen and lodgepole occur together in a stand, aspen resprouts and lodgepole pine seedlings may both become established in an herb/shrub field after fire (B2). Aspen grows quickly, however, and soon overtops lodgepole pine. Pine seedlings tend to be restricted to openings where there are no suckering aspen roots (C2). Spruce and subalpine fir regeneration may occur beneath the aspen or lodgepole pine canopy. Low-severity fires open the stand, favoring lodgepole pine seedling establishment, or possibly aspen regeneration if enough aspen stems are killed to stimulate sprouting. Without fire, the aspen overstory eventually breaks up (D2). A mixed conifer stand develops with lodgepole pine in the overstory and spruce and fir in the understory (E2). Low- to moderate-severity fires maintain this stand and all species regenerate in the openings. Aspen survives in occasional patches. As the stand approaches climax conditions, lodgepole pine drops out of the stand (F). Severe fires at near-climax or climax return the stand to the shrub/herb state.

Succession With Aspen Only (fig. 44c)—Where aspen is present, it usually resprouts after a short herb stage (A2). Resprouting shrubs and aspen may both appear the first growing season after fire. Any fire can kill resprouts. Spruce and fir seedlings are shade tolerant and able to establish beneath a canopy of aspen in any stage of development (B3 through E3). Seedlings may be smothered in aspen leaf litter, however, slowing their invasion into the stand. A low-severity surface fire may kill most conifer regeneration, but it can also damage aspen stems. If only scattered stems are killed, suckering may not be stimulated. An influx of conifers in the understory may occur in the gaps.

Moderate to severe fires return the site to herbs in any successional stage. The site is quickly repopulated by aspen suckers. Spruce and fir reestablish in openings. Without fire, the conifer understory continues its development and eventually replaces the shorter lived aspen, which is unable to propagate successfully in the shade (D3). Severe fires in the mature conifer stand cause a return to the herb stage. If remnant aspen are left, some resprouting may occur. Where most or all aspen stems are dead or decadent, fire does not cause sufficient suckering for regeneration because the root system is also weakened. Without fire, conifer density will continue to increase over time (E3, F). Conifers may become dominant on many sites in 200 to 400 years (Bartos and others 1983; DeByle and others 1987). In areas of optimum growth, such as central Utah, it may take well over 1,000 years for aspen stands to convert to climax conifers (Mueggler 1976). Climax stands old enough to be pure spruce and fir are rare. If fire occurs in one of these sites, lack of pine or aspen will mean the climax dominants also dominate seral stages.

Succession With Douglas-fir (fig. 45)—Where Douglas-fir is the dominant seral species, fires of any severity can prevent conifer development in the herb/shrub or seedling-sapling states (A,B). At later stages of stand development, severe fire has the same effect. Low-severity fires occurring in the pole through climax stages do not change stand condition much. On some sites spruce is an important associated species. Even low-severity fires can eliminate spruce because of its shallow roots. Any opening caused by spruce mortality is quickly recolonized by Douglas-fir, subalpine fir, spruce, or occasionally, white fir seedlings. Moderate fires are not likely to occur until there has been some buildup of understory dead and live fuels (D). The result of a moderate fire in the mature stand is an open Douglas-fir stand with Douglas-fir regeneration (D1). If fire does not occur, subalpine fir and spruce join the overstory and dominate the understory (E). After several centuries, a climax of pure spruce and subalpine fir is hypothetically possible (F). But pure stands are extremely rare because of the potential for fire and the longevity of Douglas-fir.

Douglas-fir may also share seral dominance with aspen (no diagram). After a stand-replacement fire, both aspen sprouts and Douglas-fir seedlings may establish on the site. But because aspen grows more quickly, it will probably dominate the site until maturity. In the understory, Douglas-fir may occur with climax spruce or fir. Low or moderate fires open the aspen stand and permit more conifer regeneration as well as aspen sprouting. Once the aspen begins to open up, Douglas-fir may seed into openings and form a multistoried stand with the climax tolerant species in the understory. Over a long period of time without fire, Douglas-fir is replaced by spruce and fir.

Succession With Mixed Species (fig. 46)—In the central and southern portions of the State, particularly at lower elevations, several seral species may be found on sites that at climax are dominated by Engelmann spruce, blue spruce, or subalpine fir. On these sites, a varying mix of conifers including Douglas-fir, white fir, subalpine fir, or the two spruces dominate succession. Aspen is a common seral species on many sites with mixed conifers. On some sites blue spruce or limber pine may also be present, although they are not included in the

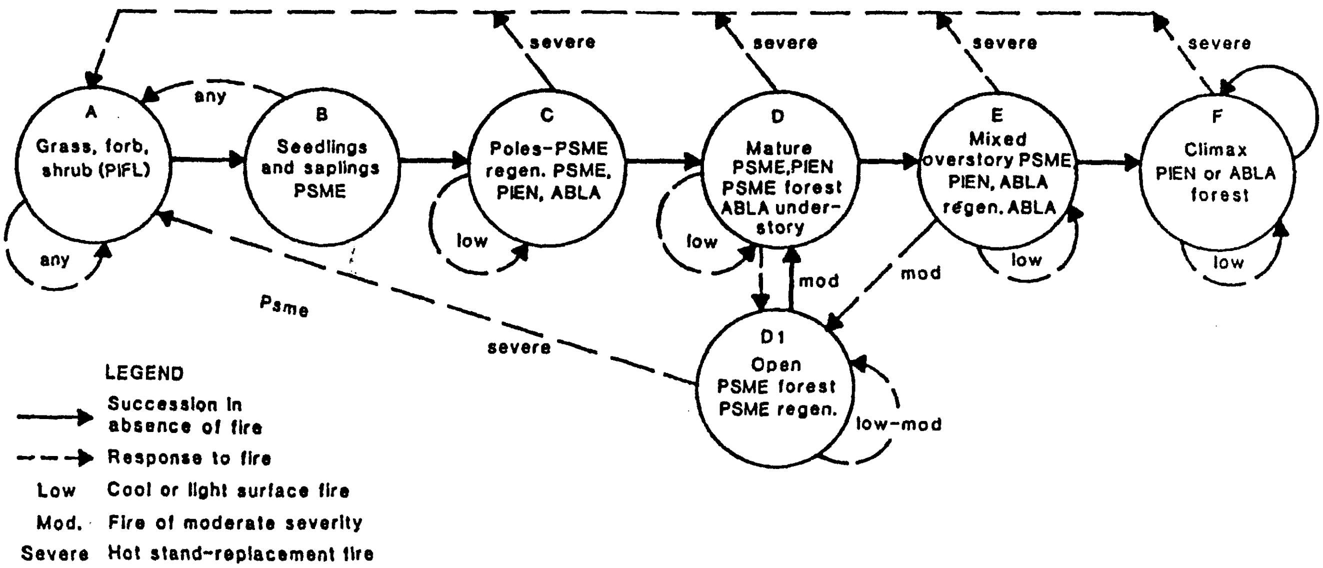


Figure 45—Hypothetical fire-related successional pathways for habitat types in Fire Group Ten where Douglas-fir is the dominant seral species.

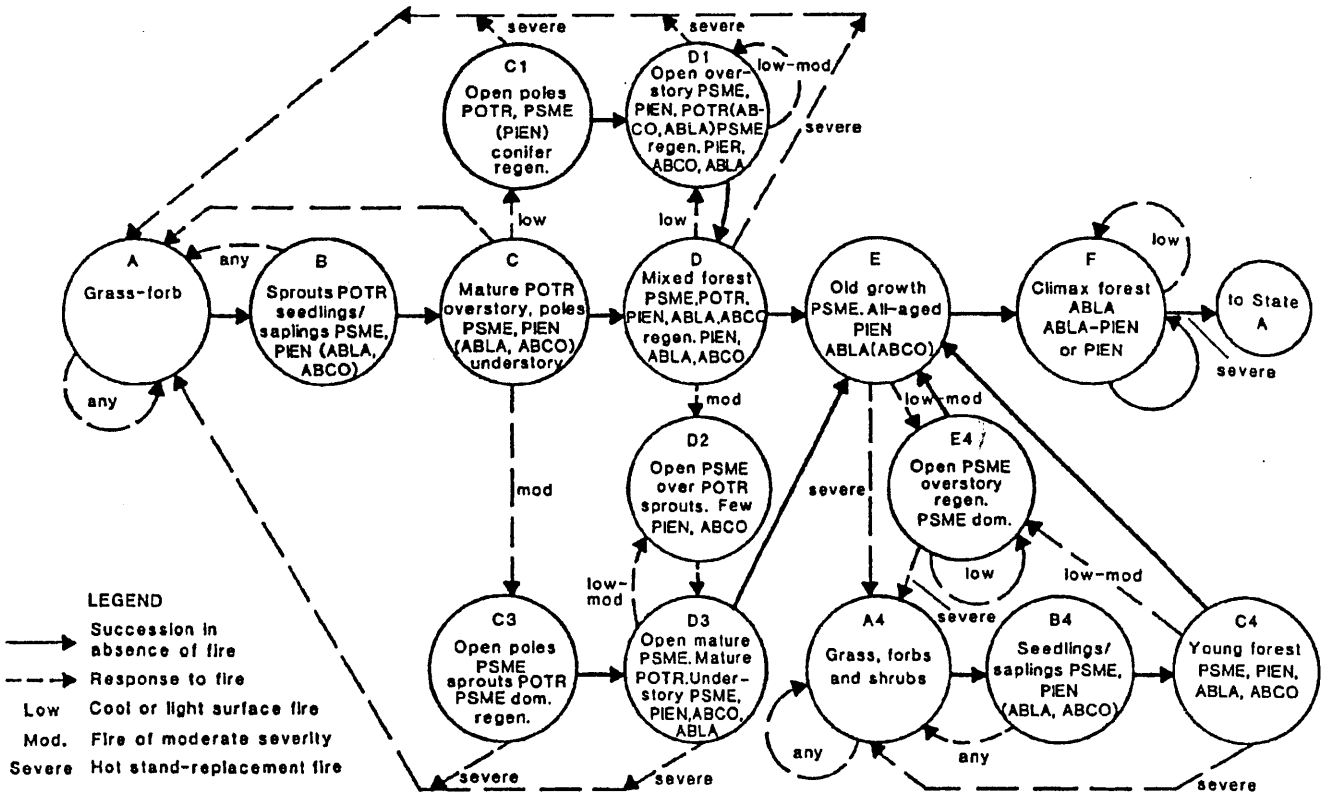


Figure 46—Hypothetical fire-related successional pathways for habitat types in Fire Group Ten where a mixture of species occur during succession.

pathway illustrated here. As is discussed in Fire Group Six (white fir), the most common presettlement fire severities in the mixed conifer type were probably low to moderate. Small fires of low severity would open gaps where one or more of the species adapted to the region could establish. A pattern of gap filling may help explain the diverse nature of these forests.

Where aspen is present, the herb stage will normally be followed quite quickly by a stand of resprouts. Repeated fire will prolong this stage because any fire will kill sprouts and conifer seedlings. The earliest seedlings will most likely be Douglas-fir and possibly blue spruce or Engelmann spruce, although white fir and subalpine fir may also be present (B). Aspen is the fastest growing species and will form an overstory above the conifers, slowing the growth of the less-tolerant species. Low-severity surface fires may remove some of the understory and could promote aspen resprouting if enough stems have been killed. The resulting open stand is made up of aspen and Douglas-fir poles (C1). Most other understory conifers will be killed, and new conifer regeneration will establish in the gaps (D1). Moderate fires in the mature stage (C) will result in an overstory of Douglas-fir by killing most aspen stems as well as the understory conifers (C3). Stands experiencing moderate fires will develop an open overstory of Douglas-fir and an understory of aspen suckers and Douglas-fir dominated regeneration. If the mature aspen and understory conifers do not burn, a mixed forest may develop (D). Again, fire in this stage favors Douglas-fir and aspen. Larger spruce and white fir can often survive low-severity fires and contribute to the regeneration of the site (D1 or D2). Without fire, as the conifer stand develops, aspen is eventually crowded out. Douglas-fir is a long-lived species and remains an important member of the overstory for a long time. An all-aged mix of white fir, subalpine fir, and spruce is associated with the old Douglas-fir (E). The effects of fire are similar to those in earlier phases, with Douglas-fir favored by low or moderate severities. Severe fires in this stage may be more likely because of fuel laddering. Severe fires return the stand to the herb/shrub stage. If fire occurs at this stage, only conifers are included in the successional process because live aspen roots are no longer in the stand (A4 through C4). Climax stands (F) may be made up of varying proportions of subalpine fir and Engelmann spruce depending on stand age and habitat type. Low- to moderate-severity fires open the stand and gaps are filled by subalpine fir and spruce seedlings since Douglas-fir is no longer present. Spruce may be favored by low-severity fires because of its somewhat greater fire tolerance and its ability to establish successfully on mineral soil. Its reinvasion of the stand will be accelerated if sufficient debris or shade are available to moderate heat and light conditions for seedlings.

Fire Management Considerations

Fire can sanitize stands, reduce fire hazard, provide a good seedbed for conifers, and regenerate aspen for wildlife and livestock browse. Fire produces a vegetational mosaic favorable for wildlife and can improve water yield by converting dense conifer stands to aspen or shrub and herbaceous cover.

Fire protection is usually an important consideration during severe burning conditions, especially where timber production is an objective. At other times, fires may be of low to moderate severity and result in only moderate damage or no damage to understory trees, despite the relatively low fire resistance of some of the species present. Large, overstory Douglas-fir should easily survive low- to moderate-severity fire.

Fire has been used to remove stands of mistletoe-infested lodgepole pine (Chonka 1988) and to reduce the food supply of spruce beetles in cull logs or windthrows (Wright and Bailey 1982).

Fire can be used to dispose of slash on logged areas, but broadcast burning for site preparation may be hampered by high duff moistures and the limited number of acceptable burning days during traditional spring and fall burning periods. Consequently, summer burning may produce better results and has become common in some areas (Crane and Fischer 1986). Debris left on exposed sites will increase regeneration success (Wright and Bailey 1982).

Aspen community classifications have recently been developed for Utah (Mueggler 1988; Mueggler and Campbell 1986) and in some areas aspen may be the natural, long-term dominant in a stand. In other areas, extensive aspen coverage may be the result of disturbance. Subalpine forests were subjected to extremely heavy logging and uncontrolled human-caused fires in the late 1800's. Conifer regeneration was inhibited by these impacts as well as by grazing and its associated soil compaction. Conifers are only now beginning to return to some sites (Mauk and Henderson 1984). Aspen communities that today appear to be climax may eventually give way to subalpine fir or spruce with continued exclusion of fire and other disturbances.

FIRE GROUP ELEVEN: MOIST TO WET SUBALPINE HABITAT TYPES

Habitat or Community Types

Abies lasiocarpa/Aconitum columbianum h.t. (ABLA/ACCO), subalpine fir/monkshood
Abies lasiocarpa/Actaea rubra h.t. (ABLA/ACRU), subalpine fir/red baneberry
Abies lasiocarpa/Calamagrostis canadensis h.t. (ABLA/CACA), subalpine fir/bluejoint
Abies lasiocarpa/Streptopus amplexicaulis h.t. (ABLA/STAM), subalpine fir/claspleaf twisted-stalk
Picea engelmannii/Equisetum arvense h.t. (PIEN/EQAR), Engelmann spruce/common horsetail
Picea engelmannii/Caltha leptosepala h.t. (PIEN/CALE), Engelmann spruce/marsh marigold
Picea pungens/Equisteum arvense h.t. (PIPU/EQAR), blue spruce/common horsetail
Conifer/*Cornus sericea* c.t. (CONIFER/COSE), conifer/redoiser dogwood
Conifer/*Aconitum columbianum* c.t. (CONIFER/ACCO), conifer/monkshood

Vegetation

Fire Group Eleven is composed of subalpine habitat types occurring in seasonally moist or wet conditions, or where soils are subirrigated and water tables remain high year-round. Subalpine forest habitat types generally found adjacent to riparian areas, on moist benches, or as stands associated with late-melting, high-elevation snowbanks are included in this grouping (fig. 47).

The riparian community type classification for Utah and southeastern Idaho (Padgett and others 1986; Youngblood and others 1985) describes several community types that occur adjacent to moist subalpine habitat types of Fire Group Eleven. Such riparian types may actually be seral stages of the Fire Group Eleven habitat types. Although our understanding of the successional relations in these plant communities is incomplete, we have tentatively included the Conifer/*Cornus sericea* and Conifer/*Aconitum columbianum* riparian community types in Fire Group Eleven.

Engelmann spruce is often a persistent seral species, the climax dominant, or a climax codominant with subalpine fir in Fire Group Eleven. On some south-central Utah sites, blue spruce replaces Engelmann spruce as the climax dominant. In addition to spruce, less important seral species may include Douglas-fir, aspen, lodgepole pine, and subalpine fir, particularly on very moist sites, where it may be the only seral species.

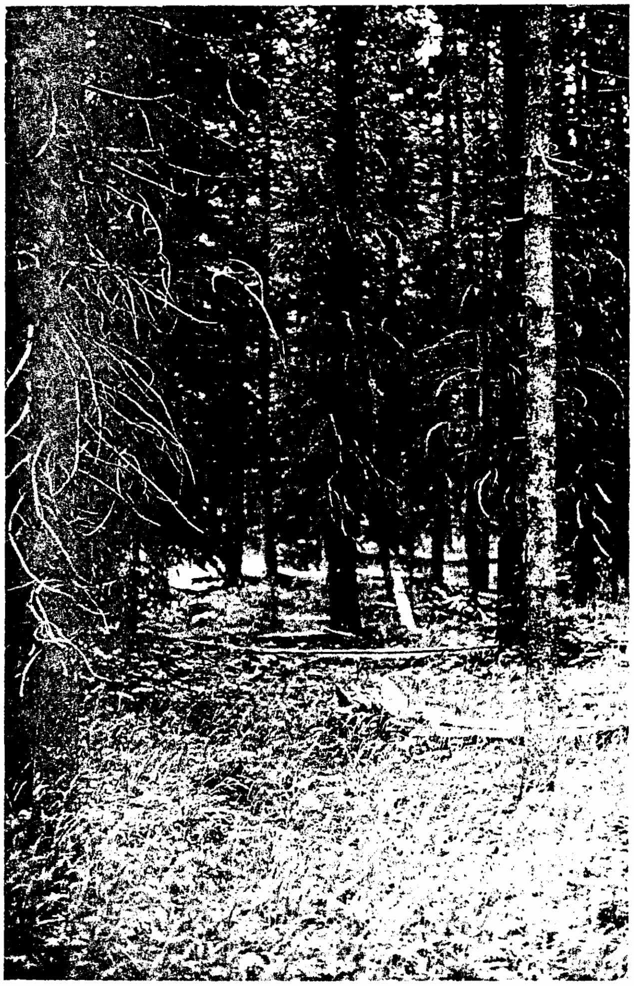


Figure 47—Moist subalpine fir/bluejoint reedgrass stand, Ashley National Forest.

The undergrowth in these moist habitat types is often lush. Common understory shrubs are *Lonicera involucrata*, *Pachistima myrsinites*, *Ribes montigenum*, *Sambucus racemosa*, *Symphoricarpos oreophilus*, *Vaccinium caespitosum*, and *V. scoparium*. There is a diversity of tall and low forbs on these sites, including *Achillea millefolium*, *Actaea rubra*, *Arnica cordifolia*, *Caltha leptosepala*, *Epilobium angustifolium*, *Equisetum arvense*, *Erigeron peregrinus*, *Geranium richardsonii*, *Mertensia ciliata*, *Osmorhiza depauperata*, *Pyrola asarifolia*, *Pyrola secunda*, *Senecio triangularis*, and *Streptopus amplexicaulis*. *Bromus ciliatus*, *Calamagrostis canadensis*, *Carex rossii*, *Deschampsia caespitosa*, *Elymus glaucus*, *Glyceria striata*, and *Luzula parviflora* are typical graminoids.

Forest Fuels

Fuels in moist subalpine fir forests resemble those described for Fire Group Ten. The large 1,000-hour time lag fuels make up the bulk of the fuel loading. The potential for Engelmann spruce to reach large diameters on these sites may result in a greater average diameter of the large woody fuels. Fires are infrequent due to the moist environment and lush shrub and herb component. There may be much rotten material and duff on the forest floor. In colder, higher elevation habitat types, the proportion of sound to rotten woody fuel may be greater because of slow decomposition rates. Fire Group Eleven stands are susceptible to severe fires when droughts occur. Stands may be killed by either surface fires or by crown fires that encroach from surrounding stands. Thin bark and shallow roots make spruce especially susceptible to mortality from hot surface fires that consume organic layers around trees.

Role of Fire

Little is known about the fire history of Fire Group Eleven sites in Utah. In general, fire is an infrequent disturbance on moist or wet sites. Although they do not occur as often as they do on drier sites, fires may be more severe because of higher fuel loads resulting from greater site productivity. Low-severity smoldering fires of restricted area probably occur most often. This type of fire may remove single trees or a small group of trees rather than an entire stand. Severe burns can result during extremely dry conditions when severe fires spread from adjacent upland sites. Crane (1982) reported estimates of 325-335 years, with a variance of 50 years as the fire-return interval of three moist spruce habitat types on the Shoshone National Forest, WY. Romme and Knight (1981) found intervals of 300 to 400 years between fires in drainage bottoms compared to 300 years for drier upland sites of the Medicine Bow National Forest in southwestern Wyoming. The mean fire-free interval for a moist *Abies lasiocarpa/Clintonia uniflora* type in northwestern Montana was estimated to be 130 years (Sneck 1977). The *Abies lasiocarpa/Galium triflorum* habitat type in western Wyoming-southeastern Idaho has comparable vegetation and site conditions to the *Abies lasiocarpa/Actaea rubra* type in Utah. Cooper (1975) commented that the *Abies lasiocarpa/Galium triflorum* type was dominated by older successional stages, which attested to the relative infrequency of fire and a rapid rate of succession.

Forest Succession

Figure 48 illustrates the hypothetical role of fire in Fire Group Eleven. Letters in this section refer to figure 48.

Fires of moderate severity are less common than either low-severity or stand-replacement fires because of the moisture regime. Severe fires destroy the stand. Following a stand-replacement fire, the initial herb stage is quickly followed by a stand of resprouting shrubs, and aspen, if it is present (B). Conifer and cottonwood seedling establishment may also occur on some sites. Any fire in either stage results in a return to the herb state (A). In the pole stage (C), rapidly growing aspen, lodgepole pine, or Douglas-fir overtop the slower growing Engelmann spruce, blue spruce, and subalpine fir. The mature forest consists of an aspen, lodegpole pine or Douglas-fir overstory with a multi-aged understory of spruce and fir (D). Low-severity fires in either of these stages open areas for conifer regeneration or aspen resprouts. In stands where more fire-resistant Douglas-fir or lodgepole pine are present, low- to moderate-severity fires may favor these species over the less-resistant spruce and fir. In the near-climax state, the seral intolerant species are gradually replaced by spruce and fir (E). Douglas-fir, because of its longevity and relative shade tolerance, may remain in the community for a long time. Fire provides a mineral seedbed that is favorable for regeneration of many conifers, particularly Douglas-fir.

At climax, spruce and fir are dominant in the overstory and the only species regenerating in the understory (F). Low-severity fires perpetuate the all-aged structure, and severe fires recycle the stand.

Fire Management Considerations

Severe fires are rare in these moist forests, but they can invade from adjacent stands during dry, windy weather. Killing the overstory by fire may have similar effects to those of logging: raised water tables and possibly increased windthrow potential among the remaining live trees. Windthrow may be mitigated as long as dead boles remain standing. A fire that burns away much of the duff may remove shallow-rooted species. Deep-seated resprouting shrubs and herbs, or annual species, will dominate the postfire site. Low-severity fires open stands, provide microsites for seedling establishment, and may stimulate aspen and shrub sprouting. Even low-severity fires may kill or damage shallow-rooted spruce directly, or weaken roots and make trees susceptible to windfall. The open canopy and upturned soil from windfall create favorable conditions for conifer regeneration. At high elevations, spruce regeneration may suffer sun scalding if there is not adequate shade after overstory removal.

Management of these sites is often oriented toward nonconsumptive values such as water production and wildlife habitat. On some sites the disturbance associated with modern fire suppression may result

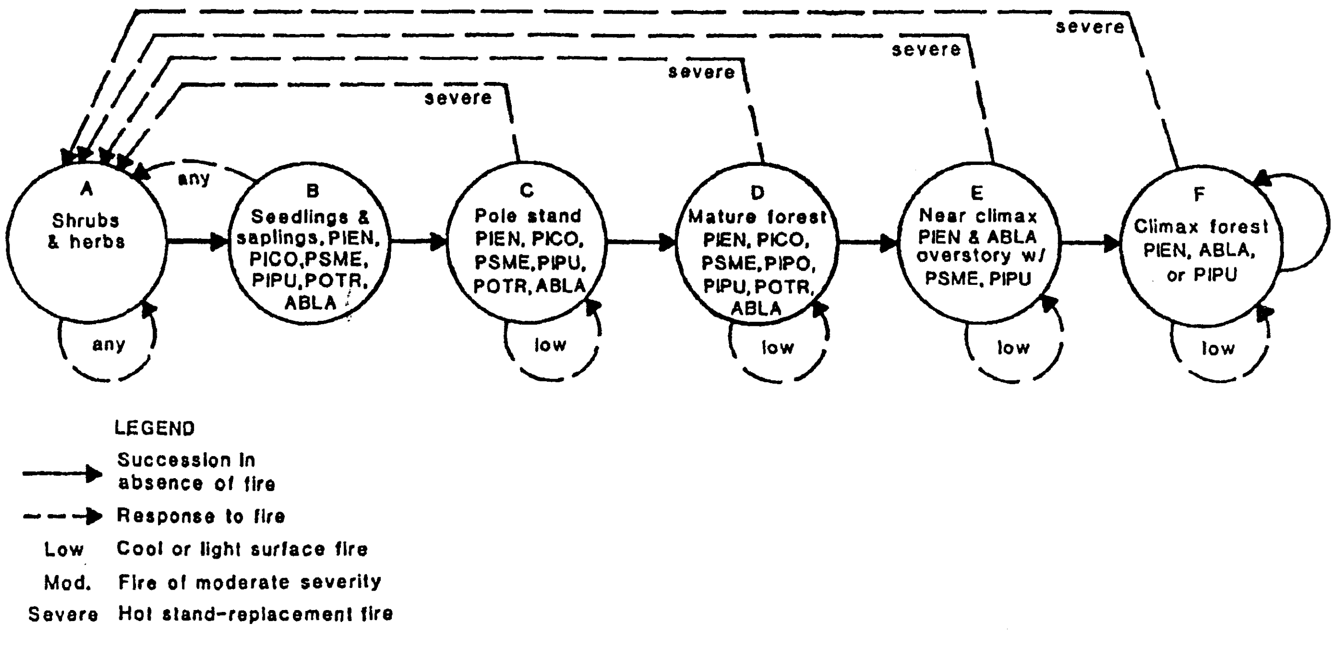


Figure 48—Hypothetical fire-related successional pathways for habitat types in Fire Group Eleven.

in more lasting damage than fire itself would cause. Fire management direction for Fire Group Eleven sites should weigh the perceived costs and benefits of fire suppression against its ecological consequences. The appropriate fire management policy may be one that allows certain ignitions to burn according to a predetermined fire management prescription (Fischer 1978).

FIRE GROUP TWELVE: COLD, UPPER SUBALPINE HABITAT TYPES

Habitat Types, Phases

Abies lasiocarpa/Ribes montigenum h.t.-*Trisetum spicatum* phase (ABLA/RIMO-TRSP), subalpine fir/mountain gooseberry-spike trisetum phase
Abies lasiocarpa/Vaccinium scoparium h.t.-*Vaccinium/scoparium* phase (ABLA/VASC-VASC), subalpine fir/grouse whortleberry-grouse whortleberry phase
Picea engelmannii/Ribes montigenum h.t. (PIEN/RIMO), Engelmann spruce/mountain gooseberry
Picea engelmannii/Vaccinium caespitosum h.t. (PIEN/VACA), Engelmann spruce/dwarf huckleberry
Picea engelmannii/Vaccinium scoparium h.t. (PIEN/VASC), Engelmann spruce/grouse whortleberry

Vegetation

Fire Group Twelve is made up of high-elevation or timberline portions of subalpine fir and Engelmann spruce habitat types that are, for the most part, too cold for Douglas-fir, white fir, blue spruce, lodgepole pine, or aspen. These forests often occur well above 10,000 ft (3,048 m). Climax subalpine fir and Engelmann spruce are usually the only seral species. Trees may not cover extensive areas. Patches of conifers intermingle with subalpine meadows. On exposed ridges, trees may form krummholz. In these harsh environments, most increase of forested area is due to layering by subalpine fir rather than seedling establishment. On dry, windy sites unfavorable for spruce and fir, limber pine or bristlecone pine may be persistent dominants. Fire effects on these forests are described in Fire Group Nine. Lower elevation portions of the PIEN/VACA and PIEN/VASC h.t.'s, where lodgepole pine occurs, are assigned to Fire Group Eight. Lower elevation portions of the ABLA/VASC h.t. are assigned to Fire Groups Eight and Ten.

The undergrowth component is not particularly diverse. Scattered shrubs and low herbaceous plants grow where there are gaps in the dense canopy. Shrubs commonly associated with high-elevation subalpine forests include *Juniperus communis*, *Pachistima myrsinites*, *Ribes montigenum*, *Vaccinium caespitosum*, and *V. scopulorum*. *Carex rossii*, *Festuca ovina*, *Poa secunda*, and *Trisetum spicatum* are typical graminoids. *Achillea millefolium*, *Antennaria microphylla*, *Arnica cordifolia*, *A. latifolia*, *Erigeron peregrinus*, and *Thalictrum fendleri* are forbs commonly encountered in these habitat types.

Forest Fuels

Moist conditions and discontinuous fine fuels keep fire hazard low in uppper subalpine forests. The greatest fire danger occurs when wind drives fire into the high country from lower, more fire-prone stands. Fuels in this type are similar to those described for Fire Group Ten. Larger diameter fuels dominate the loadings. Fuel loadings in a comparable fire group described for Montana averaged 2 tons/acre (4.5 metric tons/ha) of material one-quarter inch to 3 inches (0.64 to 7.62 cm) in diameter and about 9 tons/acre (20 metric tons/ha) of fuels over 3 inches (7.62 cm) in diameter (Fischer and Clayton 1983). The relatively low productivity of these sites may decrease the rate of fuel accumulation, and average diameters of large woody fuels will probably be smaller than those in lower stands. Countering this trend is a slower rate of decomposition. Surface fires may kill trees by heating the cambium or root tissue in krummholz, most fires spread through the crowns because of the short stature of the trees.

Role of Fire

Fire is an infrequent visitor in much of the high country. Many stands may have substantial snowpacks that may last through the summer months. Grasses and forbs cure in August or September, about the time that late summer storms often begin, effectively ending the fire season. Thus, though the incidence of lightning strikes may be relatively high, fire frequency is low. In Montana, Gabriel (1976) concluded that the fire history at high elevations in the Bob Marshall Wilderness was one of lightning strikes igniting many fires that burned small areas, from individual trees to several acres. In Utah, summer lightning is generally accompanied by rain, making fire spread unlikely. Timberline stands are frequently discontinuous, separated by talus, rocky cliffs, or expanses of herbaceous vegetation. Billings (1969) studied fire in the high-elevation "ribbon forests" of the Medicine Bow Mountains in southern Wyoming, where ribbons of trees alternate with expanses of moist meadow vegetation. Fires appeared to be relatively common, but local in extent. There appeared to be little cross-correlation between fires occurring between neighboring patches of trees.

Intervening snowglade meadows or tundra restricted fire spread. Fires in these ribbon forests may be ground or crown, with krummholz patches almost always experiencing crown fires because of the short trees. Succession after ground fires may return the stand to its prefire condition in relatively few years. After crown fires, the site is no longer ameliorated by the presence of trees, and a return to the forested state may be extremely slow. Slow regeneration adds to the difficulty in determining fire intervals, because relatively old burns may support only sparse or otherwise underdeveloped stands. Estimates of fire-free intervals range from 50 to 300 years (Arno 1986, 1990; Heinselmann 1981). Fire has its greatest impact when occasional large high-severity fires invade from lower elevation forests during severe fire conditions. Periods of high wind and low fuel moistures present the greatest fire hazard.

Forest Succession

Figure 49 illustrates the hypothetical role of fire during succession in Fire Group Twelve stands. Letters in this section refer to figure 49.

Secondary succession begins with a mixture of herbs and shrubs (A). Adverse conditions for conifer regeneration allow herbaceous plants to dominate the stand for an extended period. Fire may initiate 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 talus slippage are more important recyclers of high, unproductive sites than fire. Conifers may establish in the shelter of snags, logs, or shrubs (B). One hundred years or more may pass before conifers dominate the site. It may take another 100 years before a mature forest develops (C). Stand and fuel conditions will probably not support a fire of any consequence during this time. It may take two or three centuries to reach climax status (D). In Utah, Engelmann spruce tends to dominate the highest elevation climax stands. Eventually, stands will break up under the impact of snow and wind damage, insect and disease mortality, windthrow and senescence, creating more woody fuels. Because of the lack of different seral species, low-severity fires at all stages tend to change the age structure rather than the species composition in most high-elevation stands. Sparse fuels and unfavorable weather conditions limit the occurrence of moderate fires. Severe, stand-destroying fires, often invading from lower elevation stands, become a possibility in mature or climax stands during droughty periods. Severe fires will recycle the stand to the herbaceous state.

In high-elevation burns in Colorado and Wyoming, Stahelin (1943) found that the most important factors affecting rate of regeneration were seed tree, abundance, soil, exposure, and ground cover. Stocking seemed to be favored on north-facing slopes, lighter gravelly soils, well-scattered seed trees, and little or no graminoid cover. On these sites, 10 or more seed trees/acre were considered to be adequate to restock the site within 50 years. The sensitivity of young Engelmann spruce to sun scalding may inhibit seedling establishment unless sufficient debris is left on the ground to provide shade.

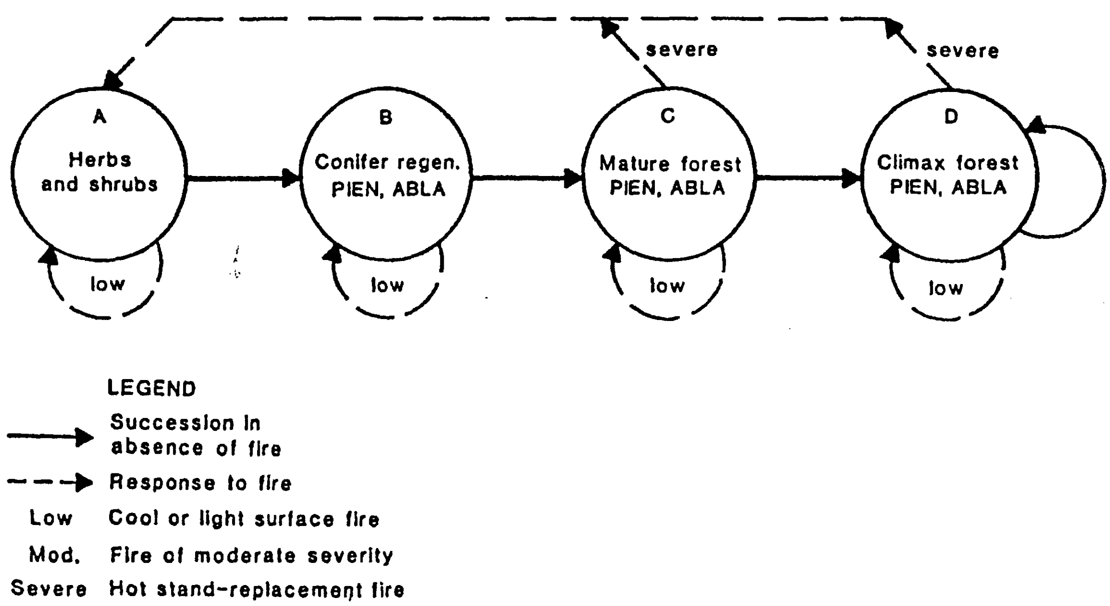


Figure 49—Hypothetical fire-related successional pathways for habitat types in Fire Group Twelve.

Fire Management Considerations

Timber production is rarely an important management objective in Fire Group Twelve forests. Watershed, wildlife, and recreation are often the dominant values. Management may be restricted by natural area or wilderness designation. Fire is infrequent, and when it does occur, damage in terms of management objectives is usually slight. These sites, however, are fragile and can easily be damaged by modern, mechanized firefighting equipment. For many Fire Group Twelve habitat types, the primary consideration should be the development of prescriptions that allow fire to more nearly play its natural role (Fischer 1984).

Because of the long fire-free intervals, past fire suppression policies have had less effect in high-elevation subalpine stands than in other habitat types. But because of their susceptibility to fires at lower elevations, subalpine stands can be affected by excessive fuel buildups in lower, more fire-prone forests. Fire management should consider this relationship.

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APPENDIX A: FOREST AND WOODLAND HABITAT AND COMMUNITY TYPES ASSIGNED TO UTAH FIRE GROUPS

Abbreviations and scientific names are from published classifications by Mauk and Henderson (1984), Youngblood and Mauk (1985), Mueggler (1988), and Padgett, Youngblood, and Winward (1989).

Abbreviation	Habitat types and phases: Scientific name	Habitat types and phases: Common name
	***ABIES LASIOCARPA* CLIMAX SERIES**	
Northern Utah		
ABLA/CACA h.t.	*Abies lasiocarpa/Calamagrostis canadensis* h.t.	subalpine fir/bluejoint reedgrass
ABLA/STAM h.t.	*Abies lasiocarpa/Streptopus amplexifolius* h.t.	subalpine fir/claspleaf twisted-stalk
ABLA/ACRU h.t.	*Abies lasiocarpa/Actaea rubra* h.t.	subalpine fir/baneberry
ABLA/PHMA h.t.	*Abies lasiocarpa/Physocarpus malvaceus* h.t.	subalpine fir/ninebark
ABLA/ACGL h.t.	*Abies lasiocarpa/Acer glabrum* h.t.	subalpine fir/mountain maple
ABLA/VACA h.t.	*Abies lasiocarpa/Vaccinium caespitosum* h.t.	subalpine fir/dwarf blueberry
ABLA/VAGL h.t.	*Abies lasiocarpa/Vaccinium globulare* h.t.	subalpine fir/blue huckleberry
ABLA/VASC h.t.	*Abies lasiocarpa/Vaccinium scoparium* h.t.	subalpine fir/grouse whortleberry
-ARLA phase	-*Arnica latifolia* phase	-broadleaf arnica phase
-CAGE phase	-*Carex geyeri* phase	-elk sedge phase
-VASC phase	-*Vaccinium scoparium* phase	-grouse whortleberry phase
ABLA/CARU h.t.	*Abies lasiocarpa/Calamagrostis rubescens* h.t.	subalpine fir/pinegrass
ABLA/PERA h.t.	*Abies lasiocarpa/Pedicularis racemosa* h.t.	subalpine fir/sickletop pedicularis
-PSME phase	-*Pseudotsuga menziesii* phase	-Douglas-fir phase
-PERA phase	-*Pedicularis racemosa* phase	-sickletop pedicularis phase
ABLA/BERE h.t.	*Abies lasiocarpa/Berberis repens* h.t.	subalpine fir/creeping Oregon-grape
-PIFL phase	-*Pinus flexilis* phase	-limber pine phase
-RIMO phase	-*Ribes montigenum* phase	-mountain gooseberry phase
-CAGE phase	-*Carex geyeri* phase	-elk sedge phase
-JUCO phase	-*Juniperus communis* phase	-common juniper phase
-PSME phase	-*Pseudotsuga menziesii* phase	-Douglas-fir phase
-BERE phase	-*Berberis repens* phase	-creeping Oregon-grape phase
ABLA/RIMO h.t.	*Abies lasiocarpa/Ribes montigenum* h.t.	subalpine fir/mountain gooseberry
-THFE phase	-*Thalictrum fendleri* phase	-Fendler meadowrue phase
-PICO phase	-*Pinus contorta* phase	-lodgepole pine phase
-TRSP phase	-*Trisetum spicatum* phase	-spike trisetum phase
-RIMO phase	-*Ribes montigenum* phase	-mountain gooseberry phase
ABLA/OSCH h.t.	*Abies lasiocarpa/Osmorhiza chilensis* h.t.	subalpine fir/mountain sweetroot
ABLA/JUCO h.t.	*Abies lasiocarpa/Juniperus communis* h.t.	subalpine fir/common juniper
South and Central Utah		
ABLA/ACCO h.t.	*Abies lasiocarpa/Aconitum columbianum* h.t.	subalpine fir/columbia monkshood
ABLA/PHMA h.t.	*Abies lasiocarpa/Physocarpus malvaceus* h.t.	subalpine fir/ninebark
ABLA/ACGL h.t.	*Abies lasiocarpa/Acer glabrum* h.t.	subalpine fir/Rocky Mountain maple
ABLA/VACA h.t.	*Abies lasiocarpa/Vaccinium caespitosum* h.t.	subalpine fir/dwarf huckleberry
-PIEN phase	-*Picea engelmannii* phase	-Engelmann spruce phase
ABLA/VAGL h.t.	*Abies lasiocarpa/Vaccinium globulare* h.t.	subalpine fir/blue huckleberry
ABLA/VAMY h.t.	*Abies lasiocarpa/Vaccinium myrtillus* h.t.	subalpine fir/dwarf billberry
ABLA/BERE h.t.	*Abies lasiocarpa/Berberis repens* h.t.	subalpine fir/creeping Oregon-grape
-PIFL phase	-*Pinus flexilis* phase	-limber pine phase
-PIEN phase	-*Picea engelmannii* phase	-Engelmann spruce phase
-BERE phase	-*Berberis repens* phase	-creeping Oregon-grape phase
ABLA/RIMO h.t.	*Abies lasiocarpa/Ribes montigenum* h.t.	subalpine fir/mountain gooseberry
-MEAR phase	-*Mertensia arizonica* phase	-tall bluebell phase
-RIMO phase	-*Ribes montigenum* phase	-mountain gooseberry phase
ABLA/CAGE h.t.	*Abies lasiocarpa/Carex geyeri* h.t.	subalpine fir/elk sedge
ABLA/JUCO h.t.	*Abies lasiocarpa/Juniperus communis* h.t.	subalpine fir/common juniper
ABLA/CARO h.t.	*Abies lasiocarpa/Carex rossii* h.t.	subalpine fir/Ross sedge

(con.)

APPENDIX A (Con.)

Abbreviation	Habitat types and phases: Scientific name	Common name
	***PICEA ENGELMANNII* CLIMAX SERIES**	
Northern Utah		
PIEN/EQAR h.t.	*Picea engelmannii/Equisetum arvense* h.t.	Engelmann spruce/common horsetail
PIEN/CALE h.t.	*Picea engelmannii/Caltha leptosepala* h.t.	Engelmann spruce/elkslip marshmarigold
PIEN/VACA h.t.	*Picea engelmannii/Vaccinium caespitosum* h.t.	Engelmann spruce/dwarf blueberry
PIEN/VASC h.t.	*Picea engelmannii/Vaccinium scoparium* h.t.	Engelmann spruce/grouse whortleberry
South and Central Utah		
PIEN/RIMO h.t.	*Picea engelmannii/Ribes montigenum* h.t.	Engelmann spruce/mountain gooseberry
	***PICEA PUNGENS* CLIMAX SERIES**	
Northern Utah		
PIPU/AGSP h.t.	*Picea pungens/Agropyron spicatum* h.t.	blue spruce/bluebunch wheatgrass
PIPU/BERE h.t.	*Picea pungens/Berberis repens* h.t.	blue spruce/creeping Oregon-grape
South and Central Utah		
PIPU/EQAR h.t.	*Picea pungens/Equisetum arvense* h.t.	blue spruce/common horsetail
PIPU/JUCO h.t.	*Picea pungens/Juniperus communis* h.t.	blue spruce/common juniper
PIPU/BERE h.t.	*Picea pungens/Berberis repens* h.t.	blue spruce/creeping Oregon-grape
	***PINUS CONTORTA* CLIMAX SERIES**	
Northern Utah		
PICO/CACA c.t.	*Pinus contorta/Calamagrostis canadensis* c.t.	lodgepole pine/bluejoint reedgrass
PICO/VACA c.t.	*Pinus contorta/Vaccinium caespitosum* c.t.	lodgepole pine/dwarf blueberry
PICO/VASC c.t.	*Pinus contorta/Vaccinium scoparium* c.t.	lodgepole pine/grouse whortleberry
PICO/JUCO c.t.	*Pinus contorta/Juniperus communis* c.t.	lodgepole pine/common juniper
PICO/ARUV c.t.	*Pinus contorta/Arctostaphylos uva-ursi* c.t.	lodgepole pine/bearberry
PICO/BERE c.t.	*Pinus contorta/Berberis repens* c.t.	lodgepole pine/creeping Oregon-grape
PICO/CARO c.t.	*Pinus contorta/Carex rossii* c.t.	lodgepole pine/Ross sedge
	***ABIES CONCOLOR* CLIMAX SERIES**	
Northern Utah		
ABCO/PHMA h.t.	*Abies concolor/Physocarpus malvaceus* h.t.	white fir/ninebark
ABCO/OSCH h.t.	*Abies concolor/Osmorhiza chilensis* h.t.	white fir/mountain sweetroot
ABCO/BERE h.t.	*Abies concolor/Berberis repens* h.t.	white fir/creeping Oregon-grape
-SYOR phase	-*Symphoricarpos oreophilus* phase	-mountain snowberry phase
-BERE phase	-*Berberis repens* phase	-creeping Oregon-grape phase
South and Central Utah		
ABCO/PHMA h.t.	*Abies concolor/Physocarpus malvaceus* h.t.	white fir/ninebark
ABCO/ACGL h.t.	*Abies concolor/Acer glabrum* h.t.	white fir/Rocky Mountain maple
ABCO/CELE h.t.	*Abies concolor/Cercocarpus ledifolius* h.t.	white fir/curlleaf mountain mahogany
ABCO/ARPA h.t.	*Abies concolor/Arctostaphylos patula* h.t.	white fir/greenleaf manzanita
ABCO/QUGA h.t.	*Abies concolor/Quercus gambelii* h.t.	white fir/Gambel oak
ABCO/BERE h.t.	*Abies concolor/Berberis repens* h.t.	white fir/creeping Oregon-grape
-JUCO phase	-*Juniperus communis* phase	-common juniper phase
-BERE phase	-*Berberis repens* phase	-creeping Oregon-grape phase
ABCO/JUCO h.t.	*Abies concolor/Juniperus communis* h.t.	white fir/common juniper
ABCO/SYOR h.t.	*Abies concolor/Symphoricarpos oreophilus* h.t.	white fir/mountain snowberry

(con.)

APPENDIX A (Con.)

Abbreviation	Habitat types and phases — Scientific name	Common name
	***PSEUDOTSUGA MENZIESII* CLIMAX SERIES**	
Northern Utah		
PSME/PHMA h.t.	*Pseudotsuga menziesii/Physocarpus malvaceus* h.t.	Douglas-fir/ninebark
-PAMY phase	-*Pachistima myrsinites* phase	-myrtle pachistima phase
PSME/ACGL h.t.	*Pseudotsuga menziesii/Acer glabrum* h.t.	Douglas-fir/mountain maple
PSME/OSCH h.t.	*Pseudotsuga menziesii/Osmorhiza chilensis* h.t.	Douglas-fir/mountain sweetroot
-PAMY phase	-*Pachistima myrsinites* phase	-myrtle pachistima phase
PSME/CARU h.t.	*Pseudotsuga menziesii/Calamagrostis rubescens* h.t.	Douglas-fir/pinegrass
PSME/CELE h.t.	*Pseudotsuga menziesii/Cercocarpus ledifolius* h.t.	Douglas-fir/curlleaf mountain-mahogany
PSME/BERE h.t.	*Pseudotsuga menziesii/Berberis repens* h.t.	Douglas-fir/creeping Oregon-grape
-CAGE phase	-*Carex geyeri* phase	-elk sedge phase
-JUCO phase	-*Juniperus communis* phase	-common juniper phase
-SYOR phase	-*Symphoricarpos oreophilus* phase	-mountain snowberry phase
-BERE phase	-*Berberis repens* phase	-creeping Oregon-grape phase
PSME/SYOR h.t.	*Pseudotsuga menziesii/Symphoricarpos oreophilus* h.t.	Douglas-fir/mountain snowberry
South and Central Utah		
PSME/PHMA h.t.	*Pseudotsuga menziesii/Physocarpus malvaceus* h.t.	Douglas-fir/ninebark
PSME/CELE h.t.	*Pseudotsuga menziesii/Cercocarpus ledifolius* h.t.	Douglas-fir/curlleaf mountain-mahogany
PSME/ARPA h.t.	*Pseudotsuga menziesii/Arctostaphylos patula* h.t.	Douglas-fir/greenleaf manzanita
PSME/CEMO h.t.	*Pseudotsuga menziesii/Cercocarpus montanus* h.t.	Douglas-fir/true mountain-mahogany
PSME/QUGA h.t.	*Pseudotsuga menziesii/Quercus gambelii* h.t.	Douglas-fir/Gambel oak
PSME/BERE h.t.	*Pseudotsuga menziesii/Berberis repens* h.t.	Douglas-fir/creeping Oregon-grape
-PIPO phase	-*Pinus ponderosa* phase	-ponderosa pine phase
-BERE phase	-*Berberis repens* phase	-creeping Oregon-grape phase
PSME/SYOR h.t.	*Pseudotsuga menziesii/Symphoricarpos oreophilus* h.t.	Douglas-fir/mountain snowberry
	***PINUS PONDEROSA* CLIMAX SERIES**	
Northern Utah		
PIPO/CAGE h.t.	*Pinus ponderosa/Carex geyeri* h.t.	ponderosa pine/elk sedge
PIPO/FEID h.t.	*Pinus ponderosa/Festuca idahoensis* h.t.	ponderosa pine/Idaho fescue
-ARPA phase	-*Arctostaphylos patula* phase	-greenleaf manzanita phase
-ARTR phase	-*Artemisia tridentata* phase	-big sagebrush phase
-FEID phase	-*Festuca idahoensis* phase	-Idaho fescue phase
South and Central Utah		
PIPO/CELE h.t.	*Pinus ponderosa/Cercocarpus ledifolius* h.t.	ponderosa pine/curlleaf mountain-mahogany
PIPO/ARPA h.t.	*Pinus ponderosa/Arctostaphylos patula* h.t.	ponderosa pine/greenleaf manzanita
PIPO/ARNO h.t.	*Pinus ponderosa/Artemisia nova* h.t.	ponderosa pine/black sagebrush
PIPO/PUTR h.t.	*Pinus ponderosa/Purshia tridentata* h.t.	ponderosa pine/antelope bitterbrush
PIPO/QUGA h.t.	*Pinus ponderosa/Quercus gambelii* h.t.	ponderosa pine/Gambel oak
-SYOR phase	-*Symphoricarpos oreophilus* phase	-mountain snowberry phase
-QUGA phase	-*Quercus gambelii* phase	-Gambel oak phase
PIPO/SYOR h.t.	*Pinus ponderosa/Symphoricarpos oreophilus* h.t.	ponderosa pine/mountain snowberry
PIPO/MUMO h.t.	*Pinus ponderosa/Muhlenbergia montana* h.t.	ponderosa pine/mountain muhly
	***PINUS FLEXILIS* CLIMAX SERIES**	
Northern Utah		
PIFL/CELE h.t.	*Pinus flexilis/Cercocarpus ledifolius* h.t.	limber pine/curlleaf mountain-mahogany
PIFL/BERE h.t.	*Pinus flexilis/Berberis repens* h.t.	limber pine/creeping Oregon-grape
South and Central Utah		
	No h.t.'s differentiated	

(con.)

APPENDIX A (Con.)

Abbreviation	Habitat types and phases: Scientific name	Common name
	***POPULUS TREMULOIDES* SERIES**	
POTR/AMAL /PTAQ c.t.	*Populus tremuloides/Amelanchier alnifolia /Pteridium aquilinum* c.t.	aspen/serviceberry/bracken fern
POTR/AMAL /TALL FORB c.t.	*Populus tremuloides/Amelanchier alnifolia* /Tall Forb c.t.	aspen/serviceberry/tall forb
POTR/AMAL /THFE c.t.	*Populus tremuloides/Amelanchier alnifolia /Thalictrum fendleri* c.t.	aspen/serviceberry/Fendler meadowrue
POTR/AMAL-SYOR /CARU c.t.	*Populus tremuloides/Amelanchier alnifolia -Symphoricarpos oreophilus/Calamagrostis rubescens* c.t.	aspen/serviceberry-mountain snowberry/pinegrass
POTR/AMAL-SYOR /TALL FORB c.t.	*Populus tremuloides/Amelanchier alnifolia -Symphoricarpos oreophilus*/Tall Forb c.t.	aspen/serviceberry-mountain snowberry /tall forb
POTR/ARTR c.t.	*Populus tremuloides/Artemisia tridentata* c.t.	aspen/big sagebrush
POTR/CARU c.t.	*Populus tremuloides/Calamagrostis rubescens* c.t.	aspen/pinegrass
POTR/CARO c.t.	*Populus tremuloides/Carex rossii* c.t.	aspen/Thurber fescue
POTR/TALL FORB c.t.	*Populus tremuloides*/Tall Forb c.t.	aspen/tall forb
POTR/JUCO /CAGE c.t.	*Populus tremuloides/Juniperus communis /Carex geyeri* c.t.	aspen/common juniper/elk sedge
POTR/JUCO /LUAR c.t.	*Populus tremuloides/Juniperus communis /Lupinus argenteus* c.t.	aspen/common juniper/silvery lupine
POTR/PTAQ c.t.	*Populus tremuloides/Pteridium aquilinum* c.t.	aspen/bracken fern
POTR/SARA c.t.	*Populus tremuloides/Sambucus racemosa* c.t.	aspen/red elderberry
POTR/STCO c.t.	*Populus tremuloides/Stipa comata* c.t.	aspen/needle-and-thread
POTR/SYOR /CARO c.t.	*Populus tremuloides/Symphoricarpos oreophilus /Carex rossii* c.t.	aspen/mountain snowberry/Ross sedge
POTR/SYOR /CARU c.t.	*Populus tremuloides/Symphoricarpos oreophilus /Calamagrostis rubescens* c.t.	aspen/mountain snowberry/pinegrass
POTR/SYOR /THFE c.t.	*Populus tremuloides/Symphoricarpos oreophilus /Thalictrum fendleri* c.t.	aspen/mountain snowberry/Fendler meadowrue
POTR/SYOR /FETH c.t.	*Populus tremuloides/Symphoricarpos oreophilus /Festuca thurberi* c.t.	aspen/mountain snowberry/Thurber fescue
POTR/SYOR /TALL FORB c.t.	*Populus tremuloides/Symphoricarpos oreophilus* /Tall Forb c.t.	aspen/mountain snowberry/tall forb
POTR/VECA c.t.	*Populus tremuloides/Veratrum californicum* c.t.	aspen/western false-hellebore
POTR-ABLA /AMAL c.t.	*Populus tremuloides-Abies lasiocarpa /Amelanchier alnifolia* c.t.	aspen-subalpine fir/serviceberry
POTR-ABLA /CAGE c.t.	*Populus tremuloides-Abies lasiocarpa /Carex geyeri* c.t.	aspen-subalpine fir/elk sedge
POTR-ABLA /CARO c.t.	*Populus tremuloides-Abies lasiocarpa /Carex rossii* c.t.	aspen-subalpine fir/Ross sedge
POTR-ABLA /JUCO c.t.	*Populus tremuloides-Abies lasiocarpa /Juniperus communis* c.t.	aspen-subalpine fir/common juniper
POTR-ABLA /SYOR/THFE c.t.	*Populus tremuloides-Abies lasiocarpa /Symphoricarpos oreophilus/Thalictrum fendleri* c.t.	aspen-subalpine fir/mountain snowberry/Fendler meadowrue
POTR-ABLA/SYOR /TALL FORB c.t.	*Populus tremuloides-Abies lasiocarpa /Symphoricarpos oreophilus*/Tall Forb c.t.	aspen-subalpine fir/mountain snowberry /tall forb
POTR-ABLA /TALL FORB c.t.	*Populus tremuloides-Abies lasiocarpa* /Tall Forb c.t.	aspen-subalpine fir/tall forb
POTR-ABCO /ARPA c.t.	*Populus tremuloides-Abies concolor /Arctostaphylos patula* c.t.	aspen-white fir/greenleaf manzanita

(con.)

APPENDIX A (Con.)

Abbreviation	Habitat types and phases: Scientific name	Common name
POTR-ABCO /POPR c.t.	*Populus tremuloides-Abies concolor /Poa pratensis* c.t.	aspen-white fir/Kentucky bluegrass
POTR-ABCO /SYOR c.t.	*Populus tremuloides-Abies concolor /Symphoricarpos oreophilus* c.t.	aspen-white fir/mountain snowberry
POTR-PIPU Cover Type	*Populus tremuloides-Picea pungens* Cover type	aspen-blue spruce
POTR-PIFL Cover Type	*Populus tremuloides-Pinus flexilis* Cover type	aspen-limber pine
POTR-PIPO Cover Type	*Populus tremuloides-Pinus ponderosa* Cover type	aspen-ponderosa pine
POTR-PICO /CAGE c.t.	*Populus tremuloides-Pinus contorta /Carex geyeri* c.t.	aspen-lodgepole pine/elk sedge
POTR-PSME /AMAL c.t.	*Populus tremuloides-Pseudotsuga menziesii /Amalanchier alnifolia* c.t.	aspen-Douglas-fir/serviceberry
POTR-PSME /JUCO c.t.	*Populus tremuloides-Pseudotsuga menziesii /Juniperus communis* c.t.	aspen-Douglas-fir/common juniper
POTR/ASMI c.t.	*Populus tremuloides/Astragalus miser* c.t.	aspen/timber milkvetch
POTR/BRCA c.t.	*Populus tremuloides/Bromus carinatus* c.t.	aspen/mountain brome
POTR/POPR c.t.	*Populus tremuloides/Poa pratensis* c.t.	aspen/Kentucky bluegrass
POTR/JUCO /ASMI c.t.	*Populus tremuloides/Juniperus communis /Astragalus miser* c.t.	aspen/common juniper/timber milkvetch
	RIPARIAN COMMUNITIES	
CONIFER/ACCO	Conifer/*Aconitum columbianum* c.t.	conifer/monkshood
CONIFER/COSE	Conifer/*Cornus sericea* c.t.	conifer/red-oiser dogwood

APPENDIX B: COMMON AND SCIENTIFIC NAMES MENTIONED IN TEXT

Common name	Scientific name
Trees	
Alder-leaf mountain mahogany	*Cercocarpus montanus*
Arizona pine	*Pinus ponderosa* var. *arizonica*
Ashe juniper	*Juniperus ashei*
Aspen	*Populus tremuloides*
Bigtooth maple	*Acer grandidentatum*
Blue spruce	*Picea pungens*
Boxelder	*Acer negundo*
Chokecherry	*Prunus virginiana*
Common juniper	*Juniperus communis*
Cottonwood	*Populus* spp.
Curlleaf mountain-mahogany	*Cercocarpus ledifolius*
Douglas-fir	*Pseudotsuga menziesii*
Engelmann spruce	*Picea engelmannnii*
Gambel oak	*Quercus gambelii*
Interior ponderosa pine	*Pinus ponderosa* var. *scopulorum*
Limber pine	*Pinus flexilis*
Lodgepole pine	*Pinus contorta* var. *latifolia*
Mexican pinyon	*Pinus cembroides*
Pinyon	*Pinus edulis*
Ponderosa pine	*Pinus ponderosa*
Quaking aspen	*Populus tremuloides*
Red-osier dogwood	*Cornus sericea*
Rocky Mountain juniper	*Juniperus scopulorum*
Rocky Mountain maple	*Acer glabrum*
Serviceberry	*Amelanchier alnifolia*
Singleleaf pinyon	*Pinus monophylla*
Subalpine fir	*Abies lasiocarpa*
Thinleaf alder	*Alnus incana*
Two-needle pinyon	*Pinus edulis*
Utah juniper	*Juniperus osteosperma*
Western bristlecone	*Pinus longaeva*
White fir	*Abies concolor*

Scientific name	Common name	Common synonym
Shrubs		
Acer glabrum	Rocky Mountain maple	
Amelanchier alnifolia	serviceberry, shadbush, saskatoon	
Arctostaphylos patula	greenleaf manzanita	
Arctostaphylos uva-ursi	kinnikinnick, bearberry	
Artemisia arbuscula	low sagebrush	*Artemisia arbuscula* ssp. *arbuscula*
Artemisia nova	black sagebrush	
Artemisia tridentata	big sagebrush	
Berberis repens	Oregon-grape	*Mahonia repens* creeping Oregon-grape
Ceanothus fendleri	Fendler mountain-lilac	
Ceanothus greggii	desert mountain-lilac	
Ceanothus velutinus	snowbrush ceanothus	
Cercocarpus ledifolius	curlleaf mountain-mahogany	
Cercocarpus montanus	alderleaf mountain-mahogany	
Chrysothamnus nauseosus	rubber rabbitbrush	
Chrysothamnus viscidiflorus	viscid rabbitbrush	
Clematis columbiana	Columbia clematis	
Cornus sericea	red-osier dogwood	*Cornus stolonifera*
Gutierrezia sarothrae	broom snakeweed	

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APPENDIX B (Con.)

Scientific name	Common name	Common synonym
Haplopappus suffruticosus	singlehead goldenweed	
Holodiscus dumosus	mountain spray	*Holodiscus discolor*
Juniperus communis	common juniper	
Juniperus horizontalis	creeping juniper	
Linnaea borealis	twin-flower	
Lonicera involucrata	black twinberry	
Lonicera utahensis	Utah honeysuckle	
Mahonia repens	Oregon-grape	*Berberis repens*
Pachistima myrsinites	mountain lover	
Physocarpus malvaceous	mallow-leaved ninebark	
Potentilla fruticosa	shrubby cinquefoil	
Prunus virginiana	chokecherry	
Purshia mexicana var. *stansburiana*	cliff-rose	*Cowania mexicana* var. *stansburiana*
Purshia tridentata	bitterbrush	
Quercus gambelii	Gambel oak	
Ribes aureum	golden currant	
Ribes cereum	wax or squaw currant	
Ribes lacustre	swamp black gooseberry	
Ribes montigenum	gooseberry currant	
Ribes viscosissimum	sticky currant	
Rosa gymnocarpa	baldhip rose	
Rosa nutkana	nutka rose	
Rosa woodsii	woods rose	
Rubus parviflorus	thimbleberry	
Salix spp.	willows	
Salix scouleriana	Scouler willow	
Sambucus racemosa	red elderberry	
Shepherdia canadensis	soapberry	
Sorbus scopulina	Rock mountain ash	
Symphoricarpos albus	white snowberry	
Symphoricarpos longiflorus	long-flower snowberry	
Symphoricarpos oreophilus	mountain snowberry	
Vaccinium caespitosum	dwarf huckleberry	
Vaccinium globulare	dampwoods blueberry	
Vaccinium myrtillus	dwarf bilberry	
Vaccinium scoparium	grouseberry	
Grasses		
Agropyron cristatum	fairway or crested wheatgrass	
Agropyron desertorum	standard wheatgrass	*Agropyron cristatum*
Bouteloua gracilis	blue grama	
Bromus ciliatus	fringed brome	
Bromus tectorum	cheatgrass, downy chess	
Bromus carinatus	mountain or California brome	
Calamagrostis canadensis	bluejoint reedgrass	
Calamagrostis rubescens	pinegrass	
Carex hoodii	Hood sedge	
Carex rossii	Ross sedge	
Carex geyeri	elk sedge	
Dactylis glomerata	orchard grass	
Deschampsia caespitosa	tufted hairgrass	
Elymus elymoides	squirreltail	*Sitanion hystrix*
Elymus glaucus	blue wildrye	*Elymus virescens*
Elymus trachycaulus var. *trachycaulis*	slender wheatgrass	*Agropyron trachycaulum*
Festuca ovina	sheep fescue	
Festuca ovina var. *arizonica*	Arizona fescue	*Festuca arizonica*

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Scientific name	Common name	Common synonym
Festuca ovina var. *ingrata*	Idaho fescue	*Festuca idahoensis*
Festuca thurberi	Thurber fescue	
Glyceria striata	fowl mannagrass	*Glyceria elata*
Hilaria jamesii	galleta	
Koeleria macrantha	prairie junegrass	*Koeleria pyramidata*
Leucopoa kingii	spike fescue	*Hesperochloa kingii*
Leymus salinus	Salina wildrye	*Elymus salinus*
Luzula parviflora	millet woodrush	
Melilotus officinalis	yellow sweet-clover	
Muhlenbergia montana	mountain muhly	
Pascopyrum smithii	western wheatgrass	*Agropyron smithii, Elymus smithii*
Poa fendleriana	muttongrass	
Poa pratensis	Kentucky bluegrass	
Poa secunda	Sandberg bluegrass	*Poa sandbergii, P. nevadensis*
Pseudoroegneria spicata	bluebunch wheatgrass	*Agropyron spicatum*
Stipa comata	needle and thread grass	
Stipa nelsonii	Nelson needlegrass	*Stipa occidentalis*
Stipa hymenoides	Indian ricegrass	*Oryzopsis hymenoides*
Stipa lettermanii	Letterman needlegrass	
Thinopyrum intermedium ssp. *intermedium*	intermediate wheatgrass	*Agropyron intermedium*
Trisetum spicatum	spike trisetum	
Forbs		
Achillea millefolium	milfoil yarrow	
Aconitum columbianum	monkshood	
Actaea rubra	baneberry	
Agastache urticifolia	horse-nettle	
Allium acuminatum	tapertip onion	
Antennaria microphylla	rosy pussytoes	
Aquilegia caerulea	Colorado columbine	
Arnica cordifolia	heartleaf arnica	
Arnica latifolia	broadleaf arnica	
Aster spp.	aster	
Aster engelmannii	Engelmann aster	
Astragalus miser	weedy milkvetch	
Balsamorhiza sagittata	arrowleaf balsamroot	
Caltha leptosepala	marsh-marigold	
Clintonia uniflora	queencup beadlily	
Corallorhiza maculata	spotted coralroot	
Cryptantha spp.	cryptanth	
Delphinium spp.	larkspur	
Descurania richardsonii	Richardson tansymustard	
Disporum trachycarpum	fairy bells	
Dracocephalum parviflorum	American dragon head	
Epilobium angustifolium	fireweed	
Equisetum arvense	horsetail	
Erigeron peregrinus	strange daisy	
Eriogonum racemosum	redroot buckwheat	
Fragaria virginiana	mountain strawberry	
Galium aparine	cleavers bedstraw	
Galium triflorum	sweet-scented bedstraw	
Geranium richardsonii	Richardson geranium	
Geranium viscosissimum	sticky geranium	
Hymenoxys richardsonii	Colorado rubberweed	

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APPENDIX B (Con.)

Scientific name	Common name	Common synonym
Lathyrus pauciflorus	Utah sweetpea	
Lathyrus lanzwertii	Lanzwert sweetpea	
Lupinus spp.	lupine	
Lupinus argenteus	silvery lupine	
Mertensia arizonica	tall bluebell	
Mertensia ciliata	mountain bluebell	
Osmorhiza chilensis	mountain sweetroot	
Osmorhiza depauperata	blunt-fruit sweet-cicely	
Pedicularis racemosa	leafy lousewort	
Phlox spp.	phlox	
Potentilla gracilis	slender cinquefoil; potentilla	
Pteridium aquilinum	bracken fern	
Pyrola secunda	Secund wintergreen	
Pyrola asarifolia	liver-leaf wintergreen	
Rudbeckia occidentalis	western coneflower	
Sanquisorba minor	burnet	
Sedum lanceolatum	common stonecrop	
Senecio stretpanthifolius	manyface grounsel	
Senecio triangularis	arrowleaf groundsel	
Smilacina racemosa	false Solomon-seal	
Smilacina stellata	starry false-Solomon-seal	
Solidago spp.	goldenrod	
Solidago parryi	Parry goldenweed	*Haplopappus parryi*
Solidago sparsiflora	alcove goldenrod	
Stellaria jamesiana	tuber starwort	
Streptopus amplexifolius	clasping twisted-stalk	
Swertia radiata	elkweed	*Frasera speciosa*
Thalictrum fendleri	Fendler meadowrue	
Veratrum californicum	false hellebore	
Vicia americana	American vetch	
Viguiera multiflora	showy goldeneye	
Viola spp.	violet	
Viola adunca	blue violet	
Wyethia amplexicaulis	mulesears	

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