Utah State University

DigitalCommons@USU

Aspen Bibliography

Aspen Research

1990

Aspen ecology and management in the western United States

Norbert V. DeByle

Follow this and additional works at: https://digitalcommons.usu.edu/aspen_bib

Part of the [Forest Sciences Commons](#)

Recommended Citation

DeByle, Norbert V. 1990. Aspen ecology and management in the western United States. Aspen Symposium '89 : Proceedings. General Technical Report NC-140. North Central Forest Experiment Station Forest Service, U.S. Department of Agriculture St. Paul, Minnesota. 11-20.

This Contribution to Book is brought to you for free and open access by the Aspen Research at DigitalCommons@USU. It has been accepted for inclusion in Aspen Bibliography by an authorized administrator of DigitalCommons@USU. For more information, please contact digitalcommons@usu.edu.

Norbert V. DeByle¹

ABSTRACT.--Quaking aspen occurs on more than seven million acres of the interior western United States. It is seral on most sites, usually giving way to more shade-tolerant conifers. Regeneration is almost exclusively by root suckering -- seedlings are a rarity. Discrete clones that occupy several acres are the rule on mountainous western landscapes. Management practices reflect the values of this ecosystem. These values, in decreasing order of importance, are: livestock forage, wildlife habitat, watershed cover, esthetics and recreation, and wood products. Wood products are gaining in importance, thus encouraging more active management of this important type.

This paper emphasizes those aspects of the ecology and management of quaking aspen (*Populus tremuloides* Michaux) that are unique to the montane interior West of the United States and adjacent Canada. Much of the information in this paper comes from DeByle and Winokur (1985) -- which is an extensive, 283-page, literature review and state-of-the-art document. The reader is referred to it for citations of the original sources of publications and ideas prior to 1985. Citations made in that review do not appear in this paper.

ECOLOGY

Quaking aspen has a greater range than any other tree species on the continent. In the interior West it is confined to relatively moist sites (16 to 40+ inches annual precipitation) that have cold winters and a reasonably long growing season. These conditions restrict aspen to low elevations and often south slopes in the northern portions of its range. It grows at progressively higher elevations southward along the Rocky Mountains. At the southern end of its range in Mexico it is virtually restricted to mountain tops. Most commercial sawtimber concentrations are confined to elevations between 7,000 and 10,000 feet in the Rocky Mountains of Colorado, northern New Mexico, and southern Utah. Despite the spotty distribution (Fig. 1), two Rocky Mountain states -- Colorado and Utah -- are among those with more than one million acres of aspen (Table 1).

Regeneration by seed is a rarity, despite large quantities of viable seed being produced almost every year. Asexual regeneration by root suckering has produced clones that commonly are much larger than those found in the Lake States or elsewhere in the East. Clone sizes of 2 to 5 acres are common; clones up to 100 acres in size have been found. Most small groves of aspen on the western landscape are individual clones, they often have a domed shape, with younger suckers on the periphery. Even where stands are extensive, the clones are discrete and, because of large morphological variation among them, obvious to most observers.

¹Norbert V. DeByle, Associate Professor, Forest Resources Dept., Utah State University, Logan, Utah 84322-5215

Figure 1.--The range of aspen in the conterminous western United States (Little 1971).

Table 1.--Area (in thousands of acres) of aspen forests in the interior West.¹

	Commercial	Noncommercial ²	Total
Idaho	99	305	404
Montana	46	209	255
South Dakota	21	2	23
Wyoming	210	257	467
Utah	717	931	1,648
Colorado	2,854	628	3,482
Nevada	6	221	227
New Mexico	338	98	436
Arizona	112	13	125
TOTAL	4,403	2,664	7,067

¹Acreage from Green and Van Hooser (1983).

²Noncommercial acreage includes land that is reserved from cutting and that which is incapable of producing more than 20 cubic feet of wood per acre per year.

The morphology of individual trees in the Lake States and the West is similar, except that the bark on western aspen remains smooth throughout the tree's life. Rough, fissured bark is found only on the lowest couple feet of the bole, even on the largest trees. Sometimes gnawing by rodents will produce corky, roughened bark up to the snowline (3 to 5-feet); and sometimes gnawing by wintering elk (Cervus elaphus) produce rough patches about 5 to 7 feet above the ground.

Aspen is a shade intolerant species that commonly occurs in even-aged stands, especially on sites where competition with more shade-tolerant tree species is intense, as in the Lake States. Most western aspen stands are even-aged and single storied, with all stems originating over a 2- to 4-year period. Some are two-storied, with veterans in an overstory that survived stand decline (from a light fire, high mortality from disease or insects, or commonly from a period of overgrazing). These two-storied stands usually have an understory of essentially even-aged suckers that originated when conditions were favorable, such as after heavy grazing ceased. Despite its intolerance, aspen in the West often occurs as climax stands that are nearly all-aged. They regenerate as the overmature stand breaks up and increased radiation reaches the forest floor. Climax aspen stands do not occur on sites with significant conifer invasion.

In the West, most aspen trees live longer and grow more slowly than those in the Lake States. Tree ages in excess of 100 years are common. However, on most sites, we can expect stand breakup at 120-140 years. Early sucker growth is slower than in the Lake States, taking 2 to 5 years to reach breast height. On montane sites with deep snowpacks, these young suckers are commonly flattened and sometimes damaged by settlement or creeping of the snowpack. Later growth on good sites will reach 80 feet or more at 80 years.

ASSOCIATED VEGETATION

Aspen can be found growing in association with a wide variety of vegetation. Not only is it distributed over a broad latitudinal range, but it also grows along moist stream bottoms, on dry ridges and south slopes, on both shallow and deep soils, and on soils derived from a variety of parent materials. It grows in all mountain vegetational zones from the alpine to the basal plain. Both the tree species with which aspen is associated and the understory composition vary widely over this broad amplitude. For example, in a sample of over 2,000 aspen communities in four physiographic provinces (Central Rocky Mountains, Basin and Range, Colorado Plateau, and Southern Rocky Mountains), only one species, mountain snowberry (Symphoricarpos oreophilus), occurred in at least half the communities in all four provinces (Mueggler 1985).

Most aspen communities are multilayered. Sufficient light penetrates this deciduous tree canopy to support a lush understory. This is in marked contrast with the paucity of herbs and shrubs in nearby stands of conifers. In some communities, a tall shrub stratum occurs beneath the aspen trees, forming an intermittent layer from 6 to 12 feet high. Chokecherry (Prunus virginiana) and serviceberry (Amelanchier alnifolia) are most common. Low shrubs and tall forbs frequently form a continuous stratum about 3 to 4 feet tall. Snowberry and rose (Rosa spp.) are the most common shrubs, and species of Agastache, Aster, Senecio, and Rudbeckia are the most common tall forbs. A stratum of low forbs (usually species of Thalictrum, Galium, Osmorhiza, and Valeriana) and/or grasses (species of Agropyron, Bromus, Elymus, and Poa) and sedges (Carex spp.) is always present (Mueggler 1985). In the western U.S., annual production of this undergrowth commonly exceeds 1,000 pounds per acre. Production of a ton per acre on very good sites during years of copious precipitation is not uncommon.

In much of the West, aspen is the only deciduous tree on upland sites. Commonly it is a seral tree in coniferous forests, associated most often with subalpine fir (Abies lasiocarpa), but also with Engelmann spruce (Picea engelmannii), white fir (Abies concolor), blue spruce (Picea pungens), Douglas-fir (Pseudotsuga menziesii), lodgepole pine (Pinus contorta), ponderosa pine (P. ponderosa),

and sometimes at higher elevations with limber pine (P. flexilis) (Mueggler 1985). After a stand replacement fire or similar perturbation, aspen may dominate a site for 50 to 200 years; but, if a seed source is present, many of the associated conifer species will slowly replace the aspen in the overstory tree canopy.

In recent years, most of the western aspen ecosystem has been classified into either habitat or into community types. These classifications have helped put order into the chaos facing managers of this widespread and diverse forest type (Mueggler 1985, 1988).

INSECTS AND DISEASES

Aspen is prone to attack by many diseases. Only a few, particularly the cankers, are likely to kill the adult tree. But many weaken the tree and make it susceptible to death from some other cause. Several fungi attack the foliage. The most common is black leaf spot, caused by Marssonina populi, which often causes widespread defoliation of mature aspen after wet weather early in the growing season. Ink spot, caused by Ciborinia, is a similar foliage disease that is common in the West.

Decay of aspen boles is important to management for wood products. It becomes important at about 80 years and controls the upper limits of rotation ages at about 120 years. About a dozen fungi species will decay living trees; the most important of which is Phellinus tremulae. Other fungi decay the butts and roots of aspen and make it subject to windthrow.

Aspen is very susceptible to infection by several cankers. Among these, sooty-bark canker, caused by Cenangium singulare, is the most lethal in the West. It will kill the bark and girdle the stem in a few years. Black or target canker, caused by Ceratocystis fimbriata, is perhaps most frequently encountered. The important canker of the Lake States, hypoxylon canker, caused by Hypoxylon mammatum, has caused only minor impact in the West.

Aspen is host to at least 33 insect species, but only a few will kill otherwise healthy trees. Others, however, provide portals for disease entry. The defoliating insects are most conspicuous. Among these, the western tent caterpillar (Malacosoma californicum) periodically defoliates aspen over extensive areas. Outbreaks of the large aspen tortrix (Choristoneura conflictana) and the aspen leaf-tier (Sciaphila duplex) sometimes occur. Potentially the most destructive insects are those that bore into the bark and wood. Among several important borers, the poplar borer (Saperda calcarata) is very common and may directly cause mortality.

WILDLIFE AND LIVESTOCK

The aspen forests in the West provide important habitat for many species of wildlife. In the coniferous forests, aspen groves may be the only source of abundant forage; in the grasslands they may be the sole source of cover. A primary value of the western aspen ecosystem during the past century has been production of forage for both wildlife and domestic livestock. There are at least 135 species of birds and 56 species of mammals that inhabit the aspen type. This diversity and species richness reflects the variation in this ecosystem over a wide geographic area, as well as the variety of understory types, elevational zones, and associated tree species within the aspen type locally.

Some birds, such as the sandhill crane (Grus canadensis), are part of the ecosystem locally; others, such as the western wood-pewee (Contopus sordidulus), are a part of almost the entire western aspen ecosystem. Among the game birds, there are six species of ducks, two species of forest grouse, two of pigeons, the sharp-tailed grouse (Tympanuchus phasianellus), and the wild turkey (Meleagris gallopavo) that inhabit aspen forests. Perhaps only one-half to two-thirds of the bird species found in aspen and mixed aspen-conifer forests actually breed in this habitat.

The many mammal species found in the western aspen ecosystem range in size from the dwarf shrew (Sorex nanus) to the bison (Bison). Several species appear to prefer the aspen type and are important as game, for aesthetics, or have an obvious impact on the plant community. These species include: moose (Alces), elk (Cervus elaphus), deer (Odocoileus spp.), snowshoe hare (Lepus americanus), cottontail rabbit (Sylvilagus nuttallii), beaver (Castor canadensis), porcupine (Erethizon dorsatum), and pocket gophers (Thomomys talpoides).

The many species of wildlife, particularly the mammals, and domestic livestock (sheep and cattle) have major impacts on the aspen ecosystem. Grazing by cattle and sheep of the undergrowth has been the primary consumptive use of the aspen forest type in the West. In addition, wild ungulates graze the abundant and succulent forage under aspen, often selecting this forage source over several others available in the vicinity. Excessive use by ungulates, both wild and domestic, can have adverse effects on both the understory plant community and aspen regeneration. Trampling by ungulates also impacts these strata of the aspen community and sometimes has adverse effects on aspen regeneration. Pocket gophers, though subterranean, also are grazers. They are ubiquitous in western aspen forests, and in some stands are abundant enough to consume as much as a quarter of the below-ground plant productivity. Mineral soil constantly is being brought to the surface of the forest floor by pocket gopher activity.

Browsing has a direct impact on aspen trees. Domestic sheep, deer, elk, and moose all will readily browse aspen. In too many instances, one or more of these species has been responsible for decimating young stands of aspen suckers or of preventing sucker development under a degenerating overmature stand of aspen trees. In addition to browsing, elk on their winter range have a predilection for chewing the bark off aspen trees. Barking provides entry for pathogens and sometimes girdles even mature trees. Voles, hares, and porcupines also bark aspen, but cause little impact on the montane aspen communities of the western U.S. During population eruptions, snowshoe hare damage to aspen regeneration in the boreal forest of Canada and Alaska can be significant.

FIRE

Fire plays an important role in the aspen ecosystem. Most aspen forests in the West are seral and have been dependent upon fire for their perpetuation. If not burned, they would have been replaced by conifers, or, on drier sites, by shrubs and grasses. Among the fire types, aspen is somewhat of an anomaly because it is difficult to burn. However, this thin-barked species is readily killed by fire and the root system responds with copious, rapidly growing, root suckers. Even a mere scattering of aspen in the coniferous stand commonly will restock the area with a new aspen forest after severe fire. The even-aged stands of aspen now prevalent throughout the West owe their origin to fire.

The lack of fire control, and perhaps the use of fire by aboriginal man, contributed to a much greater fire frequency in the past than exists today. In recent decades, the few fires that occurred in the aspen type contributed little to aspen regeneration. We calculated a fire return interval at present of 12,000 years (DeByle et al. 1987). In much of this century, the lack of fire as a stand-replacement mechanism no doubt has been the cause for most of the aspen stands in the West being in the mature to over-mature age classes. In the Intermountain Region, 78% of the stands inventoried were 80 years or older (Mueggler 1989).

It appears that a moderate intensity fire that kills most or all the overstory will stimulate adequate suckering (Brown and DeByle 1987). Herbage production also increases for several years following fire (Brown and DeByle 1989). Both grasses and forbs increase after low to moderate fire severity, forbs increase most after high severity fires. Aspen sucker production comes from deeper roots after fires of high severity, increasing from an average depth of 2 or 3 inches to about 4 inches (Brown and DeByle 1987).

If fire occurs at infrequent intervals (e.g., 50-150 years) and is intense enough to kill most of the aspen and competing conifers, then most aspen sites in the West will retain viable stands of aspen. More frequent fires may adversely effect site quality for aspen. Complete fire protection will allow conifers to take over the majority of sites. Without human intervention, fire appears to be necessary for the continued well-being of aspen on most sites where aspen is seral.

RESOURCES AND VALUES

In contrast with most other vegetation types, the aspen forest type in the montane West possesses several resource values, none of which dominates and controls its management.

The undergrowth in aspen stands produces nearly as much forage as adjacent meadows. This complex mix of grasses, forbs, and shrubs has furnished excellent range for cattle and sheep in the West for more than a century. Livestock grazing continues to be the leading use on many acres.

The aspen ecosystem also provides habitat for a myriad of wildlife species, several of which are important game animals. Among these, the wild ungulates also forage upon the aspen undergrowth, and in some instances, compete with domestic livestock. The juxtaposition of aspen stands with open meadows, conifer forests, brushfields, and riparian zones on the western landscape provides an especially rich complex of wildlife habitats. The value of aspen to wildlife is recognized as perhaps equal to its importance as livestock range on increasingly large acreages.

Aspen provides excellent cover on the mid- to high-elevation watersheds in the mountains. This deciduous ecosystem protects the soil and prevents erosion on steep mountain slopes. It consumes less water than conifer forests on similar sites, largely because it is defoliated during half the year. Annually, in the Rocky Mountains, about 12 inches of water is yielded to streamflow from typical aspen forests that receive 24 to 30 inches precipitation. The importance of this water is increasing as human populations grow and make greater demands on a limited and largely fixed supply of this essential resource.

Aspen in the West is rapidly increasing in value as a wood resource. There is approximately 4.2 billion cubic feet of growing stock available on the 4.4 million acres of commercial aspen land. Only a couple decades ago, aspen was considered a weed tree except for a few specialty products, such as excelsior. As recently as 1975 only 0.1% of the net volume was cut annually. Today it is being harvested for dimension stock, matchsticks, excelsior, particleboard and flakeboard, firewood, paneling, and other uses. It is still much underutilized, but markets are developing. However, much of the aspen in the mountains is on relatively remote and inaccessible sites, where its value as wood probably never will justify road construction to permit its harvest. Also, the aspen in the interior West is too far from paper mills to permit its economical harvest as pulpwood -- a principal use in the Lake States.

Whether or not aspen trees are directly utilized, they have value silviculturally as a nurse crop for shade-tolerant species that do not become established in full sunlight, such as Engelmann spruce, white fir and subalpine fir. These species can grow well under aspen, but later may require aspen removal for optimum growth. In a sense, aspen also serves as a nurse crop for its forage-rich undergrowth. On many sites, without the shade of overstory aspen, many of the shade-tolerant undergrowth species, particularly forbs, would die.

Aspen stands on the mountainous western landscape, especially when growing in a mosaic of meadows, conifer stands, and barren, rocky mountain peaks, have great aesthetic appeal. This value is especially great in the autumn when the aspen clones are in full color -- ranging from pale yellow to orange. This amenity is becoming increasingly important as our population grows and expands its outdoor recreational pursuits. Quaking aspen also has increased greatly in popularity as a landscape plant in urban and suburban areas in the Rocky Mountain states.

MANAGEMENT

The aspen ecosystem may be managed for one or more of the assets already discussed. It is truly a multiple-use type, but with a limited market for its fiber. Most forest types are managed for their economic value as timber. This value is the source of money for management activities. In contrast, the principal uses of the aspen ecosystem have seldom generated enough money to actively manage the overstory portion. In the past, adequate measures have not been taken to ensure that this seral species is retained where other resources benefit from its presence. This, coupled with an effective fire control program, has placed many aspen forests in jeopardy of soon being replaced by conifers through natural succession. Management intervention is needed to retain these seral aspen stands, to maximize wood fiber yields, to provide an optimal variety of wildlife habitats, to retain the rich forage resource under seral aspen, and to provide maximum yields of high-quality water. Fortunately, wildland managers in the West recognize this problem and today are increasing their efforts to effectively treat and manage the aspen in their jurisdictions.

In some instances, the manager may wish to convert some sites now in aspen to other vegetation (e.g., conifers for greater monetary return, grassland for greater water yields and a different forage mix, etc.). In others, the aspen on the site may need to be modified to optimize its value and uses (e.g., all-aged stands of aspen may be regenerated as an array of even-aged stands to maximize production of wood fiber). But, in most instances today, the manager will be taking steps to retain seral or deteriorating aspen in the forest complex.

Two conditions determine the management direction needed to maintain aspen stands: (1) the status of aspen-to-conifer succession, and (2) the status of aspen regeneration in a deteriorating stand. If the stand is rapidly being taken over by conifers, the conifers must be reduced through clearcutting, burning, or at least through selective removal. This removes the competing trees and, in most instances, will stimulate additional aspen suckering. If conifers are not invading, then conditions need to be provided to encourage enough sucker initiation and growth to replace the aging trees. Mueggler (1989) provided a general decision model to determine the type of action needed to maintain aspen stands (Fig. 2). Spraying in that model refers to top-killing the aspen overstory with herbicides. (It can be as effective as fire or clearcutting for stimulating copious aspen sucker development.) "Adequate" sucker reproduction depends upon the uses and values of the stand being managed. Wood fiber production and some wildlife habitats would require uniform and full or nearly full stocking, perhaps beginning with a sucker stand of 8-10,000 per acre; whereas sufficient aspen to shade the undergrowth or to provide an aesthetically pleasing setting could, to the timber manager, be very grossly understocked with only, say, 500 or 1000 suckers per acre.

Aspen-to-conifer succession may progress rapidly over several decades, or it may progress insidiously over hundreds of years. Action to maintain aspen on the site must be taken before major mortality of the aspen overstory occurs due to overtopping by invading conifers. This action might be selective cutting to remove the conifers, clearcutting both conifers and aspen, a stand replacement prescribed fire, or some other means of setting back succession and stimulating aspen regeneration.

Pure aspen stands that are beginning to break up should have sufficient advance regeneration to replace the overstory. If sucker reproduction is inadequate, small, and obviously not developing into saplings as openings occur, then management action is required. If browsing by livestock or big game is responsible for the lack of reproduction, then protection from this impact for several years should permit adequate sucker-to-sapling development. If it is due to a problem inherent to the clone(s) on that site, then more drastic means of altering the hormonal balance to trigger sucker development is in order. Clearcutting, prescribed fire, or herbicide spraying to top-kill the aspen overstory may be used (Mueggler 1989).

Figure 2.--Decision model for maintaining aspen stands in the West (from Mueggler 1989).

Partial cutting can successfully regenerate some aspen clones, whereas others need a major disturbance to trigger suckering. Partial cutting should not be used in commercial quality stands. The residual stems are too frequently damaged by logging and will become diseased. Those that survive cannot be harvested later without damaging the new stand, they must be left to become overmature and die.

Prescribed fire can be used to regenerate aspen in stands with a great enough fuel load to produce fire-line intensities that kill 90% or more of the trees. This is accomplished with flame heights of at least 2 feet, which produce char heights of a foot or more on aspen stems (Brown and DeByle 1987). Unfortunately, effective prescribed fires are limited to stands with an understory of shrubs or with a fairly heavy cover of cured herbaceous vegetation (Brown and Simmerman 1986).

Livestock grazing or heavy use by big game can destroy aspen regeneration, even when a dense stand of suckers comes up after clearcutting or fire. This is especially true on small clearcuts or burns that attract ungulates to the heavy crop of palatable forage. Careful grazing management, especially of sheep, is necessary for at least 3 to 5 years after suckers arise so they will outgrow the reach of browsing livestock. In critical areas we have recommended fencing; but in most, rest rotation grazing, good herders, and proper placement of salt blocks and water will satisfactorily control animal use.

Concentrations of big game, especially elk, can be very destructive to aspen regeneration. Most damage is done to aspen on winter and spring range. Again, fencing can be used, but this is prohibitively expensive. Herd size control by hunting is the most satisfactory answer if aspen is to be retained on heavily used ranges.

Rotations of aspen for sawlog production in the West should fall between 80 years (when decay and deterioration of overstory trees begins) and 140 years (when mean annual increment culminates in the better quality stands). A tentative rotation of 110 years is suggested for stands with site indexes greater than 75 feet (at 80 years), and 120 years for those with site indexes between 60 and 75 feet. A precommercial thinning at about 20 years will put greater growth on the remaining stand. Thinning of aspen, a species that is self thinning as the stand develops, is an economically questionable practice today. Thinning also has an adverse effect on habitat for some wildlife species.

The aspen ecosystem can be managed for several resources simultaneously. But, on any given site, aspen usually has been managed primarily for a single resource. High quality clones on good sites are best suited for sawtimber, those on medium sites for other wood products, and poor clones and clones on poor sites for wildlife or forage production. Aesthetics may be emphasized in key recreation areas. Management for water yield may be the primary consideration on important watersheds.

Even when management focuses on one resource, the others may be affected and must be considered. For example, abundant forage will be produced even under the most intensive management for timber, aspen ranges will yield good quality water under all but the most abusive livestock or game management practices, and the aspen-conifer-meadow mix in the montane setting will retain its scenic qualities under intensive management for any other single resource.

Most techniques for managing other forest types, especially hardwoods, for scenic and recreational values can be applied to the aspen type. Aspen fits well into management for dispersed recreational activities; but, it does not tolerate concentrated use, such as that found in established campgrounds. Carving on trees, vandalism, destruction and removal of young suckers, and trampling of the soil will eventually destroy the aspen in these areas of concentrated use. Aspen can best be used as a scenic resource for recreation purposes in summer and autumn. It also is a preferred forest type on and near ski areas and cross-country ski trails.

Aspen ecosystem management to maximize both forage production and water yields is quite compatible. Both are greater without conifers in the stand. Aspen clearcuts yield more water and produce more forage than do the nearby aspen forest. These facts point to short rotations of, say, 40 or 50 years in areas where water and forage are the prime values.

Aspen ecosystem management for wildlife becomes quite complex. The myriad of species require a broad array of habitats. Management for selected game species continues to be emphasized, but there is a growing tendency to manage for species and habitat diversity. Perhaps providing a balance of aspen age and size classes in small even-aged units on the landscape best fits the above objectives. The mixed aspen-conifer forest appears to provide the greatest variety of niches, and thus the greatest species diversity. Hence, in contrast with management for maximum forage and water yields, the mixed forest should be retained for best wildlife habitat. Overmature aspen trees, especially after decay begins, provide excellent homes for cavity nesting birds. In any management scheme, aspen snags can be retained without damage to other resources.

In summary, I again refer you to our 1985 book, "Aspen: Ecology and Management in the Western United States" (DeByle and Winokur 1985), as the source for most of the information in this paper. In this book we have 32 pages of listed literature citations as well as many observations and management suggestions by the 21 contributing authors. This paper is only a short synopsis of that volume as well an update of some aspects, such as fire management, in which recent research has made significant contributions.

LITERATURE CITED

- Brown, J.K., and N.V. DeByle. 1987. Fire damage, mortality, and suckering in aspen. *Can. J. For. Res.* 17(9):1100-1109.
- Brown, J.K., and N.V. DeByle. 1989. Effects of prescribed fire on biomass and plant succession in western aspen. USDA For. Serv. Res. Pap. INT-412. 16p.
- Brown, J.K., and D.G. Simmerman. 1986. Appraising fuels and flammability in western aspen: A prescribed fire guide. USDA For. Serv. Gen. Tech. Rep. INT-205. 48 p.
- DeByle, N.V., C.D. Bevins, and W.C. Fischer. 1987. Wildfire occurrence in aspen in the interior western United States. *West. J. Appl. For.* 2:73-76.
- DeByle, N.V., and R.P. Winokur, eds. 1985. Aspen: Ecology and management in the western United States. USDA For. Serv. Gen. Tech. Rep. RM-119. 283 p.
- Green, A.W., and D.D. Van Hooser. 1983. Forest resources of the Rocky Mountain States. USDA For. Serv. Resour. Bull. INT-33. 127 p.
- Little, E.L., Jr. 1971. Atlas of United States trees: Vol. 1. Conifers and important hardwoods. USDA For. Serv. Misc. Pub. 1146. 9 p. + 202 maps.
- Mueggler, W.F. 1985. Aspen communities in the interior West. P. 106-111 *in* Proc. Soc. Am. For. Nat. Conv., Fort Collins, CO.
- Mueggler, W.F. 1988. Aspen community types of the Intermountain Region. USDA For. Serv. Gen. Tech. Rep. INT-250. 135 p.
- Mueggler, W.F. 1989. Age distribution and reproduction of Intermountain aspen stands. *West J. Appl. For.* 4(2):41-45.
- Shepperd, W.D. 1985. Aspen ecology and management in the central and southern Rocky Mountains. P. 233-236 *in* Proc. Soc. Am. For. Nat. Conv., Fort Collins, CO.