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Red Fir Ecology and Management

ABSTRACT

Red fir forests have been less affected by humans than the mixed conifer forests, because they were not burned nor cleared for mining, and because they were too far from the early markets for timber. Therefore until recently there has been less research and experience in their ecology and management than in the mixed conifer forests.

Forest soils are likely to be more affected by management than those in the mixed conifer forests because a large share of their nutrient capital is in the forest floor. Thus logging and scarification for site preparation site must be done with considerable care.

Regeneration can be obtained by natural seeding, advanced regeneration and by planting. It appears that regeneration following timber harvest or fire can be achieved. The potential for regeneration varies throughout the Sierra. In the southern Sierra, shade along with ample seed supply appear to be important for regeneration on south, exposed sites. Panting is less likely to succeed on these sites than on north slope, unless shelter trees are left to provide shade. Advanced regeneration is frequently present in the understory of red fir stands. If logging is done carefully, it will respond and grow. Along with new natural seedlings and planting on some sites, advanced regeneration can provide adequate regeneration.

Red fir forests have the potential for high yields of wood. It can grow at high densities for long periods of time and then respond to thinning or density management. Thus, it can be managed under a variety of silvicultural systems, including evenage systems with long rotations and unevenaged systems.

INTRODUCTION

Red fir forests are a major component of the forest cover of the Sierra Nevada. Most of the early work on forest ecology and management was done in the mixed conifer forest where

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the early timber harvest was concentrated, and where fire was much more common. There is a growing body of knowledge about red fir forests and their management. Information ranges from research on basic ecology and on silviculture including: regeneration, thinning and regeneration methods. Much of the current work is being done mainly in the southern Sierras, earlier work was done further north. The purpose of this paper is to summarize information from the literature and experience that provides a back ground for silvicultural practices for managing red fir forests.

Ecological Understanding

Of the forest systems directly influenced by modern human activity, one of the least altered from its "natural state" is perhaps the Red Fir forest, an ecosystem dominated by its defining species, California Red Fir (*Abies magnifica*) and the varietal Shasta red fir (*A. magnifica* var. *shastensis*). Although most extensive in the higher elevations of California's Sierra Nevada, these forests also occupy equivalent elevational positions from the central and southern Cascades of Oregon into the northern coast ranges of California (Laacke 1990). Red fir is probably the least altered of the Sierra Nevada ecosystems for a combination of reasons: first, the short time during which these systems have been subject to significant harvest or road building activity; second, the relative lack of species capable of replacing those present; and third, the characteristics of natural fire in red fir.

A combination of heavy snows, long winters, short growing seasons, soils with nutrients accumulated in the forest floor, and a variety of other attributes associated with high-elevation, mountainous terrain made the red fir forests less suited to agriculture and other uses compared to lower elevation forests. As a result, large scale human access to the high country was postponed until very late in the process of European settlement. Barring local impacts, such as the narrow corridors harvested for fuel wood during building of the railroads and concentrations of livestock around new population centers (Leiberg 1902)**,** incursion into the red fir forests was late in coming. The extensive pine and mixed-conifer forests at lower, more accessible elevations in the Sierra Nevada and elsewhere were available to produce the wood needed. Logging had begun by 1943 (Oostings and Billings 1943) but it wasn't until the two decades following 1953 that harvest of red fir forests began to be significant (Bolsinger 1980). Even so, as recently as 1962, the standard silviculture textbook (Baker 1962) stated that little silviculture information about red fir and that the type remained too small, variable and secondary in value to merit special consideration.

Many of the same physical and climatological characteristics that had limited human presence in the red fir forests also limit the number and kinds of plants and animals that can flourish there. Although far from depauperate, the red fir forest may generally contain fewer and a less diverse flora and fauna than do lower elevation forests (Barbour and Woodward 1985, Gordon and Bowen 1978). For example, the number of vertebrate wildlife species that are present in red fir forests as permanent residents or even as transients is significantly less than forests lower in elevation (Laudenslayer and Grenfeld 1983, Mayer and Laudenslayer 1988, Timossi et al. 1993, Zeiner et al. 1988). Red fir supports fewer species in nearly all categories and is most deficient in those that are present all year (between 46 and 54% of the other forest types.)

The red fir forests are generally included of several plant associations especially in the southern and central Sierra (USDA 1994). There are potentially competitive tree species all through the red fir forest (white fir, Jeffrey pine, incense-cedar, sugar pine at lower elevations; western white pine, lodgepole pine). Frequently these species are part of with different plant associations (for example red fir/lodgepole pine/hawksweed) and successional trends and respones to disturbance and management can vary considerable among associations. Red fir is well adapted to heavy snows and ice; saplings bent double by the snow can straighten during the next growing season (Gordon 1978). White fir has complementary ecological capabilities although it may be generally better suited to elevations below the red fir and, in the ebb and flow of climate change, forests dominated by either red fir or white fir probably "move up and down hill".

Because red fir forests are located in the high elevations with a short summer, it is perhaps surprising that wildfire frequencies in red fir are not particularly different, now or in the past, than forests of lower elevations. Fire affects in red fir forests are differently than in mixed conifer and eastside pine forests. Although moderate to high severity fires do occur in red fir and produce large patches of regeneration, fire regimes in red fir forests appear to be dominated by low- and moderate-intensity fires that result in small scattered groups of regeneration (Kilgore 1971, Kilgore 1973, Agee 1990, Taylor 1993, Taylor and Halpern 1991) rather than extensive areas of even age stands. Fires appear to be a major historic element in creating small openings in dense forests and preparing seedbeds for regeneration. However the history of fires in red fir forest has not been well documented throughout the range of this forest type. The pattern of small groups of even-sized (and sometimes even-aged) trees is similar to that produced by windthrow, insect kill, lightning, or pathogens. All of these variables results in creation of sites for establishment of new seedlings, thinning of small trees, and release existing regeneration to grow faster. These disturbance factors result in the naturally patchy distribution of different size trees in the red fir forest.

It is often assumed that red fir stands are even-aged (Rundel et al. 1988) because the trees are even-sized. However, even aged stands, including even-aged by small group stands, are probably unusual in natural red fir. Regeneration can be a continuous process over reasonably large areas, occurring beneath existing trees and in openings created by fire, windthrow, insects, and disease (Barbour and Woodward 1985, Taylor and Halpern 1991). The shade tolerant nature of the species allows reasonable growth to occur under a variety of conditions and as a result, trees in even-sized stands, or clumps, can vary in age by more than 100+ years.

A major consideration in red fir forest management is the nature of its soils (see Poff and Powers). Soils are young, and much of the nutrient capital occurs in dead organic material or the forest floor. Thus, silvicultural systems and harvesting techniques that avoid widespread soil disturbance, are likely to be a good management practices for the future.

The reasonably extensive harvest and management efforts of the last 30 or so years concentrated on artificial regeneration even though successful artificial regeneration of red fir was rare until the latter years of this period when enough was learned about nursery culture and handling of red fir to make it possible. Because of this difficulty large amounts of Jeffrey pine (a natural component of the red fir forest) were planted as it was possible to achieve successful artificial regeneration with the pine in some cases. On the larger plantations and wildfire rehabilitation efforts, planting Jeffrey pine had the effect of temporarily changing the forest from red fir to pine. However, natural red fir seedlings became dominant even before the pines reach maturity.

Management of Red Fir Forests

Most of the information developed from experiments with regeneration and tests of different regeneration methods was done in the red fir/ white fir association and much of it at Swain Mountain. Therefore the following discussion is mainly relevant to management of red fir-white fir not mixture of red fir and lodgpole pine or hemlock.

Silvicilturally, red fir forests are quite different than pine and mixed conifer forests, because the management of these forests focuses primarily on a single tree species with little opportunity for managing mixtures of conifers and hardwoods. The primary reason for silvicultural practices in red fir forests is for wood production. There is less reason to treat stands to reduce fire hazard and insect impacts. Fire potential is inherently much lower in these forests than in the other Sierra Nevada forest types. Even though there may be considerable dead organic matter and fuel concentrations in red fir forests, intense, stand replacing fires covering large areas have been uncommon. Also, there has not been the general occurrence of insects that have been common in mixed conifer forests or white fir stands/red fir at the lower elevations, even during the droughts of the 1980's and 1990's. Dwarf mistletoe that is common in red fir forests and large trees that often have stem decay in them, may be an important part of wildlife habitat. These factors undoubtedly reduce the yield of merchantable timber, but they also have significant wildlife habitat value. Their net effect depends upon the relative importance of timber production and habitat.

Some management might improve wildlife habitat. Even though these forests are generally quite dense and their understories typically have sparse or non-existent layers of shrubs or herbs, some management could be done to enhance habitat for wildlife that use shrubs forbs and grasses for cover and forage. At lower elevations there is generally a seed bank of *Ceanothus* and *Manzanita sp.* and other species in the forest floor (Quick 1959 and Weatherspoon 1987), that produces a substantial cover if trees are removed by timber harvest or fire and many of these are preferred browse species. Red fir seedlings become established beneath these shrubs and eventually overtop and replace them. This is usually a fairly long process and the shrub communities are likely to persist for 30 to 50+ years before being replaced by the fir.

Another case where some management for other than timber production may be beneficial is the thinning of dense, young stands of red fir that have been established after timber harvest or other disturbance. Red fir natural regeneration often produces young stands with very high stocking (800+ seedlings/acre). These stands have the potential for becoming quite dense and for growing only very small trees in the near future. Thinning dense, young stands to produce larger trees in a shorter time may benefit both wildlife and timber production objectives.

Potential for Wood Production

Red fir stands have the potential for high yields of commercial wood. Even though initial stand growth is often slow, growth rates may accelerate after about 50 years of age. Growth remains high for a number of years. For example, Shumacher (1928) reports net volumes on average site quality at age 50 that range only from 2,450 to 5,000 ft^3/acre but increase considerably from 11,650 to 23,000 ft^3/acre at 120 years. Since mortality was not measured in this study, actual yields would probably be greater. Furthermore, red fir stands respond well to thinning even at relatively old ages. Oliver (1988) reports the results of thinning 100 year old stands of red fir and white fir whose basal areas ranged from 320 to 498 ft^2/acre before thinning and 142 to 363 ft^2/acre after thinning. Volume increments for 10 years after thinning ranged from 189 to 337 ft^3 or 1,404 to 1,776 bd. ft/acre/year. Compared to ponderosa pine, for example, red fir stands can grow at high densities for long periods of time and still maintain stand and individual tree vigor. This positive response to a partial cutting over a wide range of stand densities suggests that there is considerable silvicultural flexibility and a range of options for managing red fir. When thinning is undertaken, however, excessive damage to the boles of remaining trees must avoided to prevent infection by decay fungi .

Natural Regeneration

Natural regeneration is common in red fir forests (Barbour and Woodward 1985). Throughout unmanaged stands, there are often seedlings and saplings of a wide range of sizes and ages that occur in openings caused by death of individual or small groups of overstory trees (Taylor and Halpern 1991). Seedlings and saplings are common in stands in which sanitation and salvage, which harvested individual trees. Natural regeneration is favored by a good seed supply, some shade during the first 2 - 3 years following germination and a mineral soil seed bed (Gordon, 1970). High temperatures in undisturbed forest floor organic layers cause high rates of mortality of 1 to 2 year old red fir. Thus, shade aids seedling establishment on undisturbed sites (Ustin et al. 1984). Also exposure of mineral soil aids survival because temperatures at the seedlings stems are reduced and probably the effects of pathogens are decreased. Gordon (1970) reports lower maximum temperatures (150^{o} F) on mineral soil than in one inch deep forest floor (163^{o}F), but even with mineral soil seed beds, shade enhanced survival.

A study of different regeneration methods (Gordon, 1979) in red fir and red and white fir stands verified the importance of abundant seed, seed bed preparation, and shade for natural regeneration. Seedlings were most abundant on the narrowest clearcuts and under shelter woods with the largest number of trees. Ten years following harvesting seedlings were present from several seed crops, but they were most abundant from the crops that most closely followed disturbance from logging. In this experiment, even the minimum number of seedlings that occurred on the clearcuts exceeded the stocking (300/acre) required by state law (Gordon, 1979).

Seedlings that become established in small openings in the understory of red fir stands grow slowly. But they can respond to the removal of overstory trees by logging or natural disturbance. For example, Gordon (1973) reports the response of natural red fir regeneration to removal of the overstory. Trees ages were 39 to 45 years at time of release and height ranged from 2.2 to 5.0 feet. For about 5 years after overstory removal, there was no increase in growth. However, after 10 -12 years, average height growth increased four times and annual rings per inch decreased from 70 to 100 to 7 to 12 rings per inch (Gordon, 1978). He concluded that advanced regeneration would restock the site and produce a new stand. Similarly, Oliver (1985) found red fir seedlings and saplings that appeared to be badly damaged grow ing rapidly after thinning or complete overstory removal.

The work discussed above (Gordon1970, 1973, 1979) was begun in the late 1950's and early 1960's mainly at Swain Mountain on the Lassen National Forest. The stocking and growth of regeneration on these study sites remain high although the growth of the seedling growth was inversely related to the density of the overstroy trees (Laacke and Tomascheski In press). Recent observations indicate that on some sites, the effects of making openings in red fir forests may cause regeneration problems in the future. The initial openings had little regeneration of grasses or sedges immediately following cutting. However, the density of these species increased and apparently developed their potential for regeneration. In subsequent cutting in adjacent stands, these species were much more aggressive and formed dense covers sooner than in the initial cutting. Based on experience on other sites, it is likely that populations of gophers will also likely increase with the cover of grasses and sedges.

Artificial Regeneration

Planting is also a method of red fir regeneration that has been developed over the last two decades. Studies of seed production (Gordon 1978); collection (Oliver, 1974); nursery production and handling of seedlings have developed insight into the physiology of this species and its response to nursery, storage, and planting techniques. A key to the production of planting stock is obtaining dormancy in the nursery and lifting at the proper time so that seedlings have the potential for vigorous root growth after planting (Jenkinson et al. 1993). Cold storage for about 4 months between the time of lifting and out planting.

Planting at high elevations late spring and early summer is difficult. Deep snow may prevent access to planting sites until late spring or early summer when long days and elevated temperatures cause more demand for water than the small root systems of the seedlings can supply. Planting just after snow melt, in cold soils, delays initiation of seedling root growth and the seedling tops can desiccate before their roots can supply water. Research indicates that with proper handling of seedlings, site preparation, and attention to weather and soil conditions, sufficient rates of seedling survival can be obtained. Operationally success of planting red fir has not been as successful as planting ponderosa pine and Douglas-fir.

A further difficulty of red fir plantation establishment on some sites is the combination of herbaceous vegetation gopher browsing. Where dense herbaceous communities provide summer habitat for gophers, above- and below- ground brow grazing on planted and natural red fir seedlings in the summer and winter can be fatal. Although resistance to gopher damage increases with tree size, even large saplings (3 m+) are damaged and killed when gopher populations age high (Gross and Laacke 1984).

Silvicultural Systems

Information in the literature and experience suggest that red fir can be managed under a variety of stand structures and silvicultural systems (Gordon, 1970); however, long-term experience and records of red fir management are lacking. Natural evenage stands of white fir and red fir have developed after large fires; however, stand establishment may take considerable time. Burned sites were initially stocked with shrubs. Then after about 30 to 50 years, the fir seedlings that became established under the shrubs overtopped them and formed dense evenage or even size stands. These stands appear to become unevenaged disturbance occurs in them. After about 100 - 120+ years, perhaps longer, gaps are formed in these stands from root diseases, snow, wind and insects; regeneration occurs in the gaps and the development of an unevenage stand begins.

Evenage management, should be tried at least on a limited basis. One drawback to this system appears to be that shrubs, grasses, sedges invade after clearcutting and retard seedling establishment. Also, gophers often occupy clearcuts and delay regeneration establishment. Because of slow red fir establishment on some clearcuts throughout the Sierras, Jeffrey pine was planted. On most of these sites, red fir became established under the shrubs, along with the Jeffrey pine. In time, these stands will likely become red fir. How long it will take will vary from site to site depending upon the relative stocking and growth rates of the two species.

An important consideration in the management of red fir forests is nutrient conservation. Compared to other forest types, apparently in true fir forests a large proportion of the forest nutrient capital is in the litter on the forest floor (Powers and Edmund 1992). Therefore, practices such as broadcast burning of slash that oxidizes the organic matter could result in considerable loss of nitrogen. Some disturbance of the forest floor and exposure of mineral soil is needed for natural seedling establishment, however.

The choice of regeneration method and silviculture system will likely vary with management objectives but also with location within the Sierra. It appears that unevenage management or systems that make small openings in the forest canopy are suitable for managing red fir on a range of sites , although shelterwood and clearcutting methods will likely work on north slopes and more generally in the northern Sierras.

With careful logging and site preparation on many sites natural regeneration will become established Either group selection, single tree selection , or a combination of these methods could be used. When beginning to implement these systems, natural openings that contain natural regeneration could be expanded in order to release established seedlings and saplings, and to obtain additional regeneration at the edges of the openings (Gordon 1973). In dense stands, thinning and making openings in the overstory by removing one to three large trees would likely provide sites for natural regeneration. Soil disturbance associated with logging would probably expose sufficient mineral soil to provide a suitable seed bed. As with any ground based logging methods, a careful planning and use of designated skid trails is needed to minimize soil compaction. Trees to be left after logging would depend upon stand management objectives. Groups of large (40 in. + DBH) old trees , some with decay and mistletoe in them could be retained for cavity nesters, aesthetics, a more diverse structure, or old growth component. Among them could be grown smaller vigorous trees. This combination of groups of small and large trees would yield timber and provide a continuous forest cover, except where openings (1 to 2+ acres) were made to provide patches of shrubs or to regenerate fir.

Ferrell (1980, 1983) has provided guidelines for assessing tree fir vigor and mortality based on crown characteristics. The guidelines can be used to determine which trees are likely to die or produce snags and cavities and which are the trees that are rapidly growing into the larger size classes and producing merchantable wood. They are quantitative guides for determining trees to leave or remove to regulate stand density in thinning or unevenage silvicultural systems.

Initial guidelines for unevenage management can be approximated from information in the literature. Assuming average stand diameters of 30 - 36 inches, Gordon's (1979) regeneration cuttings at Swain Mountain left about 50 to 70 ft^2/acre basal area in the heaviest cut (10 trees/acre remaining) and from 150 - 210 ft^2/acre basal area in the lightest cut (30 trees/acre remaining). Most regeneration occurred at the higher densities. Furthermore, these densities were within the range (137 - 263) in which Oliver (1988) found substantial volume and diameter growth rates. Windthrow averaged less than one tree/acre over all of Oliver's thinning treatments. On windy, exposed ridges more blowdown could be expected. However, Gordon (1973) found less windthrow among shelterwoods and small openings than along clearcut edges. Thus, it appears that with careful selection of leave trees, logging systems planning and implementation, regeneration can be obtained and diverse stand structures can be maintained.

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