JOHN C. TAPPEINER
USDI Forest and Rangeland Ecosystem Science Center
and
College of Forestry
Oregon State University
Corvallis, Oregon

P.M. MCDONALD
USDA Forest Service
Pacific Southwest Research Station
Redding, California

12

Regeneration of Sierra Nevada Forests

ABSTRACT

The purpose of this document is to summarize the literature and experience with regard to regeneration of Sierra Nevada forests. We have drawn heavily on studies that focus on the regeneration of mixed conifer and true fir forests--that is mainly on studies conducted in the Sierra Nevada on ponderosa and sugar pine, white fir, red fir and Douglas-fir. Most of Natural regeneration from seed, planting, and advanced regeneration can all be used to regenerate Sierra Nevada forests.

Regeneration is a critical part of forest management, because it helps to insure that forests maintain the desired species composition and stocking after fire, logging, insect epidemics or other distubances to the forest. We stress that the knowledge of the principles of forest regeneration alone does not insure successful regenration. On-site assesment of such factors as seed prodcution, potential affects from competing species, as well as planting techniques, and seedling handling in the nursery are most important. See Hobbs et al. (1992) for a thorough treatment of many phases of forest regeneration.

INTRODUCTION

The ability to regenerate forests after disturbances such as fire, timber harvest, housing developments, etc., is an important part of forest management in the Sierra Nevada. Methods of regeneration include: a) natural seedling establishment after disturbance, b) planting, and c) advanced regeneration - seedling, saplings already on the site prior to disturbance. All methods can be successful, but their use must be determined site by site after evaluating variables such as species of seed sources; microclimate; soils; potential competition from shrubs; vigor, species, and distribution of advanced regeneration; and the desired species composition of the future stand. In practice, combinations of these methods can be used, and sometimes all three may be used simultaneously.

On sites managed for timber production, federal and state regulations have a major influence on the method of regeneration used. Generally the regulations require that sites be regenerated within 3 to 5 years of the removal of the large trees in the stands. Thus managers often choose to plant in order to insure compliance with regulations.

The need to develop reliable methods to regenerate Sierra forest was recognized well over a half century ago (Dunning 1923). Large fires from mining, logging, and railroads had resulted in hundreds of thousands of acres of shrub fields, and it was apparent that they would return to forests only very slowly, and that the future stands would often be true fir, not mixed conifer.

Baker's (1955) analysis of regeneration practices in California was an important step in a concerted effort to develop reforestation practices for Sierra forests. He pointed out that summer drought and competition for soil water from shrubs and other vegetation were major variables in reforestation and that a seedling's ability to become established in these conditions depended upon its physiological condition, genetics (seed source) and often upon a reduction in competition to make soil moisture available to regeneration. Using these principles, from about 1955 through 1980 forest research and management organizations focused on the development of regeneration methods. This work resulted in guidelines for seed collection and handling, nursery production and planting of seedlings, and site preparation and vegetation controls (Schubert and Adam 1971). Major improvements for production and establishment of planting stock were being developed, and work on natural seedling establishment and effectiveness of advance regeneration was also underway during this period. In the 1960's it was recognized that competition from shrubs and sprouting hardwoods was affecting the growth and survial of conifer plantation, and consequently work was done to understand the nature of competition and how to control it (Conard and Radosevich 198 , McDonald and Fiddler 1993a, 1993b).

Natural Conifer Regeneration

Sierra Nevada conifers have the potential for successful natural regeneration on many sites. Most of today’s Sierra Nevada forests were established naturally from seed. The key questions concerning natural regeneration is not if it will succeed but how long will it take, and what will be the stocking rate, species composition, structure, and growth rate of the next forest? In the interest of forest management for multiple resources, what is the role of natural regeneration? How can natural regeneration and planting be combined to insure a forest that provides future societies a range of options?

Factors Affecting Natural Regeneration

For natural regeneration to be successful, there must be adequate seed supply, and seedlings must germinate on microsites where there is a reasonable probability of survival. Sierra Nevada conifers collectively produce seed on a fairly regular basis. However, for any one species, annual production and years between adequate seed crops vary enormously (Tappeiner 1966, McDonald 1992). For example, Fowells and Schubert (1956), who studied cone and seed production from 1926 to 1953 in the central Sierra Nevada, report only about six adequate seed crops for ponderosa pine and three or four for sugar pine during this period. Cone and seed predation by insects, rodents (Tevis 1953) and birds were often high; over 30% of the pine cones produced, but only 10% of the white fir cones. Cone and seed production of the true firs is more consistent than for pines (Gordon 1986).

Seedfall and dispersal generally occur in September and October. During the winter, seed overcomes dormancy, but it is also susceptible to further predation. Beetham (1962) working in the southern Sierra Nevada found that seed predation of sugar pine and ponderosa pine was high, but it was negligible for incense cedar, white fir, and giant sequoia. Similarly Tevis (1953) found that chipmunks preferred seed of the pines to those of white fir and incense cedar. Predator preference for Douglas-fir cones and seed appears to be similar to sugar and ponderosa pine (Tappeiner 1966). Seed dispersal does not appear to be limiting where there has not been extensive disturbance. However, after large fires that kill many trees in young forests, lack of seed could substantially reduce the stocking of the next stand, and the rate of forest development.

Survival of first year conifer seedlings is strongly dependent upon microsite and weather. A favorable microsite (Ustin et al.1984, Laacke and Tomocheski 1986, Tappeiner and Helms 1971, Gordon 1970 and 1978, Stark 1963, Schubert 1956, Baker 1952) generally consists of:

1. a light shade that reduces the evaporative capacity of the air and the high and low extreme temperatures at the soil surface sites;

2. bare mineral soil or a fire or mechanical disturbance to the forest that reduces the habitat of pathogen, invertebrates and rodents (Baker 1951, Gordon 1970 and 1979, McDonald 1976a&b, 1973);

3. lack of vegetation that severely competes for light and soil water, or that produces heavy litter-fall that covers seedlings.

These three conditions are optimal for early seedling establishment; the extent to which they must be met depends upon variables such as weather, miocroclimate (slope, aspect), and species. For example, condition two appears to be more important for sugar pine and ponderosa pine than it does for true fir and incense cedar (Seter et al 1986, Tappeiner and Helms 1971). Conditions one and three might become less important on north-northeast slope during a relatively cool summer.

Note that timing of the occurrence of these conditions is also important. A fire may result in a mineral soil seed bed (#2) suitable for Douglas-fir, ponderosa or sugar pine, but these species might not produce seed for several years following the fire, or the seed source may be destroyed. After a fire, on many Sierra sites, a dense shrub community becomes established which would slowly (50+ years) be overtaken by white fir that become established beneath the shrubs. So the potential for either rapid growth of a pine stand or the very slow, gradual development of a fir stand depends upon the timing and coincidence of soil disturbance and seed production. Generally the true firs, especially white fir, can become established in low light environments on undisturbed forest floor . . . environments in which Douglas-fir and ponderosa pine would not survive. However, true fir growth is often very slow in these environments (Tappeiner and Helms 1971) and older seedlings (20-30+ years) may die if there is no disturbance to the overstory that increases light.

Natural regeneration of conifers has been studied under operational implementation of silvicultural systems. The strip and uniform shelter wood methods have resulted in successful regeneration of white and red fir (Gordon 1970, 1979, Laacke and Tomacheski 1986) and mixed conifer forests (McDonald 1976b, 1983, and Dunlap and Helms 1983).

<u>Advance Regeneration</u>

Advance regeneration of all species, but particularly of white fir, red fir, and incense cedar and tanoak often occurs in the understory of natural and managed stands. It is often the result of an opening of the canopy by thinning or windthrow, for example, or natural variation of canopy density. Populations of natural seedlings may be considered "seedling banks" (Grime 1981). Natural seedlings become established in the understory and grow slowly or persist for many years. If there is a disturbance to the overstory some may respond and become the new overstory trees. Also, older seedlings may die, and be replaced in the understory by new germinants (Tappeiner and McDonald 1984).

Several studies indicate that after release from overstory trees, advance regeneration will grow quite well and provide the stocking for a new stand (Tesch and Korpella 1993, Helms and

Standiford 1985, Oliver 1985, Gordon 1973, Dunning 1923, and Van Alten 1959). The rate of growth of advanced regeneration after release can be predicted from measurement of pre-release live crown percent and annual height growth (Helms and Standiford 1985). Douglas-fir seedlings that are bent and otherwise damaged during logging may recover in about five years (Tesch et al. 1993). However, damage to white fir may cause serious stem decay (Aho and Filip 1982).

Advance regeneration may regenerate a stand after logging, windthrow or insect and disease mortality, but it is not likely to survive intense fire. On sites where advanced regeneration is irregularly distributed and composed of only shade-tolerant species it may be desirable to interplant with pine and/or Douglas-fir to insure a well-stocked mixed conifer stand. On dry sites, especially on the eastside of the Sierra, advanced ponderosa pine regeneration is much more common, but on some sites, interplanting may be used to insure sufficient stocking.

Conclusions

A summary of the literature and experience with natural regeneration of Sierra Nevada conifer indicates that:

- Shade tolerant species such as California white fir, incense cedar, and red fir reproduce well in microsites ranging from exposed to shaded understory. The true fir species will seed into shrub communities, overtop them, and eventually produce pure stands.

- Ponderosa pine, Douglas-fir, sequoias, and sugar pine will not reproduce reliably in shaded understory sites, nor in brushfields. Timing of disturbance to the forest floor in an open environment and seed availability is necessary for their establishment. In addition, competition from shrubs and grasses must be minimal for the first several years.

- A light shade aids early establishment. Too much shade will reduce later seedling growth.

- Natural regeneration of Sierra Nevada conifers can be used to regenerate sites after logging providing that there is a sufficient seed source, the proper microenvironment, and that forest managers can use the necessary treatments: for example, timing scarification of the forest floor to coincide with a seed crop; controlling grass and shrub communities.

- Use of advance regeneration is a good method of regenerating a stand after disturbance. Careful logging and interplanting with shade intolerant species are often required to insure future well-stocked mixed conifer stands.

Planting

The ability to successfully plant the major tree species is an important part of forest management of Sierra forests. Planting can be used, if needed, to rapidly regenerate sites after disturbance. It is also a method of keeping shade-intolerant species like ponderosa pine, sugar pine, and giant sequoia in the mixed conifer forests. For example, on many sites after a large, intense fire, pine seed may not be available for natural regeneration. Consequently, the site may be covered with stands of shrubs, which after 50+ years may be overtopped or replaced by white fir, since pine would not become established under a cover of shrubs. However, planting pines immediately after fire will generally insure that those species will be a part of the future stand.

Today there are at least five nurseries (both agency and commerical) that can produce conifer seedlings for reforestation of Sierra Nevadas species. The major environmental variable that constrains tree seedling establishment in Sierra forests is the summer drought. Variables such as browsing by vertebrates and invertebrates, cold spring or fall temperatures, or other factors are locally important, but periods of high temperatures and low precipitation often extending from late spring through early fall are of overriding importance. Seedlings must be in a physiological condition and in a microenvironment that enables them to survive on the water that is stored in the soil after the rains stop. This means that they must be able to produce roots that can extract water from the soil, and that the planting site is free of intense competition for soil water from other plants.

The original research on the physiology of ponderosa pine seedlings showed that nursery practices greatly influenced the seedlings' capacity to produce roots (Stone, and Schubert 1959; Stone et. al. 1962; Stone and Jenkinson 1970 and 1971). For example, if seedlings are lifted from the nursery bed too early in the fall, before cold weather has induced dormancy, or too late in the winter, when top growth has begun, their capacity to produce new roots is greatly reduced.

Jenkinson has continued this research using root growth capacity (RGC or the potential to produce new roots after being outplanted)) as an index of seedling vigor. He has documented that root growth capacity is directly related to survival of field planted seedlings (Jenkinson 1976, 1978, 1979, and 1980). Furthermore, the development of RGC in the nursery is dependent upon the seed source, and that it has a strong genetic component. For example, for some Sierra Nevada ponderosa seed sources RGC peaks about mid-January; some maintain high RGC from November to February, while RGC for other seed sources peaks in January or February (Jenkinson 1980). Similar patterns occur for red and white fir.

Sowing schedules also and seed handling are also important. Sowing sugar pine and Douglas-fir in the winter increases the vigor of the resulting seedlings. For example, sugar pine seedlings from February sowings averaged 1.4 to 2.1 times taller than those from April or May sowings (Jenkinson 1993b). Also, they were much less susceptible to soil borne pathogens and seedling survival was 5 times greater with early sowings. Apparently early sowing enables beneficial mycorrhizal infection of seedlings in the colder soils, while pathogenic fungi are favored by warmer soils. Later sowing (April and May) works well for ponderosa and Jeffrey pine, however.

The results of the work on seedling physiology can be summarized as “windows” within which nursery and outplanting operations should occur in order to maintain seedling RGC, and thus insure a high probability of survival of planted seedlings. Nursery sowing should be done early enough to avoid pathogen activity and enhance mycorrhizal infection of seedlings. A lifting window “opens” about December after a sufficient fall and early winter cold period and is generally “closed” in February or early March by warming and potential for top and root growth. Seedlings must be lifted during this window and put in cold storage to maintain their RGC.

A planting window occurs between the period of soil warming to 40^{o}F+ in the spring and soil surface drying in the early summer.Actual dates vary with elevation and aspect of the planting site. Thus forest managers must schedule planting operations to correspond to the availability of warm soils with plentiful soil moisture. This often means that they must have access to cold storage facilities so that they can maintain RGC while waiting for proper planting conditions.

Vegetation Management

On most sites throughout the Sierra Nevada there is the potential for rapid establishment of shrubs, herbs, and grasses after disturbance from fire or logging. Control of competing vegetation and its effects on conifer stand establishment has received lots of attention from both forest management organizations and researchers, after it was recognized that competition from shrubs and herbaceous plants (sometimes along with poor quality planting stock) was often the cause of plantation failure. On some sites sprouting hardwoods are also a major component of the reestablishing vegetation. Buried seed of shrubs such as deerbrush, ceanothus, cherry and manzanita are often present on many sites. Disturbance stimulates their germination and a dense shrub community results. Also shrubs and hardwoods sprout from buds on below-ground burls or at the base of their stems. Bearclover and bracken fern often have a dense network of rhizomes below-ground from which aerial stems are produced after disturbance. On the east side of the Sierra, grasses are often the major invaders after disturbance.

Shurbs and herbs are an important part of forest stands because, for example, they provide habitat for various wildlife species, fix nitrogen on some sites, help stabilize soil nutrients, and prevent erosion. However, depending upon their density, these plants may be severe competitors not only with conifers, but among themselves. For example, dense covers of hardwoods (Harrington et al. 1991 and Hughes et al. 1987) will overtop and kill shrubs and herbs that are preferred browse, as well as causing conifer mortality or severely limiting conifer growth. McDonald and Fiddler (1989) documented the effect of manzanita on a native grass (Stipa sp.) and found that Stipa density ranged from 50,000 plants/acre on sites where there was little manzanita to only 553 plants/acre on sites well stocked with manzanita.

In the Sierra Nevada, the major impact of shrubs and hardwoods is likely to be on the species composition of the next stand. Ponderosa and sugar pine and Douglas-fir are generally not likely to become established under a dense cover of shrubs. The true firs, especially white fir are best suited to these conditions. If pine and Douglas-fir seed is present and germinate within 1-2 years after disturbance then it is likely that these species will be present in the next stand. If not, the stand will probably remain a shrub community for many years (50+ yr) and then slowly be overtopped by white fir, providing a fir seed source is present.

The effects of competition on conifer growth is well understood (Walstad and Kuch 1987, Tappeiner et al.1991 ,McDonald and Fiddler 1989). Competition reduces conifer seedlings growth in both height and diameter, and it may make them susceptible to insects as well as grazing damage from rodents and ungulates (McDonald and Radosevich 1992, Tappeiner and Radosevich 1982). In many cases competition for soil moisture, combined with damage, results in seedling mortality. For example, McDonald and Radosevich (1992) reported that survival of 8-year-old ponderosa pine seedlings was reduced from 90% of maximum to less than 20% as shrub biomass increased form about 1000 kg/ha to 7000+ kg/ha. Most shrub communities in the Sierra are capable of producing well over 7000 kg/ha above ground biomass (Hughes et al. 1987).

The options for controlling competing vegetation during conifer regeneration include mulching to control grasses and herbs, manual control by cutting or grubbing, grazing and herbicides. McDonald and Fiddler (1993) have recently evaluated these alternatives for the Sierras. Based on their 40 studies in a range of vegetation types in California, and on other research, they concluded that all methods will release conifer seedlings from severe competition and enable the development of a new stand. Because herbicides were effective in controlling shrubs, the density or numbers of herbs and grasses was usually greater following their use of herbicides, than after manual treatments or grazing.

The land managers' objectives and costs also dictate the choice of methods. If regeneration and a new stand of conifers is important, then release is needed only to insure survival and eventual growth of enough trees of the proper species to produce the desired future stand. This may require only a spotwise manual cutting of shrubs or hand application of herbicide. No treatment at all may be needed if conifer are established soon after disturbance and/or only moderately dense shrub communities develop. If, on the other hand, rapid stand growth for cover, slope stabilization or wood production is desired, then more intensive treatments will be considered. As stated above, state and federal regulations regarding the time required to establish regeneration will also affect the decision on methods of vegetation control.

Literature Cited

Aho, P. E., and G. M. Filip. 1982. Incidence of wounding and Echinodontium tinclorium infestation in advanced white fir regeneration. *Canadian Journal of Forest Research* 12:705-708.

Baker, F. S. 1942. Reproduction of ponderosa pine at low elevations in the Sierra Nevada. *Journal of Forestry* 40:401-404.

Baker, F. S. 1951. Reproduction of pine on old railroad grades in California. *Journal of Forestr*y 49:577.

Baker, F. S. 1955. *California forest regeneration problems. State of California* Division of Forestry, Sacramento, CA. 45p.

Beetham, N. M. 1962. *The ecological tolerance range of the seedling stage of Sequoia gigantea.* Dissertation Abstracts 24:479-480.

Conard, S. G., and S. R. Radosevich. 1982. Post-fire succession of white fir in the northern Sierra Nevada. *Madrono* 29: 42-56.

Dunning, D. 1923. Some results of cutting in the Sierra Nevada forests of California. *U.S. Department of Agriculture Technical Bulletin 1176.*

Dunlap, J. M., and J. A. Helms. 1983. First year growth of planted Douglas and white fir seedlings under different shelterwood regimes. *Forest Ecology and Management* 5:255-268.

Fowells, H. A., and G. H. Schubert. 1951. Natural reproduction in certain cutover pine-fir stands. *Journal of Forestry* 49:192-196.

_______ and ______. 1956. Seed crops of forest trees in the pine region of California. *U.S. Department of Agriculture Technical Bulletin 1150.*

Fowell, H. A., and N. Stark. 1965. Natural regeneration in relation to environment in the mixed conifer forest type of California. *U.S. Department of Agriculture, Forest Service Research Paper PSW 24,* Berkeley, CA

Gordon, D. T. 1970. Natural regeneration of white and red fir--influence of several factors. *U.S. Department of Agriculture, Forest Service Research Paper PSW 58,* Berkeley, CA.

_____________ 1973. Released advanced reproduction of white and red fir...growth, damage, mortality. *U.S. Department of Agriculture, Forest Service Research Paper PSW 95,* Berkeley, CA.

_____________1978. White and red fir cone production in northeastern California: Report of a 16 year study. *U.S. Department of Agriculture, Forest Service Research Paper PSW 99*, Berkeley, CA. 12p.

Gordon, D. T. 1979. Successful natural regeneration cuttings in California true fir. *U.S. Department of Agriculture, Forest Service , Research Paper PSW 140*, Berkeley, CA.

Grime, J. P. 1979. *Plant strategies and vegetation processes.* John Wiley and Sons, New York, 222p.

Harrington, T. B., J. C. Tappeiner and T. F. Hughes. 1991.Predicting average growth and size distributions of Douglas-fir saplings competing with sprout clumps of tanoak or Pacific madrone. *New Forests* 5:109-130.

Helms, J. A., and R. B. Standiford. 1985. Predicting release of advanced reproduction of mixed conifer species in California following overstory removal. *Forest Science* 31:3-15p.

Hobbs, S. D. S. D. Tesch, P. W. Oyston, R. E. Stewart, J. C. Tappeiner, G. E. Wells. 1992. Reforestation practices in southwestern Oregon and northern California. *Forest Research Lab, Oregon State University*, Corvallis, OR, 465p.

Hughes, T. F., C. R. Latt, J. C. Tappeiner, and M. Newton. 1987. Biomass and leaf area estimates for varnish-leaf ceanothus, deerbrush, and white leaf manzanita. *Western Journal of Applied* Forestry 2:124-128p.

Jameson, E. W. 1952. Food of deer mice Peromyscus maniculatus and P. boylei in the northern Sierra Nevada. California *Journal of Mammology* 33:50-60p.

Jenkinson, J. L. 1980. Improving plantation establishment by optimizing growth capacity and planting times of western yellow pine. *U.S. Department of Agriculture, Forest Service Research Paper PSW-154*, Berkeley, CA. 22p.

Jenkinson, J. L. and A. H. McCain. 1993. Winter sowings produce 1-0 sugar pine planting stock in the Sierra Nevada. *U.S. Department of Agriculture, Forest Service Research Paper PSW-RP-219.* Albany, CA. 10p.

Jenkinson, J. L., J. A. Nelson, and Mary Huddleson. 1993. Improving planting stock quality--the Humboldt Experience. *U.S. Department of Agriculture, Forest Service General Technical Report PSW-GTR-143*, Berekeley, CA 219p.

Laacke, R. J., and J. H. Tomascheski. 1986. Shelterwoodregeneration of true fir conclusions after eight years. *U.S. Department of Agriculture, Forest Service Research Paper PSW 184*, Berkeley, CA. 7p.

Laacke, R. J., and G. O. Fiddler. 1986. Overstory removal: stand factors related to success and failure. *U.S. Department of Agriculture, Forest Service Research Paper ,PSW 183,* 6p.

McDonald, P. M. 1970. Seed dispersal in small clearcuttings in north-central California. U.S. Department of Agriculture, Forest Service Research Paper PSW 150, Berkeley, CA. 5p.

McDonald, P. M. 1976a. Forest Regeneration and seedling growth from five major cutting methods in north-central California. *U.S. Department of Agriculture, Forest Service Research Paper, PSW 115*, Berkeley, CA.

__________.1976b. Shelterwood cutting in a young-growth mixed conifer stand in north-central California. *U.S. Department of Agriculture, Forest Service Research Paper 117,* Berkeley, CA.

__________.1978. *Silviculture - Ecology of three native California Hardwoods on high sites in north central California* PhD Thesis, Oregon State University, Corvallis, OR. 309p.

___________.1983. Clearcutting and natural regeneration management implications for the northern Sierra Nevada. *U.S. Department of Agriculture, Forest Service Technical Report 70,* Berkeley, CA.

___________. 1992. Estimating seed crops of conifer and hardwood species. *Canadian Journal of Forest Research* 22: 832-838.

McDonald, P. M., and G. O. Fiddler. 1993a. Feasibility of alternatives to herbicides in young conifer plantations in California. *Canadian Journal of Forest Research* 2015-2022.

________and _______. 1993b.Vegetative trends in a youngconifer plantation after 10 yrs of grazing by sheep. *U.S. Department of Agriculture,Forest Service Research Paper PSW-RP-215*, Albany CA., 9p.

Oliver, W. W. 1985. Growth of California red fir advanced reproduction after overstory removal and thinning.*U.S. Department of Agriculture, Forest Service Research Paper PSW 180*, Berkeley, CA. 6p.

_______________1986. Growth of California red fir advanced regeneration after overstory removal and thinning. *U.S. Department of Agriculture, Forest Service Research Paper PSW 180,* Berkeley, CA.

Schubert, G. H. 1956. Early survival and growth of sugar pine and white fir in clear cut openings. *U.S. Forest Service, California Forest and Range Experiment Station, Research note 117,* Berkeley, California

Schubert, G. H. , and R. S. Adams. 1971. *Reforestation practices for conifers in California, State of California,* Division of Forestry, Sacramento, CA. 359p.

Selter, C. M., W. D. Pitts, and M. G. Barbour. 1986. Site microenvironment and seedling survival of Shasta red fir. *American Midland Naturalist* 115:288-300p.

Stark, N. 1963. Natural regeneration of Sierra Nevada mixed conifers after logging. *Journal of Forestry* 63:456-60.of California.

Tappeiner, J. C. 1967. *Natural r egeneration of Douglas-fir and white fir in the SierraNevada of Califronia*, Phd Thesis , University of California, Berkekey, 237p.

Tappeiner, J. C., and J. A. Helms. 1971. Natural regeneration of Douglas-fir and white fir in the Sierra Nevada of California. *American Midland Naturalist* 86:358-370p.

Tappeiner, J. C., and P. M. McDonald. 1984. Development of tanouk understories in conifer stands. *Canadian Journal of Forest Research* 14:271-277p.

Tesch, S. D., K. B. Katz, and E. J. Korpela. 1993. Recovery of Douglas-fir seedlings and saplings wounded during overstory removal. *Canadian Journal of Forest Research.* 23:1684-1694.

Tesch, S. D., and E. J. Korpella. 1993. Douglas-fir and white fir advanced regeneration for renewal of mixed conifer forests. *Canadian Journal of Forest Research.* 23:1427-1437.

Tevis, L. P. 1953. Effect of vertebrate animals on the seed crop of sugar pine. *Journal of Wildlife Management* 1 7:128-131p.

Ustin, S. L., R. A. Woodward, M. G. Barbour, and J. L. Hatfield. 1984. Relationships between sunfleck dynamics and red fir seedling distribution. *Ecology* 65:1420-1428.

Von Althen, F. W. 1959. *A contribution to the study of edge effects on the regeneration of small forest openings in the Sierra Nevada.* M. F. Professional paper. Forestry, University of California, Berkeley.

Worthington, N. P. 1953. Reproduction following small group cuttings in Douglas-fir. *Research note 85. U.S. Department of Agriculture*, *Forest Service*, Pacific Northwest Forest and Range Experiment Station.

Back to CD-ROM Table of Contents