Chapter 13

Projected Trends in Owl Habitat

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Here we attempt to synthesize many of the analyses presented in other chapters in this document, and to look ahead to the future. As such, this chapter is necessarily more speculative and conclusions expressed here should not be viewed as hard and prescriptive. We hope, however, to highlight areas of concern for future owl habitat, and for the health of the forest ecosystem more generally. Finally, we propose alternate forest management methods that we believe have merit. We do not consider the management methods described here to be an exclusive set to be prescribed forestwide. Rather we view them as potential experiments which, if effective, will alleviate many of the shortcomings that we perceive in current management systems as they relate to owl habitat. This report covers a wide range of forest types and topographic regions. We will focus almost exclusively on the Sierran mixed-conifer forest type, as it contains an estimated 82 percent of the spotted owl sites in the Sierra Nevada and 62 percent of all known California spotted owl sites.

The Forest, Past and Present

Vegetation Dynamics

Forests of the Sierra Nevada have been impacted by nonaboriginal man over the last 150 years. The first major perturbation, on lands that now are managed by the Forest Service (FS), was the grazing of millions of sheep (Chapter 11). This grazing pressure and the fire patterns associated with its promulgation impacted regeneration and the grass/forb community. This pattern probably amplified a structure already maintained by frequent fires-one of open stands dominated by large, old trees (Chapter 12). It also resulted in excellent seed beds for tree regeneration by creating bare-soil conditions over much of the forest (figs. 13A and 13B as examples; Chapter 11).

With removal of sheep and fire, stands experienced ingrowth of conifers, dominated by shade-tolerant species such as white fir. Stands became dense, and a combination of logging and natural attrition of the old forest led to a decline in the number of large, old trees. Past logging activities that concentrated on removal of the large, valuable trees broke up the patchy mosaic of the natural forest, and this too encouraged development of dense regeneration patterns with very little horizontal heterogeneity (figs. 11P-11S; Chapter 12). These developments, particularly in Sierran mixed-conifer and ponderosa pine/hardwood forests, reduced large-diameter trees in many areas to a small, remnant population. This condition can be seen by comparing owl nest locations, which generally are in larger, denser stands in today's forest (color photos 5-9 to 5-16 as examples), to forest conditions about 1900 (figs. 13A to 13D as examples).

These changes have not occurred to the same degree in the red fir as they have in mixed-conifer and ponderosa pine types at lower-elevations. The red fir type differs from the mixed-conifer in several particulars, including in its natural disturbance regime. Fires are less frequent, occurring at intervals of 40+ years (Taylor and Halpern 1991) rather than the 5- to 30-year return periods observed in mixed-conifer stands (Chapter 12). The forest consists of blocks of various sizes, often with a high degree of horizontal heterogeneity (color photos 5-1 to 5-6). In many areas fire was the dominant disturbance factor responsible for this mosaic (Pitcher 1987). In addition, windthrow created small gaps, and red fir regeneration often established more or less continuously between disturbance events (Taylor and Halpern 1991). This led to a complex horizontal pattern with the juxtaposition of blocks of various ages and sizes. Removal of fire from the red fir type has had less impact than in the Sierran mixed-conifer type because of the longer mean fire interval. Many red fir stands would not have burned in the twentieth century even if the natural fire patterns were intact. Red fir also occurs in mostly pure stands at higher elevations. On these sites, red fir appears to be a self-perpetuating, climax species (Barbour and Woodward 1985, Taylor and Halpern 1991), and the successional trend toward more shade-tolerant species that characterizes the mixed-conifer zone is not a factor.

Red fir was also not extensively logged until recent years. Most logging of red fir in the Swain Mountain area, for instance, occurred after 1960 (Chapter 7). Partial cutting has not broken up the large-diameter groups and, in many places, the forest has never been logged (color photos 5-1 to 5-6 as examples). The pattern in red fir is more that observed in the Pacific Northwest-recent, often even-aged harvest intermingled with blocks in reasonably pristine condition. In logged areas, regeneration records maintained by the FS R5 show that survival of planted seedlings is low (Fiske pers. comm.; fig. 13E).

Fire Patterns

Fire patterns in the Sierran mixed-conifer zone have changed radically in the twentieth century. The annual acreage burned may have declined by two orders of magnitude when compared with historic levels (Chapter 12). This, in turn, has led to historically unprecedented buildups in fuels and to stand structures that are prone to crown fires (Chapter 12). Because of these conditions, fires that escape initial suppression efforts-usually those occurring during extreme weather conditions-tend to become large, stand-replacing events.

Figure 13A--Sugar and ponderosa pine in Foresthill block showing size of timber and open character of forest. Note extensive, branchless tree trunks and the absence of underbrush on the forest floor.

Date: ----------------------7 July 1911
Source: -------------------Tahoe National Forest Historical Photo
Photographer: ----------USDA Forest Service

Figure 13B--A woman and her dog following an old road through a stand of old-growth Jeffrey pines.

Date: ----------------------About 1920
Source: -------------------Lassen National Forest Historical Photo
Photographer: ----------USDA Forest Service

Figure 13C--Pure stand of cedar along Mill Creek above Morgan Springs.

Date: ----------------------About 1920
Source: -------------------Eldorado National Forest Historical Photo
Photographer: ----------USDA Forest Service

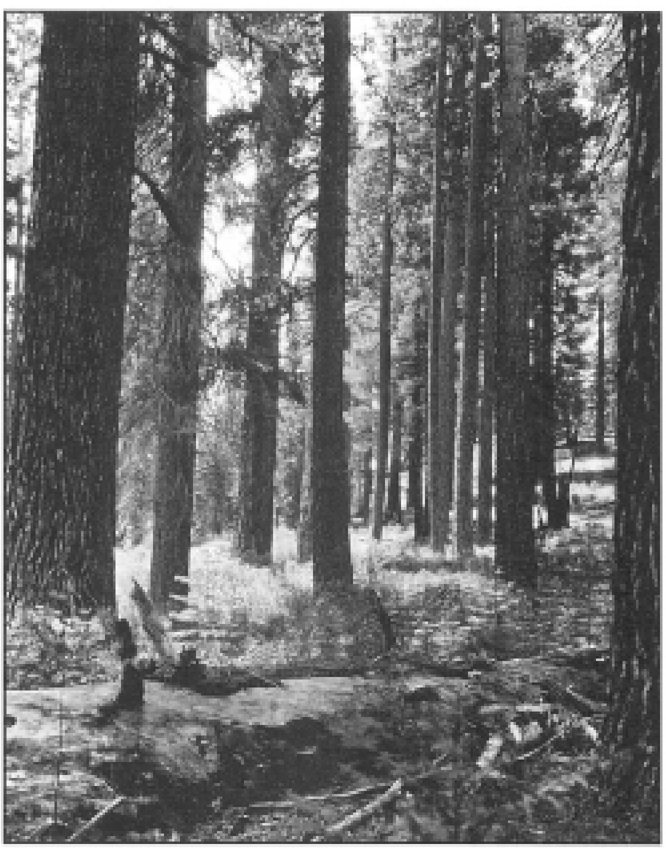

Figure 13D--Near Strawberry, a virgin forest including sugar pine, ponderosa pine, fir, and incense-cedar. Observe the downed, rotting tree and open character of the forest floor.

Date: ----------------------About 1920
Source: -------------------Stanislaus National Forest Historical Photo
Photographer: ----------USDA Forest Service

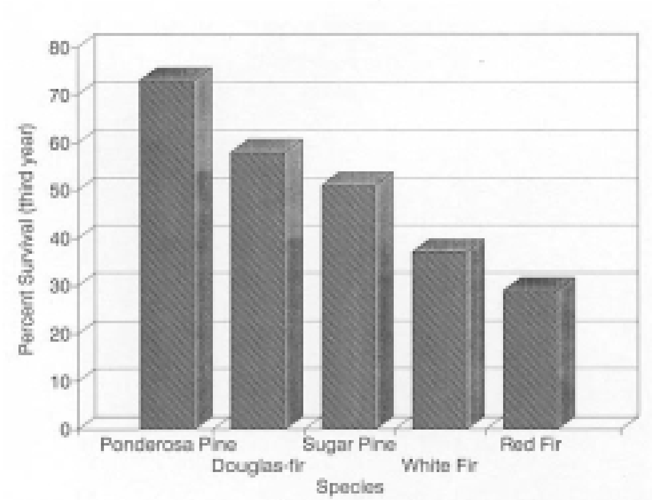

Figure 13E-Regeneration survival in plantations, by species, based on 3-year postcut inventories. Survival rates were averaged over the years 1986-1991 (Fiske pers. comm.).

Owl Habitat in Current Forests

Spotted owls in the Sierra Nevada have used all of the dense (>40 percent canopy closure) mixed-conifer stands at or greater than expected levels for nesting (Chapter 5). The only stands used significantly greater than expected, however, were dense stands with large-diameter trees [>24 inches in diameter at breast height (d.b.h.)] in the overstory. Within these stands, snag densities were higher than in the general forest matrix, and the average nest tree exceeded 40 inches in d.b.h. Most of the nest trees appeared to be old-growth remnants of stands present at the turn of the century (Chapter 5). These stands tend to be very heavily stocked with trees in smaller diameter classes (color photos 5-9 to 5-16, for example).

We have few data concerning nest stand selection in the red fir type. The nests that we observed on our field trips were in uncut blocks of timber (color photos 5-1 to 5-6, for example).

Future Trends

Human Population Trends

The human population in both the Sierra Nevada and southern California is growing rapidly (fig. 13F). Of particular concern is population growth in the foothill regions of the mid-Sierra Nevada. In these areas (Nevada, Placer, El Dorado, Amador, Calavaras, and Tuolumne Counties), human populations have increased by 50 percent over the last 10 years and are expected to continue to grow at that rate through the year 2000. From 1980 to 1990, they were among the top 10 California counties in growth. By the year 2000, the combined population of these counties is estimated to exceed 670 thousand (Rountree 1992). A large proportion of this population will be living in widely dispersed housing "in the pines." Impacts from this type of development on spotted owl habitat are unknown. We do know, however, that spotted owls currently occur in these foothill areas and that this type of housing pattern makes management and monitoring very difficult. Any resulting negative impacts on the owls will be difficult to detect and even more difficult to control.

While much of the population growth in southern California is in the basins, towns in the San Bernardino Mountains, such as Big Bear Lake, are expected to grow 50 percent by 2010 (Ruth

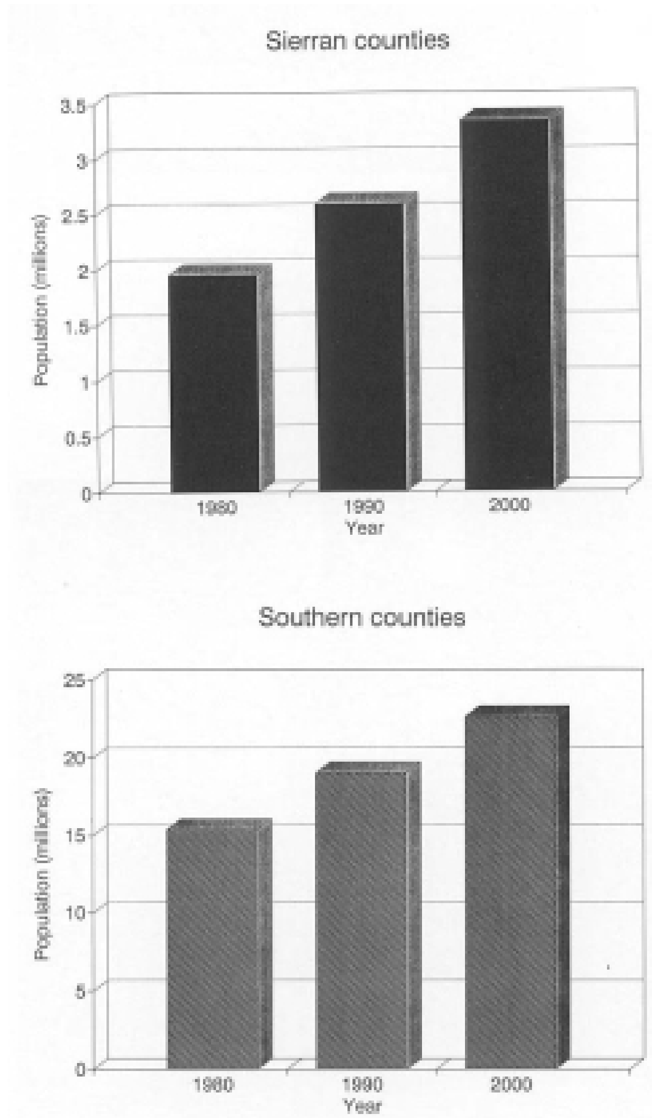

Figure 13F-Human population trends in the Sierra Nevada and southern California. Only counties containing spotted owls were included in this analysis (data from Rountree 1992).

pers. comm.). Impacts of increased population on the spotted owl in southern California will most likely be more direct than they are in the mid-Sierra Nevada. Because many owls in southern California depend on narrow riparian/hardwood forests, pressure on them will increase as waters are diverted to a variety of human needs.

Fire Trends

As the human population increases, human-caused wildfires can also be expected to increase. The presence of so many houses within the forest will shift the emphasis of fire suppression even further from one of saving forests to one of saving property. Fuels will also continue to accumulate. Especially as a direct result of our current drought, recent bark beetle infestations will contribute a major pulse of new fuels over the next few decades. The likely result is a gradual increase in the number and acreage of large, stand-replacing wildfires.

Cutting Trends: Land Management Plans

According to Land Management Plans (LMPs) collectively for National Forests (NFs) of the Sierra Nevada, 65 percent of the forested acres are classified as suitable and available for timber production (USDA, FS 1986-1991b). If we exclude from the forested base the acres that are physically unsuitable because they cannot produce timber in commercial quantities, cannot be successfully regenerated, or have unstable soils, 74 percent of the lands that can potentially produce timber will be harvested in some manner (table 13A). On many acres, harvest will be light.

Table 13A-*Categorization of forested acreage from the Land Management Plans.*

National Forest	Thousands of acres: Forested	Physically unsuitable[1]	Suitable and available[2]	Suitable and unavailable[3]
Lassen	825.1	0	596.3	228.8
Plumas	1,102.4	145.7	898.9	57.8
Tahoe	681.6	31.7	528.5	121.4
Eldorado	458.0	63.2	307.6	87.2
Stanislaus	784.6	308.3	328.5	147.8
Sierra	562.9	26.8	328.9	207.2
Sequoia	679.0	40.0	345.0	294.0
All Forests	**5,093.6**	**615.7**	**3,333.7**	**1,144.2**

[1] Includes acreage not capable of producing commercial timber, in which irreversible damage would be caused if timber were harvested, and that cannot be regenerated in 5 years after harvest.

[2] Includes lands capable of producing commercial timber that have not been withdrawn from timber management, lands that can be regenerated within 5 years after logging, and lands that can be managed for timber production without irreversible damage. Suitability here refers to areas that could physically sustain timber yields over time, not necessarily spotted owl suitability.

[3] Includes lands that are physically suitable but that have been withdrawn from timber management for dedication to other uses (for example, Wilderness Areas, Spotted Owl Habitat Areas, and so on).

Seventy-two percent of the timber volume removed from these lands will be taken through even-aged systems, the most common even-aged system being the clearcut (table 13B). Of the 528,474 acres of suitable timber land on the Tahoe NF, for instance, 68 percent will be managed for even-aged silviculture (24 percent long rotation, 44 percent short rotation) (USDA, FS 1990). On the Plumas NF, 52,000 acres are scheduled for even-aged cutting per decade and 8,000 acres for selection cutting methods (USDA, FS 1988b; table 13C).

Even-Aged Logging and Owl Habitat

Clearcuts, seed-tree, and shelterwood cutting methods all have the same goal: produce even-aged stands. In this regard, seed-tree and shelterwood systems can generally be thought of as two-stage (sometimes three-stage) clearcuts. In nearly all of these cutting systems, all of the original stand will be removed before the new stand is scheduled to be cut.

Table 13B-*Harvest volumes from the forest Land Management Plans.*

National Forest	Millions of board feet: Clearcut	Seed tree/ shelterwood[1]	Other[2]	ASQ[3]
Lassen4	40.6	23.5	31.9	96.0
Plumas	144.2	31.3	90.0	265.5
Tahoe	64.7	48.2	29.4	142.3
Eldorado	58.4	55.4	23.4	137.2
Stanislaus[4]	3.9	67.6	16.5	88.0
Sierra'	25.5	32.5	30.0	88.0
Sequoia'	64.8	3.1	29.1	97.0
All Forests	**402.1**	**261.6**	**250.3**	**914.0**

[1] Includes removal sales as well.
[2] Includes all other sale types that enter into the calculation of ASQ.
[3] Annual sale quantity.
[4] These data are given in cubic feet in the LMPs.

Table 13C--*Number of acres scheduled for logging, annually, during the first decade of draft and final Land Management Plans for Sierran National Forests, by prescription.*

National Forest	Acres per year: Clearcut	Seed tree/ shelterwood[1]	Selection[2]	Intermediate[3]
Lassen	1,600	1,000	1,400	10,200
Plumas	4,000	1,200	800	16,286
Tahoe	2,046	1,657	162	3,500
Eldorado	2,084	1,836	948	2,700
Stanislaus	510	2,386	8,7284	1,500
Sierra	1,550	1,170	2,970	4,000
Sequoia	1,734	128	742	6,727
All Forests	**13,524**	**9,377**	**15,750**	**44,913**

[1] Includes acres of overstory removal.
[2] Both group- and individual-tree selection.
[3] Includes stand improvement, thinning, salvage, etc.
[4] This figure represents the acres to be examined rather than the acres to be treated.

In terms of owl biology, the primary impact of traditional, even-aged logging practices lies in the creation of simple stand structures and, perhaps more importantly, the removal of all large, old trees from vast areas of the forest. Even if silvicultural prescriptions are modified so that snags and live culls are left at the first cutting, no provision is made for a predictable recruitment of replacement trees for these relics when they fall. This, in turn, will lead to a loss of large-diameter, downed woody materials. Log slash can create much small-diameter woody debris, but it cannot replace the large logs. In an even-aged system, these old-growth features can be recreated only by an extreme extension of the rotation interval. Even if the rotation were extended to 150 years, for instance, no trees would match the average age of the forest at the turn of the century (Chapter 11). Decadent features in stands are functions of age, not just d.b.h. (fig. 13G), and any animals that depend on decadent features (cavities, broken-tops, snags), or the large woody debris that they create, will simply drop out of these forests (see Chapters 4, 5, and 10 for examples specific to the spotted owl and its prey species). The rate of conversion to even-aged systems in the western Sierra Nevada is estimated by the LMPs to be 229,000 acres per decade.

Even on lands set for selection logging (about 80,000 acres per decade), we have no guarantee that harvest prescriptions will leave many of the large, old trees. Ideally, stands managed for individual-tree selection are harvested in a manner that brings the diameter distribution in the stand into conformity with an idealized distribution characterized by a declining exponential function (in forestry referred to as an inverse "J"). The number of large trees within the stand is dictated by the slope of this function (fig. 13H) and the specified intercept representing the number of trees in the smallest diameter class (or, alternatively, the designated diameter of the largest tree). In selection systems, timber is removed from all diameter classes, as required to maintain this diameter distribution. Little evidence exists, however, that historic patterns of partial cutting have followed classic single-tree selection theory. "Selective" harvest in the Sierra Nevada has, in the past, primarily targeted the large trees. This system, sometimes called "pick and pluck," will not produce the simple structures that characterize even-aged methods, but its effect on the presence of large, old trees is similar. If the large trees are removed and no stocking control is performed on the smaller stems, replacement trees in these diameter classes will be produced very slowly, if at all, and they will consist primarily of the more shade-tolerant species. Even with classical single-tree selection, a gradual loss of shade-intolerant species would be likely.

A large proportion of the future forest, as projected by the LMPs, will very probably be split between areas of even-aged plantations and areas of dense, and increasingly small-diameter stands.

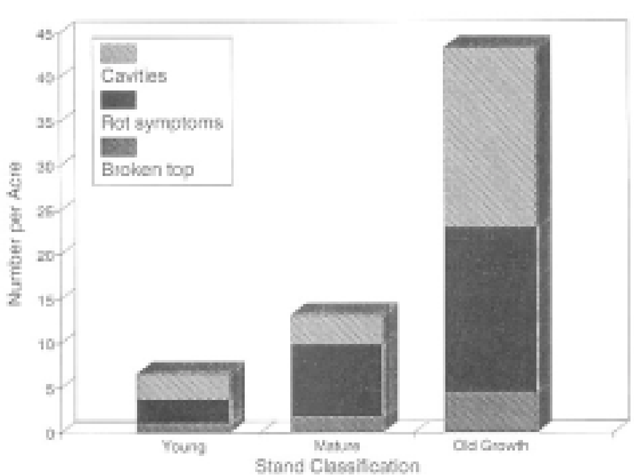

Figure 13G-Increasing decadence as a function of stand age, based on data from Bingham and Sawyer (1992).

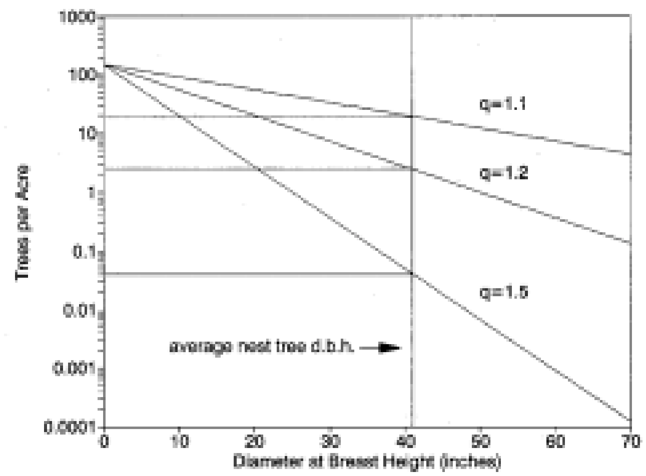

Figure 13H-Theoretical, uneven-aged distributions. Uneven-aged management allows for retention of very large trees. "Q" values of 1.2--similar to those measured in owl nest stands---will leave two to three trees per acre 40 inches in diameter at breast height on a site.

A Different Paradigm

Two important questions that the FS needs to answer are: (1) What kind of forest structures does it want to create and perpetuate? (2) Are the life history requirements of spotted owls and other species associated with late-seral forest conditions met by those forest structures? Fundamental to these questions is the paradigm that guides NF timber management. Insights to this paradigm can be gained by studying the LMPs produced by the Sierran NFs. The LMPs are as much statements of goals, priorities, and paradigms as they are implementation strategies. The scheduling appendix for timber removal on Stanislaus NF, for example, states these goals clearly:

> *A regulated forest should be regarded as an objective that may never be fully attained... However, the concept of regulation as an objective, is the tool used to control present harvest levels and plan future harvests to assure sustained yield within reasonable limits.*
>
> *A forest consisting of wild and unmanaged stands with highly variable stocking levels and age-class distribution is made to approach regulation through harvest and scheduling regeneration over a period of time called the conversion period. During the conversion period an attempt is made to meet three criteria:*
>
> 1. *Obtain the maximum yield of timber possible.*
> 2. *Provide for essentially a non fluctuating yield over the conversion period.*

3. *Provide a balance of age-classes and stocking levels capable of producing the forest's full potential timber growth at the end of the conversion period* (USDA, FS 1991b, appendix D, D-3).

This description closely follows the ideal of the "fully regulated forest" as it is presented in forest management text books (for example, Davis and Johnson 1987, chapter 14). By this definition, the regulated forest differs in fundamental ways from a wild forest, and the current status of the forest is seen as being in a conversion period in which wild stands are brought into regulated conditions through harvest and regeneration. Really only one general template is used to define a fully regulated forest-the diameter distribution, forest wide, should fit an "inverse J" distribution form, with optimized spacing (Husch et al. 1982). This pattern can be achieved through a series of large blocks (even-aged clearcutting), blocks smaller than 2 acres (group selection), or on an individual tree basis (individual-tree selection). All three models are generic, derived from European forestry in the late 1800s (Davis and Johnson 1987) and used for timber production in Europe, New Zealand--and in the Sierra Nevada. The purpose of the classic, fully regulated forest, in any of its permutations, is to allow for an even flow of wood products, not necessarily to mimic natural stand conditions and processes:

> *The essential requirements of a fully regulated forest are that age and size classes be represented in such proportion and be consistently growing at such rates that an approximately equal annual or periodic yield of products of desired sizes and quality may be obtained in perpetuity. A progression of size and age classes must exist such that an approximately equal volume and size of harvestable trees are regularly available for cutting* (Davis and Johnson 1987, p. 540).

Most other LMPs share a single emphasis concerning their paradigm for timber management. No certainty exists that ecosystem processes, whether they are the population dynamics of a single species or the successional trends of a multi-species complex, will be maintained in a fully regulated forest. The concept of forest regulation has traditionally not been defined in these terms, and the long-term ecological consequences of the paradigm are unknown.

Recent discussion has concerned a significant shift in the basic forestry paradigm, from one that stresses the production of commodities (or amenities) to one in which the maintenance of ecosystem processes is the primary goal (National Research Council 1990). This new paradigm "...involves a shift in management focus from sustaining yields of competing resource outputs to sustaining ecosystems" (Kessler et al. 1992, p. 221). Toward this objective, the goal of management activities is to maintain, protect, and, where necessary, to create natural forest structures. Logging is practiced only to the extent and in a manner that it does not impair ecological processes or environmental assets. This system does not guarantee an even flow of wood products from the forests. The efficacy of silvicultural practices is evaluated by biological rather than market-based criteria.

Under this paradigm, logging would be explicitly designed to achieve or maintain ecological goals. These goals might, for instance, include remedial actions such as the generation, within a topographically defined unit such as a drainage basin, of a pattern of stand structures that mimic historical stand conditions. Because those structures were very different from the stands that presently exist, much manipulation of vegetation will need to occur before the goal is achieved-and active management will subsequently be needed to maintain it. A great deal of sophisticated silviculture will be required. What represents a major paradigm shift is that the silviculture will not be constrained by the equal volume/equal entry area requirements that are definitional to the concept of the fully regulated forest. This is not to say that forest regulation and a sustainable yield of forest products are necessarily incompatible with ecosystem functioning. Rather, it is a question of priorities: The new paradigm "...would involve a view of forest lands-including soils, plants, animals, minerals, climate, water, topography, and all of the ecological processes that link them together-as living systems that have *importance beyond traditional commodity and amenity uses"* (authors' emphasis) (Kessler et al. 1992, p. 222).

Under this paradigm, the answer to the first question (the type of forests we want) is that we wish to create forests in which natural processes are fully functional and stable. The answer to the second question (how spotted owls fit into this structure) is the subject of the remainder of this chapter.

Current Stand Structures at Spotted Owl Nests

Nest stands have definable properties-high canopy closure, a considerable snag component, and the presence of large, old trees that are used by the owls for nest sites. To generate and maintain these stand structures we need to be more specific. Data on the silvicultural characteristics of owl nest stands is, however, surprisingly sparse.

To evaluate the diameter distributions of owl nest stands, we obtained diameter distributions for areas immediately adjacent to 24 nest trees in the mixed-conifer zone of Lassen NF and 11 nest trees in the Sierra NF. These data were based on plots

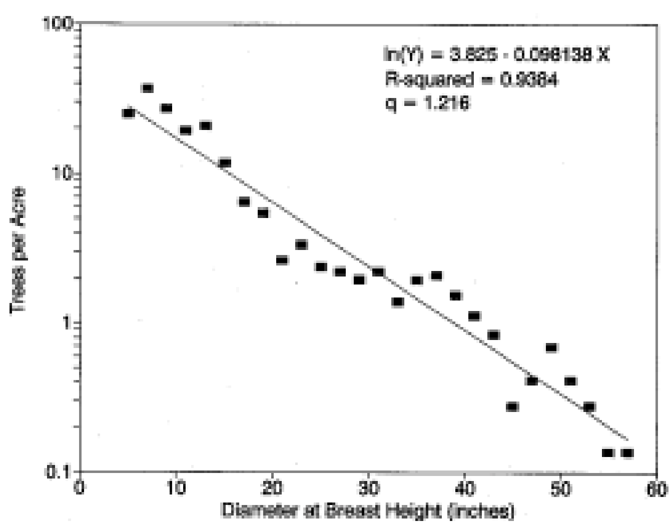

Figure 13I-Log-linear display of the mean number of trees/diameter class, based on 24 nest sites in the Lassen National Forest.

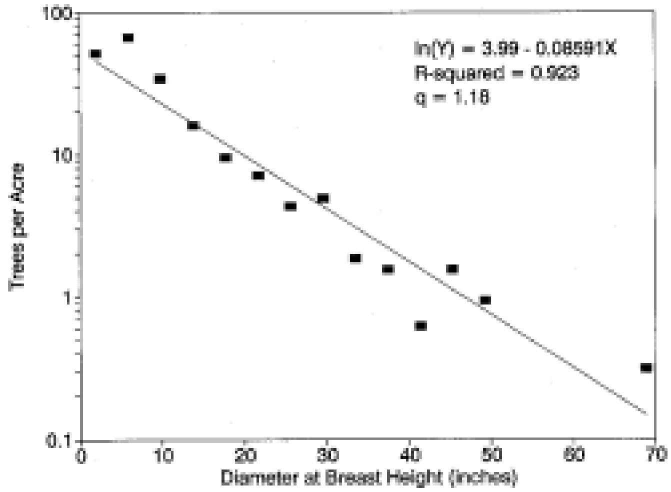

Figure 13J-Log-linear display of the mean number of trees/diameter class, based on 11 nest sites in the Sierra National Forest.

centered on the nest tree and forming a cross with the nest tree at the center. All trees 15.7 inches in d.b.h. were sampled within an area of 0.296 acre. Smaller trees were sampled within four subplots 32.8 feet square. To avoid any possible bias by the inclusion of a large, central tree, the nest tree itself was excluded from density calculations. When the natural log (In) of the mean tree density (stems/acre) for the combined plots in these two areas was regressed on d.b.h., the resulting pattern was linear (figs. 13I and 13J), suggesting a classic "inverse J" form-the idealized distribution for uneven-aged management-with a "q" value between 1.18 and 1.21 [here q is based on 2-inch d.b.h. groups (Daniel et al. 1979)]. This pattern, by itself, is not sufficient to suggest that uneven-aged management is warranted. Stands with differing structures will tend to conform to the inverse J when they are combined. Viewed individually, nest stands in Lassen NF formed three logical groups (figs. 13K and 13L). Eight of the stands lacked the larger diameter classes and conformed closely to the log-linear model. Thirteen of the stands

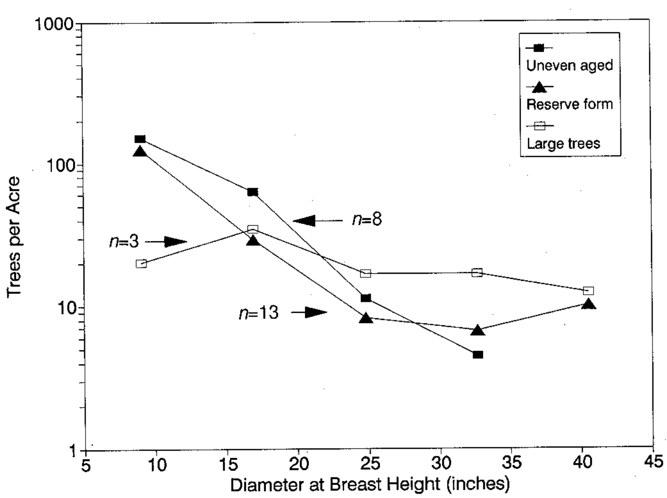

Figure 13K-Nest sites on the Lassen National Forest divided into logical groupings based on stand structure. Data presented are the mean values for each group. The groups consisted of 8, 13, and 3 sites, respectively.

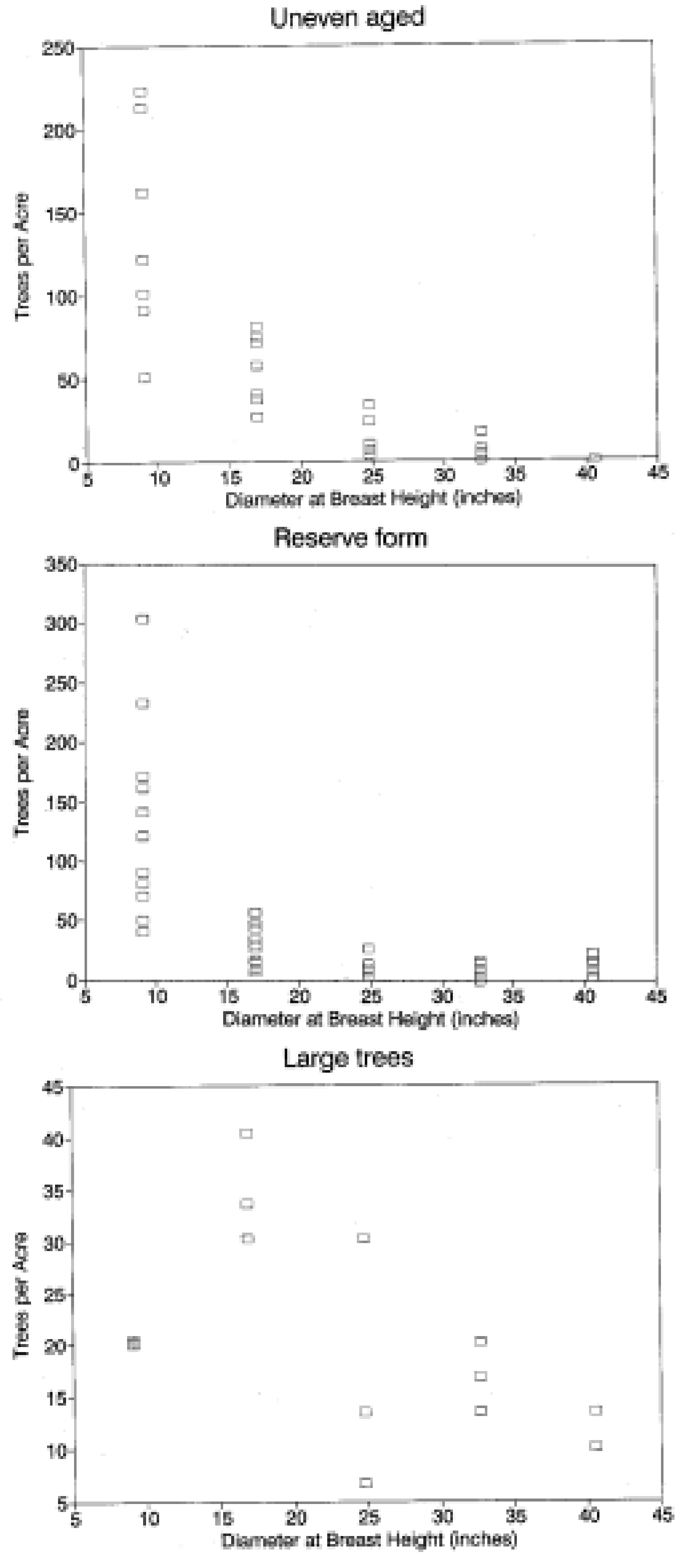

Figure 13L-Diameter distributions for the three types of nest stands measured in the Lassen National Forest. Both the "reserve form" and the "large trees" groups had more large-diameter stems than an idealized, uneven-aged stand structure would specify.

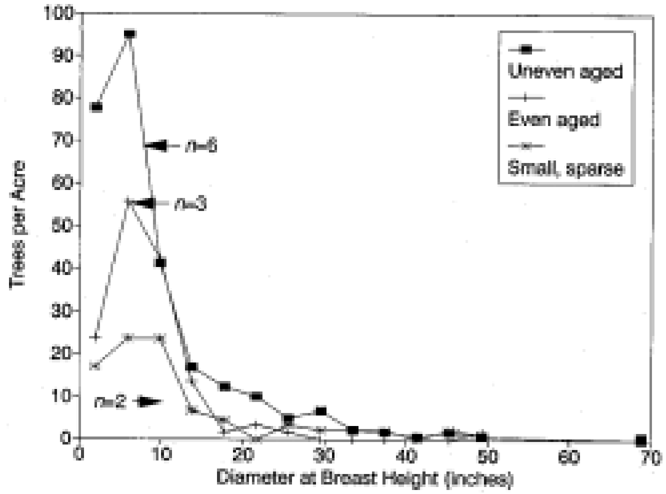

Figure 13M-Nest stand structures in the Sierra National Forest. None of these stands had a large proportion of large-diameter stems, and several were dominated by small-diameter trees,

generally conformed to the uneven-aged structure in the smaller diameter classes, but not in the large diameter classes. Three stands had most of their trees in the larger diameter classes. Nest stands on the Sierra NF also grouped logically into three classes (fig. 13M). Six of them generally fit an uneven-aged distribution form, but the others did not. Stands at two of the sites were made up primarily of stems <12 inches in d.b.h..

Most of these stand structures could be produced through a variety of management methods. Partial removal of the over story in the past and subsequent ingrowth probably led to the formation of many of these stands. We have no reason to believe that uneven-aged management, if properly applied, could not be used to maintain these structures-but the system should be sensitive to maintaining the large trees, and perhaps modified to generate "reserve form" stands. Reserve form stands are charac terized by an inverse "J" distribution in the smaller diameter classes and a normal distribution in the larger diameter classes. In all stands lacking frequent large stems, at least one large tree was present the nest tree, which was not included in the calculations.

The simple premise that forest structures similar to owl habitat can probably be created and maintained through silvicul-ture does not answer a fundamental question. In the long run, are these the types of stands we wish to maintain? We have many reasons to doubt whether these stand types represent either a necessary or ideal template as an owl nest site. Perhaps the most important reason is that dense stands characterized by single tree-sized openings would have been unusual in mixed-conifer forests before the turn of this century. Dense stands would have existed, particularly in riparian areas and at higher elevations (figs. 13C and 13D), but they would not have been widely distributed across the landscape. A second reason is that these stands are unstable-the stand structure is likely to be altered quickly and unpredictably due to the probability of stand-replacing fires or insect and disease outbreaks. We do not know whether owls inhabited the more open stands that dominated much of the landscape in the past (figs. 13A and 13B). Because such stands are rare today, we are unable to infer anything from current owl locations. We do, however, need to begin to explore potential, alternate stand structures. These structures should be chosen to better mimic natural stands, to maintain tree species diversity, and to be more resilient to wildfires.

Some Potential Management Systems for Mixed-Conifer Ecosystems

General Considerations

A fundamental assumption underlies management of owl habitat, as well as much of forest management in general: Eco-systems are inherently dynamic; they do not stand still. Changes take place both rapidly (through a variety of natural and man-made disturbances) and slowly (through climatic change and natural successional processes), and occur at many spatial and temporal scales. Changes have occurred in the past, and they will occur in the future even if we "do nothing." Given this assumption, management recommendations should consider provision of ad-equate amounts and distribution of suitable owl habitat both in the short-term and in the long-term. For the short-term, Chapter 1 details management recommendations to be applied during an interim period of at least 5 years. These recommendations are intended to provide some degree of protection to existing owl habitat and to maintain future options for whatever long-term management strategy may be adopted at the end of the interim period. Below, we offer an example of one way in which the short-term (interim period) recommendations in Chapter 1 could be implemented in stand types shown to be selected for nesting by the spotted owl. These short-term practices and resulting stand conditions are not designed to be sustainable over long periods, however. The remainder of this section, therefore, of-fers potential silvicultural strategies that might be useful for producing and maintaining owl habitat over the long-term.

An Example of a Short-Term Approach

Recommendations in Chapter 1 set limits for cutting large trees-and managing other stand components. By definition, man-agement practices cannot exceed these limits-for example, cut more large trees than specified-and still conform to the recom-mendations. In some situations, however, management objec-tives may be better achieved by not taking the recommendations to their limits. Following is one example of such an approach to interim management of *"Selected Timber Strata"* (P4G, M4G, M4N, M5G, M5N, M6-codes for timber strata defined in table 1C). (Compare item #1 under "Other Forested Public Lands" in Chapter 1.) Objectives that this example could help to meet include: (1) provide for a shorter recovery period for nesting/

roosting habitat; (2) keep some stocking in middle and lower canopy layers, both to retain existing multiple-canopy character of the stand and to ensure quicker replacement of large trees; (3) provide for some thinning in middle and lower canopy layers to promote growth of trees in these layers into desirable larger size classes; and (4) provide some quantification of fuels management treatments, including reduction of vertical fuel ladders (Chapter 12). Managers should recognize that this example (like any other that places additional constraints) is more restrictive than the basic interim-period recommendations in Chapter 1. Thus, in exchange for the potential benefits indicated above, timber volumes (and associated revenues) will generally be lower, and costs of treating submerchantable stems and other fuels will generally be higher. (Basal area limits and other quantitative data in this example are only approximations. They are not based rigorously on Chapter 5 or any other real data pertaining to owl habitat. If an approach similar to this is to be used, it should be based on the best and most nearly site-specific data available.)

A. Enter a stand for harvesting only once before a long-term strategy for managing the California spotted owl has been implemented on public lands.

B. For stands with a Dunning and Reineke (1933) site index (SI) of ≥60, enter the stand for harvesting only if total basal area of live trees ≥5 inches d.b.h. is greater than 200 square feet per acre. Harvesting will not reduce total basal area to less than 200 square feet per acre or canopy closure to <40 percent. For stands with SI <60, the corresponding basal area limit is 160 square feet per acre. To the extent possible, a mix of tree species should be retained.

C. Remove no live tree ≥30 inches in d.b.h.

D. For stands with SI ≥60, limit cutting in the 21- to 30-inch d.b.h. class so that the combined basal area of live trees in d.b.h classes 21-30 inches and 30+ inches is no less than 120 square feet per acre. A wildlife biologist should be involved in training tree markers to identify potential nest and roost trees in the 21- to 30-inch d.b.h. class so that those trees (including live culls) will be retained as part of the residual basal area. In stands currently having less than 120 square feet per acre basal area in those two size classes, no cutting of trees 21-30 inches d.b.h. will take place. For stands with SI <60, the corresponding basal area limit is 100 square feet per acre.

E. For stands with SI ≥60, limit cutting in the 11- to 20-inch d.b.h. class so as to retain a basal area of at least 60 square feet per acre in that diameter class. In stands currently with basal area <60 square feet per acre in that d.b.h. class, no cutting of trees 11-20 inches d.b.h. will take place. If the stand is entered for harvesting, and if current basal area in the 11- to 20-inch d.b.h. class is >80 square feet per acre, this diameter class will be thinned to a basal area of 60 to 80 square feet per acre. For stands with SI <60, the corresponding range of basal areas would be 40 to 60 square feet per acre.

F. Limit cutting in the 5- to 10-inch d.b.h. class so as to retain a basal area of at least 20 square feet per acre in that diameter class. In stands currently having <20 square feet per acre basal area in that d.b.h. class, no cutting of trees 5-10 inches in d.b.h. will take place. If the stand is entered for harvesting, and if current basal area in the 5- to 10-inch d.b.h. class is >30 square feet per acre, this diameter class will be thinned to a basal area of 20 to 30 square feet per acre. Trees cut in the 5- to 10-inch d.b.h. class will be removed from the stand. Utilization of these trees is encouraged.

G. If the stand is entered for harvesting, and if canopy cover in trees 0-4 inches in d.b.h. is, greater than 20 percent, trees will be felled, crushed, masticated, or otherwise rearranged to reduce canopy cover in that size class to no more than 20 percent. The surface fuel bed resulting from these trees, as well as slash from logging of larger trees, should be treated mechanically or with prescribed fire to reduce wildfire hazard to an acceptable level. The emphasis should be on reducing vertical and horizontal continuity of fuels and associated risk of crown fires, especially in the vicinity of large trees. Fuel treatments and logging activities should be designed to minimize disturbance of duff and coarse woody debris. In most cases this will preclude machine piling of slash. Where prescribed burning is used, it should be done when lower duff and large woody debris have high moisture contents to minimize consumption of these materials.

H. Follow guidelines in Chapter 1 for retention of snags and downed wood.

Some Potential Long-Term Strategies

A full discussion of management activities that may be appropriate to manage for owl habitat over the long-term is beyond the scope of this chapter. Instead, our purpose is to provide a sampling of ideas and considerations to stimulate thinking. Innovative managers and resource specialists may be able to use some of these ideas as a starting point in developing suitable management regimes to fit their local conditions and needs. On public lands, initial (interim period) implementation of the long-term strategies described here would be compatible with recommendations (Chapter 1) for *"Other Timber Strata"* used for nesting by owls but not significantly selected in relation to availability. We encourage managers of private lands to explore these approaches as well. Treatments should be viewed as ongoing management experiments (adaptive management, Chapter 2). Effects of treatments on stand structure and key ecosystem components should be carefully monitored, and owl habitat models should be tested. These experiments would incorporate information from monitoring and research activities into feedback loops that would serve to improve both our management practices and our knowledge of what constitutes suitable owl habitat.

Although the scenarios discussed below describe generalized target stand structures and associated management practices primarily at the stand level, great flexibility exists for distributing variations and combinations of these structures across the landscape and through time. In these scenarios, silviculture would be viewed as the art and science of shaping stands and landscapes to meet management objectives-spotted owl habitat in this case. Timber volume would be an output of, rather than a driving force for, the silviculture undertaken to meet management objectives. Protection of current or future habitat would continue to be a primary concern. Accordingly, appropriate fuels management would be integrated with silvicultural activities.

We focus here on good-quality nesting and roosting habitat for the spotted owl as the "target" conditions for management activities. Foraging habitat appears to be more variable and less restrictive (Chapter 5), and its requirements should be met more easily and with a wider range of management practices. In contrast, successful management to produce, maintain, improve, and protect nesting and roosting habitat may require significant changes from conventional management practices. Some institutional barriers may need to be overcome. It will be more complex and expensive but should provide new and stimulating professional challenges for a variety of specialists to exercise creative thinking and pursue interdisciplinary objectives and activities.

We make several simplifying assumptions about attributes of suitable nesting/roosting habitat (Chapter 5) to help define target stand structures and associated management practices: (1) high canopy closure; (2) stand basal area and canopy closure distributed among two or more size classes of trees; (3) diversity of tree species within the stand; (4) "adequate" numbers of large live trees; (5) "adequate" numbers of large snags; and (6) "adequate" quantities of duff and large woody debris.

Accepting these six assumptions places limits on the range of stand structures that can be targeted by management. Both classical, even-aged silviculture and the classical, single-tree-selection form of uneven-aged silviculture have difficulties in meeting one or more of these assumptions, for reasons discussed below. We believe that two other kinds of stand structures-mosaics of small, even-aged groups or aggregations, and two- or three-storied stands-hold greater promise for producing and maintaining suitable owl habitat over the long-term. We recommend that these two structures, together with their associated silvicultural and fuels management practices, receive emphasis in long-term, adaptive management experiments concerned with owl habitat. Both can be considered intermediate between even- and uneven-aged (single-tree selection) management. But they can be thought of as representing two ends of a continuum,, with many intermediate structures differing in density and spatial arrangement of age/size-classes to help meet various specific objectives and to increase diversity across the landscape. Even- and uneven-aged (single-tree selection) methods should be included in these experiments, but at a reduced level.

Even-Aged Silviculture

The requirement for two or more size-classes of trees (assumption #2 above) probably could be met with even-aged silviculture, but it would involve significant modifications from conventional practice. The natural segregation of crown classes could be emphasized by "thinning from the middle"-that is, thinning in codominant and intermediate trees, thereby promoting the separation of dominant from suppressed crown classes and increasing growth in the dominants. Suppressed trees probably would not survive long enough to be of much value for owl habitat unless stand density were reduced below usual target stocking levels, or the lower canopy level consisted largely of shade-tolerant species. The latter scenario probably would be more practical and sustainable in mixed-species stands.

Assuming that such an approach eventually would meet needs for a two- or more-storied stand, the rotation age necessary to meet tree size and decadence requirements (assumptions #4 and #5) probably would be much longer than called for in currently practiced even-aged management. As compared with alternative silvicultural methods, the rime from plantation establishment to achievement of conditions suitable for owl nesting and roosting is likely to be much longer. This long time period would necessitate development and/or retention of suitable replacement habitat in the interim.

Whatever may be the disadvantages of even-aged silviculture with respect to owl habitat, even-aged plantations in the Sierra Nevada will continue at some level for the foreseeable future, if for no other reason than because severe wildfires will continue to occur. Even-aged plantations, therefore, should be included in owl-related management experiments.

Uneven-Aged Silviculture Using Single-Tree Selection

To meet the need for tree species diversity (assumption #3 above), stand openings must be large enough to permit regeneration of shade-intolerant species such as ponderosa pine. This requirement generally is not met with the single-tree selection form of uneven-aged silviculture, at least where openings are mostly the size of individual large trees rather than groups of trees. Furthermore, retention of the smallest size-classes of trees well distributed through a stand-a necessity for sustaining this stand structure through time-creates dangerous fuel ladders and makes prescribed burning or other fuels management treatments essentially impracticable. As described earlier, many owl nesting stands had roughly an inverse J-shaped diameter distribution characteristic of uneven-aged stands. Composition of the smaller size classes, however, was strongly weighted toward shade-tolerant species, especially white fir. This resulted from many decades of fire suppression, augmented by partial cutting and preferential harvest of pines. In the absence of stand openings by cutting or by natural agents of disturbance such as fire and. insects, these stands will become increasingly dominated by shade-tolerant conifers. Single-tree selection should be included at a reduced level in management experiments to evaluate changes in structural attributes, owl use, managerial difficulty, and costs of implementation. Combining single-tree selection with group selection (discussed below) may work to maintain some vertical structure while permitting regeneration of shade-intolerant species.

Mosaic of Small, Even-Aged Groups

One kind of structure that may have promise for production and long-term maintenance of owl habitat is a multi-aged mosaic of small, even-aged groups or aggregations. Groups would generally range in size from about 2 acres down to a quarter-acre, or possibly less. Probably this type of structure best approximates presettlement stand structures (Chapter 12), thus warranting serious consideration. Openings would be sufficiently large to permit regeneration of shade-intolerant as well as shade-tolerant species. Multiple size classes in general would be separated horizontally rather than vertically, but in sufficient proximity to satisfy this attribute of suitable owl habitat. The horizontal separation of size classes also would confer some degree of resistance to crown fires (Chapter 12).

Group selection cuttings, or modifications thereof, would be used to create and maintain this structure over time. Keeping track of a large number of small openings and groups for management purposes, long considered a major obstacle to the use of group selection, should be significantly easier with the advent of geographic information systems and satellite-based global positioning systems. Treatments certainly would be more complex and more expensive than with even-aged management, however, especially on steeper slopes.

Viewed from the standpoint of area regulation-approximately equal areas maintained in each of several age-classes-a given "stand" of, say, 20-100 acres under steady-state conditions might contain three to six or more different age-classes. Each age-class would comprise many small, variable-sized aggregations and occupy a total area roughly equal to the area of the entire stand divided by the number of age-classes. "Rotation age"-the age at which the oldest aggregations would be regenerated-could be as long as needed to meet and maintain targets for large and/or decadent trees and snags. Periodic entries preceding regeneration cutting for a given age-class could be used to adjust stand structure to meet desired habitat attributes. These intermediate treatments might include thinning to speed development of large trees or to alter species composition, creating snags by girdling or other means, or wounding selected trees to induce decay. In practice, these intermediate treatments would take place within the various age-classes (aggregations) in the stand when the oldest age-class is being regenerated. As an example, if six age-classes and a 240-year "rotation" were selected, entries could be made every 40 years to regenerate one-sixth of the stand and conduct appropriate intermediate cuttings in the remainder of the stand. Or 20-year entries could be made, but regeneration cuttings would be made only every other entry. Successive age-classes would be separated by about 40 years.

In groups to be regenerated, all trees could be removed or, especially in larger groups, scattered live trees and/or snags could be retained. To facilitate fuels treatment and reduce damage to the surrounding stand, cut trees should be felled as much as possible into the newly created opening. Site preparation/fuels treatment methods used on clearcuts should be usable in these small openings, although they are likely to be much more expensive. One promising possibility may be jackpot burning of slash concentrations in the opening at a time of year when fire would not spread into the adjacent stand, thereby minimizing the need for firelines. Shortly thereafter, the rest of the stand could be underburned during somewhat drier conditions. Alternatively, the rest of the stand could be underburned at the same time as the openings. Local trials would help define a workable regime. In any case, we recommend that fuels be treated after each entry into the stand to reduce chances of severe wildfire. Various fuels-treatment methods may be appropriate for a given area. Prescribed underburning, however, has the advantage that it would begin to restore the natural role of fire and associated processes in the ecosystem (Chapter 12). In the scenario described earlier, with successive age-classes separated by 40 years, the youngest (40-year-old) trees probably would be large enough to tolerate an underburn without excessive mortality, assuming early vegetation management to permit relatively rapid early growth.

Openings could be regenerated either naturally or artificially, and with or without vegetation management. Even with planting and vegetation management, growth of tree seedlings would be slower in an opening typical of group selection than in a larger opening because of competition for site resources from large trees surrounding the opening. Without planting and some control of nonconifer vegetation, however, development of conifers could be delayed for several decades. Fuels treatment would be complicated as well.

Development of a mosaic of small groups could be initiated in a wide range of stand conditions-for example, an older plantation, a variable-aged young-mature stand, or an old stand becoming excessively unbalanced in terms of size-class distribution or species composition.

Two- or Three-Storied Stands

Another kind of structure that might be suitable for production and maintenance of owl habitat is a two- or three-storied stand. It differs from the even-aged aggregation structure in that each age/size-class would be more or less uniformly distributed throughout the stand (although many variations in spatial arrangement would be possible). In a two-storied stand, the upper canopy would be sufficiently open to permit regeneration of shade-intolerant species in the understory. If a third canopy layer were to be managed, both of the upper two canopy layers would need to be thinned enough to allow regeneration and growth of multiple species. Typically, this kind of structure would be initiated with a shelterwood cutting. After regeneration is established, the overstory would be retained indefinitely-a practice referred to as irregular shelterwood-instead of being removed as occurs with even-aged management. Understocked stands, traditionally a high priority for clearcutting, could instead be underplanted, leaving most of the overstory in place. An overstory infected with dwarf mistletoe could be underplanted with species other than the one(s) infected.

If desired, this kind of structure could be initiated relatively early in the life of a plantation by having a heavy commercial thinning double as a shelterwood-type regeneration cutting. The cut would be followed by site preparation/fuels treatment and underplanting with the desired mix of species. Throughout the "rotation" of such a stand, thinnings could be applied as needed to maintain desired size classes and species. These should be followed by prescribed burning or other fuels treatments. Snags could be created as needed. Once created, the stand would never be devoid of large trees: each regeneration cutting would be accompanied by retention of some trees in one or two overstory layers. Thus a relatively short period of time would elapse between a regeneration cutting and restoration of a desired stand structure.

Fuels treatments, including use of prescribed burning, should not be particularly difficult for a two-storied stand. Initial site preparation/fuels treatment before establishment of the understory would be the same as for a shelterwood cut. Subsequent treatments would be comparable to those for an even-aged plantation. Separation of canopy layers normally would be sufficient to keep wildfires out of overstory crowns. A three-storied stand could be somewhat more problematical, in terms of maintaining adequate stocking of shade-intolerant species, protecting the small understory during fuels treatments, and keeping wildfires out of the overstory. In all these respects, a three-storied stand would begin to approach conditions in a single-tree selection stand.

Conclusions

We believe that the dynamic trends in forest structure and fuels profiles that are occurring on NFs in the Sierra Nevada are cause for concern. The most troubling aspects are the loss of old, large-diameter trees and associated woody debris, a shift toward more shade-tolerant species, the buildup of fuels associated with mortality in the small diameter classes, and the continued presence of abundant ladder fuels that enable crown fires to occur. We do not believe the management directions elucidated in the current LMPs alleviate these trends; in fact, single-tree selection systems are likely to accelerate them. Even-aged systems can reduce fuel loadings and encourage the growth of shade-intolerant species, but they do so at the expense of the remnant large trees. We believe that other options exist that could deal directly with these concerns. Management plans should focus on addressing undesirable trends, designing potential solutions, and proceeding experimentally to implement those plans on the landscape.

Owl habitat can be described in terms that are compatible with silvicultural methods. In this chapter we have presented preliminary examples of how this process might proceed. The FS can easily gather basic stand-level statistics from known owl nest stands throughout the range of the California spotted owl. To date, most of the data collected are either very coarse (for example, at the timber strata level) or based on ocular estimation and, therefore, are not as reliable as we would like.

Looking to longer-term solutions, we need to begin changing the forest structure back to a form more akin to historical patterns: to generate fire-resistant structures with small-scale horizontal heterogeneity and a significant large-tree component. The silvicultural systems suggested here provide for the maintenance of large trees and complex stand structures, while significantly decreasing the risk of catastrophic wildfire. Through management experiments, we need to ascertain which, if any, of these stand structures may also be suitable for spotted owls.

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