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Developing and Managing Sustainable Forest Ecosystems for Spotted Owls in the Sierra Nevada

Jared Verner and Kevin S. McKelvey

Abstract

Studies of the California spotted owl have revealed significant selection for habitats with large, old trees; relatively high basal areas of snags; and relatively high biomass in large, downed logs. Based on planning documents for national forests in the Sierra Nevada, we projected declining amounts of older-forest attributes. Region 5 has adopted measures to retain these attributes, generally distributed throughout the conifer zone, for an interim period. We believe that a long-term strategy for the owls, and for other species associated with older forests, must retain some level of these attributes that otherwise can take over a century to develop after regeneration harvests.

Introduction

A recent assessment of the status of the California spotted owl (scientific names are given in the Appendix) demonstrated the importance of retaining some levels of older-forest attributes in conifer forests of the Sierra Nevada to maintain a viable population of the owls there (Verner and others 1992b. Based on this information, guidelines are presently in place for national forests (NF's) in the Sierra Nevada to maintain future options for the owl for an interim period. The intent during this interim is to focus research oil obtaining a more detailed characterization of suitable habitat for the owls and to obtain more certain estimates of population trends. Our objectives in this paper are to summarize those aspects of the owl's ecology that relate to older-forest attributes, to discuss those attributes in terms of past and present forest management, and to provide some thoughts about future directions for managing NF's in the Sierra Nevada.

Chief Research Wildlife Biologist anal Project Leader, USDA Forest Service, Pacific Southwest. Research Station, Fresno, CA; and Research Forester, USDA Forest Service, Pacific Southwest Research Station, Arcata, CA (respectively).

The California Spotted Owl

General Biology

Spotted owls in Sierran conifer forests use home ranges on the order of thousands of acres. For example, home ranges of eight pairs during the breeding period in mixed-conifer forests in the southern Sierra Nevada averaged 3,420 acres (SD = 858) (Zabel and others 1992a). Above about 4,000 feet elevation in the northern and 4,500 feet in the southern Sierra Nevada, northern flying squirrels are the owl's predominant prey. Gophers are also important, with a variety of other small mammals, a few bird species, and even some insects being taken (Verner and others 1992a). Dusky-footed woodrats dominate the diets of the owls at lower elevations, with a cutoff probably between 4,000 and 4,500 feet in elevation, depending on latitude. Courtship and nest-site selection generally begin in late February or early March and many pairs are still feeding fledglings by mid- to late September. Clutch size ranges from one to three eggs, but nearly all clutches contain two. In a given year, almost none to almost all territorial pairs may nest; owl biologists consider it a "good year" when at least half of the pairs nest. Studies of radio-tagged spotted owls in the Sierra Nevada indicate that about 45 percent of the birds with summer home ranges in conifer forests migrate to lower-elevation oak-pine woodlands for the winter (Verner and others 1992a).

Habitat Relations

This section summarizes available evidence on the structure and composition of suitable habitat for spotted owls in Sierran conifer forests. Ninety-one percent of all known sites of California spotted owls are in the Sierra Nevada, and 81.5 percent of those are in mixed-conifer forests. The remainder occur in red fir (9.7 percent), ponderosa pine/hardwood (6.7 percent), foothill riparian/hardwood (1.6 percent), and eastside pine forests (0.5 percent). (An "owl site" is defined as an area with unspecified dimensions where a single owl or a pair of owls has been located, usually repeatedly.)

Major studies have investigated habitat relations of the owls in four general areas from throughout the length of the Sierra Nevada. From north to south, study areas were in (1) the Lassen NF (Zabel and others 1992a): This study area was primarily at high elevations (5,500 to 7,200 feet) in forests of red and white-fir, and secondarily in some lower-elevation habitats dominated by pines and mixed-conifer forests. The area was a mosaic of partial retention cuts, clearcuts and uncut stands (old-growth). (2) the Tahoe NF (Call 1990): This study area was primarily in mid-elevation mixed-conifer forest at 2,200-5,200 feet. The past history of logging there created a diverse mosaic of different stand ages, types, and densities. (3) the Eldorado NF (Laymon 1988, Bias 1989, Lutz 1992): This extended from low- and mid-elevation mixed-conifer forest to higher-elevation fir forest (1,000-7,400 feet). Logging activity there was strongly influenced by ownership patterns. About 44 percent of the land was in private industrial forests occupying alternate sections in a "checkerboard" pattern with Federal lands (Bias and Gutiérrez 1992). (4) the Sierra NF (Verner and others 1991): This study area included two distinct habitat types-one dominated by mixed-conifer forest at elevations from about 4,500 to 7,500 feet, the other dominated by hardwoods in oak-pine woodlands and relatively dense riparian /hardwood forests at elevations from about 1,000 to 3,500 feet. Results from only the conifer portion of the study area are included in this report.

Extensive and intensive analyses of results from these studies revealed consistent, and often statistically significant, selection in relation to several habitat attributes (Gutiérrez and others 1992; Verner and others 1992c; Zabel and others 1992a, 1992b). Most nest sites were selected in dense stands (at least 70 percent canopy cover) of mixed-conifer forest, and more than half were in stands with average quadratic-mean diameters of canopy trees >24 inches in diameter at breast height (d.b.h.) Results of identical analyses in roost stands produced parallel results. Nest and roost stands showed consistent, often significant differences from random locations in the forest in having higher canopy cover, greater snag basal area, greater total basal area of live trees, and greater softwood basal area. Mean values for canopy cover ranged from about 75 to 96 percent in the different studies, and 80 percent of all nest trees were in stands with at least 70 percent canopy cover. The studies in nesting and roosting stands suggested a range for total basal area of live trees from 185 to 350 square feet per acre, and basal area of large snags (>15 inches in d.b.h. and >20 feet tall) from 19 to 31 square. feet per acre, and a range of 10 to 30 tons per acre of relatively large downed woody material (at least 11 inches in diameter).

Many of these parameters varied considerably, and not all measures of habitat used by spotted owls and at random locations differed significantly within a given study. The data were, however, consistent and mutually supportive among all studies. California spotted owls in these several studies selected nest and roost stands that were denser than average, that contained a large-tree component, that included more large snags than random sites, and that had considerable biomass of relatively large downed wood. We know of no studies that contradict these findings.

Results of similar analyses at foraging locations indicated that the owls foraged in stands characteristic of nest and roost sites, as well as in a wide variety of other habitats having lower canopy cover and a greater range of tree sizes and ages. Nonetheless, in comparison with random locations within the forest, owls tended to forage in sites with higher canopy closure; greater basal areas of live softwoods and of live softwoods and hardwoods combined; greater basal area of snags; and more dead-and-downed wood. In general, they foraged in forests of intermediate to old age, typically with >40 percent canopy closure.

Data from 124 nests in Sierran conifer forests provided the most conclusive evidence of selection for very large, old trees by the owls. Nest trees averages about 96 feet in height and 45 inches in d.b.h.; canopy cover in the nest stands averaged about 75 percent (table 1). The diameters of nest trees were significantly greater than the average tree in today's conifer forest (fig. 1). Only 2.3 percent of trees ≥10 inches in d.b.h. in the Tahoe NF's M4G stands were ≥40 inches in d.b.h., compared to 64.5 percent of the nest trees in Sierran conifer forests that were that large. Similarly, 89.5 percent of trees in the M4G stands that were ≥10 inches in d.b.h. were <30 inches in d.b.h., but only 13.1 percent of the nest trees were that small. It is important to note that this comparison should reduce the likelihood of detecting spurious patterns of selection

Table 1-Nest stand and nest tree characteristics of California spotted owls in Sierran conifer forests (based on Gutiérrez and others 1992)

	Northern Sierra Nevada	Southern Sierra Nevada
Number of nests	83	41
Nest trees:		
Number in conifers	79	29
Number in hardwoods	4	12
Number living	61	29
Number (lead	22	12
Mean elevation (in feet, ± SD)	5,284 ± 922 *n* = 65	5,750 ± 1,355 *n* = 41
Mean canopy cover of nest stand (percent ± SD)	75.4 ± 17.2 *n* = 28	75.5 ± 27.4 *n* = 17
Mean diameter at breast breast height (inches ± SD)	43.5 ± 14.7 *n* = 81	46.7 ± 19.6 *n* = 41
Mean height (feet ± SD)	96.8 ± 36.7 *n* = 75	95.0 ± 52.7 *n* = 40
Nest types:		
Cavities	55	27
Broken-tops	9	4
Mistletoe platforms[a]	4	2
Other platforms[b]	15	2

[a] Platform developed on top or a dwarf mistletoe broom.
[b] For example, a platform atop an old hawk nest, or one created by accumulated debris in the fork of a tree with two or more leaders.

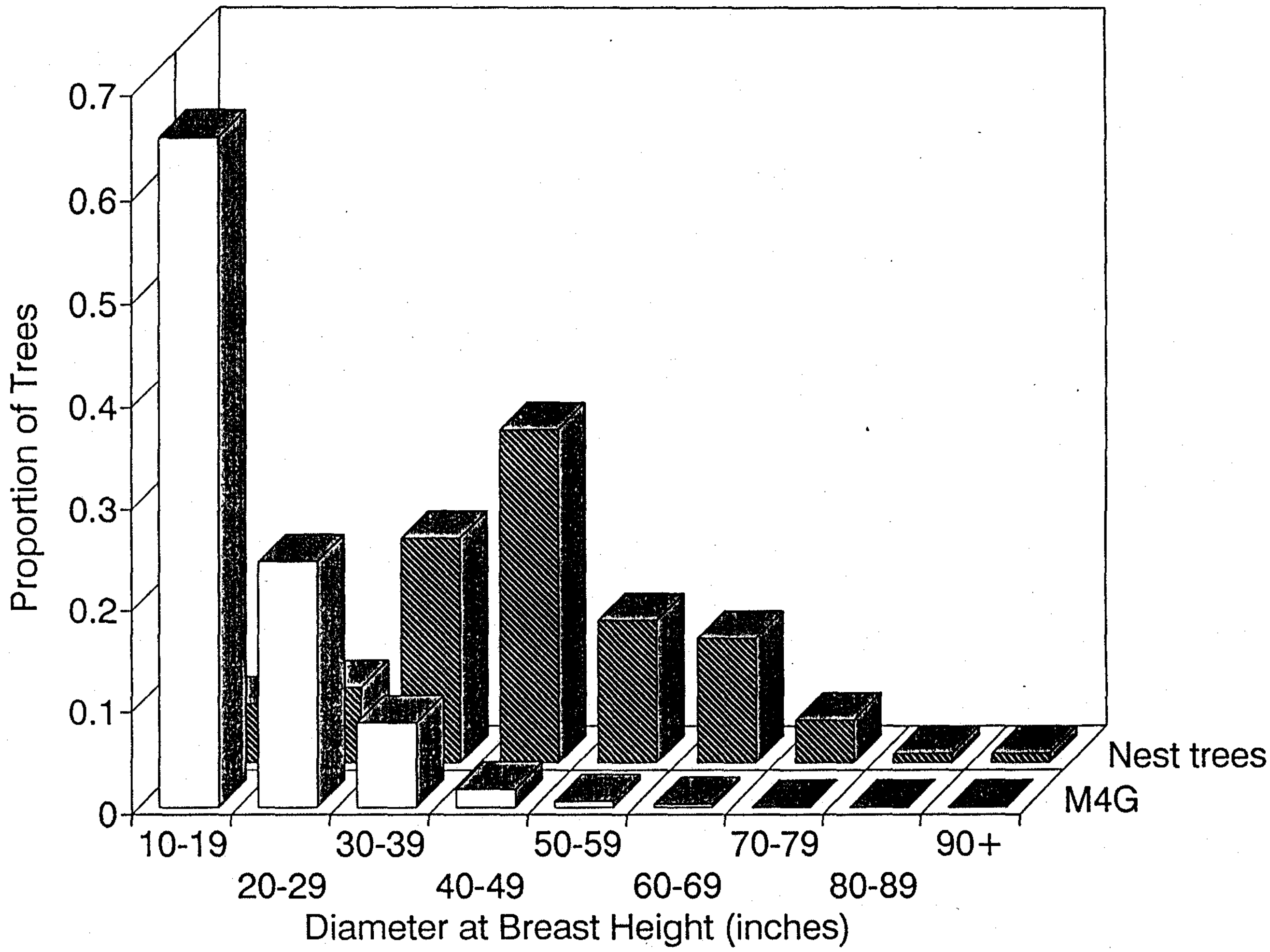

Figure 1-A comparison of the diameter distributions of nest trees used by California spotted owls in conifer forests of the Sierra Nevada and of all trees ≥10 inches in d.b.h. as measured in M4G stands (nixed-conifer, overstory canopy dominated by trees ≥24 inches in d.b.h., and canopy cover ≥70 percent) on the Tahoe National Forest.

for large trees, because the comparison is based on tree sizes only in M4G stands. These are stands of mixed-conifer forest with the canopy dominated by stems ≥24 inches in d.b.h., and canopy cover ≥70 percent-they have a higher density of large trees than most other timber strata. Data from industrial timberlands are consistent with these findings (unpublished document by Robert J. Taylor, 1992, entitled "California spotted owls on industrial forests," California Forestry Association, Sacramento, CA). No data from any study support a contradictory view for conifer forests in the Sierra Nevada.

A prevalence in these forests of cavity nests (66 percent), nests on broken-topped trees (10 percent), and nests on mistletoe brooms (5 percent) (Gutiérrez and others 1992, table 5I) showed that most nest trees were not only large but also old and decadent. Age data presented in Gutiérrez and others (1992, table 5M), collected in the San Bernardino Mountains in southern California, suggested nest tree ages generally ranging upward from 200 years. We lack data to directly age nest trees used by spotted owls in the Sierra Nevada. To obtain age estimates for these trees on the seven westside NF's in the Sierra Nevada, we analyzed the inventory data that provide the basis for size, age, and growth rates of the various timber strata. Timber strata were included in the analysis if they were westside types. The large-tree grouping in the inventory data included trees ≥39 inches in d.b.h.; we used these data to compare with nest trees ≥40 inches in d.b.h. Any negative bias in age estimates that may have resulted from this is probably too small to be of consequence.

Data from 86 strata were available from the Lassen, Plumas, Tahoe, Eldorado, Stanislaus, Sierra, and Sequoia NFs. Based on inventory protocols, ages of

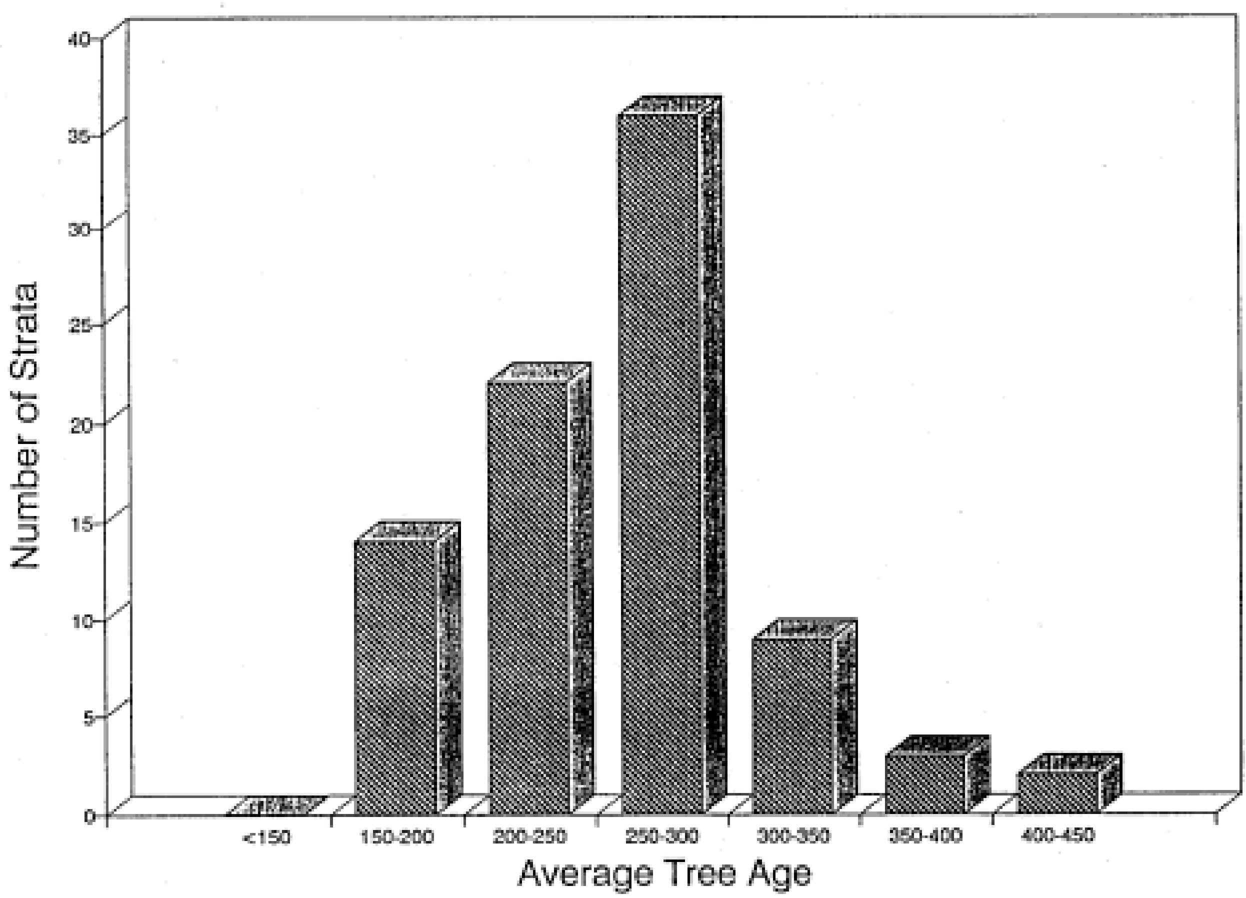

Figure 2--Distribution of the mean ages of trees ≥39 inches in d.b.h. in a sample of timber strata from westside national forests in the Sierra Nevada (*n* = 86).

relatively few trees were measured in each stratum. Because trees in this diameter class are relatively rare, much of the variability in sample estimates may he due to small sample sizes. Nevertheless, only 16 percent of the strata sampled had average ages of <200 years for trees ≥39 inches in d.b.h. The mean ages of trees in this size class in these strata ranged from 156.8 to 438.0 years, with an overall average age of 258.1 years. Most strata-level age estimates averaged between 250 and 300 years (fig. 2). Age estimates for the strata important for nesting by spotted owls were consistent with this finding. We believe: the data justify a conservative assessment that the majority of nest trees used by spotted owls in Sierran conifer forests were at least 200 years old.

Result of this and the several other studies of habitat attributes important to the owl consistently highlight the importance of very large, decadent trees. These trees are important not only in providing nest sites, but also in providing the snags that later fall, to become decaying logs that enrich the forest floor. From a silvicultural standpoint, to reliably maintain a supply of these trees in the landscape requires either maintaining older trees or more quickly producing trees that have old-tree attributes. This means more than just quickly generating large-diameter trees (although this is a starting point). The trees must have structural characteristics similar to current nest trees. Most of the cavities used by spotted owls are created naturally, where large branches pull out as a result of heart rot, leaving large-diameter holes. Clearly, then, important features of these trees include flattened crowns (broken tops and platforms) and large limbs, as well as the presence of rot in the upper stem.

Physiologically, we are looking at manipulating the shift, front excurrent, (obvious central stem, single leader) to decurrent (multiple leaders without an obvious central stem) growth-a shift in conifers that is linked to tree age and site quality (Daniel and others 1979, p. 121). We also need to explore the dynamics of rot and determine whether heart-rot

Figure 3-Nest tree with adult and two fledglings; the cavity above the birds, in the main stem to the right, may have housed the nest, at least 60 feet above the ground. The tree was a sugar pine at an elevation of 7,000 feet on the Tahoe National Forest. (photo by John S. Senser, 26 June 1991).

patterns generally associated with older trees can be encouraged through cultural techniques. An approach would be to consider attributes of current nest trees (e.g., fig. 3) and test various options that might generate trees with the same appearance and rot, characteristics more quickly through silvicultural manipulation. For example, Hall and Thomas (1979, p. 139) suggested that old-growth conditions in the Blue Mountains of Oregon and Washington could be produced through stand manipulation if the rotation were extended to 240 years. Their silvicultural prescription included thinning during early stages of stand development, and counted on logging damage to encourage the formation of heart rot in the stand. Until tested, however, the possible outcomes of this prescription remain uncertain. Logging damage, for instance, may produce root, rot rather than the desired heart rot.

If we cannot generate old-tree structures in younger trees, we will be left with the only other possibility-to retain significant old-tree components within the stands. In any case, this is the only reasonable approach in the near-term. This logic is at the heart of the recommendations in the "CASPO Report," (Verner and others 1992c), summarized below in the section entitled "Interim Guidelines."

In spite of the extensive amount of information available on the habitats selected by the owl for nesting, roosting, and foraging, we still lack the needed information to characterize the structure and composition of habitats that will assure persistence of spotted owl populations in the Sierra Nevada. This is the case for at least three reasons: (1) the habitats used by the owls are structurally and floristically very heterogeneous, and they have been degraded by human activities over the past century; (2) the studies have not been underway long enough; and (3) nearly all data on owl habitats in Sierran forests were obtained during a prolonged and severe drought in California. Nesting by the owls tended to be sporadic during the study period, and fewer than 20 percent of pairs under study nested in some years. Because not all pairs nest in all years, they need to he studied over relatively long periods to determine whether their reproductive output is sufficient to sustain a regional population. Existing demographic studies have not been underway long enough to make this determination with any degree of certainty.

Status of the California Spotted Owl Population in the Sierra Nevada

The most recent assessment of the status of the owl's population in the Sierra Nevada (Noon and others 1992) failed to reject the null hypothesis that the population was stable or increasing. Demographic studies had been underway in four locations--Lassen NF (2 years), Eldorado NF (6 years), Sierra NF (2 years), and Sequoia/Kings Canyon National Parks (NP's) (4 years). Based on detailed knowledge of the histories of color-banded owls, researchers estimated age-specific rates of reproduction and mortality, and identified all cases in which owls disappeared from territories and were replaced (or not) by other owls.

Owl banding had been underway long enough to estimate population trends in only two study areas-Eldorado NF and Sequoia/Kings Canyon NP's. The estimates suggested about a 5 percent annual rate of population decline (alpha = 0.05; P = 0.1271) from 1986 through 1991 in the Eldorado NF population, and about a 3 percent annual rate of population decline (alpha = 0.05, P = 0.2709) in the Sequoia/Kings Canyon NP's population from 1988 through 1991. These estimates were not significantly <1.0, so we cannot conclude that the populations were declining. Each test, however, had a power of only 0.30 to detect a real decline of 5 percent per year. This means that, even if the populations actually had that rate of decline, it would not be detected 70 times in every 100 studies of equivalent size. The low power resulted from a relatively small number of marked birds, and the large standard errors of parameter estimates (Noon and others 1992). The correct inferences to draw from these results are that we cannot be certain about the true trends of these populations during the periods of study.

If the quality of owl habitat has undergone a gradual decline in the Sierra Nevada, the effects may be subtle and difficult to detect. Because we lack adequate, historical inventories of Sierran owls, we have nothing to compare with present inventories. The current distribution and abundance of the owls, however, suggest no decline in their overall distribution in the Sierra Nevada, but it is less clear whether any decline in abundance has occurred within any forest type. Relatively few large areas exist that leave sufficiently low densities of owls to engender some concern. The observed (nonsignificant) declines in the Eldorado and Sequoia/Kings Canyon populations may have reflected the fact that both studies were done coincident with the severe and prolonged drought in California. These studies are continuing in an effort to determine the true trends of the populations.

Sierran Forests-Past, Present, and Future

The Past

Sierran forests prior to European settlement of the west were characterized by extensive canopies dominated by large trees, relatively open understories with only occasional fuel ladders, and probably relatively little surface fuel (figs. 4 and 5). This condition has been markedly changed

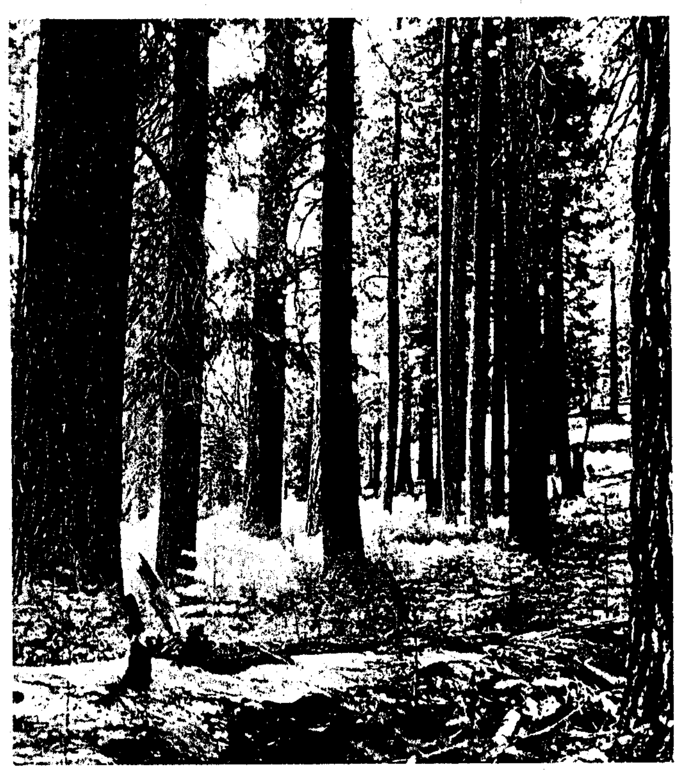

Figure 4-A virgin forest near Strawberry, on the Stanislaus National Forest. Conifers in this stand included sugar pine, ponderosa pine, true fir, and incense-cedar (USDA Forest Service file photo, 1920).

Figure 5-A stand of old-growth Jeffrey pines on the Lassen National Forest (USDA Forest Service file photo, about 1920).

in various ways by human activities, however, especially during the past, 150 years (McKelvey and Johnston 1992). Major impacts resulted from grazing by a million or more sheep from the early 1860's through the first decade or so of this century; peak numbers occurred in the 1870's. Extensive early logging took place coincident with sheep grazing, primarily at low elevations near towns, mines, and along transportation corridors. Timber production reached a peak about 1950 (McKelvey and Johnston 1992, figure 11T), dropping some from that level but remaining relatively high in most years since. Fire suppression began in the early part of this century and became increasingly aggressive as time passed.

The coincidence of at least four factors, early in this century, resulted in a major pulse of regeneration (fig. 6). These were (1) "churning" of the soil by sheep, and later removal of the sheep from the land during the first decade of the century; (2) onset of a wetter-than-normal climatic cycle during most of the century; (3) removal of dominant, overstory trees by logging; and (4) development of increasingly aggressive fire suppression. As a result, forests in the Sierra Nevada were subject to extensive development, of fuel ladders, accumulation of surface fuels, and ingrowth of shade-tolerant conifers such as white fir and incense-cedar (e.g., figs. 7 and 8) (McKelvey and Johnston 1992, Weatherspoon and others 1992). A decline in the number of large, old trees resulted from logging and natural attrition of the old forest. Past logging activities that concentrated on removal of the largest, most valuable trees broke up the patchy mosaic of the natural forest, further enabling the development of dense conifer regeneration. These events, especially in ponderosa pine and mixed-conifer forests, reduced large-diameter trees in many areas to small remnant populations. These changes have not occurred to the same degree in the red fir type, where fires were less frequent historically, and where logging was generally uncommon until recent decades.

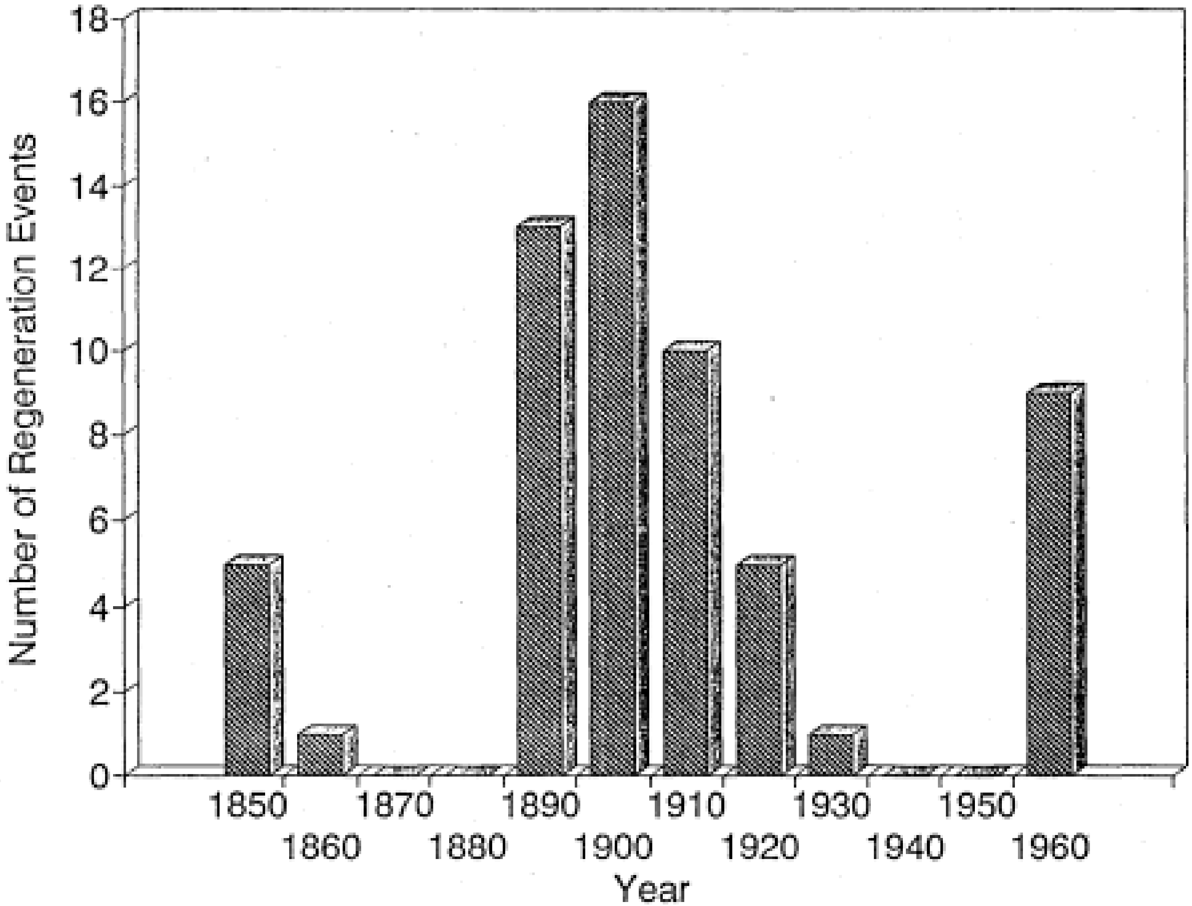

Figure 6-Periods of significant regeneration on sites within Sequoia National Park. This figure was developed by combining data from tables in appendices of Vankat (1970).

Figure 7-Mixed-conifer forest at an elevation of 2,800 feet on the Eldorado National Forest; note the extensive surface and ladder fuels (photo by John S. Senser, 24 June 1991).

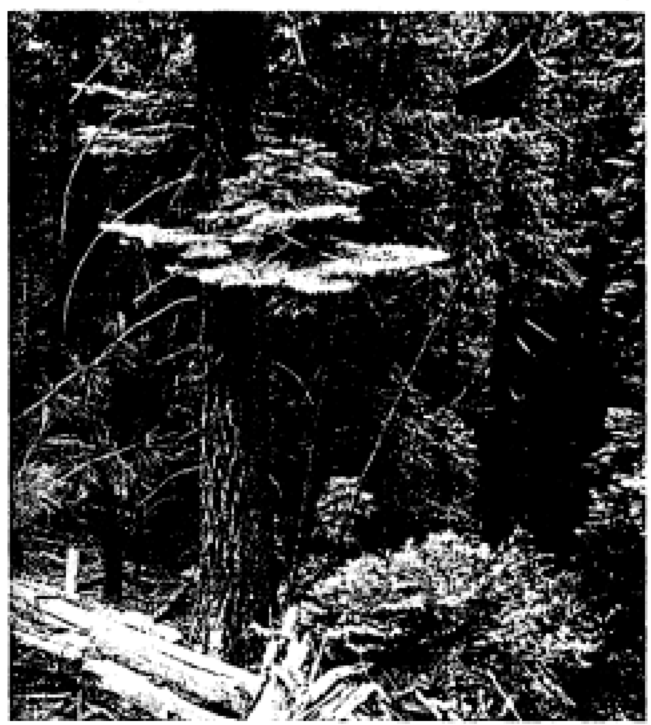

Figure 8-Mixed-conifer forest at all elevation of 4,400 feet on industrial forestland within boundaries of the Tahoe National Forest; note the surface and ladder fuels.

The Present

Because of current stand structures and excessive fuel loadings in much of the Sierran mixed-conifer type, fires that escape initial attack-usually fires occurring during extreme weather conditions-tend to become catastrophic. Fire trends in the Sierra Nevada can be expected to continue along their current trajectories, with more frequent catastrophic fires. As the human population increases in Sierran forests and woodlands, the presence of numerous houses within the forest will shift further the emphasis of suppression from saving forests to saving property. Fuels also continue to accumulate, with the recent drought-induced bark beetle infestations contributing a major pulse of new fuels over the next few decades. We expect the net result to be a much higher incidence of stand-destroying fires in the future than was the case prior to this century. Those fires will continue to destroy remnant, individual old trees, stands of old trees, and other old-growth attributes.

The Future

Logging trends based on Land Management Plans (LMP's) of NF's in the Sierra Nevada also pointed to a continuing decline in the number of old trees and remnant stands of old-growth forest. Sixty-five percent of the forested lands on Sierran NF's were classified as suitable for timber production (McKelvey and Weatherspoon 1992). Discounting forested acres that could not produce timber commercially because they were too poor in quality, they could not be successfully regenerated, or they had unstable soils, 74 percent of the lands that could potentially produce timber would have been harvested in some manner. Seventy-two percent of the timber volume would have been taken through even-aged systems-mostly clearcuts. Of the 528,474 acres of suitable timberlands on the Tahoe NF, for example, 68 percent were slated for even-aged silviculture (24 percent long rotation, 44 percent short rotation) (McKelvey and Weatherspoon 1992). On the Plumas NF, 52,000 acres were scheduled for even-aged cutting per decade, with 8,000 acres in selection cutting methods.

Clearcut, seed-tree, and shelterwood cutting techniques all have the same goal: produce even-aged stands. In this regard, seed-tree and shelterwood systems usually can be thought of as two-stage (sometimes three-stage) clearcuts. Few stands were scheduled to retain the seed trees. In terms of owl biology, the primary impact of traditional, even-aged silviculture lies in the creation of simple stand structures and, probably more importantly, the removal of all large trees from vast areas of the forest. Even if prescriptions were modified to leave snags and live culls at the first cutting, no provision was made for a predictable recruitment of replacement trees for these relics when they fell. This, in turn, would have led to a loss of large-diameter downed logs important in the production of fungi that are a primary food source for flying squirrels-the main prey of spotted owls in Sierran mixed-conifer forests (Verner and others 1992a). 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 he created 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 beginning of this century in the Sierra Nevada (McKelvey and Johnston 1992). Decadent tree features (e.g., cavities, broken-tops, snags) in stands are functions of age, not just d.b.h. Without those features, animals that depend on them, or the large woody debris they create, would simply drop out of the forest ecosystems.

Even on lands planned for selection harvest (about 80,000 acres /decade), harvest prescriptions did not guarantee retention of any large, old trees. Ideally, stands managed for individual-tree selection are logged in a manner that brings the diameter distribution in the stand into conformity with an idealized distribution, characterized by a declining exponential function (the inverse "J" curve). The number of large trees in a stand is dictated by the slope of this curve and the designated diameter of the largest tree. In selection harvests, timber is taken from all diameter classes as needed to maintain this diameter distribution. Little evidence exists, however, that historical patterns of partial cutting have followed the classic single-tree theory. "Selection" harvest in the Sierra Nevada has, in the past, primarily targeted the large trees. This system, sometimes called "pick and pluck," does not produce the simple, even-aged structures that characterize clearcutting techniques, but its effect on the presence of large, old trees is similar. If the large trees are removed and no stocking control is done 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.

The future forests of the Sierra Nevada, as projected by the LMP's, would have been split between areas of even-aged plantations and areas of dense and increasingly small-diameter stands. Given these projections, it seems most likely that the forest to be generated by adherence to the LMP's would have been susceptible to severe fire disturbance, nearly devoid of large, old trees, and depauperate in terms both of plant and animal species that depend on attributes of the older forests that were common last century. The key elements of spotted owl nest and roost stands definitely would have declined sharply over most of the Sierra Nevada in the next few decades. Without them, a hiatus of well over 100 years would pass before more would grow to take their place. In the process, the spotted owl would probably be markedly reduced in numbers over most of the Sierra Nevada, possibly with viable subpopulations surviving in Yosemite and Sequoia/Kings Canyon NPs.

What Does it All Mean?

We are uncertain whether the Sierran populations of spotted owls are to decline. Continued adherence to the LM P's in effect in 1992, however, would have continued to erode the abundance and distribution of those key habitat attributes consistently associated with occupancy and nesting by the owls. Unchecked, we believe this trend would have led to significant declines in the abundance and distribution of the owls in the Sierra Nevada. Of greatest concern to us at this time is the possibility of the rapid disappearance of large, old, and generally decadent trees selected for nesting by the owls. These same trees eventually become the large snags, and finally the large fallen logs, that we believe are important for maintaining suitable owl habitat. Once gone, they could not he replaced quickly.

In addition to our concern about, the loss of key "old-forest" attributes, we believe that, the extensive accumulation of surface and ladder fuels in the relatively dry, ponderosa pine and mixed-conifer forests on the western slopes of the Sierra Nevada will foster major stand-destroying fires. Recent Sierran fire history teaches us that these fires can engulf tens of thousands of acres in a matter of a few days. In such events, essentially all resource values are eliminated or seriously degraded, not just vast acreages of suitable owl habitat.

Dealing with the Current Situation

Interim Guidelines

Uncertainties about (1) the real status of owl populations in the Sierra Nevada and (2) the specific details of habitat structure and composition that would assure self-sustaining populations of owls precluded recommendations for long-term management of the owl. Instead, the Technical Assessment Team recommended an interim approach to allow more time for research to eliminate some of the uncertainties (Verner and others 1992c).

The Team identified eight major factors of concern in habitats of California spotted owls in the Sierra Nevada (table 2). These involved projected declines in the older attributes of forests believed to be important to the owl, the long recovery time for owl habitat after regeneration harvests, and the excessive accumulation of surface and ladder fuels. Recommendations in the CASPO Report were later adopted as the preferred alternative in an Environmental Assessment (EA) of the owl in the Sierra Nevada (USDA Forest Service 1992). The Decision Notice (Stewart 1993) set March 1, 1993 as the start date for a 2-year interim period to implement the spotted owl guidelines, during which time a full Environmental Impact Statement dealing with this matter is to be completed.

Interim guidelines (summarized in table 3) stress protection of nest, and roost areas; retention of large, old trees, large snags, and large, downed logs; and efforts to begin dealing with the excessive surface and ladder fuels that have developed in Sierran conifer forests since the first decade or so of this century. Specifically, the guidelines require delineation of a 300-acre "Protected Activity Center" (PAC) around known owl sites. Commercial logging is excluded in PAC's, but light underburning is allowed in certain circumstances to deal with fuels problems. Within "Selected Timber Strata" (those shown to be significantly selected for nesting by the owls), guidelines suggest removal of no live

Table 2---Summary of major factors of concern in habitats of California spotted owls in the Sierra Nevada, reasons for those factors, and their impacts on the owls (taken from Verner and others 1992c)

Factor	Reason(s) for the factor	Impact on spotted owls
Decline in abundance of very large, old trees	Selective logging of the largest trees from stands	Loss of the owl's preferred nest sites
Long recovery period for spotted owl habitat after logging	Selective logging of the largest trees from stands	Less of total landscape in suitable owl habitat at any given time
Ingrowth of shade-tolerant tree species, creating unnaturally dense stands with ground-to-crown fuel ladders	Selection harvest; aggressive fire suppression; sheep grazing, which created ideal seedbeds for conifer germination late last century	Increased threat of stand-destroying fires
Excessive build-up of surface fuels	Aggressive fire suppression over the last 90 years, leading to higher densities of trees, more competition for space and water, so a higher death rate of trees	Increased threat of stand-destroying fires
Loss of large-diameter logs from the decaying wood source on the ground	Intentional fires by sheepherders; selective logging of largest trees; piling and burning logs after logging; domestic fuel-wood removal	Potential decline in flying squirrel densities via loss of fungi that are a dietary staple for the squirrels
Decline in snag density	Selective logging of the largest trees from stands; salvage logging; fuel-wood removal	Loss of potential nest sites for owls; loss of den sites for flying squirrels; loss of a source of large logs for decay needs on the ground
Disturbance and/or removal of duff and topsoil layers	Sheep grazing; mechanical disturbance from logging equipment, skid trails, and so on; increased surface fuels that burn hot enough to destroy duff layer	Potential decline in flying squirrel densities via loss of fungi that are a dietary staple for the squirrels
Change in composition of tree species (fewer pines and black oaks, more firs and incense-cedar)	Selective logging of the largest trees, particularly pine species, from stands; aggressive fire suppression	Some loss of nest sites; other effects unknown

trees ≥30 inches in d.b.h.; retention of at least 40 percent of the basal area, starting with the largest tree and working down toward the 40-percent basal area limit; and maintenance of 40 percent canopy cover. Within "Other Timber Strata" (those known to be used for nesting but not significantly selected by the owls), guidelines suggest removal of no live trees ≥30 inches in d.b.h., and retention of at least 30 percent of the basal area, starting with the largest tree and working down toward the 30-percent basal area limit. The guidelines also specify targets for retention of snags and large downed logs in owl habitat. Finally, one of the strongest recommendations in the CASPO Report was to undertake activities, such as biomass sales, that would begin to lessen the threats of catastrophic fires in Sierran conifer forests.

The primary intent, of all these guidelines is to retain key attributes for owls throughout Sierran conifer forests in a way that will maintain options for later implementation of along-term strategy. In addition, by retaining very old trees, large snags, and large downed logs, the guidelines shorten the recovery time after logging in suitable owl habitat. Indeed, because guidelines for "Selected Timber Strata" require retention of at least 40 percent canopy cover, we suspect that these stands will

Table 3-Summary of primary recommendations for stand retention and special stand treatments to maintain options for spotted owls on public timberlands in the Sierra Nevada during an interim period (taken from Verner and others 1992c).

Attributes	Protected[a] activity centers	Selected[b] timber strata	Other[c] timber strata	Salvage sales
Large, old trees				
Basal area	No logging	Keep 40 percent, from largest healthy trees and culls	Keep 30 percent., from largest healthy trees and culls Retain at least 50 square feet per acre	Does not apply
D.b.h.	No logging	Retain all live trees ≥30 inches	Retain all live trees ≥30 inches	Does not apply
Percent canopy cover	No reduction	≥40 percent	No restriction	No restriction
Snags	No reduction	Retain largest down to a total of 20 square feet per acre	Retain largest (town to a total of 20 square feet per acre	Retain largest. down to a total of 20 square feet per acre; take no snag ≥30 inches in d.b.h.
Dead-and-downed woody material	Retain at least 3-5 percent of ground cover; at least three logs 20 inches in diameter lay 20 feet long	Retain at least 3-5 percent of ground cover; at least three logs 20 inches in diameter by 20 feet long	Retain at least 3-5 percent of ground cover; at least three logs 20 inches in diameter by 20 feet long	Retain at least 3-5 percent of ground cover; at least three logs 20 inches in diameter by 20 feet long
Fire threats	Light under-burning	Positive fuels management	Positive fuels management	Positive fuels management

[a] Block of 300 acres of suitable nesting/roosting habitat delineated around nest site or primary roost site in all known spotted owl sites in the Sierra Nevada.
[b] Timber strata significantly selected for nesting by spotted owls in the Sierra Nevada.
[c] Other timber strata used for nesting by spotted owls in the Sierra Nevada, but not significantly selected.

be used for foraging by tile owls within 5 years of logging. Without, retention of the older stand elements, recovery to suitable foraging habitat after logging would likely take at least 60-80 years, and recovery to suitable nesting habitat could take as long as 150-200 years.

Implementing the guidelines also has the inherent potential to deal aggressively with the fuels problem. Most timber sales following the guidelines could be classified as commercial thinning operations or biomass sales. Their effect would be to remove significant amounts of the fuel ladders. If properly done in terms of fuels treatments, surface fuels would also be reduced to acceptable levels.

We have encountered essentially no opposition to our conclusions about the seriousness of the present fuels conditions in Sierran conifer forests. This is a problem clearly visible to all who care to look. But adoption of the CASPO guidelines in the EA has created a storm of protest from the timber industry in California and from some timber staffs on NF's in the Sierra Nevada. A primary concern has been the lack of availability of trees larger than 30 inches in d.b.h. Estimates indicate that about 50 percent of the potential timber volume is in these large trees, so projections suggest a marked drop in timber volume from sales in the Sierra Nevada. At least some mills are not equipped to handle smaller logs efficiently, and owners of others that are so equipped assert that they cannot sustain their operations if they lack access to at least some larger logs. We do not know how valid these assertions are, but we know that mills in the southeastern United States maintain viable operations without large logs.

A point that we believe has been overlooked so far is reflected in the concern about potential volumes under the EA guidelines. At least from an ecological standpoint, or the standpoint of the spotted owl in the Sierra Nevada, timber volumes under CASPO guidelines need not be reduced from past years. Indeed, it would be preferable if they were increased, because that would result in many more acres being treated and the fuels problem being further reduced. Large, stand-replacing fires, such as those in the Stanislaus-Complex Burn of 1987 (145,000 acres) or the Cleveland Burn of 1992 on the Eldorado NF (25,000 acres), can remove as much owl habitat as decades of clearcutting.

Perhaps the most significant challenge in this arena is the lack of funding now available (1) for the extra planning needed to implement the EA and (2) to deal aggressively with the fuels situation. Even if a timber sale can be offered, it may generate insufficient revenues to pay for the needed fuels reduction. This is a real problem, but it is not a reason to discard our responsibility to deal effectively with an escalating fuels situation. We need to educate the Public, the Congress, and the Administration about the seriousness of this situation. Undoubtedly its solution lies in spending much more money than has been the case historically. If we fail to do this, we will continue to experience catastrophic fires in the Sierra Nevada, and we will most likely lose more in the long run than it would cost now to assure adequate protection for these resources.

A View to the Future

Several lines of research and development need to he explored. For example, we still lack a full understanding of the many linkages in forest. ecosystems that directly or indirectly influence the ability of spotted owls to reproduce at rates sufficient to balance their death rates. We need to develop silvicultural methods and logging systems that retain specified levels of key elements of older forests that are important for ecosystem integrity. The relatively new "cut-to-length" and "forwarding" systems developed by the Scandinavians are promising examples. We also need silvicultural research on ways to create stand attributes that are generally associated with species that are highly adapted to older forests. We also need to understand better the nature of old-growth forests prior to European settlement, (as opposed to current old-growth forests, which have been strongly affected by fire exclusion, past sheep grazing, and other anthropogenic factors), because the presettlement forests should provide conservative models of sustainable forest ecosystems.

In recent years, the spotted owl has been a beacon for contentious issues in forest management in all of the far-western States. Millions of dollars have been spent in research and management, singularly directed at this species. We cannot know how history will evaluate these expenditures, but at least the owl is a reasonably effective "umbrella" for many other species --both animals and plants- that are best adapted to older forests. This is the case primarily because individual owl pairs have extraordinarily large house ranges, so maintenance of enough habitat to assure a viable population of the owls provides for the needs of numerous other species with lesser area requirements.

Attitudes are changing now about how to deal with the challenges posed by threatened and endangered (T&E) species. The Forest Service is shifting its emphasis toward more integrated management of multiple resources-so-called ecosystem management. What this means, how we will do the managing, and how researchers will evaluate results still remain to be seen. But this is a promising shift, one that should have been made many years ago. Maintaining the integrity of ecosystems should markedly reduce the likelihood of adding to the current list of T&E- species. We contend, however, that lessons learned from intensive studies of individual species like the spotted owl and fisher will serve us well, at least initially. For example, whatever long-term strategy may be adopted for California spotted owls, we believe it will include measures to retain some level of very large, old trees, large snags, and large downed logs. We also hope that it will reduce the need to set aside areas managed exclusively for one or a limited number of uses or resources. Numerous species of plants and animals will benefit from management changes implemented at a landscape scale.

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Appendix

Common and Scientific Names Used in Text

Plants

Dwarf mistletoe . . . . *Arceuthobium* spp. Bieberstein
Sugar pine . . . . *Pinus lambertiana* Douglas
Ponderosa pine . . . . *Pinus ponderosa* Douglas ex Lawson
Jeffrey pine . . . . *Pinus jeffreyi* Greville and Balfour
White fir . . . . *Abies concolor* Gordon and Glendinning
Red fir . . . . *Abies magnifica* A. Murray
True fir . . . . *Abies* spp. Miller
Incense-cedar .. . . *Libocedrus decurrens* Torrey
Oak . . . . *Quercus* spp. Linnaeus

Animals

California spotted owl . . . . *Strix occidentalis occidentalis* Xántus de Vesey
Northern flying squirrel . . . . *Glaucomys sabrinus* Shaw
Dusky-footed woodrat . . . . *Neotoma fuscipes* Baird
Gophers .. . . *Thomomys* spp. Wied-Neuwied
Fisher . . . . *Martes penanti* Erxleben