SECTION III

Biological and Physical Elements of the Sierra Nevada

Back to CD-ROM Table of Contents

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21

Assessment of Late-Successional Forests of the Sierra Nevada

ABSTRACT

Late-successional, including old-growth, LS/OG, forest conditions were assessed for the Sierra Nevada using stand structural criteria as measures of the level of LS/OG forest function, such as in providing habitat for LS/OG-related species. Larger landscape units (polygons) which were relatively uniform in type and distribution of vegetation patches were mapped using available imagery, maps, ground-based information and the expert interpretations of resource specialists. Characteristics of the major patch types in each polygon were identified and tabulated and a composite late-successional structural ranking was calculated for each polygon on a scale that extended from 0 (no contribution to LS/OG forest function) to 5 (very high level of contribution to LS/OG forest function). Maps and databases were used in assessing current LS/OG forest conditions in the Sierra Nevada and, in other SNEP exercises, constructing and evaluating alternative management scenarios. Forests with high LS/OG structural rankings are currently uncommon in the Sierra Nevada; only 8.2% of the mapped polygons had structural rankings of 4 or 5. Commercially important forest types—such as the mixed conifer and eastside pine forests—are particularly deficient relative to their potential as a result of past timber harvesting. Key structural features of LS/OG forests—such as large-diameter trees, snags, and logs—are generally at low levels. On the positive side, the forest cover in most areas is not highly fragmented by clear-cutting and stands have sufficient structural complexity to provide for at least low levels of LS/OG forest function. National parks provide the major concentrations of high-ranked LS/OG forest with about twice as many polygons in moderate to very high rankings as adjacent National Forest lands. Furthermore, much of the remaining highly-ranked LS/OG forest on national forests is unreserved and potentially available for harvest. Forest health is generally good in the Sierra Nevada; areas of epidemic mortality are localized in subregions such as the eastern face of the Sierra Nevada. The current extent of high-quality LS/OG forest is believed to be far below levels that existed prior to western settlement; based upon several lines of evidence, the majority of commercial forestlands were probably occupied by such forests at that time. If maintenance of high-quality LS/OG forest ecosystems is adopted as public policy, a program needs to be initiated that will 1) maintain existing high-quality LS/OG forests; 2) restore such conditions where existing LS/OG forests are insufficient to achieve objectives; 3) restore fire as an important process and to reduce risks of catastrophic loss; and 4) restore structural complexity in the matrix. Elimination of timber harvest within existing high-quality LS/OG forests for at least an interim period and restoration of low- to moderate intensity fire to existing and prospective LS/OG forest ecosystems are probably the most important immediate actions. Larger management units, called Areas of Late-successional Emphasis, are proposed as an approach which incorporates both reserves and areas managed intensively to reduce the potential for catastrophic fire. Restoration of LS/OG structures and functions in the matrix is also very important and can be achieved by developing and applying silvicultural prescriptions which restore and maintain key LS/OG structures, such as large-diameter trees and the snags and logs derived from them.

INTRODUCTION

Late-successional, including old-growth, forests are an important resource on federal lands in the Sierra Nevada. Late-successional forests are typically forests that have developed over one to many centuries without a major disturbance—i.e., a disturbance which destroyed much or all of the stand. Interest in late-successional forests reflects the fact that they

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Back to CD-ROM Table of Contents

fulfill many important functions for human society such as by 1) providing critical habitat for many wildlife species as well as other elements of biological diversity; 2) performing important ecological functions as part of the carbon (or energy), nutrient, hydrologic and other material cycles in the Sierra Nevada, North America, and the globe; and 3) providing important inspirational, recreational, and cultural resources. The broader category of late-successional forests, incorporating both old-growth and mature forests, is used here since mature forests (stands with tree dominants 100 to 200 years old) often provide some habitats and services comparable to truly old forests; the acronym LS/OG (late-successional, including old growth) is used hereafter to refer to this array of forest ecosystems.

The significance of LS/OG forests is emphasized by the specific charge to Sierra Nevada Ecosystem Project (SNEP) to provide an assessment of the condition and distribution of these forests. The United State Congress provided this direction in language that was a part of two bills in the House of Representatives in 1992 (see appendix A in Sierra Nevada Ecosystem Project 1994): HR 5503 (passed) called for a "scientific review of the remaining late-successional forest in the National Forests of the Sierra Nevada" including production of "maps identifying the old-growth forest ecosystems"; HR 6013 (proposed) identified six tasks including an inventory of "watersheds and late-successional forests" and recommendation of alternative management strategies [for] watersheds and late-successional forests". The congressional direction was incorporated in the charges provided by the SNEP Steering Committee.

An assessment of the distribution and condition of forests contributing to late-successional forest function on federal lands in the Sierra Nevada is the subject of this paper. We begin by briefly reviewing the diversity of forest types and conditions and the methodology adopted; the mapping and characterization exercise made extensive use of resource specialists familiar with on-the-ground conditions. Subsequently, we report our findings regarding quality and distribution of forests contributing to late-successional forest function including differences among major forest types and lands administered by different agencies. Our purpose is to provide both an information base on late-successional forests and some interpretation of the findings for interested individuals, including resource managers and decision makers.

FOREST ECOSYSTEMS OF THE SIERRA NEVADA

Primer on Forest Ecosystems

An introduction to ecosystem, disturbance, and succession concepts is useful in understanding both the late-successional assessment and its implications so we begin with a primer on aspects of forest ecosystems.

The ecosystem is a holistic concept which incorporates both organic and physical components—biotic (e.g., organisms) and abiotic (e.g., climatic conditions)—and their relationships. There are numerous perspectives on how ecosystems are structured and how they work (see, e.g., Likens 1992); one useful approach is to recognize that ecosystems have three primary attributes—composition, function, and structure (Franklin in press). It is important to recognize that ecosystems are dynamic rather than static and that much of this dynamism involves responses to disturbances, both natural and human. The ecosystem concept is also very flexible as to spatial dimensions; the scale of an ecosystem is defined by the particular application—i.e., the functions that are of interest.

Composition, Function, and Structure of Ecosystems

Composition refers to the organisms which are present in an ecosystem and their relative proportions. The complement of species that are present is one common measure of biodiversity but there are others, such as measures of equitability among species and of functional diversity. The bulk of the species are, of course, small, inconspicuous organisms, such as insects, fungi, and bacteria, but size is not a measure of importance since many of these species are critical elements in maintaining the productivity of the ecosystem such as by decomposing organic material and releasing nutrients or, in the case of mycorrhizal-forming fungi, assisting vascular plants in acquisition of moisture and nutrients.

Function refers to the work carried out by ecosystems; it is important to understand that all forests are working ecosystems providing a variety of goods and services to human kind not just forests managed for timber production. Productivity, through the capture of the sun's energy by photosynthesis and its conversion to various organic materials, is an important example. Primary production by green plants is, of course, the energetic basis or basic source of "food" for most life forms as well as providing the marvelous structures that we harvest for wood. Other examples of important ecosystem functions are conservation of nutrients and soil, regulation of the hydrologic cycle, and provision of habitat for wildlife and other organisms.

Structure refers to the numbers, sizes, and kinds of "pieces" of the ecosystem and their spatial arrangement. Forest ecosystems may have a wide variety of organic structures such as live trees of various species, sizes, and conditions as well as snags (standing dead trees) and logs which are, of course, derived from live trees. "Logs" are defined here as tree boles or stems or pieces of such boles present on the forest floor primarily through natural processes and not pieces of felled trees created in logging activities. Structurally diverse ecosystems have a wide variety of life forms and structures.

Spatial patterns are as important as the diversity of individual structures in describing and understanding stand structure. What is the spatial arrangement of the individual structures? Are they uniformly distributed throughout the ecosystem or do they have an irregular or clustered distribution?

Examples of important stand-level structural patterns in forests are openings (gaps) in overstory canopies and development of multiple or vertically continuous canopy layers.

Structure is commonly emphasized in ecological and forestry analyses because 1) structure can function as a surrogate or indicator for species or processes (functions) that are difficult to measure directly and 2) structure is what we commonly manipulate through management. Many organisms are difficult to observe directly as are many processes, such as productivity. Structural measurements are, therefore, often used as surrogates or substitute measures of such organisms or processes, since they are relatively easy to make. For example, structures required as habitat for specific wildlife species (such as large-diameter, hard snags for pileated woodpeckers) are often used as indicators of suitable habitat for dependent organisms. The Wildlife Habitat (WHR) guidelines utilize such structural indicators. Similarly, productivity is often measured by observing changes (increases or decreases) in structures (e.g., tree dimensions) in stands rather than through laborious measurements of photosynthesis and other processes.

Structure is the attribute of ecosystems that humans generally manipulate either directly, as in logging, or indirectly, as through fire control or prescribed burning programs. Silviculture is based primarily on structural manipulation—although humans may also directly manipulate composition through removal or addition of specific species.

Succession and Disturbances

Ecosystems are constantly undergoing changes in composition, structure and function as a result of interactions among the organisms and changes in abiotic conditions. Some of these involve long-term directional (as opposed to cyclical) changes which are typically referred to as succession. Succession is most commonly thought of in terms of species changes, such as from an early colonizing or pioneer species to late arriving species; while common such compositional changes are not universal. However, succession in forests always involves structural and functional changes. Ecosystems that have reached a point where changes in composition and structure are very slow or imperceptible are often referred to as late-successional. Late-successional ecosystems may still be very dynamic, such as in turnover of individual trees, but with very little net change in conditions in the stand. In the Sierra Nevada many late-successional forests typically incorporated periodic, light to moderate intensity wildfires which helped maintain high levels of structural diversity within small areas.

Severe disturbances, such as wildfire, windstorm, insect outbreaks, or timber harvest, can disrupt the gradual, internally-driven successional changes in ecosystems; the level of disruption depends upon the type, intensity, and frequency of the disturbance. Most disturbances leave behind large numbers of surviving organisms and organic materials, which are sometimes referred to as biological legacies; most disturbances do not kill all organisms present, let alone sterilize the site. Such legacies can be very important because it means that much of the recovery will be based on organisms and materials already in place rather than requiring recolonization of the site from outside. Since most forest disturbances kill trees but consume little of the wood, legacies of particular significance to forest ecosystems are dead trees in the form of snags and down logs. The numerous legacies, including living trees as well as snags and logs, are a primary reason why clear-cutting is not like most natural disturbances.

Ecosystems at the Landscape Level

Much of ecology and resource management, including ecosystem science and forestry, has focused at the scale of the single stand or patch. For example, activities have often been planned and conducted at the level of a forest stand or a stream or river reach without regard for conditions in the surrounding area.

Problems invariably arise when activities or interpretations lack a larger spatial or landscape context. For example, unacceptable cumulative effects on water quality can result when a management activity, such as road building, is not considered in relation to other management activities that have been carried out or are planned within a watershed. Extensive dispersed patch clear-cutting can result in a landscape condition known as forest fragmentation in which large blocks of continuous forest are broken into small patches with significant changes in their ecological properties (Franklin and Formann 1987).

Boundaries between ecosystems, or edges, are a very important consideration in landscape ecology. Adjacent patches have significant reciprocal influences on each other which are sometimes known as edge effects. Extent of edge effects varies with the parameter of interest; for example, whether the issue of interest is tree mortality, predation on songbird nests, or air temperature (Chen et al. 1992, 1993). The greater the contrast in structural conditions between the two patches, the more intense the interaction and depth of edge effects. Maximum interactions or edge effects occur where conditions are extremely contrasting, such as along an edge between a recent clear-cut and an old-growth forest; for example, on a hot, dry summer afternoon the clear-cut may affect relative humidity and wind speed for 400 m or more into an old-growth stand (Chen et al. 1993).

Landscape-level perspectives are critical in understanding and managing ecosystems to achieve desired objectives. Recognizing the scale and pattern of patches of different ecosystem types and conditions and its relationship to the spatial patterns in the intensity of disturbances can be very important. Landscape-level perspectives also help in recognizing the linkages between terrestrial and aquatic ecosystems.

Major Forest Types and Their Characteristics

The forests of the Sierra Nevada are very complex in composition, structure, and function. This complexity reflects 1) the wide variations in environmental conditions on both a local and a regional scale, 2) a rich flora, and 3) a highly varied history of natural and human disturbances. The importance of environmental diversity in creating a complex template is easily understood: forests occupy a large elevational and latitudinal range and a wide range of geological substrates, landforms, and soil types. Hence, moisture, temperature, and nutrient regimes are extremely varied and often contrast over very short distances, such as on adjacent opposing aspects. Disturbances then interact with the flora on this template to produce truly complex mosaics of forest and other plant communities. Plant community classifications developed by agency and academic ecologists (e.g., Barbour 1988; Sawyer and Keeler-Wolf 1995) quantify much of this richness.

In this report we aggregate forests into a relatively few major forest type groupings in order to simplify the analysis while still recognizing some of the important variability. These groups differ in a variety of important factors including species composition, function (including productivity), structure, environment, and disturbance patterns. The forest type groupings are

- Foothills pine and oak
- Westside mixed conifer
- White fir
- Red fir
- Jeffrey pine
- Subalpine
- Eastside pine
- Eastside mixed conifer and white fir
- Piñon and juniper
- Riparian hardwood

Aspects of the distribution, composition, and disturbance regimes of these type groups are provided in table 21.1. Forest type groups are illustrated in figures 21.1 through 21.23. Westside mixed conifer forests (figures 21.2–21.8) are found at middle elevations on the western slopes of the Sierra Nevada. The subalpine forest type (figures 21.14–21.19) includes a diversity of forest conditions found at high elevations throughout the Sierra Nevada and the White Mountains. These forests vary widely in density and structural complexity but include large areas of low tree density. Lodgepole pine–dominated forests are a major component of the subalpine forest type group and display a broad array of structural conditions; figures 21.16–21.19 are all from the same polygon in Yosemite National Park. Pure or mixed stands of piñon pine and juniper are characteristic of the eastern margins of the Sierra Nevada, White Mountains, and Modoc Plateau (figures 21.21–21.23). The general distribution of the type groups is illustrated in plate 21.1.

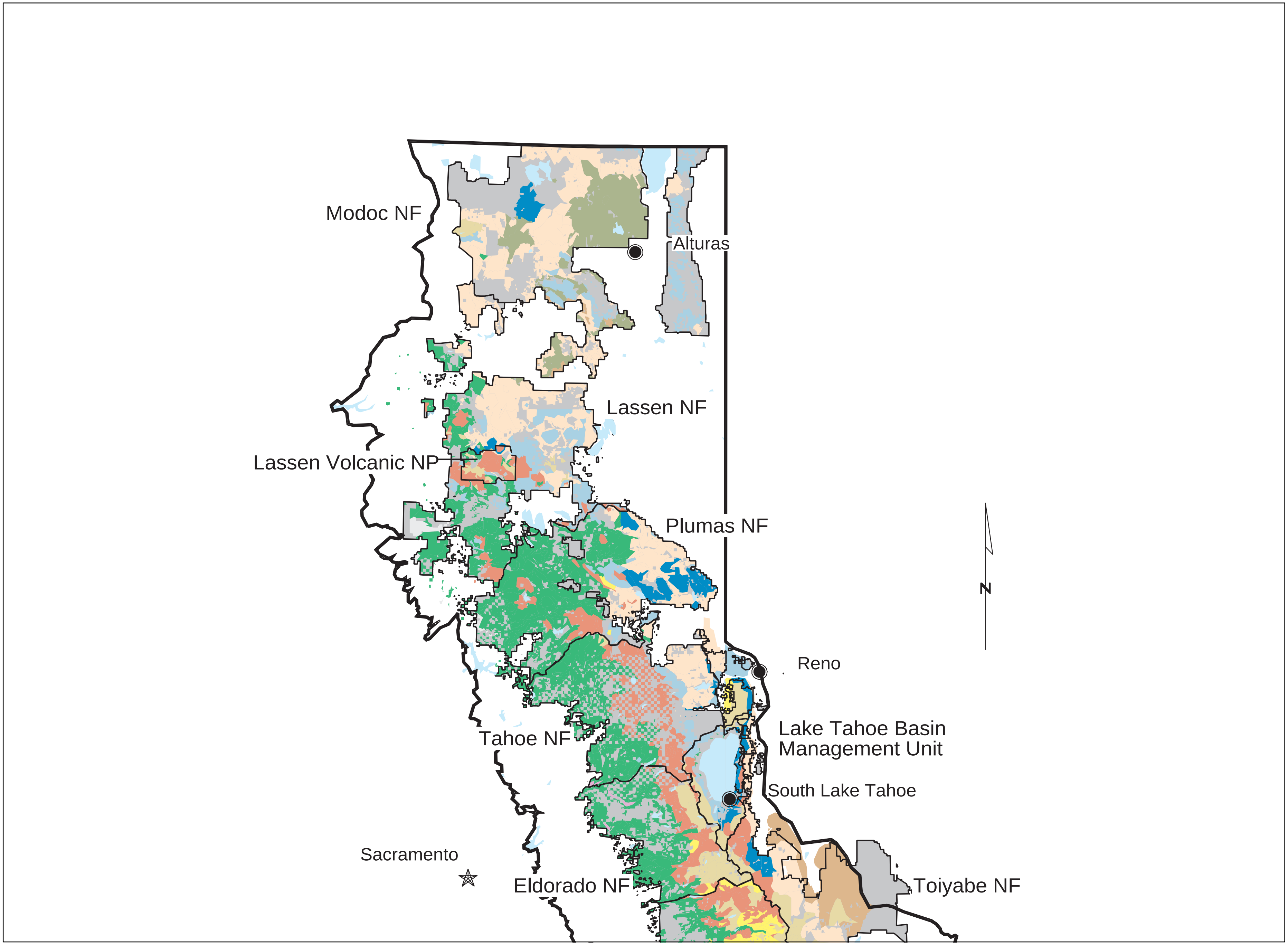
METHODS USED IN ASSESSMENT

Major Issues and Assumptions

The Sierra Nevada provides a very challenging region for assessing late-successional, including old-growth, LS/OG forest conditions. Most fundamental is the necessity to define a set of criteria by which you can recognize late-successional forests. Such assessments, while still difficult, are relatively straightforward in regions like the Pacific Northwest where infrequent disturbances typically produced large patches with dense overstory canopies dominated by cohorts of relatively shade-intolerant trees. Dominant age classes—and, hence, old-growth—is relatively easily identified by both age and structural analyses (e.g., Johnson et al. 1991; Franklin and Spies 1991a, 1991b). Furthermore, timber harvest has been almost exclusively by clear-cutting. Hence, in the Coastal Ranges and the Cascade Range, the high level of structural contrast makes distinctions between natural and managed stands particularly easy.

The forests of the Sierra Nevada are quite varied in their intrinsic structure and in the structural and compositional characteristics induced by natural, as well as human, disturbances. Although many old, uncut forest stands in the Sierra Nevada are dense, closed-canopy old-growth forests like those found in the Pacific Northwest many LS/OG forests are not of this type. Many high-quality LS/OG forests in the Sierra Nevada have low to moderate overstory tree densities, moderate canopy cover, and gaps of sufficient size for successful reproduction of the relatively shade-intolerant pioneers, such as pines and a variety of brush species (figures 21.24–21.25). Wildfires of light to moderate intensity and moderate to high frequency have been important in creating and maintaining this structure. Periodic, localized extensive mortality from bark beetles has also been important.

Selective timber harvest—the dominant approach in the Sierra Nevada—has helped maintain much of this structural complexity. Late in the nineteenth and early in the twentieth century, timber harvest approximating clear-cutting did occur on private lands in the Sierra Nevada (some of which were later incorporated into the national forests) although partial cutting was probably the more common practice. On the majority of federal timberlands clear-cutting has occurred only during the last several decades, however. Even-aged management, including shelterwood, seed tree, and clear-cutting, was initially utilized on stands with moderate and low stocking and did not preclude continued selective harvest in sig-


Modoc NF
Alturas
Lassen NF
Lassen Volcanic NP
Plumas NF
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Reno
Lake Tahoe Basin
Management Unit
South Lake Tahoe
Tahoe NF
Sacramento
Eldorado NF
Toiyabe NF

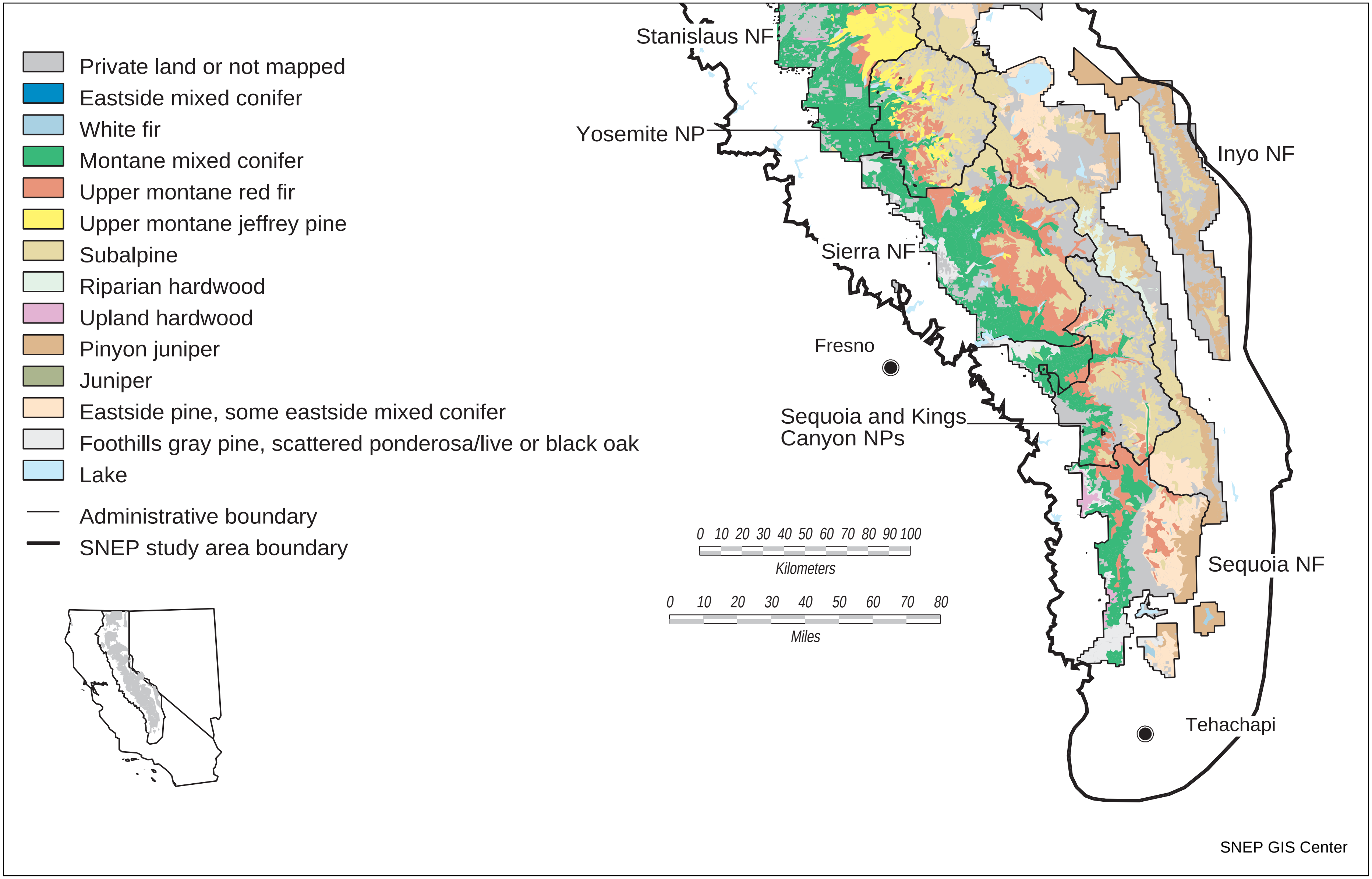


PLATE 21.1

Distribution of the major forest type groups in the Sierra Nevada.

TABLE 21.1

Characteristics of the major forest type groups of the Sierra Nevada.

	Dominant Trees				Presettlement Fire Regime	
Forest Type	**Northern Sierra**	**Southern Sierra**	**Landscape Patterns**	**Primary Disturbances**	**Northern Sierra**	**Southern Sierra**
Foothill Pine & Oak	Foothill pine, ponderosa pine, blue oak, live oak, Douglas fir	Foothill pine, ponderosa pine, blue oak, live oak	mostly open structure, limited patches of dense forest, frequent natural openings (chaparral & outcrops)	fire, insects, pathogens, drought	low severity regime: frequent, low intensity fires	same
Westside Mixed Conifer	Douglas fir, ponderosa pine, sugar pine, white fir, incense cedar, black oak, tanoak	ponderosa pine, sugar pine, incense cedar, black oak, giant sequoia, Jeffrey pine	primarily continous forest with few extensive natural openings (eg outcrops)	fire, insects, pathogens, drought	low to moderate severity regimes: areas > 50" annual ppt likely mixture of low and moderate intensity fires in complex mosaic with sufficient variability in interval to perpetuate Douglas fir; areas < 50" annual ppt likely more dominantly low intensity fires. Infrequent large-scale high severity fires.	low severity regime: dominantly low intensity fires
White Fir	white fir	same	same as westside mixed conifer	insects, pathogens, fire, drought	moderate severity regime: frequent but variable extent or frequency, variable intensity with small patches of moderate to high intensity	same?
Red Fir	red fir, lodgepole pine, western white pine	same	fine to moderate scale high patch diversity of natural openings (meadows, outcrops) and open or closed forest; large extensive patches limited	insects, pathogens, fire, drought, wind, avalanche	moderate severity regime same as white fir	moderate severity regime same as white fir
Jeffrey Pine (upper montane)	Jeffrey pine	same	generally extensive uniform patches of very open forest or woodland interspersed with small pockets of denser forest	insects, pathogens, fire, drought	low severity regime: low intensity and/or small extent of fires due to discontinuous fuels	low severity regime
Subalpine	lodgepole pine, mountain hemlock, western white pine, whitebark pine	lodgepole pine, mountain hemlock,western white pine, whitebark pine, limber pine, foxtail pine, western juniper	highly variable patterns but generally diverse patch mosaic with large meadows, small patches of dense forest embedded in a large matrix of open forest or scattered trees and rock outcrops	avalanches, wind	low severity regime: low intensity and/or small extent of fires due to discontinuous fuels and infrequent ignitions (due to precipitation) associated with lightning	

continued

TABLE 21.1 (continued)

Forest Type	Dominant Trees: Northern Sierra	Dominant Trees: Southern Sierra	Landscape Patterns	Primary Disturbances	Presettlement Fire Regime: Northern Sierra	Presettlement Fire Regime: Southern Sierra
Eastside Mixed Conifer & White Fir	white fir, ponderosa pine, Jeffrey pine (some Douglas-fir, sugar pine & incense cedar)	white fir, Jeffrey pine	variable patterns, most often occur in a coarse-scale mosaic with eastside pine related to aspect	fire, insects, pathogens, drought	low to moderate severity regime: frequent low intensity fires, but with variable intervals enabling recruitment of Douglas fir and white fir to large sizes; greater proportion of moderate intensity fires than eastside pine due to greater productivity and fuel accumulations from variable intervals	same
Eastside Pine	ponderosa pine, Jeffrey pine, lodgepole pine	Jeffrey pine, lodgepole pine	large, continous patches of open forest that are often interspersed with large meadows, grasslands/shrublands	fire, insects, pathogens, drought	low severity regime: dominantly frequent, low severity fires	same
Pinyon & Juniper	western juniper	Utah and western juniper, pinyon pine	large continuous savannas and woodlands	fire, grazing, woodcutting	low severity regime: frequent low intensity fires	same
Riparian Hardwood	black cottonwood, aspen	water birch, black cottonwood, aspen	streamside strips	flood, debris flow	low severity regime: infrequent fire	same

FIGURE 21.1

Representative stand of foothill pine and oak forest, found at lower elevations on the western slopes of the Sierra Nevada, near Johnsville, California, on Sequoia National Forest; late-successional structural ranking of 1 (rangewide standard).

FIGURE 21.2

Young plantation of ponderosa pine on the Sierra National Forest; late-successional structural ranking of 0 (rangewide standard).

nificant parts of the forest. Earlier partial cutting retained at least modest levels of forest cover and many structures (e.g., trees, snags, and logs) from previous stands. Forest conditions are, of course, highly modified over much of the mid- and low-elevation range, compared with pre-Euro-American arrival (McKelvey and Johnston 1992). However, the extreme contrasts that exist between managed and natural forests in the Pacific Northwest are currently not the norm in the Sierra Nevada, despite centuries of human activity.

Hence, it was necessary in this assessment to develop a process which recognized and accounted for the role of a much broader range of forest stands and conditions than in previous assessments of LS/OG forests. We began by considering potential bases for assessing late-successional quality. For several reasons, including the uneven-aged nature of many stands, tree ages were rejected as a primary criterion. After extensive discussion with other scientists, both inside and outside SNEP, our decision was to utilize structural features as the basis for

FIGURE 21.3

Young mixed conifer stand on Plumas National Forest; late-successional ranking of 1 (rangewide standard).

assessing the level of late-successional attributes in a forest (LS/OG quality) or, more accurately, the contribution of a stand or landscape segment to late-successional forest function in the Sierra Nevada.

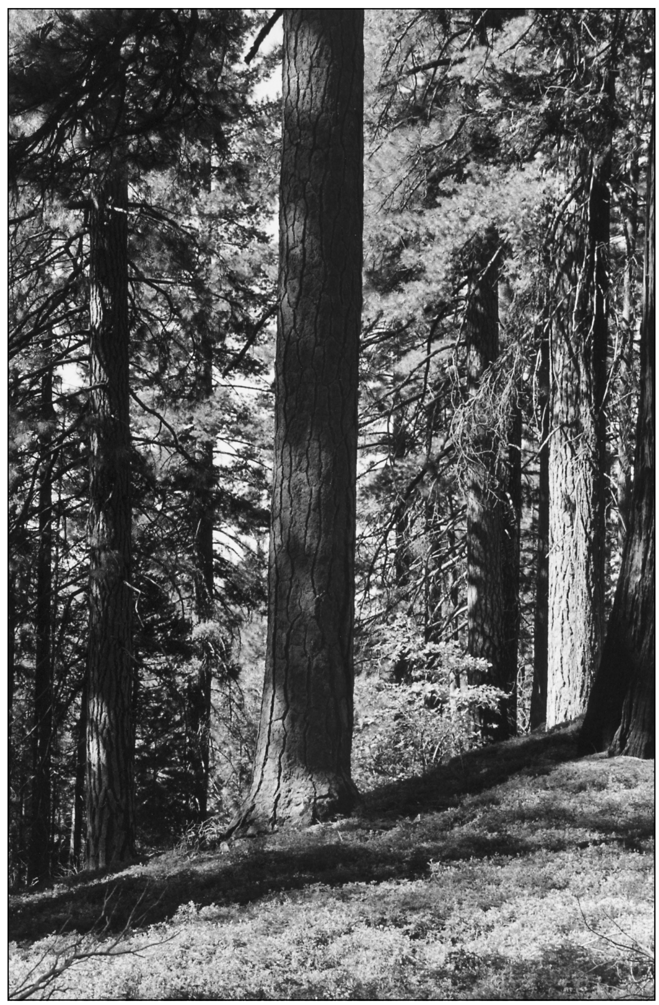
Several specific challenges were present once structural features were adopted as the primary criteria:

- Identifying the appropriate structural features to use as criteria in the analysis;
- Developing a gradient or continuous scale (based on structural features) for rating the contribution of forests to late-successional forest function in the Sierra Nevada; and
- Dealing with the complex, fine scale-mosaic of stands characteristic of many Sierra Nevada landscapes.

High levels of spatial heterogeneity of structure over a broad range of scales is common throughout much of the Sierra Nevada. Structural complexity is typical of many of the forest stands on both the vertical and horizontal dimensions (figures 21.24–21.25). For example, late-successional, mixed conifer stands commonly incorporate a full range of tree species, sizes and conditions, including a component of large-diameter trees—producing the vertical complexity. These are not uniformly distributed throughout the stand, however, so small openings or semi-openings exist where tree reproduction is successfully established. Indeed, many high-quality late-successional mixed conifer and pine forests in the Sierra incorporate all tree stages within a single stand, from seedlings and saplings to large, decadent trees. Hence, it is important to recognize that structural complexity in both the vertical and horizontal dimensions is characteristic of many Sierran LS/OG stands.

FIGURE 21.4

Moderate density old-growth stand dominated by sugar and Jeffrey pine and incense cedar with understory of bear clover. Open stands of this type have high fire resilience and respond well to prescribed burning. Located in Yosemite National Park; late-successional structural ranking of 4 (rangewide standard).



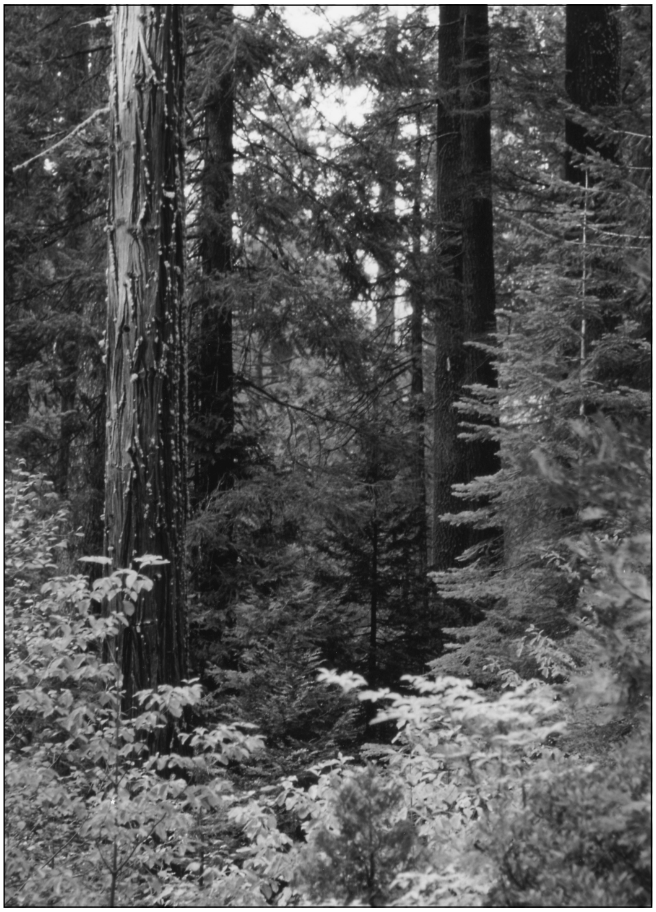


FIGURE 21.5

Dense old-growth mixed conifer stand with high-canopy coverage and abundant large-diameter trees on Eldorado National Forest; late-successional structural ranking of 5 (rangewide standard).

FIGURE 21.6

External view of mixed conifer stand dominated by sugar pine and white fir in Yosemite National Park; late-successional structural ranking of 5 (rangewide standard).

FIGURE 21.7

Dense pine reproduction in small opening created by prescribed burning. Same stand as in figure 21.4.

FIGURE 21.8

Stands with giant sequoia have been incorporated into the westside mixed conifer type group in this analysis. Such stands typically have very high structural complexity and late-successional rankings of 4 and 5 (this stand) unless previously logged; Log Creek drainage, Sequoia-Kings Canyon National Park.

There is a great deal of variability in the levels of structural complexity of Sierran forests, however, due to both natural and human disturbances. Absolute distinctions between "old-growth and non-old-growth", "late-successional and early successional", and managed and natural stands are not possible. There are stands which make extraordinarily high contributions to late-successional forest functions and are clearly the best remaining examples of old-growth forests (e.g., large old trees with medium to high decadence and large snags and logs); these we refer to as "high-quality" LS/OG forests. Some old and undisturbed stands, such as pine forests associated with a bear clover understory, have low tree densities and open canopies; these provide different, but important, habitat conditions than LS/OG forests which have high densities, especially of shade-tolerant species such as white fir.

Many forests with a varied history of management practices and disturbances have highly simplified structures but still make at least some contribution to late-successional forest function and many could potentially, under appropriate management, make additional contributions over time. Highly simplified structural conditions are typical of stands developed following clear-cutting which dramatically limit their current contribution to late-successional forest function in the Sierra Nevada.

A gradient of forest structural conditions was developed and utilized in this assessment to incorporate the variable contribution made by forest stands to late-successional forest functions in the Sierra Nevada. This gradient is partitioned into six classes recognizing a range from ecosystems which have no structural attributes characteristic of LS/OG forests and make no contribution to LS/OG function in the Sierra Nevada

FIGURE 21.9

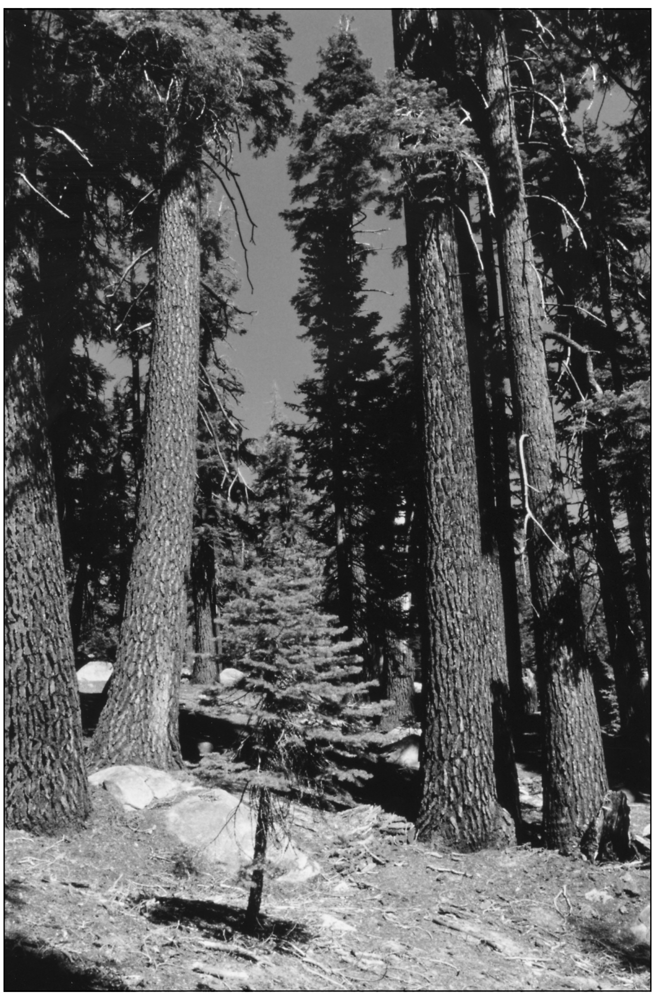
Representative stand of the white fir type group, which is typically found on cooler and moister habitats than the westside mixed conifer type; unknown location, structural ranking of 4 (rangewide standard).

FIGURE 21.10

Reproduction stand of California red fir developed following natural decline of old-growth stand; Tahoe National Forest, late-successional structural ranking of 1 (rangewide standard).

FIGURE 21.11

Old-growth California red fir stand; Yosemite National Park, late-successional structural ranking of 4 (rangewide standard).



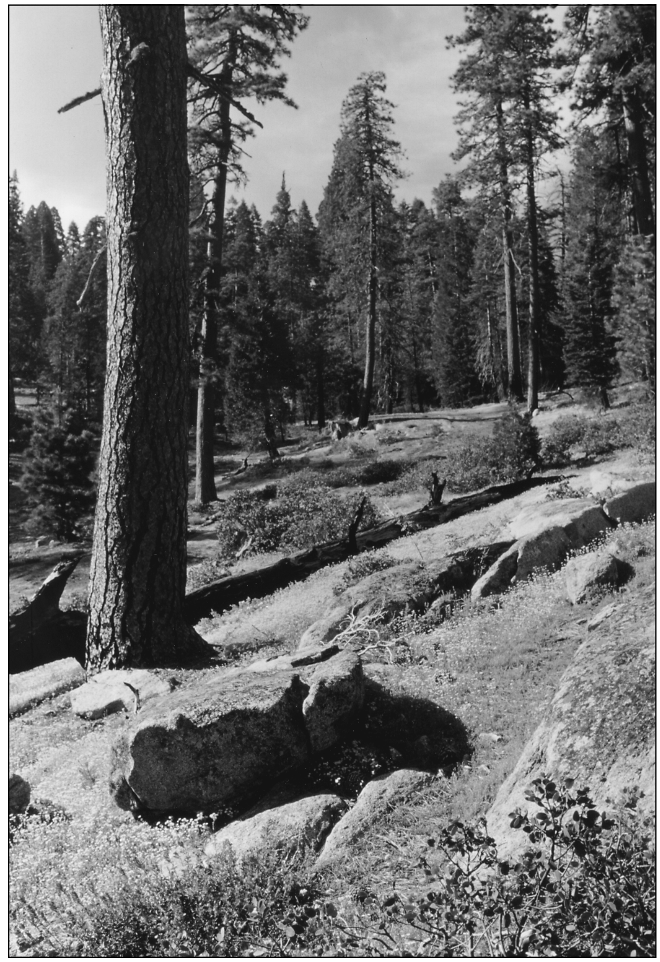


FIGURE 21.12

Low-density stand dominated by Jeffrey pine typical of those associated with granite outcrops and shallow soils; Sequoia–Kings Canyon National Park, successional structural ranking of 2 (rangewide standard).

(structural ranking of 0) to ecosystems which incorporate high levels of structural features characteristic of LS/OG forests and make high contributions to LS/OG function in the Sierra Nevada (structural ranking of 5). This gradient makes it possible to recognize the measurable contributions made by managed as well as recently disturbed forests.

Many Sierran landscapes are intricate mosaics of different forest and nonforest conditions (figures 21.26–21.28). One common pattern in forested landscapes can be described as a "fine-scale, low-contrast mosaic." Fine-scale refers to the size of patch (an area distinguishable from adjacent areas by composition and structure) which is often very small (e.g., from a fraction of a hectare to several hectares). Low contrast refers to the small structural differences between adjacent forest patches. Coarser-textured landscapes dominated by relatively few large patches of continuous closed canopy old-growth forest do exist in the Sierra Nevada, but are not as common. There are also many

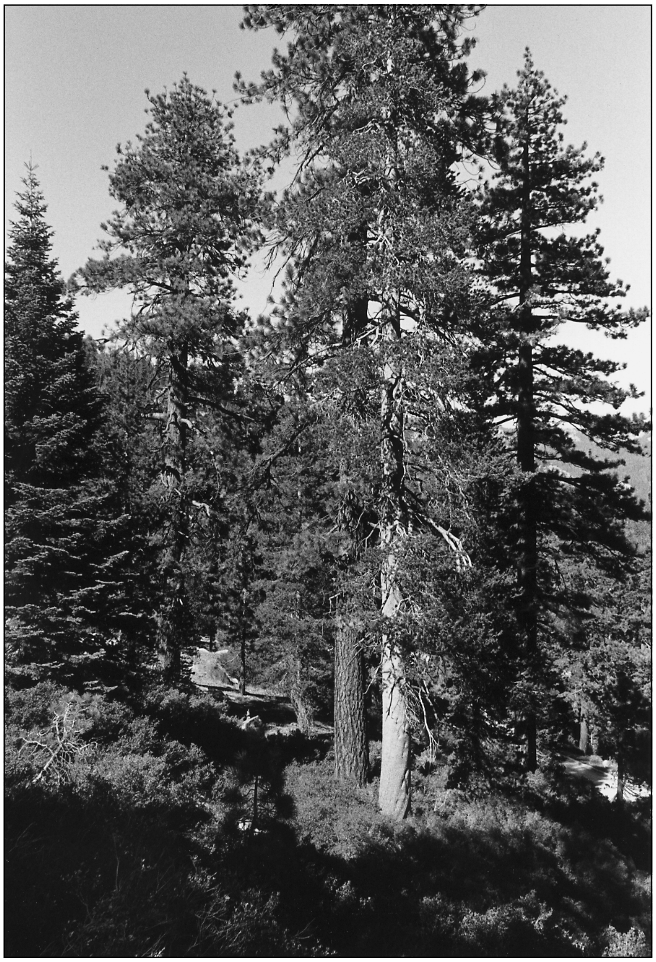


FIGURE 21.13

Mixed stand of Jeffrey and lodgepole pines and juniper on moderately deep soils; Yosemite National Park, late-successional structural rating of 4 (rangewide standard).

landscapes which are fine-scale, high-contrast mosaics but these typically represent situations where forest stands form a patchwork with rock outcrops or other nonforested conditions. These mosaics are the result of both highly localized variations in environment (e.g., soil depth and microclimate) and a complex disturbance history.

We did not feel that it would be possible to deal effectively with tens of thousands of small patches when assessing conditions and developing management scenarios over the entire Sierra Nevada. To perform an effective analysis we decided to map and analyze larger land areas (e.g., 500 to 5000 acres) which were uniform with regards to landscape pattern, i.e., type, proportion and spatial distribution of different vegetational patches. These landscape units are hereafter referred to as "polygons"; they incorporated many, often hundreds, of individual vegetational patches. The polygons represent areas which are specifically judged to be uniform in the amount, type, distribution and functional level of LS/OG forests. To exemplify the variability which might occur in a hypothetical polygon, a polygon might contain patches of: 1) Extensive, selectively cut, mixed conifer stands on gentle topography with remnant large trees and logs; 2) unlogged riparian forests with high levels of late-successional structures; and 3) interspersed open rock outcrops.

Mapping and Polygon Characterization

Successfully meeting the challenges outlined in the preceding sections, including delineation and characterization of landscape units, required full utilization of all available information. Resource specialists were the most critical, single source of information; these specialists provided the extensive, personal, on-the-ground knowledge of forest conditions. Approximately 100 resource specialists participated, gathering in Sacramento, California in March 1994 to develop the initial

FIGURE 21.14

Open subalpine forest of California red fir and western white pine; Stanislaus National Forest, late-successional rating of 2 (rangewide standard).

maps and data base; these specialists were subsequently involved in field review and revision of the late-successional maps and database developed by SNEP. Collectively these individuals represented two thousand years of professional, on-the-ground experience in such diverse areas as ecology, wildlife, silviculture, fire management and timber management. They included employees of the USDA Forest Service, USDI National Park Service, USDI Bureau of Land Management, and California Department of Parks and Recreation. To help insure that the focus was on resource conditions and not influenced by current project plans (such as for timber sales), the personnel involved were staff specialists and not line managers.

The resource specialists were provided with all available information about forest conditions in the Sierra Nevada: aerial and satellite photographs at a variety of scales; orthophotos of quadrangles; maps of forest and wildlife habitat conditions; geologic and topographic maps; inventory data; and maps and information provided by stakeholder groups. We believed that by combining these data with the collective knowledge and wisdom of the field experts, we would achieve the most comprehensive and accurate mapping of late-successional forests possible without initiating new, extensive, and expensive field data collection efforts. Since inventory data on LS/OG structural features (such as large-diameter snags) are very limited for Sierra Nevada forests, a complex synthesis of existing data with knowledge of on-the-ground conditions was essential.

Initial Mapping and Characterization

Major steps in the initial exercise consisted of 1) identifying polygons which were internally consistent in ecological features, including LS/OG function; 2) delineating the polygons on orthophotos or maps; 3) characterizing the ecological conditions of each of the homogenous patch types within each polygon; and 4) determining an overall ranking for each polygon based on its level of late-successional forest attributes.

All steps, criteria, and procedures were pilot tested on the Eldorado National Forest, and suggestions from participating forest staff were incorporated.

1. Polygons which were logical landscape units or groups of patches from the standpoint of function and characteristics were identified and mapped (figure 21.29). The objective was to map polygons that were relatively uniform throughout in terms of the major landscape elements (patch types) and their spatial relationships and which contrasted in one or more mapping criterion from adjacent areas. The size range suggested to the mappers for the polygons was 500 to 2,500 ha (roughly 1250 to 6625 acres). However, smaller polygons were allowed to distinguish unusual and important forest conditions, and much larger polygons were allowed where forest conditions were uniform over very large areas.
2. Conditions within each polygon were characterized utilizing a standard document form (see appendix F in Sierra Nevada Ecosystem Project 1994). Critical aspects of the characterization were identification of the major patch types found within a polygon, their relative importance, and a quantitative characterization of late-successional attributes (such as density and size of large diameter trees and snags) within the forested patch types in each polygon. Hence, the major patch types or ecosystems within each polygon

FIGURE 21.15

Forest landscape representative of many subalpine forest areas in the Sierra Nevada; Yosemite National Park, late-successional structural rating of 2 (rangewide standard).

FIGURE 21.16

Recently burned lodgepole pine stand; late-successional structural rating of 1 (rangewide standard).

FIGURE 21.17

Low-density stand of lodgepole pine associated with granite domes; late-successional structural rating of 1 (rangewide standard).

FIGURE 21.18

Dense, old-growth lodgpole pine stand; late-successional structural rating of 3 (rangewide standard).

FIGURE 21.19

Riparian lodgepole pine and willow community; late-successional structural rating of 2 (including adjacent dense forest, rangewide standard).

were identified and characterized even though their spatial locations within the polygon were not mapped. Also, information was initially developed (and subsequently expanded) on disturbances within the polygon, including disturbance by logging, mining, grazing, recreation, and wildfire. Thus, polygons could be classified based on different ecological or social goals. Mapping was done on Mylar laid over either standard base maps (1/2"=1 mile) or orthophoto quadrangles.

3. Patch types and polygons were ranked with regards to their contribution to late-successional forest function according to a six-point scale:

   0 No contribution

   1 Very low contribution

   2 Low contribution

3 Moderate contribution

4 High contribution

5 Very high contribution level

Quantitative standards to guide resource specialists in their ranking of patch types and polygons were provided (see appendix 21.1). Polygon rankings were ultimately based upon area-weighted averages of the ratings for the patch types within the polygon; hence, although only six classes are used in this presentation, finer scale distinctions are possible. Structural conditions found in the most productive forest types of the Sierra Nevada—Westside Mixed Conifer, White Fir, Red Fir, and Eastside Pine—provided the standards for the six-point scheme for structural complexity. Photographic examples of patch types representative of the six levels of contribution are provided in figures 21.1 to 21.23.

FIGURE 21.20

Representative stand of eastside mixed conifer and white fir type group; Plumas National Forest, structural rating of 3 (rangewide standard).

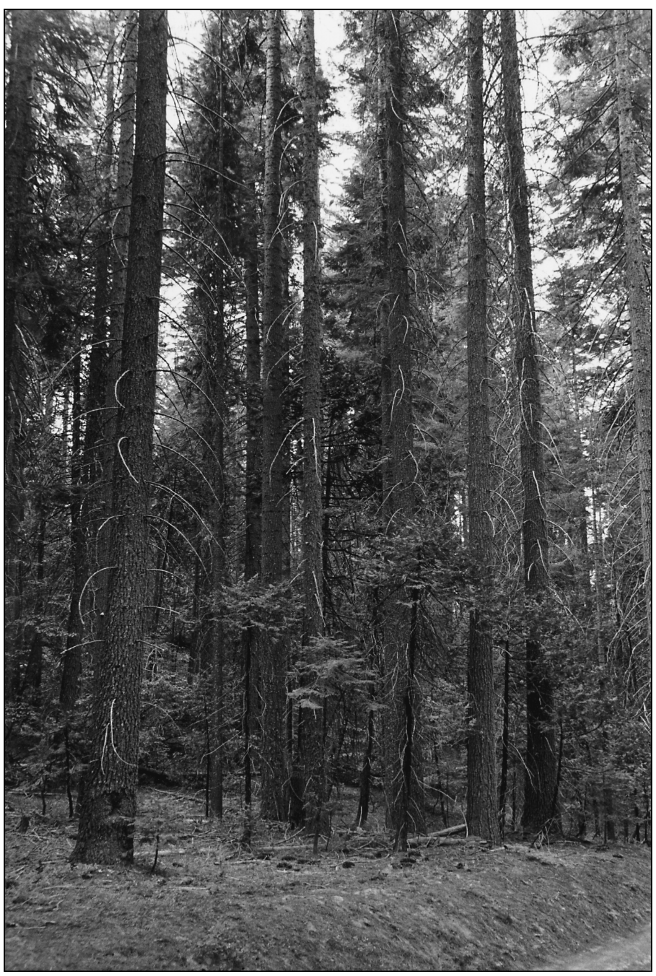


FIGURE 21.21

Young Jeffrey pine stand developed following complete harvest of the overstory trees; Inyo National Forest, late-successional structural rating of 1 (rangewide standard).

FIGURE 21.22

Unlogged old-growth Jeffrey pine stand; Indiana Summit Research Natural Area, Inyo National Forest, late-successional structural rating of 4 (rangewide standard).

4. Standardization among management areas (national forests, national parks, BLM lands, and state parks) was accomplished using a variety of mechanisms including frequent plenary discussions of issues and approaches among the resource specialists and the SNEP team leaders. Most important were the directions and standards provided to the resource specialists, and a continuing review of the mapping and characterization activity by SNEP mapping team leaders. A final review of each management unit was conducted by at least two SNEP team members to assure comparability in mapping, characterization, and ratings; the last part of this review was a check-out procedure for each resource specialist team performed by SNEP staff members to insure that maps and data sheets were complete and ready for digitizing.

FIGURE 23.23

Dense piñon pine stand on the Inyo National Forest that has a late-successional structural rating of 2 (rangewide standard).

5. Mapping delineations and polygon characterizations were entered into computerized data bases by the SNEP Geographic Information Systems (GIS) laboratory and used to produce maps and overlays of the late-successional polygons at the scale of 1/2"=1 mile as well as Sierra-wide maps at the scale of 1:633,000.

Initial polygon delineations and characterizations were completed for forests on federal and state park lands in the project study area, including the Sequoia, Sierra, Stanislaus, Eldorado, Tahoe, Plumas, Modoc, Lassen, Inyo, and Toiyabe National Forests, Lake Tahoe Basin Management Unit, and Lassen Volcanic, Yosemite, and Sequoia-Kings Canyon National Parks.

Subsequent Steps in Mapping and Characterization

An extensive series of steps to review and revise the Mark I maps and characterizations was undertaken following completion of the initial exercise in March 1994. These included: 1)

FIGURE 21.24

Vertical heterogeneity: westside mixed conifer forest transect based on a stand near Aspen Valley, Yosemite National Park (drawn by Robert VanPelt).

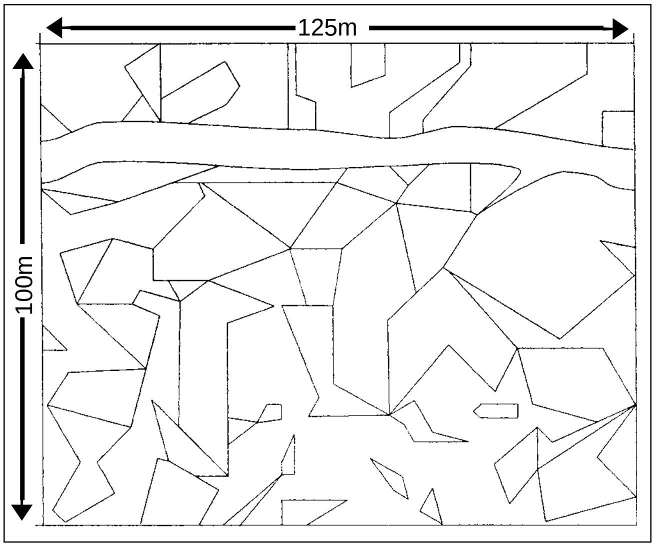


FIGURE 21.25

Horizontal heterogeneity: spatial pattern of reproduction, mature, and old tree groups, Suwanee Creek mixed conifer reference stand, Sequoia–Kings Canyon National Park; note fine-scale mosaic (based on maps from Riegel et al. 1988).

extensive field reviews of the Mark I maps by mappers and SNEP team members and revision of these maps based upon additional data; 2) independent quantitative sampling of patches and polygons to assess the quality of the mappers' characterizations; 3) development of separate structural rating scales for each major forest type group ("series-normalized" scale) to supplement the single ("Sierra-wide") scale utilized in the initial mapping effort and application of this scheme to patches and polygons; 4) external review of the map and database products by individuals knowledgeable regarding forest conditions in portions of the Sierra Nevada; and 5) final revision of the LS/OG maps and polygon characterizations by the authors.

1. Mappers and SNEP team members devoted thousands of hours to field review of the Mark I maps during the 1994 and 1995 field seasons. Mappers concentrated their field efforts in 1994 and concentrated on polygons for which they had lacked adequate information about on-the-ground conditions or about which they had questions of interpretation during the mapping exercise. During 1994 and 1995 SNEP team members conducted field checks on conditions and rankings of polygons with the objectives of visiting all management units (parks, forests, and other lands) that were part of the assessment; field examinations included the relevant mappers as well as other resource personnel for the management unit whenever possible. Priorities for the SNEP review teams were to examine:

   - any polygons about which mappers had questions (which were less than 5% of all polygons)
   - polygons representing a complete range of ratings (from 0 to 5)
   - polygons with a rank of 4 or 5.

   Field examinations by the SNEP team members ultimately included all federal land management units as well as two state parks and covered approximately 20 percent of all of the polygons and 80 percent of all polygons given a structural rank of 4 or 5. Extensive low-elevation flights were also carried out over the entire Sierra Nevada to collect additional information and photographs of conditions in the polygons not readily obtained by ground visits.

   The field review process did result in minor revision of the Mark I product: boundaries or ratings were revised on less than 5% of the polygons. SNEP team reviews judged that mapper polygon ratings followed guidelines and standards in the vast majority of cases. Less than 1% of the polygons were judged to deviate by more than 1 structural class.

2. An independent validation exercise was conducted by Dr. Philip G. Langley under contract from SNEP to quantitatively assess the quality of the late-successional patch ratings (Langley 1996). Unfortunately it was limited in size and geographic scope involving only 400 plots in mixed conifer forest. Following random selection of polygons for sampling, the relevant mappers were asked to map the distribution of patches within these polygons. Plots were than located within patch types to determine whether mappers' delineations showed distinct differences in structural criteria. Results of this validation exercise are provided by Langley (1996) and provide one measure of the quality of portions of the Mark I mapping and characterization effort; the classification accuracy ranged between 44 and 78 percent at the patch level but 82% of the patches were identified within +/- one ranking unit.

3. Late-successional structural-rating schemes—named the "series-normalized" ratings—were developed for each major forest type group during the winter of 1994-95 to supplement the single, rangewide standard used in the initial mapping effort. The original scale was based upon the conditions associated with productive westside mixed conifer, yellow pine, and red fir forests. However, there are clearly major difference in the levels of structural complexity that can be achieved among the different forest types. Subalpine lodgepole pine forests, for example, can not achieve the same level of structural richness as mixed conifer forests because of tree species and site limitations; hence, the most structurally complex lodgepole forest might only be rated as a 3 in a structural scheme based upon mixed-conifer forest.

   Consequently, it was decided to also develop structural rating scales for each forest type group in which the highest level of structural complexity that could be developed would constitute a series-normalized rating of 5. A tabular "crosswalk" was developed which allowed cross comparisons and conversions between the series-normalized and range wide structural rating schemes and all polygons were supplemented with ratings based upon the series-normalized schemes. These crosswalk tables are provided in appendix 21.1.

Ultimately, the series-normalized rankings were not utilized in this LS/OG assessment and are not reported in

FIGURE 21.26

Fine-scale, low-contrast forest mosaics are typical of much of the Westside Mixed Conifer Zone; Plumas National Forest near Quincy, California.

FIGURE 21.27

Highly fragmented landscapes with fine- to medium-scale, high-contrast patch mosaics are common at middle to high elevations where granite domes and outcrops are common; Tahoe National Forest.

FIGURE 21.28

Fragmentation of forest landscapes by clear-cutting, as illustrated here, is not nearly as common as on federal lands in Oregon and Washington; Sierra National Forest.

detail here because of their potential to mislead audiences as to the structural conditions which currently exist in the Sierra Nevada. For example, much of the subalpine forest area in the Sierra Nevada is close to their potential with regards to LS/OG condition and structural complexity and would, therefore, be ranked as 4 or 5 in a series-normalized standard; such forests by the standards of productive forest sites, such as in the mixed-conifer zone, would only have structural rankings of 2 or 3. Furthermore, such forests cannot provide the structures or structurally complex stands necessary to provide for many LS/OG-related species, such as the California spotted owl. Hence, reporting LS/OG conditions based upon a series-normalized standard could cause individuals and institutions using the assessment to grossly overestimate the amount of structurally complex LS/OG forest actually present in the Sierra Nevada.

4. External review of the maps and database products was conducted during the summer of 1995 to provide some independent assessment of the accuracy and overall quality of the products; reviewers were provided access to the maps for the individual national forests and parks (1/2" = 1 mile) as well as to the Sierra-wide maps and complete polygon database with characterizations of the patch conditions. Reviews were particularly sought from individuals that were believed to have detailed knowledge regarding on-the-ground conditions. Included were individuals associated with universities, nongovernmental organizations and forestry groups, and community organizations.

This review process provided additional detailed information regarding late-successional forest conditions. One common concern of external reviewers was the occurrence of small patches of high-quality late-successional forest (4s

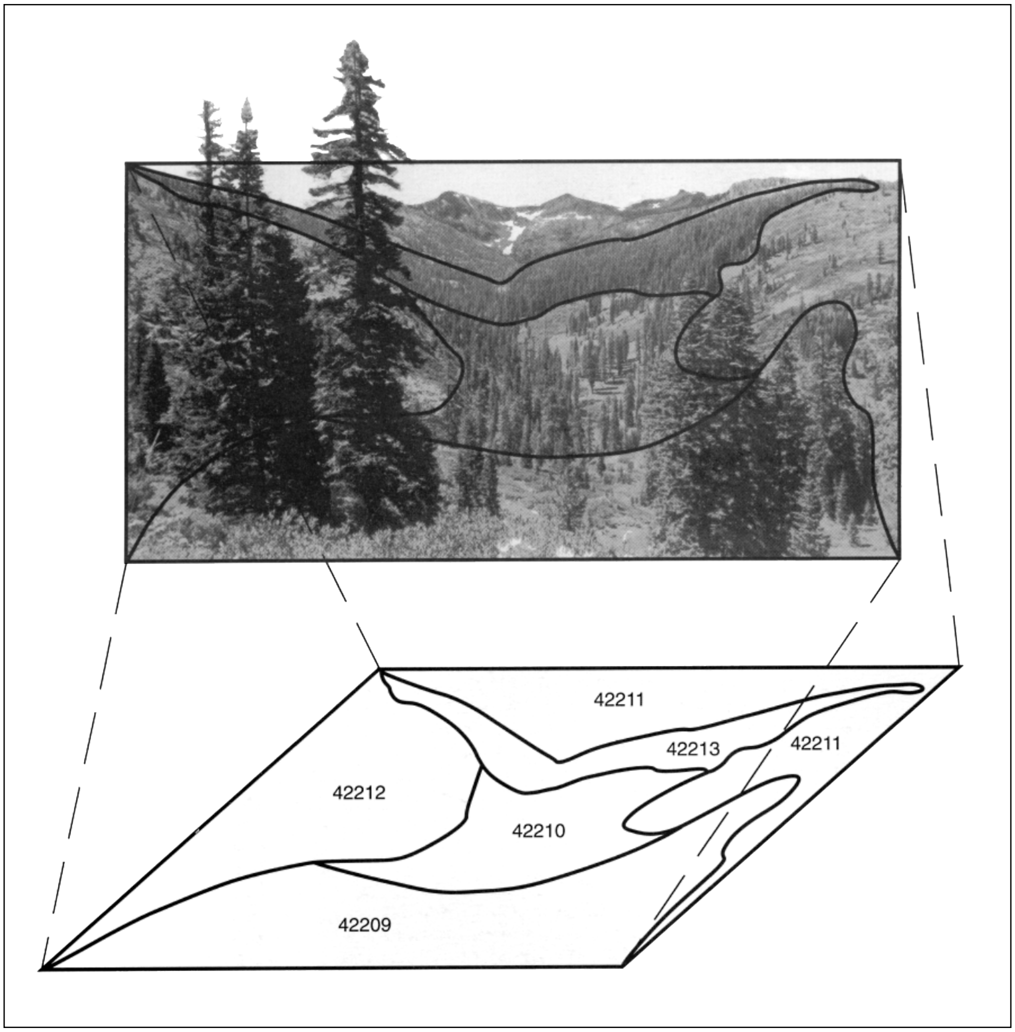


FIGURE 21.29

Division of landscape into polygons that vary in patch pattern and contribution to late successional forest function.

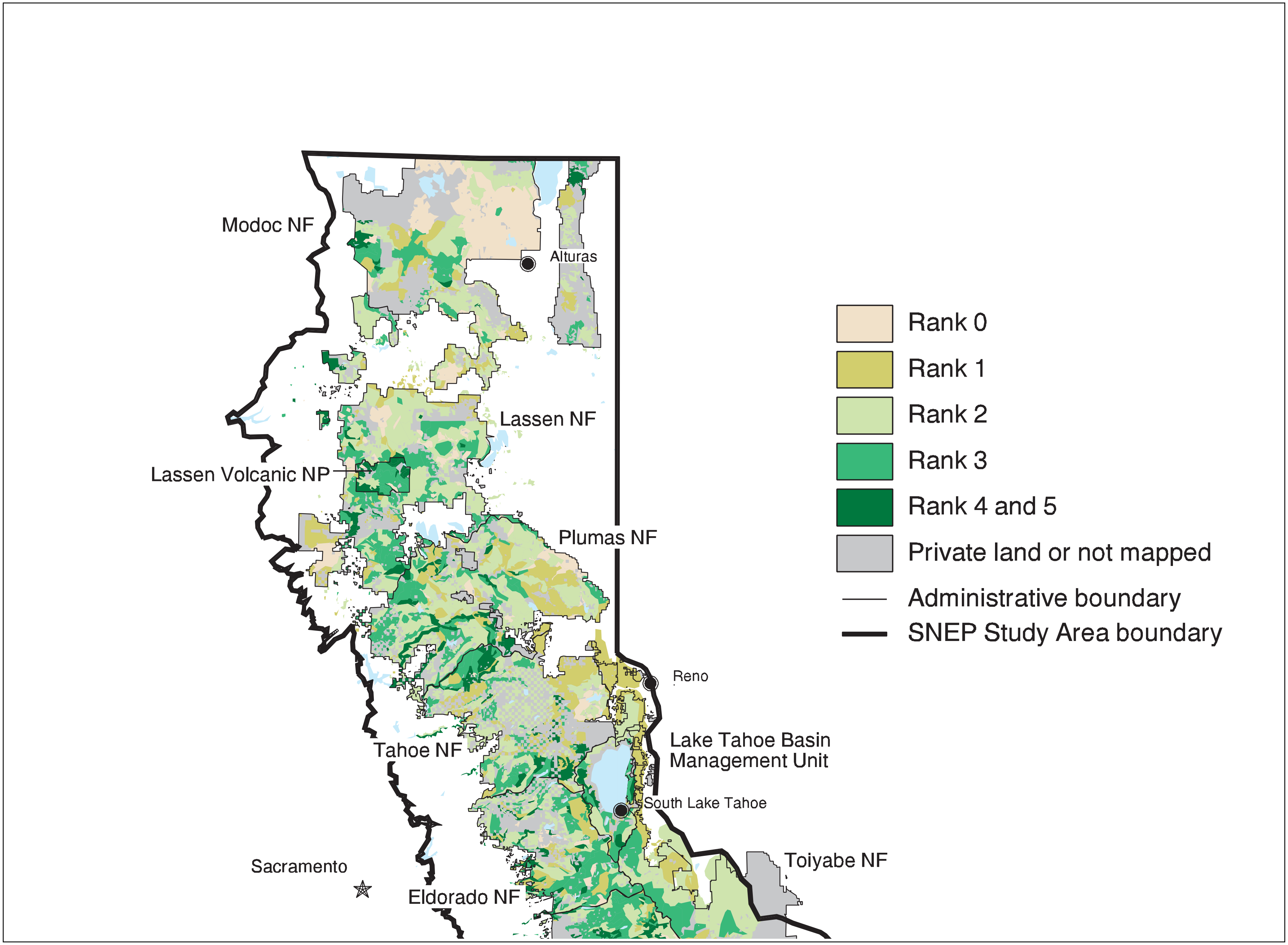
or 5s) within large polygons that had low to medium ratings (1s to 3s) in terms of their contribution to late-successional forest conditions. Such occurrences provided the possibility that important but small areas of high-quality late-successional forest could be "lost" from view. As a result of these comments, additional analyses were conducted to determine how many 3-ranked polygons that had significant patches (e.g., greater than 10 or 25% by area) of higher-rated forest conditions and where they were located. This information already existed in the database and was ultimately utilized in development of alternative management scenarios (Franklin et al. 1996).

5. Final revision of the maps was conducted by SNEP team members following these review processes. Individuals with primary responsibility for this activity were Franklin and Fites-Kaufmann.

PRODUCTS OF THE ASSESSMENT

Primary products of the assessment of late-successional and old-growth (LS/OG) forest conditions in the Sierra Nevada are maps showing the boundaries and ratings for the landscape units (LS/OG) polygons and a database providing information on the patch types and their characteristics for each polygon. Both of these products are available in digitized form.

LS/OG maps have been produced for both individual management units and for the entire Sierra Nevada. Maps for the major public land units (national forests and parks) have been produced at the scale of 1/2"=1 mile and provide more detailed information on polygon boundaries. This information has also been aggregated to produce generalized maps at the scale of the entire Sierra Nevada. Two versions of these Sierra-wide maps are reproduced as plates 21.2–21.6. Both versions are based upon the Sierra-wide structural standard; plate 21.2 provides an overview of conditions throughout the Sierra Nevada while plates 21.3–21.6 provide a more detailed, enlarged



Modoc NF
Alturas
Lassen NF
Lassen Volcanic NP
Plumas NF
Reno
Lake Tahoe Basin
Management Unit
Tahoe NF
South Lake Tahoe
Toiyabe NF
Sacramento
Eldorado NF
Rank 0
Rank 1
Rank 2
Rank 3
Rank 4 and 5
Private land or not mapped
Administrative boundary
SNEP Study Area boundary

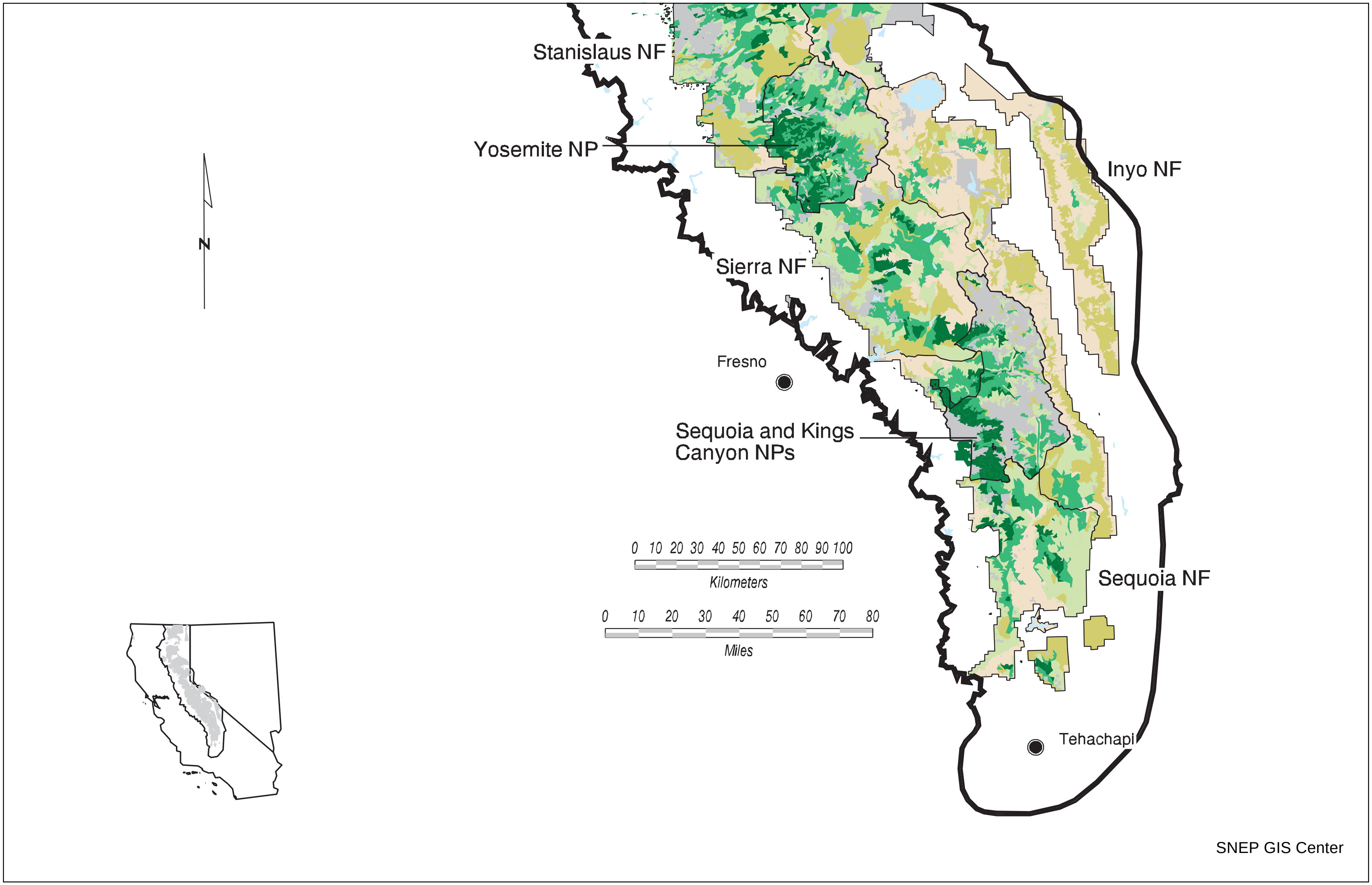


PLATE 21.2

Distribution of polygons on federal lands throughout the Sierra Nevada color-coded as to their degree of LS/OG structural complexity and contribution to late successional forest function (rangewide structural standard).

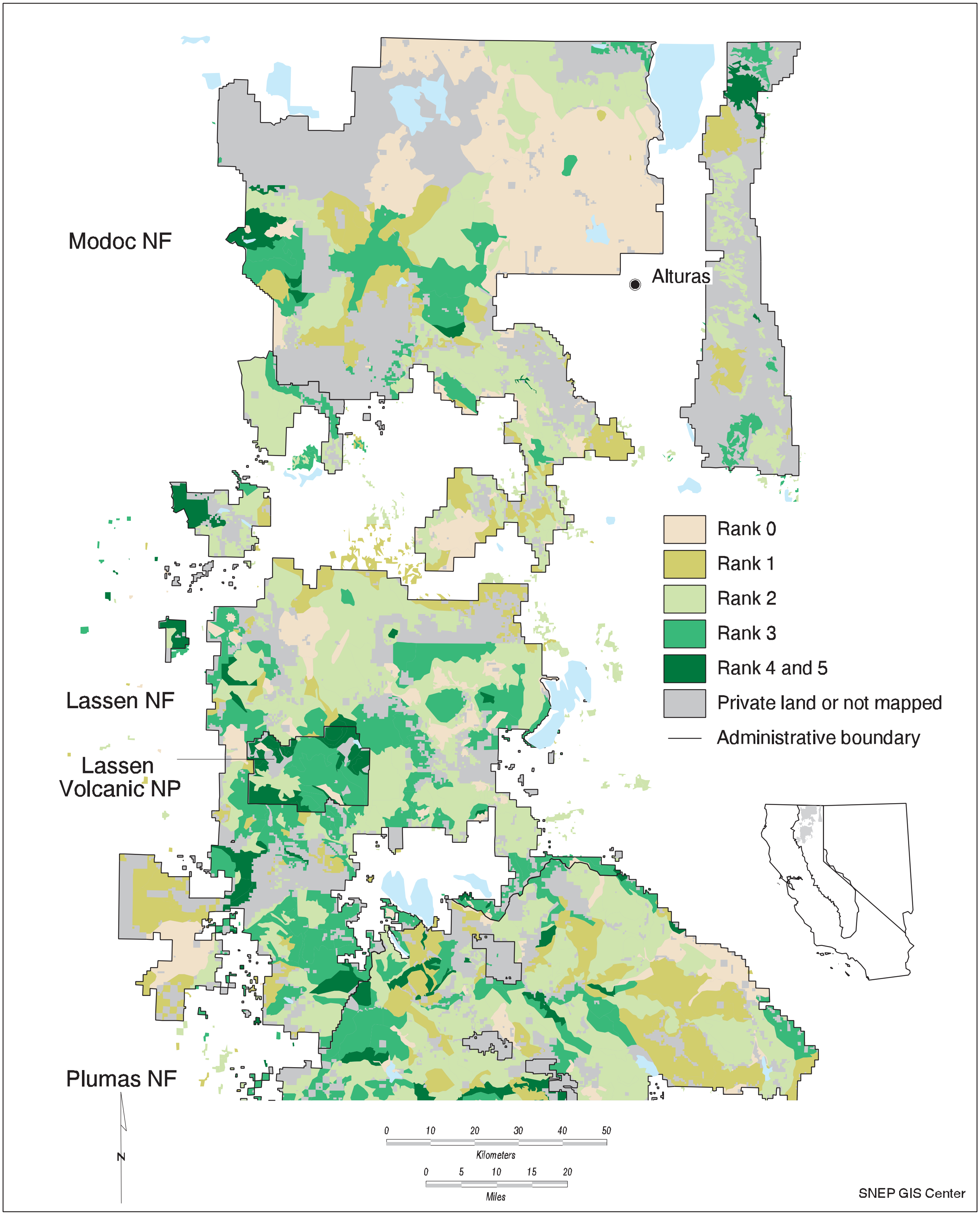


PLATE 21.3

Map of the northern section of the Sierra Nevada showing the distribution of polygons on federal lands color-coded as to their degree of LS/OG structural complexity and late successional forest function (rangewide structural standard).

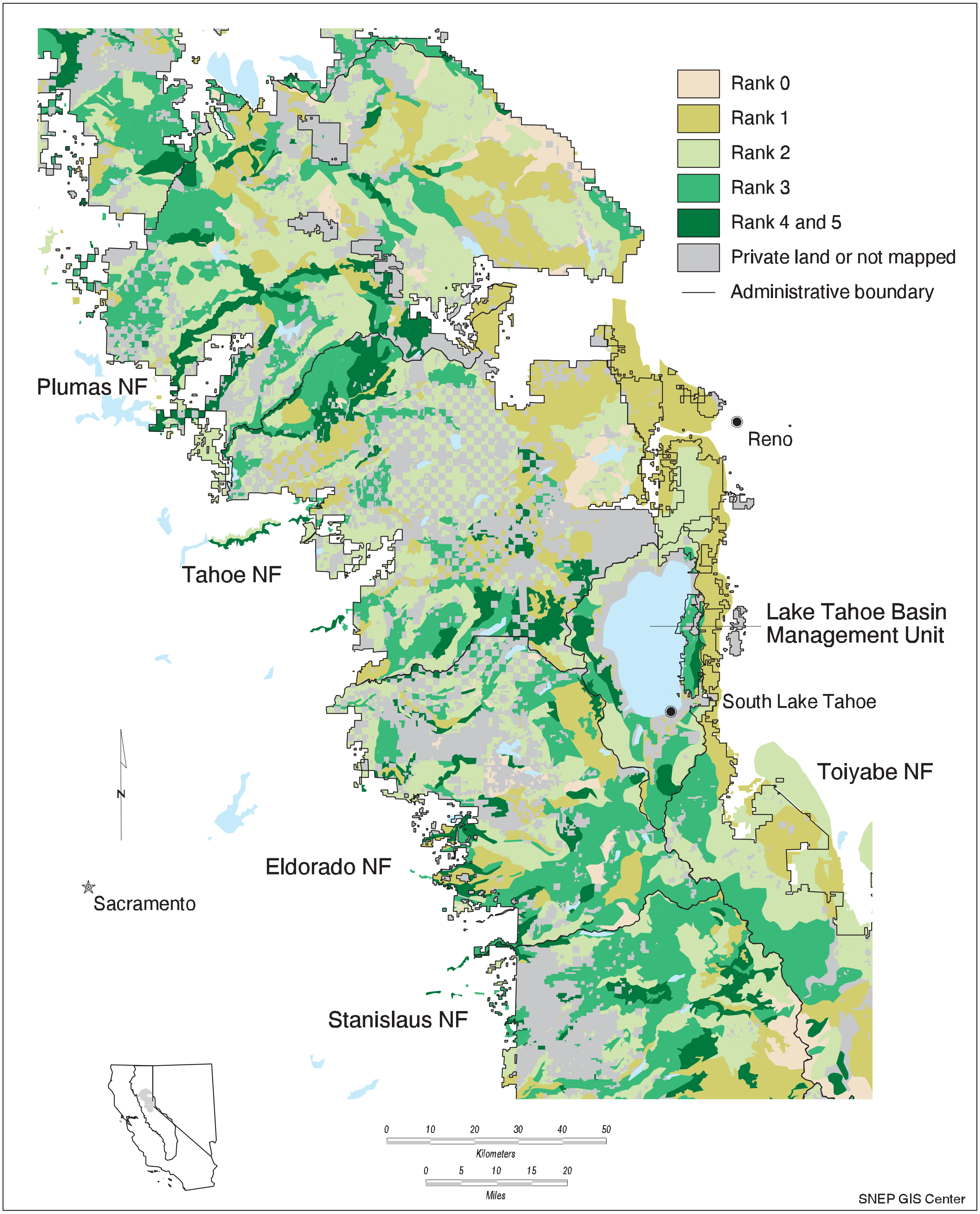


PLATE 21.4

Map of the north-central section of the Sierra Nevada showing the distribution of polygons on federal lands color-coded as to their degree of LS/OG structural complexity and late successional forest function (rangewide structural standard).

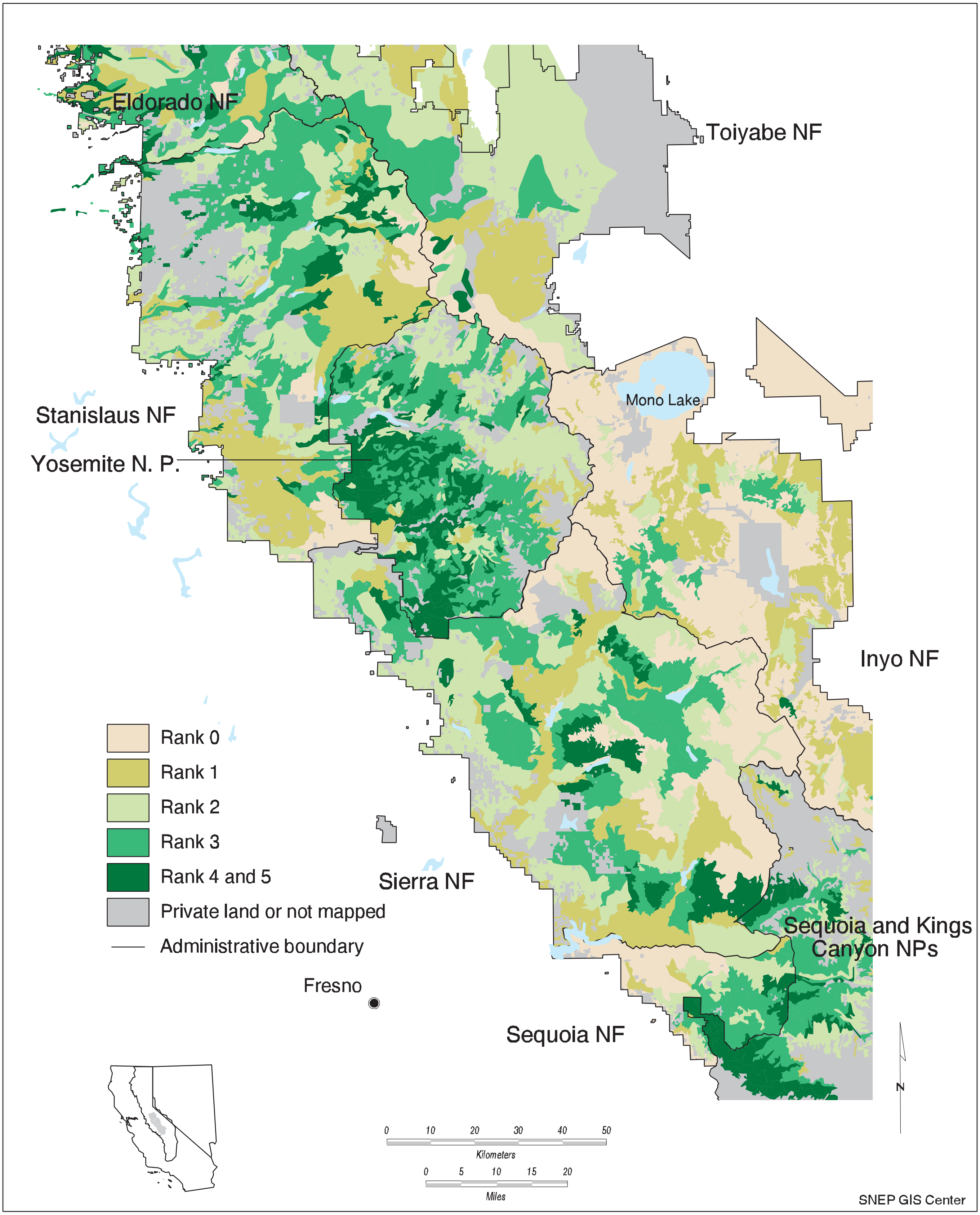


PLATE 21.5

Map of the south-central section of the Sierra Nevada showing the distribution of polygons on federal lands color-coded as to their degree of LS/OG structural complexity and late successional forest function (rangewide structural standard).

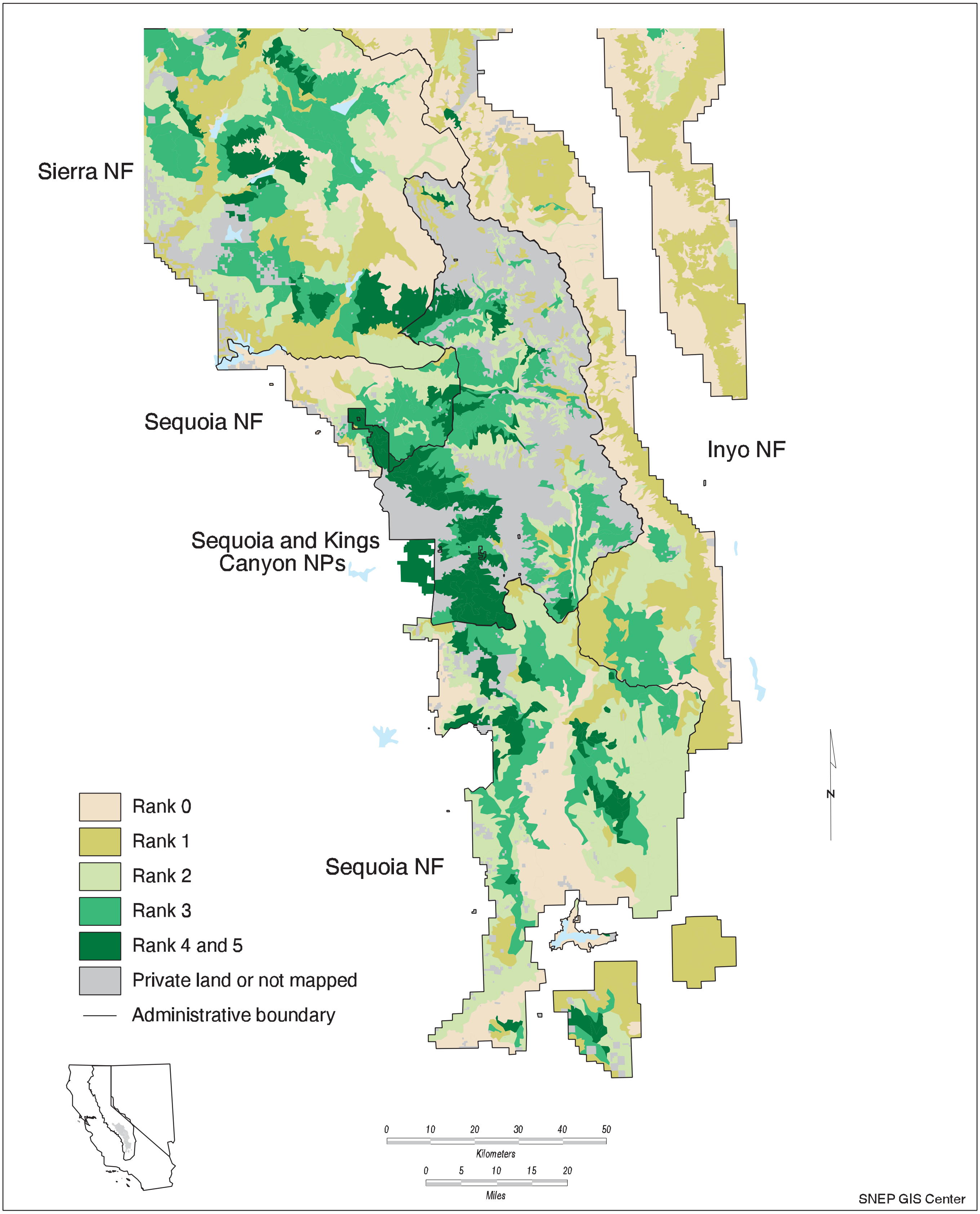


PLATE 21.6

Map of the southern section of the Sierra Nevada showing the distribution of polygons on federal lands color-coded as to their degree of LS/OG structural complexity and late successional forest function (rangewide structural standard).

TABLE 21.2

Number and average size of polygons by administrative unit.

Administrative Unit	Acres Mapped	Number of Polygons	Acres per Polygon
Eldorado NF	774,929	179	4,329
Inyo NF	2,108,445	302	6,982
Lassen NF	1,454,149	219	6,640
Lake Tahoe Basin MU	340,306	26	13,089
Modoc NF	1,602,733	140	11,448
Plumas NF	1,474,914	214	6,892
Sequoia NF	1,185,689	209	5,673
Sierra NF	1,409,418	148	9,523
Stanislaus NF	957,588	281	3,408
Tahoe NF	1,127,435	152	7,417
Toiyabe NF	1,041,264	38	27,402
Lassen Volcanic NP	105,400	33	3,194
Sequoia-Kings Canyon NP	863,025	179	4,821
Yosemite NP	751,592	280	2,684
Bureau of Land Management	133,907	412	325
California State Parks	23,857	49	487
All Units	15,354,652	2861	5,367

view. A Sierra-wide map illustrating distribution of polygons utilizing series-normalized ratings is provided in plate 21.7.

Databases include information for each polygon on the percentage of each major patch type and on tree composition, structural conditions, disturbance history, level of fragmentation due to natural (e.g., rock outcrops) and human (e.g., clearcutting) causes, and other attributes recorded by the mappers.

The polygon mapping and characterization exercise resulted in identification of 2,861 polygons with an average size of 5,367 acres over the entire study area. Results appear to be reasonably comparable across the management units in terms of the size of polygon (table 21.2) with several caveats. Polygons are generally smaller on national and state park lands than on national forest lands probably due to more detailed knowledge of vegetative conditions. In contrast, the small size of Bureau of Land Management polygons reflects the highly fragmented nature of public domain lands. Polygons are generally much larger on the eastern than on the western side of the Sierra Nevada; this was expected since forest stand conditions tend to be much more uniform over large areas east of the Sierra Nevada due to both topographic conditions and management history; good examples are the Modoc National Forest and northeastern halves of the Lassen and Plumas National Forests.

LATE-SUCCESSIONAL, INCLUDING OLD-GROWTH, CONDITIONS

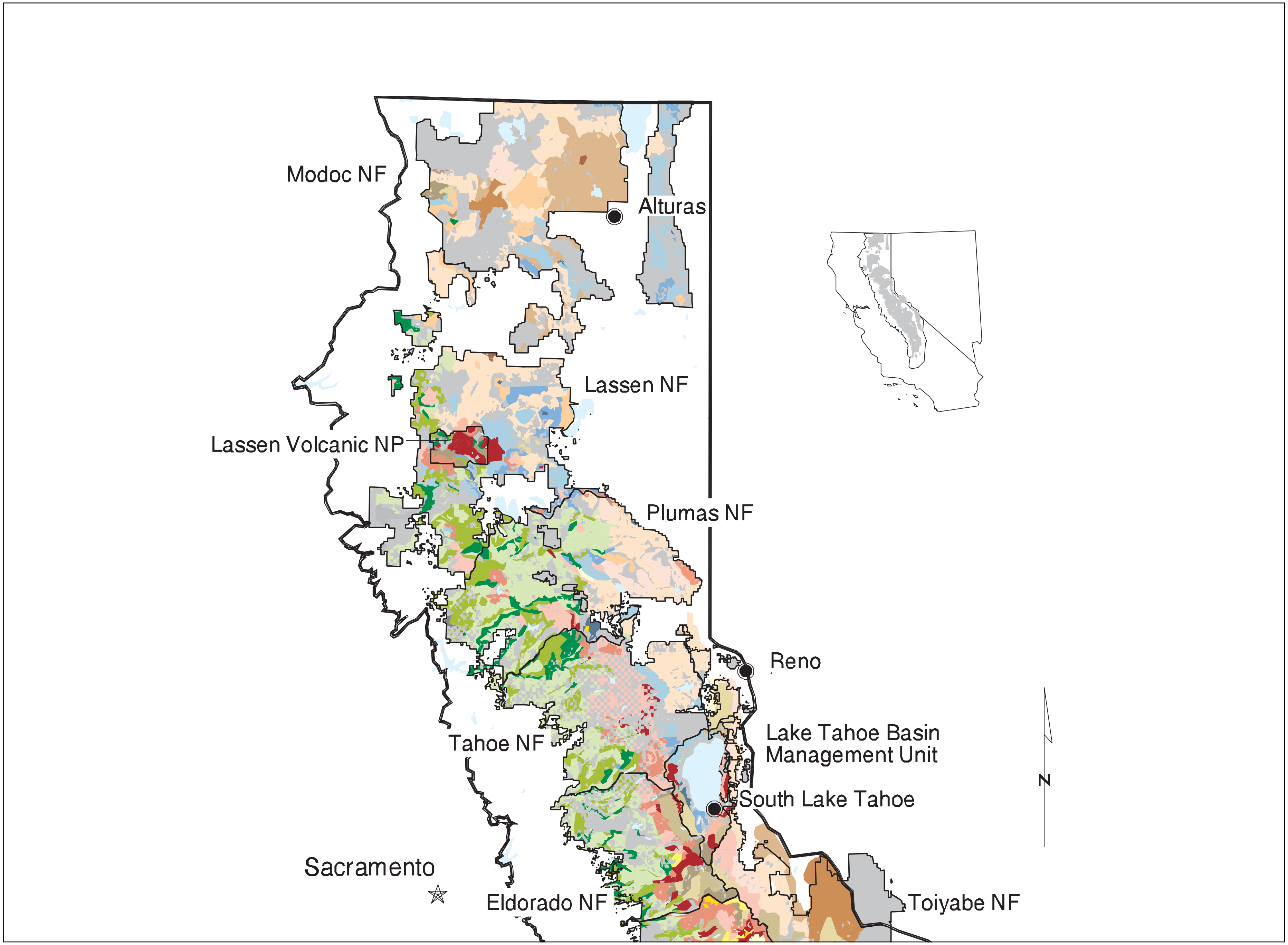
This analysis of LS/OG conditions utilizes the database created in the LS/OG mapping and characterization exercise. Most of the analysis is at the level of the polygons and only federal lands and state parks are considered. The reader is reminded that the scale of structural classes runs from 0 (no contribution to late-successional forest function) to 5 (high level of forest structural complexity and late-successional forest function). The following analysis utilizes only the range-wide structural ranking scheme in order to minimize the potential for misunderstandings with regards to the current extent of structurally complex forest stands in the Sierra Nevada; concerns with regards to the series-normalized structural scale were noted in the earlier section on mapping and polygon characterization. Basic data for the LS/OG assessment are tabulated by structural class and forest type group in table 21.3.

Structural ratings provide the basis for judgments regarding the ability of a polygon to provide for types and levels of late-successional forest functions. One example of such a forest function would be a polygon's ability to provide habitat for species which prefer or require LS/OG forest conditions,

TABLE 21.3

Percentage of polygons by major forest type group and late-successional forest ranking (rangewide structural standard) for all national forest, national park, state park, and Bureau of Land Management lands.

		Percent by Rank					
Forest Type Group	Total Acres Ranked	0	1	2	3	4	5
Foothills Pine & Oak	238,720	14	24	54	8	0	0
Westside Mixed Conifer	3,344,960	4	12	33	31	15	5
White Fir	217,583	3	16	34	33	7	7
Red Fir	1,476,390	0	9	28	34	17	13
Jeffrey Pine	339,759	1	7	28	55	9	0
Subalpine	2,025,003	5	27	32	32	4	<0.5
Eastside Pine	2,776,024	9	24	45	14	5	2
Eastside Mixed Conifer & White Fir	711,982	4	22	39	26	9	0
Pinyon & Juniper	1,461,157	19	75	5	1	0	0
Riparian Hardwood	314,197	7	47	33	7	6	0
All Forest Types	12,905,775	5	20	32	28	10	4



Modoc NF
Alturas
Lassen NF
Lassen Volcanic NP
Plumas NF
Reno
Lake Tahoe Basin
Management Unit
South Lake Tahoe
Tahoe NF
Sacramento
Eldorado NF
Toiyabe NF
N

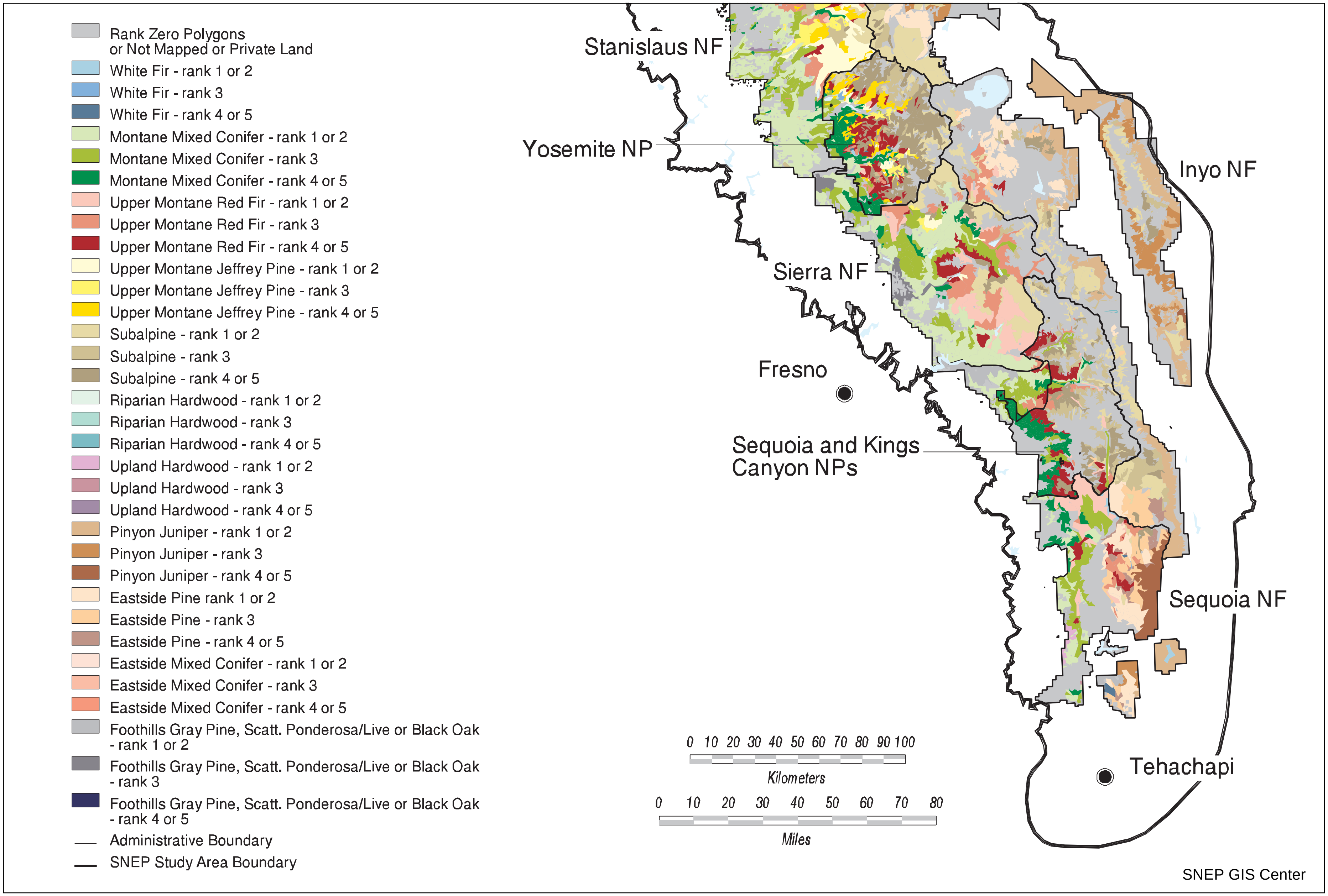


PLATE 21.7

Distribution of polygons on federal lands throughout the Sierra Nevada color-coded as to major forest type group and degree of LS/OG structural complexity (series-normalized structural standard).

such as the California spotted owl, pine marten, or fisher. Regulation of hydrogic regimes is another ecosystem function which varies with both forest structure and composition. For example, stands with high LS/OG structural ratings are likely to contribute less runoff during rain-on-snow flood events than forests on comparable sites but with lower structural ratings, resulting in lower peak flood flows. This is because of several processes, including patterns of snow interception and melt and protection of snowpack within forest stands in old-growth forests (Harr 1986, Harr, Coffin, and Cundy 1989).

The important findings with regards to LS/OG forest conditions in the Sierra Nevada are as follows:

There is relatively little high-quality late-successional forest remaining in the Sierra Nevada, particularly in the commercial forest zones. Forests which have high levels of the structural complexity expected of fully functional LS/OG forests are not common. Only 14% of the polygons have a structural ranking of 4 or 5 in the current Sierran landscape (table 21.3).

Many more polygons—28% of the total—have a structural ranking of 3. The large percentage of polygons with this ranking reflects several factors. In the case of the major commercial types, polygons rated as structural class 3 represent several different circumstances: 1) forests that have been selectively logged at light to moderate levels; 2) productive forest sites on which structurally complex, mature forests have regrown following earlier logging; or 3) naturally fragmented landscapes in which structurally complex stands are interspersed with nonforested areas. About half of the 3-ranked polygons have a significant percentage of their acreage (>25%) in patches with a structural rank of 4 or 5 (table 21.4); these are mostly polygons in productive Westside Mixed Conifer, White Fir, or Red Fir forests.

Several of the major forest type groups do not have the potential to produce stands structurally comparable to those found on the most productive forest sites and therefore make little contribution to highest ranked polygons although they do contribute to the 3-ranked polygons (table 21.3). These include the Foothills Pine & Oak, Subalpine, and Piñon & Juniper type groups. Stands belonging to these forest types may contain trees which are large or old or both and both the stands and trees are important natural features of the Sierra Nevada even if they do not display the structural complexity characteristic of high-quality late-successional forest stands on more productive sites. The low ratings for the Riparian Hardwood type group in table 21.3 are not representative of structural conditions found in this type; most riparian stands were actually included within polygons assigned to other types.

Commercially important forest types—such as the westside mixed-conifer and eastside pine forests—are most deficient in high-quality late-successional forest relative to their potential (table 21.3) and to presettlement conditions. Among the commercial forest types structurally complex forest stands are rarest in eastside ponderosa and Jeffrey pine forests; 78% of the Eastside Pine polygons have ratings of 0, 1, or 2 and less than 7% are rated at structural class 4 or 5. About 14% of Westside Mixed Conifer polygons are ranked as 4 or 5. Both type groups have been foci for commercial forest harvest activities but differ in that the Westside Mixed Conifer is well represented in national parks while Eastside Pine is not; the significance of this is discussed below.

There are several important factors contributing to the current condition of the Eastside Pine forests. Many of these stands were logged very heavily between 1860 and 1900 to support mining and railroad activities on the eastern slope of the Sierra Nevada—Comstock, Silver Mountain City, Bode, etc. Since commercial forests were much less extensive than on the western slopes of the Sierra Nevada, these activities essentially stripped many areas, such as the Lake Tahoe basin. Furthermore, most of the Eastside Pine stands are on gentle topography that is readily accessible to logging. Consequently, repeated selective harvest has been widespread throughout eastside pine forests for much of the last century.

The Westside Mixed Conifer type has also been subjected to a long history of timber harvest utilizing both selection and clearcut methods. Although 14% of the polygons assigned to this type had structural rankings of 4 or 5, two-thirds of these are found in national parks.

Among the forest types traditionally subject to significant timber harvest, polygons assigned to the Red Fir type had the highest proportions of structurally complex forest. Thirty percent of the Red Fir polygons had a structural ranking of 4 or 5 with another 34% in 3-ranked polygons (table 21.3). This probably reflects the less intensive history of logging in Red Fir than in lower-elevation forest types.

Key structural features of late-successional forests—such as large diameter trees, snags, and logs—are generally at low levels in the forests of the Sierra Nevada. The low structural ratings for many polygons reflects the widespread absence of key structural features of LS/OG forests, many of which are critical in providing for late-successional functions such as provision of habitat for many elements of biological diversity (Graber 1996). A logical inference from both the rankings and the tabulated characterizations of the patches developed in the mapping exercise is that large-diameter decadent trees and their derivatives—large snags and logs—are generally absent or at greatly reduced levels in accessible, unreserved forest areas throughout the Si-

TABLE 21.4

Proportion of 3-ranked polygons with varying percentages of included 4- and 5-ranked patches for several forest type groups (rangewide structural standard).

	Percentage of polygon in 4- or 5-ranked patches			
Forest Type Group	<5	5–25	25–50	>50
Westside Mixed-Conifer	59	9	18	14
Red Fir	48	20	13	19
Eastside Pine	60	23	12	5

erra Nevada. This reflects the selective removal of the large trees in past timber harvest programs as well as the removal of snags and logs to reduce forest fuels due to wildfire concerns. Snag removal programs have been underway on both public and private lands for over 60 years and log reduction programs have been underway for about half that period.

The inferences drawn from the SNEP LS/OG database are consistent with those of McKelvey and Johnston (1992) who compared current stand structure data from Westside Mixed Conifer forests with data collected from sample plots on the forest reserves at the beginning of the 20th century.

On the positive side, the forest cover of the Sierra Nevada is relatively intact and most forest stands have sufficient structural complexity to provide for at least low levels of late-successional forest function. Despite nearly 150 years of significant activity by western man, there is still a high level of continuity in the forest landscapes (figures 21.26–21.28). Of course, there is substantial natural fragmentation of forests at higher elevations (figure 21.13). However, high-contrast human fragmentation due to settlement clearing, mining, logging, and other activities is relatively low, particularly in comparison with the highly fragmented conditions on federal forestlands in Washington, Oregon, and northwestern California. Differences between the Sierran and Cascadian regions are clearly due to relatively recent introduction of modern clearcutting techniques on public lands in the Sierra Nevada. Partial cutting has been the most common harvest system on forestlands in the Sierra Nevada up until the 1970s and some ranger districts initiated extensive clearcutting operations as recently as the early 1980s. In contrast, dispersed patch clearcutting has been used almost exclusively on federal timberlands in the Pacific Northwest since the 1950s.

Other important factors contributing to the continuity of forest cover in the Sierra Nevada are the significant recuperative ability of forests, especially on the productive mixed-conifer sites, and active and successful reforestation programs which converted many nonstocked and understocked lands to fully stocked forest stands.

While forest continuity is high in the Sierra Nevada, as noted above, the forest structure has been greatly simplified relative to presettlement conditions so that these forests do not provide the same level of wildlife habitat and other ecological functions characteristic of high-quality LS/OG forests. Nevertheless, the majority of forests do have sufficient structural complexity to provide for at least low to moderate levels of LS/OG function. For example, about 75% of the forested polygons have a structural ranking of at least 2 (table 21.3). This rating indicates stand structural complexity comparable to 1) a maturing forest stand in the Westside Mixed Conifer zone which developed following clearcutting or 2) a stand which has been subjected to intensive selective harvest of larger-diameter trees. Forests of these types—with trees of at least moderate diameter and moderate to high canopy coverage or forests with scattered large-diameter trees—are widespread in the Sierra Nevada and provide at least some habitat and other ecosystem functions characteristic of late-successional forests.

TABLE 21.5

Differences between adjacent national forests and national parks in proportions of polygons with high rankings for late-successional forest function (rangewide structural standard).

	Percentage of Polygons	
Administrative Unit	**3+4+5**	**4+5**
Lassen National Forest	31	5
Lassen Volcanic National Park	64	35
Stanislaus and Sierra National Forests	33	9
Yosemite National Park	54	22
Sequoia National Forest	24	9
Sequoia–Kings Canyon National Park	38	18
All national forests	32	9
All national parks	50	21
All federal lands	34	11

High-quality late-successional forest areas (structural classes 4 and 5) do exist throughout the federal landbase. However, there are significant differences in the amounts of such forest among the federal management units (table 21.5).

National parks provide the major concentrations of high-quality late-successional forests, especially at the landscape level, and, on a percentage basis, have about twice as much highly-rated forest as adjacent national forests (table 21.5). The major concentrations of high-quality LS/OG forests associated with Yosemite, Sequoia-Kings Canyon, and Lassen Volcanic National Parks is apparent in plates 21.2, 21.3, and 21.4. When these properties are compared with adjacent national forest lands the percentage of structural class 4 and 5 is over twice as great on the national park lands (table 21.5); similarly, the percentages of polygons ranked as 3 or better is nearly twice as high on national park lands. Timber harvest activities on the national forest lands are almost certainly a major factor in these differences in structural complexity between adjacent national forests and parks.

The national park forests provide an important reference point for presettlement levels of high-quality late-successional forest in the Sierra Nevada. The percentage of polygons ranked as structural classes 3, 4, and 5 found in national parks probably represents conditions that were general throughout the Sierra Nevada in comparable forest types prior to initiation of timber harvest and other modern human activities. There are some factors that confound such an interpretation. For example, it can be argued that fire control programs on national parks have moved forests toward a more structurally complex state (therefore reflecting an "unnatural" condition); i.e., an assertion that wildfire control has inflated the percentage of structurally complex forests. There are counter arguments, however. For example, fire control programs have had as much effect on national forest lands. More important is the fact that Sierran stands subject to frequent to moderate fire regimes typically display high levels of structural complexity. Hence, unless there was substantially more high-intensity stand-replacement fire in the presettlement landscape then is currently believed, fire control should not have significantly altered the collective percentage of polygons ranked as 3s, 4s, and 5s. Fire control could have altered stand densities and shifted the average rating toward a higher value, however.

The distribution of national forest polygons with high-quality late-successional forest is not uniform; many high-ranked areas in the northern and central Sierra Nevada are associated with major river canyons. Many of the remaining high-quality LS/OG areas on the Stanislaus, Eldorado, Tahoe, Plumas and Lassen National Forests occur within the canyons of major river drainages along the western edges of the national forests. Most remaining high-quality LS/OG forest was expected to occur in more remote locations within the center of the range. However, many steep and relatively inaccessible canyons and canyon walls have escaped significant logging and contain good to excellent examples of structurally complex forest habitats. Polygons of this type were mapped in the American, Feather, Yuba, Cosumnes, Rubicon, Mokelumne, and Stanislaus River and the Mill and Deer Creek drainages. Since such areas are often at the interface with rural and urban environments, wildfire is a major concern if the high-quality LS/OG forest condition is to be maintained.

Much of the highly-ranked late-successional forest on national forest lands is unreserved and potentially available for harvest. About half of the remaining structurally-complex forest on national forest lands is unreserved, i.e., within the landbase potentially available for harvest. For example, 46% of the Westside Mixed Conifer polygons ranked as structural classes 4 and 5 are in the "suitable" land class under current national forest plans and therefore available for harvest. The comparable figure for polygons assigned to the Red Fir type is 30% of the 4- and 5-ranked polygons in the suitable landbase. Conversely, there is very little high-quality Westside Mixed Conifer forest found within congressionally reserved areas, such as Wilderness, except for the national parks. The percentage of high-quality LS/OG forests available for timber harvest would be less under the preferred alternative in the California spotted owl EIS (USDA Forest Service Pacific Southwest Region 1995).

We conclude this section on results with some general observations on forest health in the Sierra Nevada. These are based upon several sources of information including the LS/OG database, current research by the second author, and observations and photographs made during evaluations of the LS/OG maps, including extensive low-elevation flights over the Sierra Nevada.

Forest health in the Sierra Nevada Range is generally good; problem areas are localized. Most forest stands in the Sierra Nevada appear to be healthy; i.e., levels of mortality due to insects and disease are at levels that are normal or near normal for natural stands. Catastrophic mortality of trees in forest stands is found in particular localities many of which are close to the margins of the forested zones, i.e., near the lower elevation transitions between forests and savannas or nonforested vegetation. This is predictable since greater physiological stresses occur at such locations during periods of drought such as was recently experienced. The ecotonal areas are also the sites where some of the greatest shifts in stand density and composition have occurred as a result of fire suppression.

Forests along the eastern face and forest margins of the Sierra Nevada are the most common locale of stands which are undergoing (or have already undergone) catastrophic mortality. Examples of such stands are found on portions of the Inyo, Toiyabe, Plumas, and Lassen National Forests and in the Lake Tahoe Basin Management Unit. In many of these stands the bulk of the mortality has been in the white fir component (figure 21.30) although other species have also undergone significant mortality.

Many forests and woodlands along the western boundary of the southern Sierra Nevada have also undergone high levels of mortality, particularly of pine trees. Air pollution is an important factor in this part of the Sierra Nevada (Cahill et al. 1996) in addition to stresses associated with drought cycles. Conditions of stand collapse are not widespread at this time, however.

DISCUSSION OF FINDINGS AND IMPLICATIONS FOR MANAGEMENT

Limitations in Local Application of Database

There are limitations in how the information from this assessment can be applied. Users need to recognize that the objective of the assessment is to provide information for use in development and evaluation of policy scenarios at the scale of entire Sierra Nevada, not as a basis for site specific projects. Consequently, the databases need to be utilized with caution in interpreting localized conditions. Databases and maps should not be utilized for local management purposes without additional ground-based measurements. Detailed on-the-ground examinations are important in assessing the appropriateness of polygon boundaries, patch characterizations, and overall rating of forest structure and function from the standpoint of late-successional species and processes. The validation exercise (Langley 1996) confirms the appropriateness of the assessment at the larger scale and identifies problems that may be encountered in trying to apply the assessment within local areas without further checking.

Individuals using the LS/OG database should note that the analysis actually utilized a continuous scale of structural complexity. This perspective is sometimes lost since polygons were assigned to one of six discreet grades (0 to 6). In fact, polygon ratings were based on weighted averages which provided gradations (such as rankings of 3.1, 4.2, etc.) but the rankings were rounded to the nearest whole number on the maps and in most analyses.

Reviewers identified several problems with the continuous structural scale and the use of a weighted average to calculate overall ratings for large polygons. One of the greatest concerns was the potential for small patches of structurally complex, high-ranked LS/OG forest to get "lost" in polygons dominated by forests with low structural rankings. Polygons with overall late-successional rankings of 3 were particular problems because these polygons were numerous and many contained patches of forest with structural ranks of 4 or 5. A subsequent analysis of the 3-ranked polygons confirmed that this is a significant issue (table 21.4). For example, about 1/3 of the 3-ranked Mixed Conifer polygons had more than 25% of their area occupied by patches ranked 4 or 5. The LS/OG database can, of course, be queried to identify polygons which contain higher-ranked forest patches should subsequent users wish to do so.

Presettlement Extent of Late-Successional Forest Ecosytems

The original extent of high-quality LS/OG forests in the Sierra Nevada and its relation to current forest conditions is an issue of interest. It is our conclusion that the current extent of high-quality LS/OG forest ecosystems in the Sierra Nevada is far below levels that existed prior to western settlement. This comment is intended simply to put the current situation in a historical context, not to propose that these levels should be recreated or are necessary to maintenance of late-successional forest function in the Sierra Nevada.

Several lines-of-evidence support the conclusion that LS/OG forests were once much more extensive. Descriptions of forests in early surveys of forest reserves, such as those by Leiberg (1902), Sudworth (1900), Fitch (1900a, 1900b), and Marshall (1900), indicate that structurally-complex forests dominated by large-diameter trees were very widespread except where stands had been affected by logging or catastrophic fire. McKelvey and Johnston (1992) provide an excellent re–view of this information, including an evaluation of human

FIGURE 21.30

Major forest health problems are currently located along the margins of the forested zones, particularly at the eastern ecotone with the sagebrush and grasslands. Illustrated here is extensive mortality of white fir in a dense stand on the east slope of the Sierra Nevada, Toiyabe National Forest.

impacts between approximately the mid-19th century and the present.

The widespread condition of structurally-complex LS/OG forest ecosystems can also be inferred from the fire regime currently believed to have been characteristic of the presettlement Sierra Nevada landscape. A regimen of frequent, light- to moderate-intensity fires would result in the dominance of structurally and compositionally heterogenous forests incorporating the major structural features characteristic of high-quality LS/OG forests: large-diameter pine trees, snags, and logs and areas with low overstory density (gaps) dominated by tree reproduction and shrub communities (figures 21.24, 21.25). Structural simplification would generally occur only following more extensive, high-intensity fires, a circumstance currently believed to have been uncommon.

Current conditions in the national parks as identified in this assessment provide a third basis for drawing inferences about presettlement conditions (table 21.5). The estimate that 50% of the national park landscape is in moderate- to high-quality (structural ranks 3 through 5) LS/OG forest includes all polygons and not just those within the commercial forest types. For polygons within the national parks identified only with the five mid-elevation forest types, the percentages of various structural ranks are:

	Rank	
	3 + 4 + 5	4 + 5
All national forests	42	13
All national parks	82	55

Hence, current forests on productive sites in the national parks are overwhelmingly dominated by structurally complex conditions. Even assuming that densities and compositions have increased in these forests as a result of fire control programs, it is still reasonable to infer that most of these forest types were in stands of moderate to high structural complexity in presettlement times based upon the presumed fire regimes.

The collective inference from all lines of evidence is that stands with moderate to high levels of LS/OG-related structural complexity occupied the majority of the commercial forestlands in the Sierra Nevada in presettlement times.

Maintaining High-Quality Late-Successional Forest Ecosystems

The discussion in this section assumes that the maintenance of structurally-complex, LS/OG forest ecosystems is an objective of public policy in the Sierra Nevada and, further, that the intention is to maintain sufficient amounts of and linkages between LS/OG forests so as to provide a high probability of the long-term persistence of viable LS/OG ecosystems and associated organisms. Such a policy has not been adopted but an analysis of issues related to implementation of such a policy was a part of the SNEP assignment. We further assume that any LS/OG strategy will be integrated with other objectives including maintenance of riparian and aquatic ecosystems and activities to reduce risks of catastrophic events to acceptable levels. The discussion is focused upon the major commercial forest types of the Sierra Nevada (Mixed Conifer, Eastside Pine, White Fir, and Red Fir); most Subalpine forests are already reserved and the Foothill Pine & Oak forests of the western slopes and Piñon-Juniper woodlands of the eastside generally do not provide structurally complex forests of the type found in the densely forested zones.

The Working Group on Late-successional Conservation Strategies (Franklin et al. 1996) has identified and discussed issues associated with the development and evaluation of conservation strategies for late-successional forests in the Sierra Nevada. We rely heavily upon their conclusions as a basis for this discussion and refer the reader to their paper for more complete information. Some of the key elements of an LS/OG conservation strategy which they identify include: 1) retaining existing high-quality LS/OG forests; 2) providing for large, contiguous blocks of LS/OG forests; 3) spatially explicit planning; 4) designating reserves where maintenance of high-quality LS/OG forests is the primary objective; 5) restoring fire as an important component of management; and 6) restoring conditions in the matrix. Available information on LS/OG forest ecosystems, processes, and organisms is an important limitation in devising conservation strategies resulting in more conservative approaches than might be necessary with a larger information base.

If maintenance of high-quality LS/OG forest ecosystems is adopted as a policy objective, the goals of that program need to be defined and management programs initiated which will: 1) maintain existing high-quality LS/OG forests; 2) restore such conditions where the existing LS/OG forests are insufficient to achieve objectives; 3) restore fire as an important process in maintaining and protecting LS/OG forest ecosystems; and 4) restore structural complexity in the matrix.

If maintenance of high-quality LS/OG forests is adopted as policy on federal forestlands in the Sierra Nevada further timber harvest within existing high-quality LS/OG forest areas should be halted for at least an interim period of planning and assessment. The desirability of maintaining existing high-quality LS/OG forests in the Sierra Nevada is based upon their limited extent and a high level of uncertainty regarding our ability to fully recreate comparable stands silviculturally (Franklin et al. 1996).

The appropriate areal extent of high-quality LS/OG forests needed to achieve specific purposes is not clear from existing information. However, the current level of high-quality LS/OG forests is far below levels that existed in the presettlement landscape and as well as the natural range-of-variability. Hence, restoration of LS/OG conditions in structurally simplified stands is likely to be an important part of achieving desired amounts of LS/OG forests in some localities, particularly where levels are currently very low, such as in much of the Eastside Pine type.

Regardless of the acreage objective and of the management strategy ultimately adopted for LS/OG forest ecosystems, the interim reservation of existing high-quality LS/OG forests from further timber harvest would maintain the largest set of options out of a relatively small existing set.

Active management to restore low- to moderate-intensity fire to existing and prospective LS/OG forest ecosystems is the most important management action needed to restore more natural conditions and reduce risks of loss to catastrophic disturbances, i.e., intense stand-replacement wildfires. Such programs are an essential element in a reserve-based conservation strategy and must be carried out at sufficient scale and frequency to be effective. Passive or lassize faire approaches to management may result in unacceptable losses of such forests. Current prescribed and managed fire programs in the national parks provide a model for active management of LS/OG forest ecosystems although the scale of the national park programs may not be adequate to achieve objectives. It is probably not possible (or, perhaps, desirable) to completely eliminate the potential for stand replacement fire; rather the overall goal should presumably be to reduce the probability of such fires to levels that would allow some desired level of high-quality LS/OG forest to be maintained in the Sierra Nevada over long time periods.

Active management to reduce risks of catastrophic fire are particularly critical at the interfaces between LS/OG forests and suburban, rural, and recreational developments. The LS/OG mapping identified a number of polygons which are outstanding examples of high-quality LS/OG forests at interfaces with urban developments along the western boundaries of the national forests. Some eastside forests, such as those in the Lake Tahoe Basin, also exhibit this juxtaposition of forest and human development.

Planning for maintenance of LS/OG forest ecosystems should be at larger spatial scales—i.e., scales of hundreds to thousands of acres. One reason is to make fire management programs practical. Activities such as the development of fuel breaks cannot be designed and implemented at the level of individual small patches. Planning at larger spatial scales is also necessary to insure availability of the large contiguous blocks of high-quality LS/OG forests which may be important to some LS/OG organisms and processes (Franklin et al. 1996).

Active management programs for maintenance of high-quality LS/OG forests need to recognize the near-natural processes, structures, and populations which are a primary value of such forests. Hence, treatment of identified high-quality LS/OG areas should emphasize prescribed fire and minimize mechanical disturbances. Intensive management activities, such as creation of shaded fuel breaks, removal of small- to moderate-size trees, and other fuel reduction activities should generally be located in areas adjacent to the high-quality late-successional forests rather than within them.

Larger management units, known as Areas of Late-Successional Emphasis (ALSEs), are proposed as one zoned, landscape-level approach to maintaining concentrations of high-quality late-successional forest function. Using the ALSE approach, landscape-level (multi-polygon) areas have been identified for the western slopes of the Sierra Nevada using existing high-ranked polygons (4s and 5s) as cores (figure 21.31). Management plans for the ALSEs recognize two primary zones: 1) LS/OG reserves covering 60 to 80% of the ALSE within which prescribed burning and other less intrusive management practices are utilized and 2) intensively managed areas where activities such as shaded fuel breaks and "biomassing" can be carried out. Objectives in the intensively managed areas would be to: a) reduce the potential for catastrophic fire within the core LS/OG stands, b) facilitate movement of organisms between the core stands, and, c) produce forest products consistent with the first two provisions. Completely eliminating fire from the ALSEs is not a management objective but reducing the potential for intense, stand-replacement wildfires is a management objective.

ALSE strategies are discussed further in chapters on the SNEP policy analysis. A representative, well-distributed system of such areas for the western Sierra Nevada is illustrated in plate 21.5. Except for the Lake Tahoe Basin and Sequoia National Forest) the eastern slopes of the Sierra Nevada are not included because existing areas of high-quality LS/OG forests are insufficient to provide the core for a system of ALSEs.

Restoration of LS/OG Conditions in the Matrix

Late-successional management strategies for the Sierra Nevada must also address restoration of structural complexity in the managed forests or matrix. Forests on both sides of the Sierra Nevada have undergone significant structural simplification as a result of timber harvest. This is particularly notable in dramatically reduced numbers (or complete absence) of large-diameter trees and their derivatives (large snags and logs). High levels of structural complexity are needed in the matrix to provide for more of the functions of natural forests as outlined by Franklin et al. 1996.

The importance of matrix-based strategies for conservation of biological diversity are receiving increasing attention because of their importance in sustaining diversity, including species and processes essential to the long-term productivity of the matrix forest itself, and in improving overall landscape connectivity for organisms (Franklin 1993, 1996, Franklin et al. in press). Structural diversity within the matrix can provide refugia which will sustain species immediately following harvest and allow displaced species to repopulate or inoculate the area following stand recovery. Some of the processes and species—such as the array of fungi which can form mycorrhizae with trees and other plans—are of significant direct importance in maintaining the long-term productivity of the site.

Silvicultural harvest systems which provide for retention and long-term maintenance of structures from the existing stand—including large-diameter trees and their derivatives—would produce a struc-

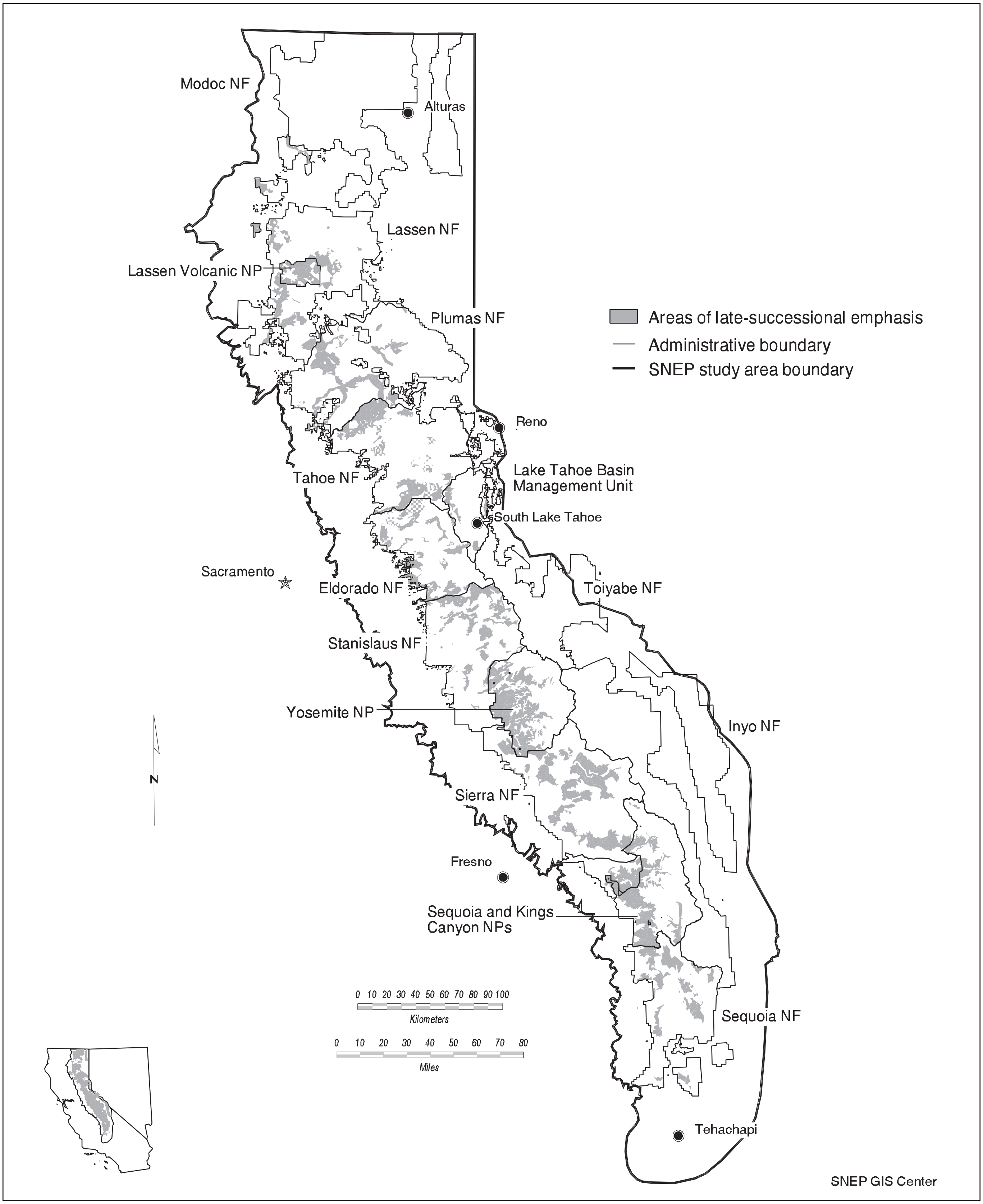


FIGURE 21.31

Distribution of proposed Areas of Late-Successional Forest Emphasis (ALSEs) in the Sierra Nevada.

turally complex managed forest matrix. Various forms of partial cutting can be designed to achieve the objective of maintaining structures at the time of harvest (Franklin et al. in press). Structural goals, such as the numbers, minimum size, and distribution of large-diameter trees, should vary according to management objectives for the stand. The importance of large-diameter snags and logs, as well as large-diameter trees, must be recognized as a part of the silvicultural design. Large-diameter trees and their derivatives fulfill many important ecosystem functions in addition to provision of wildlife habitat. For example, large trees are most likely to survive major fires to provide a legacy of live green trees in the postburn stand; i.e., the large trees substantially improve fire resiliency in the forest stands of which they are a part.

Silvicultural prescriptions for Sierra Nevada forests should also incorporate tree species as well as structural objectives. Where appropriate to site conditions, maintenance of a pine component is an important ecological objective as they provide distinctive tree, snag, and log structures. Maintaining and restoring sugar pine to mixed-conifer stands is of particular concern since this species once dominated the mixed-conifer forests in many areas (see, e.g., Sudworth 1900) and provides a unique structural resource. Sugar pine has been preferentially harvested for nearly 150 years and is currently subject to mortality from the introduced disease, white pine blister rust. Fortunately there is increasing evidence that pines can successfully reproduce under conditions of partial shade (e.g., Oliver and Dolph 1992).

Two silvicultural prescriptions have been proposed for the Sierra Nevada which will maintain or restore higher levels of late-successional forest structures. Group selection is one of these approaches. The scale of selected group that is often proposed—1 to 2 acres—is larger than the scale of mosaic of structural patches found in many natural mixed-conifer and yellow pine stands, however. Moreover, some structural retention within the groups selected for harvest may be desirable to maintain certain features (such as very large decadent trees and snags, for example) which could not be created in adequate numbers within the selected rotation period. Another approach would be to permanently reserve some groups or a portion of the matrix from harvest in order to maintain those structural features (Franklin et al. in press).

Silvicultural prescriptions which maintain or restore specific levels of structures—such as large diameter trees, snags, and logs—have not yet been extensively developed and applied. The interim CASPO guidelines (Verner et al. 1992) are a significant step toward demonstrating the practicality of prescriptions which maintain a high level of late-successional forest function while providing for significant timber harvest. Simple diameter-limit guidelines are not adequate to achieve long-term objectives, however; goals identifying the desired density, size, species composition, and distribution of large trees are needed along with multiple-entry prescriptions which systematically provide for replacements and insure that the large snags and logs derived from these trees are retained on site.

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Back to CD-ROM Table of Contents

APPENDIX 21.1

Guides to Structural Analysis and Rating of Late-Successional Forests

Examples for Westside Mixed Conifer, Red Fir, White Fir, and Subalpine forest groups of the tables used for guides in ranking late-successional structural complexity for forest patches and for crosswalking between the Sierra-wide and series-normalized structural standards. Patch codes are those used by the U. S. Forest Service Pacific Southwest Region in timber inventories and are provided only as a cross-reference to that system. Major structural criteria utilized were: size and number of large-diameter trees; coverage of overstory (OS) and intermediate (Int.) canopy levels; significant decadence in large live trees (yes or no); levels of coarse woody debris; and disturbance history of the patch. Ranking columns refer to ranking of 1) current conditions by rangewide (column A) and series-normalized (column C) standards and 2) maximum potential ranking (based on site productivity) by rangewide (column B) and series-normalized (column D) standards.

Back to CD-ROM Table of Contents

Forest Grouping: Mixed Conifer/Westside (WMC)

Patch Code	Large Trees		Canopy		Decadence of Live Large Trees	Coarse Woody Debris		Patch History		Other	Ranking			
	dbh, in.	Trees/ac	OS	Int.		Snags	Logs	Grazing	Harvest		A	B	C	D
WMC5a	>40"	>10	>60%	Y	Y	C	C	little or none	none		5	5		
WMC4a	>40"	6-10	40-60%	na	Y	C	C	little or none			4	4		
WMC4b	>40"	2-10	>60%	Y	Y	C	C	little or none			4	4		
WMC4c	>40"	>10	>60%	na	Y	F/O	F/O	little or none						
WMC4d	same as 5a but							+/-	1-10%		4	5		
WMC3a	>40"	>6	20-40%	na	Y	F/O	F/O	little or none			3	3		
WMC3b	>40"	2-6	40-60%	na	Y	F/O	F/O	little or none			3	3		
WMC3c	>30"	>6	>40%	na	Y	F/O	F/O	little or none			3	3		
WMC3d	same as 4a-c but							+/-	2-30%	harv. areas w/ 0 or no LS	3	4		
WMC3e	same as 5a but							+/-	1-03-%	"	3	5		
WMC2a	>40"	2-6	20-40%	na	Y	na/N	na/N	little or none			2	2		
WMC2b	>30"	>2	>20%	na	Y	na/N	na/N	little or none			2	2		
WMC2c	same as 4a-c but								30-60%	"	2	4		
WMC2d	same as 5a but								30-60%	"	2	5		
WMC2e	same as 3a-c but								2-30%	"	2	3		
WMC2f	>24"	>20	>60%	na	na	na	na		little or none	no signif. LS	2	4-5		
WMC1a	>30"	0.5-2	>10%	na	Y	F/O	F/O	little or none			1	1		
WMC1b	same as 4a-c, 5a but								>60%	harv. areas w/ scattered LS	1	3-5		
WMC1c	same as 3a-c but								>30%	harv. areas w/ little or no LS				
WMC1d		0	0	na	na	A	C+	+/-	little or mod	major burned area	1	3-5		
WMC1e	>24"	>20	>40%	na	na	na	na		little or none	no signif. LS structure	1	3-4		

A Range-wide Standard - Current
B Range-wide Standard - Potential
C Group Standard - Current
D Group Standard - Potential

M = many, >4/ac
C = common, 2-4/ac
F = few, 1/2 - 2/ac
O = none, 0/ac

LS= late-successional forest structure (e.g. large live trees)

Forest Grouping: Red Fir (RF)

Patch Code	Large Trees		Canopy		Decadence of Live Large Trees	Coarse Woody Debris		Patch History		Other	Ranking			
	dbh, in.	Trees/ac	OS	Int.		Snags	Logs	Grazing	Harvest		A	B	C	D
RF5a	>40"	>10	>60%	Y	Y	A	A	little or none	none	superlative; usu w/ mixed conifer	5	5	5	5
RF5b	>40"	>10	>60%	N	Y	A	A	little or none			4	4	5	5
RF4a	>40"	>6	>40%	na	Y	C	C	little or none	none		4	4	4	4
RF4b	>30"	>6	>40%	na	Y	C	C	little or none	none		3		4	4
RF4c	like RF5a, 5b, but								10%		3		4	5
RF3a	>30"	2-6	20-40%		Y	F/O	F/O	little or none			2		3	
RF3b	like RF5a, 5b, 41, 4b, but					F/O	F/O		10-30%		3		3	4
RF2a	like RF5a, 5b, 4a, 4b								30-50%		1		2	
RF2b	like RF3a								10-30%		1		2	
RF2c	>24"	>20	>40%	na	na	na	na		none	no signif. LS characteristics	1		2	
RF1a	like RF5a, 5b, 41, 4b but								>50%		1		1	
RF1b	like RF3a								>30%		1		1	
RF1c	>16"	>20	>40%	na	na	na	na		none	no signif. LS characteristics	1		1	
RF1d		0	na		na	A	C+		little or mod	major burn area	1		1	

A Range-wide Standard - Current
B Range-wide Standard - Potential
C Group Standard - Current
D Group Standard - Potential

M = many, > 4/ac
C = common, 2-4/ac
F = few, 1/2 - 2/ac
O = none, 0/ac

LS = late-successional forest structure (eg, large live trees)

Forest Grouping: White Fir/Eastside (WF)

Patch Code	Large Trees		Canopy		Decadence of Live Large Trees	Coarse Woody Debris		Patch History		Other	Ranking			
	dbh, in.	Trees/ac	OS	Int.		Snags	Logs	Grazing	Harvest		A	B	C	D
WF5a	>40"	>10	>60%	Y	Y	C	C	little or	none		5	5	5	5
WF5b	>40"	>10	>60%	N	Y	C	C	"	"		4	4	5	5
WF4a	>40"	>6	>40%	na	Y	C	C	little or none	none		4	4	4	4
WF4b	n 5a or 5b but							little or none	1-10%		4	5	4	5
WF4c	>30"	>10	>40%	na	Y	C	C	little or none	none		3	3	4	4
WF3a	>30"	6-10	>40%	na	Y	C	C	little or	none		3	3	3	3
WF3b	>40"	2-6	>40%	na	Y	F	F	"	"		3	3-4	3	3-4
WF3c	same as 5a, 5b but								10-30%		3	5	3	5
WF3d	same as 4a, 4c but								1-10%		3	4	3	4
WF2a	>30"	2-6	>20%	na	Y	F/O	F/O	little or none			2	2	2	2
WF2b	same as 5, 4a, 4c, but								30-60%		2		2	
WF2c	>24"	>20	>40%	na	na	na	na		l or none	no sig. LS	2		2	
WF2d	same as 3a but								10-30%		2		2	
WF1a		0	0	na	na	A	C+	+/-	little/mod	major burn	1		1	
WF1b	same as 3a but								>30%		1		1	
WF1c	same as 5, 4a, 4c but								>60%		1		1	

A Range-wide Standard - Current
B Range-wide Standard - Potential
C Group Standard - Current
D Group Standard - Potential

M = many, >4/ac
C = common, 2 - 4/ac
F = few, 1/2 - 2/ac
O = none, 0/ac

LS = late-successional forest structure (e.g. large live trees)

Forest Grouping: Subalpine (Includes High Elevation Lodgepole Pine) (SA)

Patch	Large Trees		Canopy		Decadence of Live	Coarse Woody Debris		Patch History		Other	Ranking			
Code	dbh, in.	Trees/ac	OS	Int.	Large Trees	Snags	Logs	Grazing	Harvest		A	B	C	D
SA5a	>30"	>10	>40%	na	Y	F	F	little or none	none	eg, mtn hemlock	3		5	5
SA4a	>30"	6-10	>20%	na	Y	F	F/O	little or none	none		2		4	4
SA4b	>24"	>10	>40%	Y	Y	C	C			eg, moist lodgepole pine	2		4	4
SA3a	>30"	2-6	>10%	na	Y	F/O	F/O	little or none	none		2		3	3
SA3b	>24"	2-10	?20%	na	Y	F	F/O	little or none	none		1		3	3
SA3c	same as 5a, 4a, 4b but							heavy &/or	1-30%		2		3	###
SA2a	>30"	0.5-2	>2%	na	Y	F/O	F/O	little or none	none		1		2	2
SA2b	>24"	0.5-2	10-20%	na	Y	F/O	F/O	little or none	none		1		2	2
SA2c	same as 5a, 4a, 4b but							+/-	30-60%		1		2	4-5
SA2d	same as 3a, 3b but								1-30%		1		2	3
SA1a	>24"	0.5-2	>2%	na	Y	F/O	F/O	little or none	none				1	1
SA1b	>30"	scattered trees, >0.5	na	na	Y			little or none	none		0		1	1
SA1c	same as 5a, 4a, 4b but								>60%		0		1	4-5
SA1d	same as 3a, 3b but								>30%		0		1	3

A Range-wide Standard - Current
B Range-wide Standard - Potential
C Group Standard - Current
D Group Standard - Potential

M = many, >4/ac
C = common, 2-4/ac
F = few, 1/2 - 2/ac
O = none, 0/ac