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ALTERNATIVE APPROACHES TO CONSERVATION OF LATE-SUCCESSIONAL FORESTS IN THE SIERRA NEVADA AND THEIR EVALUATION[1]

Working Group on Late-Successional Conservation Strategies

INTRODUCTION

Documentation of the distribution and condition of old-growth forests in the Sierra Nevada and advice regarding the management of this resource is an explicit responsibility of the Sierra Nevada Ecosystem Project (SNEP). The United States Congress provided this direction in language that was a part of two bills in the House of Representatives in 1992 (see Appendices A and C in Sierra Nevada Ecosystem Project (1994)): HR 5503 (passed) called, in part, for a "scientific review of the remaining old growth in the national forests of the Sierra Nevada . . . "; HR 6013 (proposed) called, in part, for "recommendations of alternative management strategies to protect and enhance . . . late-successional forests and their dependent and associated species, including a determination of whether late-successional reserves are necessary . . . and if such reserves are necessary, what lands should be included in such reserves."

The linkage between these two bills was stated in the charge from the SNEP Steering Committee to the SNEP Science Team: "The Forest Service's recommended approach is to develop a study based on achieving the general requirements of HR 5503 and attempt to meet the intent of the ecosystem study established in HR 6013 (Appendix E of the Sierra Nevada Ecosystem Project (1994))." To fulfill this responsibility, SNEP is committed to design and evaluate a range of strategies with regards to whether they provide: 1) sufficient, well-distributed, high-quality LS/OG forest to sustain the organisms and functions associated with such systems; and 2) conditions that facilitate connectivity for organisms moving between LS/OG forest areas. Some conceptual development needs to precede such evaluations, however.

Before commencing the design of a conservation strategy the objectives and critical elements for such a strategy need to be explicitly identified and their importance evaluated. Critical elements of a conservation strategy for late-successional and old-growth (LS/OG) forests were the topic of a Sierra Nevada Ecosystem Project working group that met in Corvallis, Oregon on December 7, 1995 and January 18, 1996. The objective of this working group was to develop a basic framework for evaluating the effectiveness of alternative conservation strategies that have been or will be proposed for late-successional forests in the Sierra Nevada.

Questions that emerged in the working group as central to the design and evaluation of conservation strategies for LS/OG forests in the Sierra Nevada were:

1. Do distribution and quality of LS/OG forests need to be an explicit management objective?
2. Is it important to retain existing high-quality LS/OG forests as part of a conservation strategy?
3. Is there a need for large blocks of high-quality LS/OG forest habitat?

[1] *Sierra Nevada Ecosystem Project: Final Report to Congress*, Addendum. Davis:University of California. Centers for Water and Wildland Resources. 1996.

4. Is it important to have a well-distributed and representative system of LS/OG forest areas?
5. Do conservation strategies need to be spatially explicit?
6. Are the matrix and connectivity between high-quality LS/OG forest areas important?
7. Is restoration an important part of a LS/OG conservation strategy?
8. Are reserves important to the conservation of high-quality LS/OG forests?

Participants in the workshop considered each of these issues and reached conclusions which are briefly presented in the following sections.

Conservation strategies covering a spectrum of approaches which have been developed by SNEP and others are presented in the second section of the report. Although some of these strategies were initially identified with individuals, they are restructured here to illustrate the consequences of general and recognizably different strategies. Additional approaches to conservation of LS/OG forests can be created by mixing the strategies presented here in order to integrate the positive features from several strategies.

The commercial forests found on both slopes of the Sierra Nevada are the primary focus for this paper, specifically: 1) yellow pine forests (characterized by ponderosa or Jeffrey pine); 2) mixed-conifer forests characterized by sugar pine, ponderosa pine, white fir, incense-cedar, and Douglas-fir; and 3) white fir and red fir forests characterized by white fir and California red fir, respectively. These forest types provide the majority of structurally-complex forests in the Sierra Nevada and they are the ecosystems where conflicts between timber production and environmental values, such as protection of watershed integrity and conservation of forest-dwelling species, are most intense. Subalpine forests, low-elevation woodlands and savannas, and pinyon-juniper woodlands are not emphasized. The nature and significance of late-successional conditions are poorly understood for these forest types and, in any case, they generally provide few of the structurally complex forests which are characteristic of more productive habitats. In addition, general management objectives have largely been determined for subalpine forests because most of them have already been included in national parks and wilderness.

Assessments of existing LS/OG conditions and the ratings of structural complexity referred to in this report were developed by SNEP and are reported elsewhere (Franklin and Fites 1996). Forest structural complexity is ranked from no contribution (0) to very high contribution (5); structural features incorporated in the rankings are weighted to those features characteristic of late-successional forests, such as large diameter trees, snags, and logs. Ratings used in this analysis are based upon a single, Sierra-wide structural standard for all forest types and not on the "series-normalized" approach in which separate structural standards are created for each major forest type; i.e., structural standards were constant rather than relative to forest type. The working group felt that the Sierra-wide structural ratings provide the clearest perspective on overall forest structural conditions in the Sierra Nevada whereas ratings according to the series-normalized standard can be misleading as to the real extent of forests with high levels of structural complexity. For example, the best of the structurally complex subalpine forests (rated 5 by a series-normalized standard) are far simpler in structure than even moderately complex forests in the mixed-conifer zone. For more detail on the scheme for structural assessment and rating, see Franklin and Fites (1996).

This paper is divided into sections outlining: 1) important principles in design of an LS/OG strategy and 2) evaluations of alternative LS/OG strategies which have been proposed. Design criteria and the evaluation are based on available scientific information and on logical inferences from this information base. The focus is on ecological criteria although there are important social issues involved in the selection of a strategy, such as the consistent availability of funds needed to carry out management activities such as prescribed burning.

PRINCIPLES: WHAT ARE THE IMPORTANT CONSIDERATIONS?

High-Quality LS/OG Forests as a Management Objective

Does the maintenance of high-quality LS/OG forests need to be explicitly recognized as a management objective or can it be achieved peripherally through programs or policies focused primarily on other objectives, such as management of the California spotted owl, maintenance of forest health, production of timber, or provision of dispersed recreational activities? This is, perhaps, the simplest of the questions addressed in this paper.

The best way to insure that LS/OG forest conditions of the desired quantity and quality are maintained in the Sierra Nevada is to have such a goal explicitly stated and addressed as a part of any management strategy. It is unlikely that such forests will be present in the landscapes of the Sierra Nevada at desired quantities and qualities as a by-product of other management objectives. For example, plans which provide for habitat needs of the California spotted owl may not provide for maintenance of significant amounts of intact undisturbed LS/OG forest even though such forests typically provide excellent habitat for the species (Verner et al. 1992). Even in national parks, maintenance of high-quality LS/OG forests will not necessarily result from recreationally-oriented management objectives; indeed, without explicit recognition of the LS/OG objectives, such conditions could be lost such as by the removal of dead and decadent trees.

Society has clearly indicated an interest in LS/OG forest ecosystems for their intrinsic values, including habitat for associated species and processes, as evidenced by the congressional request for this study. Yet, management scenarios have been and continue to be proposed for the Sierra Nevada (e.g., USDA Forest Service 1995) which do **not** specifically provide for maintenance of blocks of high-quality LS/OG forests as an objective.

We conclude that the objective of maintaining high-quality LS/OG forests needs to be explicitly recognized as an important element of a conservation strategy for late-successional forest ecosystems in the Sierra Nevada.

Retention of Existing High-Quality LS/OG Forests

Is it important to retain existing high-quality LS/OG forest areas as a part of a conservation strategy? A recurring question in development of conservation strategies is the importance of existing areas of high conservation value, particularly in relation to the alternative of creating such forest in other areas which are currently of lower quality. Reasons for proposing such shifts include concerns with: 1) the geographic distribution or ecological representativeness of existing LS/OG forest areas; 2) anticipation of loss of areas to disturbance processes (such as fire); and 3) possibility of utilizing valuable commodities, such as the large-diameter trees found in high-quality LS/OG forests.

Existing high-quality LS/OG forests in the Sierra Nevada are important because: (1) such forests are very limited in extent, particularly for commercially important forest types (Table 1) (Franklin and Fites 1996); and (2) we do not know how to create, with reasonable certainty, comparable forest ecosystems. For example, high-quality westside mixed-conifer LS/OG forests (structural classes 4 and 5) are estimated to cover only about 16 percent of the Sierra Nevada (Table 1); old-growth yellow pine forests contain less than 2 percent high-quality LS/OG forests (Table 1). These levels are far below the levels of high-quality LS/OG forests that are believed to have been present prior to western settlement (Franklin and Fites 1996). Hence, high-quality LS/OG forest ecosystems are a scarce resource within the commercial forest types of the Sierra Nevada.

Re-creation of comparable forests--meaning complete LS/OG forest ecosystems--through silvicultural treatments is theoretically possible but highly conjectural given our level of knowledge about late-successional forest ecosystems (Sierra Nevada Ecosystem Project 1996) and the very long time periods required for development of some of the structures. If such forests were composed solely of large-diameter trees and the snags and logs derived from them, creation of high-quality LS/OG forest habitat might be relatively straightforward. In fact, such ecosystems involve thousands of organisms and processes mostly unknown both as to kind and importance. Spatial patterns in structures and organisms--and their ecological consequences--are also unknown, particularly below ground and within canopies. Hence, for the foreseeable future, any conservation strategy based upon re-creation of high-quality LS/OG conditions has very high levels of uncertainty regarding its effectiveness--it is a high risk strategy. **A strategy of retaining existing high-quality late-successional forest ecosystems has the highest probability of providing for organisms and types and rates of processes characteristic of these forest ecosystems--recognized and unrecognized.**

Even with greatly improved knowledge about forest ecosystems and development and implementation of appropriate silvicultural prescriptions, long periods (one to two centuries at a minimum) would be required for development of fully developed, high quality LS/OG conditions. Hence, in the short term, the only way to be assured of fully-functional LS/OG forest ecosystems is by retaining the remaining areas of such forests.

Creation of a completely managed "shifting mosaic" of "old-growth" forests is sometimes proposed as an alternative to retention of existing LS/OG forests on the basis that existing LS/OG forests will, at some point, be destroyed by a catastrophic event. Putting aside the questionable assumption that we know how to create high-quality LS/OG forests through silvicultural treatment (preceding paragraph), shifting-mosaic proposals generally do not recognize the reality that natural catastrophic disturbances are not likely to occur at designated locations within the "regulated" landscape, i.e.,

ADDENDUM

Table 1. Percentage of total acres for each major commercial forest type in the Sierra Nevada by late successional structural ranking (range-wide structural standard); calculated from acreages of polygons of different structural ranks assigned to these forest types.

FOREST TYPE	AGENCY*	TOTAL ACREAGE	Structural Ranks						
			0	1	2	3	4	5	4+5
Westside Mixed Conifer	NF	3,053,628	4.2	17.8	35.5	30.9	10.2	1.3	11.5
	NP	242,369	--	3.1	7.4	22.9	28.9	37.6	66.6
	ALL	**3,295,997**	**3.9**	**16.7**	**33.3**	**30.3**	**11.9**	**4.0**	**15.8**
Red Fir	NF	1,169,040	--	10.3	39.0	33.6	15.1	2.0	17.1
	NP	257,852	--	1.0	5.2	34.0	17.8	42.1	59.8
	ALL	**1,426,892**	--	**8.6**	**32.9**	**33.7**	**15.6**	**9.2**	**24.8**
White Fir,	NF	754,671	5.7	18.8	34.1	33.8	6.8	0.8	7.6
Eastside Mixed Conifer	NP	8,655	--	16.9	--	44.9	20.5	17.6	38.2
	ALL	**763,326**	**5.7**	**18.8**	**33.7**	**34.0**	**6.9**	**1.0**	**7.9**
Eastside Pine	NF	1,735,570	14.0	23.6	49.7	11.5	1.0	0.1	1.1
	NP	7,069	--	--	2.0	--	27.8	70.2	98
	ALL	**1,742,639**	**14.0**	**23.5**	**49.5**	**11.5**	**1.1**	**0.4**	**1.5**

* NF = National forest lands plus 16,483 acres administered by Bureau of Land Management. NP = National park lands.

within the locations selected for harvest or managed "rotation" of stands. Hence, the total acreage--meaning the collective area within the region being planned--allocated to a desired LS/OG condition must be sufficient to maintain the viability of the LS/OG system in the face of probable losses to catastrophic events. If losses of LS/OG forest to natural disturbances are not consider.d, catastrophic events in the regulated or shifting-mosaic landscape will, at some point, reduce the acreage of high-quality LS/OG below minimum desired levels.

We conclude that retention of existing high-quality LS/OG forest areas is an important part of a conservation strategy for late-successional forest ecosystems in the Sierra Nevada for the foreseeable future. Only these forests will have a high probability of incorporating the organisms, structural features, and processes characteristic of complete LS/OG ecosystems.

Provision for Large Blocks of LS/OG Habitat and Incorporation of Ecosystem Dynamics

Are large blocks of high-quality LS/OG habitat an important part of a conservation strategy? A recurring question in development of LS/OG conservation strategies is whether large blocks of contiguous LS/OG forest (e.g., several hundreds to thousands of acres) are important or whether required conditions can be achieved in smaller blocks (e.g., tens to a few hundred acres) of comparable aggregate acreage. To an extent, this is a replay of the classical "SLOSS" question in conservation biology--"single large or several small reserves" (Noss and Cooperrider 1995). As will be seen the large block issue involves operational (management) as well as biological concerns.

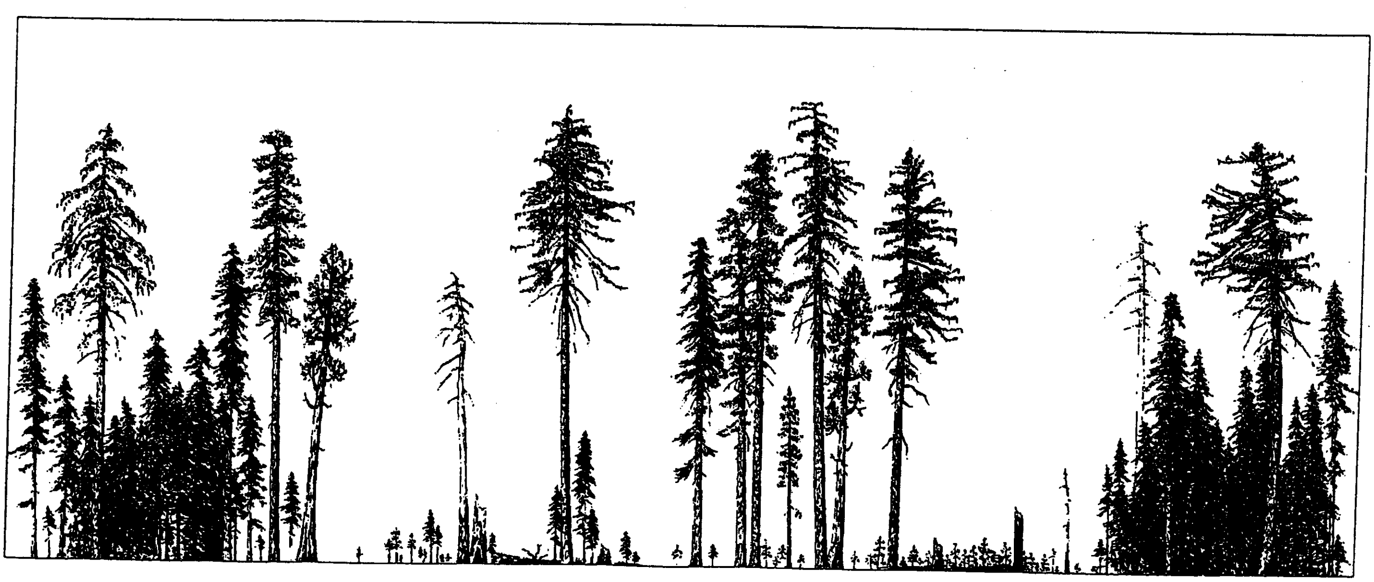
We begin with the observation that **large contiguous areas of high-quality LS/OG forests did occur in the**

presettlement landscape of the Sierra Nevada. Many LS/OG forests in the Sierra Nevada are complex fine-scale mosaics of varied stand structures, including areas of both low and high overstory densities. It is often assumed that high-quality LS/OG forests consist only of those portions dominated by large trees. However, high-quality LS/OG forests actually incorporate the full range of vertical and horizontal structural heterogeneity represented in the mosaic (Figure 1); many high-quality LS/OG forests are not just the areas dominated by closed canopies or large, old trees. It is important to note that the relatively open patches typical of natural forests are generally smaller (e.g., 0.01 to 0.5 ha) and retain more structural complexity (snags, logs, and larger trees) than openings created by traditional group selection harvest prescriptions. Representative large LS/OG forest blocks can still be observed at some locations in the Sierra Nevada, such as at lower elevations in the South Fork of the Tuolumne River in Yosemite National Park.

We can infer from the presettlement occurrence of large contiguous blocks of high-quality LS/OG forests that organisms or processes may exist in the Sierra Nevada that prefer or require such conditions. **Are we currently aware of organisms, processes, or conditions that require larger contiguous blocks of high-quality LS/OG forest habitat or, insofar as we are aware, can all species requirements be met with a system of small blocks?** In the Sierra Nevada there is no scientific consensus on this issue. Neither the interim strategy adopted for the California spotted owl (Verner et al. 1992) nor Alternatives C (original preferred) and D (reportedly as ultimately selected) in the California Spotted Owl EIS (USDA Forest Service 1995) provides for large intact blocks of old-growth forest; the inference is that no featured species require large blocks of late-successional forest. This is an assumption, however; Graber (1996) and Verner (personal communication) have both noted that a habitat requirement for large blocks of LS/OG forest neither has been proven or disproven for vertebrate species in the Sierra Nevada. Hence, any vertebrate management policy which does not provide for large contiguous blocks of LS/OG forest incorporates significant uncertainty regarding its effectiveness.

A general principle in conservation biology is that "large blocks of habitat, supporting multiple pairs [of target species] are superior to small blocks of habitat with only one or a few pairs" (Thomas et al. 1990). In the case of the Sierra Nevada there is some evidence that some vertebrates may require large blocks of late-successional forest habitats for their long-term persistence. For example, demographic model simulations indicate that the California spotted owl consistently persists longer using a conservation strategy with fewer large reserves (sufficient

Figure 1.--Cross-section of a typical westside mixed-conifer old-growth forest ecosystem illustrating the structural complexity and spatial patterning (horizontal heterogeneity) typical of high-quality (structural classes 4 and 5) old-growth forest ecosystems.



for 10-20 owl pairs) than with many small reserves (sufficient for 1-3 owl pairs) (Andersen and Mahato 1995).

Similarly, there is a substantial body of scientific evidence and opinion that some furbearers, including fisher, marten, and wolverine, require large blocks of LS/OG forest for their survival (see statements by Powell, Kucera, and Barrett in Yassa and Edelson 1994). Their occurrence is related to overall stand structural conditions, such as dense multi-storied canopies, as well as to an abundance of individual structures, such as large trees, snags, and logs (e.g., see Allen 1983). Furthermore, these species have relatively large home ranges and may be relatively sensitive to habitat fragmentation by roads and large openings, although, again, evidence is mixed. Blocking effects of roads and other small linear clearings on movements of organisms, whether for foraging, migration, or dispersion, is distinct from but related to provision of large blocks. Roads and other small linear clearings are likely to be less common in large blocks managed for LS/OG habitat than in more fragmented landscape designs.

Large LS/OG blocks are important to ensure that complete landscape units--and their associated genetic and ecologic variability--are incorporated within the LS/OG conservation strategy. Larger blocks will incorporate forests on various landforms, slopes, and aspects as well as gradients or "catenas" extending from riparian zones to hot, dry slopes and ridgetops. Entire vegetation mosaics, including the ecotones or transitions between major plant communities, can be readily incorporated. This is important to ensure that patterns of genetic and ecosystem variability are present as well as to provide for organisms and processes found primarily in ecotonal areas.

Large LS/OG blocks are important to incorporate natural patterns of disturbance and successional stage resulting in the complex mosaics typical of high-quality LS/OG forests. Frequent, light to moderate fire is probably the most common disturbance in these forests and is important in creating small openings as well as reducing overall stand densities. Fire is probably also important in maintaining habitat for many organisms, from microbes and fungi to vascular plants and vertebrates, and in energy and nutrient cycling processes. Provision for fire, either by prescription or managed wildfire approaches, is easier with large management units, especially units which incorporate natural boundaries such as ridgelines. Large areas are also needed to provide for the vertical heterogeneity or patch mosaic that is characteristic of many high-quality LS/OG stands in the Sierra Nevada (Figure 1).

Finally, large (landscape-level) LS/OG areas are important for practical management. Design and implementation of presuppression strategies, such as creation of shaded fuel (fire) breaks to reduce the potential for spread of catastrophic fire events either into or through areas of LS/OG forest emphasis, need to be carried out at large spatial scales for both technical and economic reasons. This is also true of activities within LS/OG forests, such as prescribed burning. Attempting to manage small areas as LS/OG forests can make such programs impractical. The importance of implementing fire management strategies, such as creation of fuel breaks and reduction of fuels by prescribed fire and silviculture, at larger spatial scales, is indicated by model simulations (Johnson, Sessions, and Franklin 1996).

We conclude that provision for large blocks of LS/OG forest habitat is an important part of any conservation strategy for late-successional forest ecosystems in the Sierra Nevada because: 1) some species may require such conditions; 2) large blocks did exist in the presettlement landscape; 3) large blocks more readily accommodate incorporation of complete landscape units, including ecotones; 4) large blocks better allow for incorporation of natural patterns of disturbance and complex stand mosaics; and 5) large blocks, bounded by natural topographic features, are easier to protect from catastrophic fire. Incorporating large blocks in an LS/OG conservation strategy addresses both the issues of: 1) uncertainty with regards to the effectiveness small-block management strategies, particularly with regards to species requirements; and 2) the necessity for incorporating natural stand dynamics and reducing losses of LS/OG habitats to catastrophic fire.

Provision for Representative System of LS/OG Areas

Is it important to design conservation strategies so as to incorporate representative examples of LS/OG forest conditions? The major forest types and species of the Sierra Nevada are widely distributed geographically and elevationally which, in turn, reflects the complex environmental mosaic characteristic of the range. Environmental variability is itself associated with major variations in the genetic composition of constituent species, community composition, disturbance regimes and successional responses, and autecological responses of species (such as growth rates). Retaining examples of the major variants in these conditions is, therefore, an important element of any strategy for conserving biological diversity.

A conservation strategy for LS/OG forests should incorporate representative examples of these varied conditions in order to incorporate the full range of genetic variability as well as variation in the patterns and rates of ecosystem processes. There are several accepted ways for assessing the degree to which representative areas are incorporated into a conservation plan. For example, including examples of all relevant plant associations or habitat types will provide for much of the environmental and compositional variability. Another technique is to be sure that areas are included throughout the elevational, latitudinal, and longitudinal distribution of a type.

We conclude that incorporation of a representative cross-section of habitat conditions, including different productivity classes and plant associations, is an important element of a conservation strategy for late-successional forest ecosystems in the Sierra Nevada.

Importance of Spatially-Explicit Design

Should conservation strategies be spatially explicit and, if so, why? The spatial arrangement of particular forest conditions or habitat is fundamental to understanding and assuring that a strategy will be functional--i.e., that it will fulfill the intended objectives. **The importance of spatial context is not always fully appreciated by proponents of particular strategies who may focus simply on the amount of a given habitat (e.g., LS/OG forest) and not the size, distribution, and landscape context of these habitat patches.**

Place and pattern are critical, however, with important elements including patch size, shape, distribution, and context (juxtaposition with other patch types) (for a generic reference on these issues see Forman 1995). Size and shape of LS/OG habitat patches influences their ability to provide conditions characteristic of unmodified LS/OG forests. If patches are too small or elongated they may be subject to extensive external influences--**edge effects**--from adjacent contrasting patch types (see, e.g., Forman 1995 and Chen, Franklin, and Spies 1992, 1993). The level of contrast with the surrounding patches of habitats is also critical in determining the intensity and depth of edge effects; edge effects will be much more intense where the adjacent patch has a high level of contrast with the LS/OG forest, as in the case of a clearcut patch, than in cases of low contrast, as in the case of a selectively logged forest patch. Another contextual factor is the overall condition of the landscape matrix in which the LS/OG patch is embedded; this will be an important factor affecting the movement of organisms between LS/OG habitat patches as will be noted later in this paper.

The ability to provide spatially explicit depictions of particular conservation strategies is also very important to 1) insure that a theoretical model will actually work in the real forestscape and 2) make apparent to stakeholders the actual appearance of a policy alternative. We are not talking about stand-level depictions of forest structure here, as valuable as they may be but, rather, the ability to display the geographical distribution of the various habitat conditions on the actual landscape over time. Maps or GIS depictions of this type provide a "reality" or reference point that is invaluable in communicating consequences of alternative approaches.

Levels of uncertainty, both technical and social, are greatly increased if spatially explicit depictions cannot be produced for a particular strategy. Asserting that so much of a particular habitat will be maintained in a landscape without specific identification of the size, location and context of those patches is likely to be unconvincing to informed stakeholders--and appropriately so. Many of the problems that developed with national forest management plans during the 1980s resulted from the use of models which did not have a spatial component; inappropriate conclusions about achievable levels of allowable cuts were a common result, since spatial constraints on management, such as those related to "green-up" or cumulative watershed impacts, could not be assessed.

We conclude that spatially explicit planning is an important part of a conservation strategy for late-successional forest ecosystems in the Sierra Nevada to: 1) ensure that the essential spatial pattern (including patch dimensions and context) of LS/OG areas can be achieved and 2) display these patterns for other scientists, decision makers, and stakeholders. Higher levels of uncertainty are likely to be associated with conservation strategies that cannot be displayed spatially than with those that can be displayed.

Importance of Connectivity and Management Practices in the Matrix

Is connectivity between areas of LS/OG forest necessary? Further, is the condition of the matrix important to LS/OG conservation strategies beyond its importance in controlling connectivity? The issues of connectivity and the condition of the matrix are strongly related so they are considered together here. **Matrix** is defined here most broadly as the non-LS/OG portions of an existing or proposed landscape.

Providing for connectivity--the movement of organisms between areas of LS/OG forest--is a critical element of any conservation strategy. Movement of organisms between habitat islands is essential to provide for gene flow between different populations as well as to repopulate patches from which populations are lost (Noss and Cooperrider 1994). Connectivity is also an issue in considering ecosystem and landscape responses to long-term climatic changes. In a landscape where habitat islands are highly disconnected, the ability of organisms to migrate to more suitable landscape areas is lost.

Conditions in the matrix are the primary factor controlling connectivity in the landscape (Franklin 1993) even though much of the focus of conservation biology has been on corridors, strips of suitable habitat connecting habitat islands (Forman 1995). Although corridors can be important for some organisms, the majority of LS/OG organisms probably do not preferentially utilize corridors; their mobility will be largely determined by conditions in the matrix (see, e.g., the reasoning of Thomas et al. 1990 and the Forest Ecosystem Management Assessment Team 1993). In island biogeographic terms, if the matrix "sea" is deep, wide and dangerous because of environment or predators--connectivity will be poor; completely cleared areas are an example for many forest organisms. Alternatively, the matrix "sea" can be made shallower and less hostile by providing habitat stepping stones which provide protective cover. Managing the matrix to provide conditions that enhance movement is, therefore, a critical element of a conservation strategy.

The matrix is also of critical importance in any forest conservation strategy quite apart from its role in connectivity (Franklin 1993). Many, if not most vertebrate species living in the forests of the Sierra Nevada, depend strongly upon specific structural features (see Graber 1996; Verner et al. 1992). This is equally true for many other organisms including fungi, invertebrates, and bryophytes. Many of these species can probably be sustained throughout much of their range within the Sierra Nevada by maintaining suitable structures in the matrix, providing for better distribution and higher population levels. This is, in fact, the interim California spotted owl strategy (Verner et al. 1992). The preferred alternative of the draft environment impact statement for the Sierra Nevada national forests (USDA Forest Service 1995) also assumes that habitat needs for all LS/OG-related species, including owls and fur bearers, can be met by maintaining structurally-complex managed forests.

A further important point about sustaining many structurally-dependent organisms in the matrix has to do with their continued functioning within the managed forests. Many of the organisms that are sustained by such a strategy have important functional roles in the forest ecosystem. Examples include many invertebrate species that are detritivores and predators and parasites on herbivorous insects and fungi which are mycorrhizal associates. Maintaining populations of such organisms is of direct relevance in maintaining the health and productivity of the managed forests; conversely, their elimination can potentially have significant negative consequences.

Large, old trees and their derivatives (large snags and logs) are among the most important structural elements needed in the matrix to provide habitat for an array of organisms and to facilitate connectivity (e.g., Verner et al., 1992, Graber 1996). These structures are at very low levels in much of the Sierra Nevada as a result of past logging activities (e.g., Verner et al. 1992, Franklin and Fites 1996). Hence, restoring such structural features to the matrix is an important element of any conservation strategy. Of course, densities of such structures did vary in presettlement forests and any set of goals can reflect such historic variability.

We conclude that stand structural complexity in the matrix is an important element of a conservation strategy for late-successional forest ecosystems in the Sierra Nevada in order to: 1) facilitate connectivity between LS/OG emphasis areas; 2) provide sufficient dispersed habitat for species dependent upon on individual LS/OG structures; and 3) sustain species and processes essential to long-term productivity and health of matrix lands. The most important structural elements that are needed in the matrix are large-diameter trees and their derivatives (large snags and logs).

Provision for Restoration

Does a conservation strategy need to provide for restoration of LS/OG conditions? The amounts of existing structurally-complex LS/OG forests are far below the levels that were believed to have been present in the presettlement landscape (Franklin and Fites 1996). There are lines of evidence that suggest that such forest structural conditions once occupied 2/3 or more of the Sierra Nevada landscape. Currently, high-quality LS/OG forests occupy only about 16 percent of the landscape occupied by commercially important forest types (Table 1); for the ponderosa and Jeffrey pine types on the east side of the Sierra Nevada it is much less than that (Table 1).

Even more important is the fact that levels of structurally complex forests and of LS/OG structures appear to be below levels that are desirable from the standpoint of maintaining LS/OG-related species and functions. For example, structural conditions in many matrix areas appear too simplified to adequately provide for dispersed habitat and for connectivity for LS/OG-related organisms. This circumstance is not surprising given the traditional emphasis in forest management on simplification of forest stands.

The removal of fire as a significant process in the LS/OG forests is, in itself, as important as the structural simplification that has occurred through timber harvest during the 20th century. Frequent, light to moderate intensity fire was an important process in the presettlement LS/OG forests. Fire control programs largely eliminated this process from many stands despite the numerous important roles that it plays in influencing stand structure and composition and ecosystem processes, such as nutrient cycling. Hence, restoration of this fire to LS/OG forests may be as important as restoration and maintenance of specific structural features.

We conclude that restoration of LS/OG forest areas and of LS/OG structures in the matrix is an important part of any conservation strategy for late-successional forest ecosystems in the Sierra Nevada. This is particularly critical for the yellow pine forests found on the east side of the Sierra Nevada. Key structural elements that need to be restored are large, old trees, snags, and logs. Restoration of light- to moderate-intensity fire regimes to many LS/OG stands is also important.

Role of Reserves in Conserving LS/OG Forest Ecosystems

Are reserves important for conservation of LS/OG forest ecosystems? Discussion of this question must begin with clarification of the term, "reserve," a word that has been used in highly varied ways. As used here, reserves are defined as areas where maintenance of high-quality LS/OG forests is emphasized and activities that detract from this objective are minimized or eliminated.

Implicit is our usage of the term reserve is the notion that **reserve areas would be managed actively to achieve the primary objective of maintaining high-quality LS/OG forests; i.e., they are not areas where all human activities are excluded.** However, to achieve their objectives, managers should favor the use of the least intrusive methods and most natural agents, such as fire, consistent with the practical achievement of the goal of maintaining high-quality LS/OG forests. This will decrease the probability that LS/OG organisms, structures and processes will be lost or altered in reserves as a result of the unknown and unintended consequences of management.

Although the most appropriate management activities for late-successional reserves are prescribed fire and managed wildfires, mechanical treatments are also likely to be important in some portions. These include forest stand thinning to reduce fuel levels and creation of shaded fuel breaks. Mechanical treatments have significant potential negative impacts on LS/OG forest ecosystems, however, including disturbance to the soil and litter layers, soil compaction, and mechanical damage to residual tree boles and root systems. The National Park Service approach to management of mixed-conifer and other forests in Yosemite and Sequoia-Kings Canyon National Parks provides one model (Parsons and van Wagtendonk, in press); while mechanical activities are not prohibited, fire is the preferred management tool. Mechanical treatment of fuels may be more critical in some portions of national forests than in national parks, such as in areas adjacent to urban developments or in young even-aged stands which lack structural complexity.

In any case, management activities within reserves should be planned so that some significant portions are kept entirely free of mechanical disturbances. The concept of Areas of Late Successional Emphasis (ALSE) presented in Franklin and Fites (1996) (see Appendix 1) incorporates both core areas of high-quality LS/OG forests, where prescribed fire is the primary management tool, with other forest areas, where mechanical treatments to reduce fuels are allowed.

There are, of course, a number of implementation issues concerning the use of prescribed fire. These include concern over smoke management and urban encroachment. Prescribed burning also has to be carried out repeatedly and on a large scale to be effective (Johnson, Sessions, and Franklin 1996) and this requires an adequate and stable source of funds.

Given the notion of managed LS/OG reserves, we can return to the original question: does a conservation strategy require areas where the maintenance of high-quality LS/OG forests has priority. Our answers to earlier questions are the basis for a logical response. Earlier we concluded that important elements in a LS/OG conservation strategy included: 1) retention of existing high-quality LS/OG forests, including some larger blocks; 2) a system of representative LS/OG areas; and 3) a spatially explicit system. To simultaneously achieve all of these objectives **a system of LS/OG reserves is required,**

meaning a series of areas identified and managed so as to maintain high-quality LS/OG forest ecosystems, organisms, and processes.

We conclude that reserves, defined as areas where maintenance of high-quality LS/OG forest conditions is the primary goal, are important elements of a conservation strategy for late-successional forest ecosystems in the Sierra Nevada. Active management of these "reserves" is appropriate, with an emphasis on use of natural agents, such as fire.

Summary of Conclusions About LS/OG Strategies

Were the federal government to adopt as a policy the conservation of high-quality LS/OG forest ecosystems important elements of such policy are apparent. A comprehensive strategy for conservation of LS/OG ecosystems would:

Incorporate maintenance of LS/OG ecosystems as an explicit objective;
Retain existing high-quality LS/OG forests;
Incorporate large, contiguous blocks of LS/OG forests, to provide (1) for natural patterns of ecosystem dynamics and (2) for effective management units;
Provide for structurally-complex conditions in the matrix for purposes of (1) connectivity and buffering of LS/OG forests and (2) sustaining more species and functions in the matrix;
Provide for representative LS/OG areas which cover the range of habitats and conditions;
Incorporate a spatially-explicit design to achieve both technical and social objectives;
Provide for restoration of forest structure and composition where LS/OG values are needed but have been lost; follow the general rule of "keep it where you have it and build it where you need it"; and
Incorporate LS/OG reserves in the sense of areas where maintenance of high-quality LS/OG forest ecosystems is the primary objective.

ALTERNATIVE DESIGNS: HOW WELL DO THEY COVER THE ELEMENTS?

In this section of the report we present and evaluate a series of alternative conservation strategies in the context of the conclusions reached in the preceding section. As noted in the introduction our objective is to evaluate the effectiveness of different landscape designs in providing for late-successional forest values. It is obviously possible to modify many of these strategies so as to achieve more desirable outcomes or to produce hybrids by combining elements of two or more strategies. However, we have purposely tried to make the comparison among strategies as clear as possible.

There are three parts to this section evaluating alternative designs: 1) Basic assumptions common to all designs; 2) brief description of six different approaches; and 3) a comparative analysis of the degree to which each approach--and current and proposed policies for federal and nonfederal lands--addresses the important elements of an LS/OG conservation strategy as identified in the first section of this paper.

Assumptions Common to all Conservation Strategies

There are some general assumptions which are relevant to all of the strategies except where a particular strategy specifically excludes its application. First, we assume that equivalent acreages of non-Wilderness lands are devoted to maintenance of LS/OG forest habitat and, further, that the structural goals are comparable (structural classes 4 and 5). Where allocations are at the levels of patches or polygons we assume that a variety of stand structural conditions are represented.

Second, most of the strategies presented incorporate some common approach to management of the riparian zone and the matrix. A riparian example might be the two-tiered approach considered by Sierra Nevada Ecosystem Project (1996) although alternative strategies are possible. Similarly, it is assumed that areas between LS/OG forests (the matrix) are managed to provide additional habitat and to facilitate movement of LS/OG-related organisms.

Third, we assume that activities to maintain and restore LS/OG conditions will be undertaken as needed to fulfill the goals in each scenario. In effect, we assume that any technical, social, and economic issues associated with a scenario, such as availability of funds, are resolved (see discussions in Johnson, Sessions, and Franklin 1996).

Fourth, all of the strategies and current and proposed forest policies for federal and nonfederal lands incorporate concerns for forest protection, including potential for intense, stand-replacing wildfire. There are substantial differences among strategies in their approach to this problem, however, such as in the relative emphasis on reduction of fuels through mechanical approaches (e.g., timber harvest) and by prescribed fire and on the balance between risk of catastrophic fire and maintenance of more natural forest structures and processes. Model simulations provide some insight into these tradeoffs (Johnson, Sessions, and Franklin 1996).

Finally, we assume that these general strategies, if actually implemented, would be open to modification based upon local knowledge. For example, strategies involving mapped LS/OG areas might undergo boundary adjustments based upon detailed study of topographic and stand conditions.

Alternative LS/OG Conservation Strategies

The six conservation strategies that we considered for LS/OG forests are presented here. Strategies labeled as LS/OG-based utilize the landscape polygons identified and mapped by SNEP (Franklin and Fites 1996) as basic building blocks; these polygons include patches with highly varied LS/OG ratings. Patch-based strategies do **not** utilize the polygons, but are, instead, based upon individual patches. The locations of such patches may be generally, but not specifically, known from the SNEP data on patch types developed for each polygon.

1) LS/OG-Based: Areas of Late-Successional Forest Emphasis (LS/OG Based:ALSEs). Areas of Late-Successional Emphasis (ALSE) are landscape units based upon one or (usually) multiple LS/OG polygons. "ALSE" was selected as the label rather than "reserves" to acknowledge the need for an active management approach to maintenance of high-quality LS/OG forest ecosystems, which is a primary management objective. As is discussed below, a major objective in designing larger areas of LS/OG emphasis was creation of efficient management units, such as for implementing activities to reduce the potential for loss to catastrophic fire. This strategy is also outlined in Sierra Nevada Ecosystem Project (1996) as "Strategy 1: Areas of Late Successional Emphasis."

The ALSE concept incorporates within its boundaries areas that are effectively LS/OG forest reserves as well as areas that are more intensely managed. Approximately 1/2 to 2/3 of the ALSE would be zoned where management will be primarily by use of prescribed fire or managed wildfire and where mechanical disturbances will be minimized or prohibited. In the remainder of the ALSE area management could include a variety of activities such as prescribed fire, thinning (with or without removal of fuels and commercial products), and creation of shaded fuel breaks. Detailed management plans would be developed for each ALSE to reflect the specific goals and conditions (see Appendix 1 for an exemplary ALSE on the Eldorado National Forest).

The ALSE identified in this strategy are centered on LS/OG polygons with high (class 4 and 5) structural ratings to which selected adjacent polygons are added to provide larger management units. Identifying boundaries that could be managed to reduce the potential spread of catastrophic fire into the ALSE was an important criterion.

2) LS/OG-Based: High-Quality LS/OG Polygons (High-Quality LS/OG). Late-successional reserves in this strategy include **all** LS/OG polygons which have structural ratings of 4 and 5 plus polygons with a structural ranking of 3 which have >10 % patches with a structural rating of 4 or 5 (i.e., the highest quality polygons with a structural rank of 3).

3) Partially LS/OG-based: High-ranked Polygons plus Restricted Lands (Mixed LS/OG & Noncommercial). Late-successional reserves in this strategy include all polygons with high structural rankings (class 4 and 5) plus areas which are already restricted or removed from commercial timber production, such as steep unstable slopes and scenic areas. A version of this strategy has been outlined for the Eldorado National Forest in Sierra Nevada Ecosystem Project (1996) as "Strategy 3: Integrated Case Studies."

4) Patch-based. In this strategy, all forest patches with a high (class 4 and 5) structural rating are allocated to LS/OG forest conservation along with sufficient additional patches of medium (class 3) structural rank to provide an acreage equivalent to other approaches. This alternative is designed to retain **all** of the best LS/OG forest patches. We have stipulated no rule for selection among the patches with a structural ranking of 3, although several rules are possible, including sequential selection based on quality (i.e., grade within structural class 3) and geographic selection to provide either larger or more dispersed LS/OG forest patterns. Under this strategy the general location of the patches (i.e.,to the level of polygon) is known but not specific locations of patches within polygons.

5) Distributed Fine-Scale Patches. In this strategy a constant percentage of each watershed with federal ownership in the Sierra Nevada is to be maintained in forest patches with complex forest structure (class 4 and 5). The objective of this strategy is to provide a fully distributed system of high-quality LS/OG forest patches without regard to current forest condition; hence, such forests would be created where they currently exist and eliminated where such forests are in excess of the target acreage. There is no requirement that existing high-quality LS/OG forest patches be retained as initial elements in implementing this strategy but it might be logical to do so. An adaptation of this strategy is outlined in Sierra Nevada Ecosystem Project (1996) as "Strategy 2. Distributed Forest Conditions".

6) Uneven-Aged Managed Mosaic. In this strategy the objective is to manage the entire forest mosaic so as to provide structurally complex forests throughout the landscape. A specific structural objective is to attain the same distribution of acres in different LS/OG structural rankings as under the ALSE approaches but without any specification with regards to minimum size of patches. One objective in this strategy is to fully display the consequences of an approach in which **all of the forest landscape is ultimately harvested through a partial cutting approach, including all existing high-quality LS/OG forest.**

Analysis of Alternative Strategies and Critical Design Elements

The six alternative approaches are analyzed in relation to important design elements for a LS/OG conservation strategy in the matrix provided in Table 2. An additional element, consideration of effects on timber harvest levels (Allowable Sale Quantity or ASQ), has been added. In addition, the intersection of the criteria with current policies for nonfederal lands and current and proposed policies for federal lands are shown in Table 2. Current federal policies for late-successional forests are considered to be Alternative A of the California spotted owl EIS (USDA Forest Service 1995) for the national forests and current plans for the national parks; proposed policy for the national forest lands is considered to be a modified version of Alternative D and not the original preferred Alternative C (USDA Forest Service 1995). Neither current nor proposed federal policies recognizes maintenance of high-quality LS/OG forest ecosystems as a specific management goal although there are references to old-growth forests. The California State Forest Practices Code is the basis for late-successional forest policy on the nonfederal lands; this policy has been analyzed in detail by Menning, et al. (1996). The following discussion is structured around the design elements for a conservation strategy (the columns on Table 2).

The explicit goal of maintaining high-quality LS/OG forests is by definition an element of all of the conservation strategies we outline (Table 2). Although current forest plans and the preferred alternative in the California spotted owl EIS (USDA Forest Service 1995) do address forest-dependent wildlife they do **not** explicitly address the goal maintaining high-quality LS/OG forest ecosystems. Indeed, late-successional or old-growth forests are not even subheadings in the EIS Table of Contents (USDA Forest Service 1995). Maintenance of high-quality LS/OG forest ecosystems is also not explicitly addressed by the master plans for the national parks in the Sierra Nevada. The focus on giant sequoia in both forest and park plans might be viewed as an exception although this is a focus on a species and not on an ecosystem. Current forest policy on nonfederal lands does not have an explicit goal of maintaining high-quality LS/OG forests although it does have a goal of maintaining some forests of this type in landscapes where they are otherwise absent (Menning, et al. 1996).

Retention of existing high-quality LS/OG forests varies widely among the alternative conservation strategies (Table 2). The "Patch-Based" strategy is the most effective, scoring 10 out of 10, since retention of all existing patches is the basic design element! The remaining strategies rank from 0 to 9 on a 10-point scale. The "High-Quality LS/OG" strategy is slightly superior to the "LS/OG-Based: ALSE" strategy since it systematically incorporates all 3-ranked polygons which have more than 10% of LS/OG forest patches with ratings of 4 and 5. The rating in Table 2 is based on the assumption that the "Distributed Fine-Scale Patches" strategy will incorporate at least some of the existing high-quality LS/OG forest patches as part of its LS/OG system. The "Uneven-Aged Managed Mosaic" is given a zero rating because all of the landscape will eventually be harvested under a pure form of this strategy leaving no existing LS/OG forest patch undisturbed. The current and proposed policy for federal lands is given credit in Table 2 for the fact that these policies would almost certainly protect some of the existing high-quality LS/OG forest patches in areas reserved from timber harvest. Policy for non-federal lands provides for retention of variable amounts of LS/OG forest and structures and does not effectively address quality of the retained material.

Provision of large blocks of contiguous LS/OG forest also varies widely among the alternative conservation strategies (Table 2). The reader should recall that substantial patchiness is a part of a high-quality LS/OG

Table 2. Matrix relating various conservation strategies (top) and curent and proposed federal policies and current non-federal forest land policy (bottom) to important elements or concerns in design of a conservation strategy for late-successional and old-growth (LS/OG) forests in mixed-conifer, white fir and yellow pine (ponderosa and Jeffrey pine) types of the Sierra Nevada.

CONSERVATION STRATEGY	Maintaining high-quality LS/OG forest ecosystems as objective?	Retains existing high-quality LS/OG? (0-10)	Provides for large blocks of LS/OG forest? (0-10)	Incorporates natural ecosystem dynamics?	Provides for representative LS/OG system?	Spatially explicit design?	Provides for connectivity & matrix conservation?	Provides for LS/OG restoration?	Emphasizes effects on timber harvest?
LS/OG Based: ALSEs[1]	Yes	7	9	Yes	Yes	Yes	Yes	Yes	No
High -Quality LS/OG[2]	Yes	8-9	7	Yes	Yes	Yes	Yes	Yes	No
Mixed LS/OG & Non-Commodity[3]	Yes	5	6	Yes	Yes	Partial	Yes	Yes	Yes
Patch-Based[4]	Yes	10	0	No	No	Partial	Could	Could	No
Distributed Fine-Scale Mosaic[5]	Yes	3	0	No	Yes	No	Yes	Yes	No
Uneven-Aged Managed Mosaic[6]	Yes	0	0	No	Yes	Yes	Yes	Yes	Yes
CURRENT & PROPOSED POLICIES									
Current Federal Plans[7]	No	2-3	2	No	No	No	No	No	Yes
Current Federal Plans + CASPO[8]	No	2-3	2	No	No	Partial	Yes	Yes	No
Proposed Federal Plan (Alternative D)[9]	No	2-3	2	No	No	Partial	Limited	Limited	Yes
Current Policy For Non-Federal Lands[10]	No	Variable	0	No	No	No	At very low level	No	Yes

[1]ALSEs are Areas of Late Successional Emphasis and utilize the landscape polygons created in the SNEP LS/OG forest assessment (Franklin and Fites, 1996); ALSEs are centered on the polygons with LS/OG structural ratings of 4 & 5, plus adjacent polygons to create logical management units.
[2]Utilizes polygons with LS/OG structural ratings of 4 & 5 and polygons ranked 3 which have >10% patches ranked as structural class 4 & 5.
[3]Utilizes polygons with LS/OG structural ratings of 4 & 5 plus other selected areas restricted for timber production.
[4]All patches with structural rating of 4 & 5 plus selected 3-ranked patches necessary to achieve acreage target.
[5]Percentage of each watershed allocated to small patches of high LS/OG structural quality.
[6]Managed entire forest mosaic for a selected level of LS/OG structural complexity.
[7]Current plans for the national forests and national parks.
[8]Current plans for federal lands plus CASPO interim management guidelines on national forest (from Verner, et al. 1992).
[9]Current plans for federal lands modified by Alternative D for national forest lands (from USDA Forest Service, 1995)
[10]Current California State Forest Practices rules.

forest landscape; continuous, dense, closed canopy forests are **not** an essential condition. All of the LS/OG-based strategies provide for large blocks with the ALSE-based strategies scoring highest in this regard. The remaining strategies are given a zero rating although it could be argued that the "Uneven-Aged Managed Mosaic" would produce large contiguous blocks of structurally complex forest habitat. Current and proposed policies for federal lands are given a low rating rather than a zero simply based on retention of existing roadless areas; unfortunately much of the high-quality existing LS/OG forests are not within recognized roadless areas or congressionally-protected lands (Franklin and Fites 1996). Policy for non-federal lands does not require retention of large blocks of LS/OG habitat and, in fact, is antithetical to this objective because the requirements for LS/OG retention are minimal where large amounts of such forest are already maintained (Menning, et al. 1996).

Rankings with regards to incorporation of natural ecosystem dynamics into the conservation strategy essentially parallels the ratings for large blocks (Table 2). This is based upon the premise that the only way in which the patterns of **natural** ecosystem dynamics can be incorporated is by having larger management units; natural dynamics is considered to be predominantly a pattern of disturbance associated with light to moderate fire of high to moderate (5 to 30 year) frequency. Incorporating this pattern of disturbance and the spatially complex pattern of patches that it produces (e.g., Figure 1) requires relatively large blocks of LS/OG forest habitat. The "Uneven-Aged Managed Mosaic" might be viewed as incorporating natural ecosystem dynamics but the spatial pattern which management will impose is almost certain to differ from that created through natural disturbances and will, in fact, alter the pattern of disturbance.

Most of the conservation strategies will result in a representative system of LS/OG areas either purposely or as a by-product of the design (Table 2). The "Patch-Based" strategy will not. LS/OG-based strategies do so to varying degrees since they incorporate larger landscape units and not simply the existing patches of high-quality LS/OG forests. Similarly, the "Distributed Fine-Scale Patches" and "Uneven-Aged Managed Mosaic" approaches are landscape-level strategies that will provide for broad geographic representation. Current and proposed policies for federal lands do not directly address the issue of representativeness. The emphasis in the nonfederal policy on greater retention in areas currently lacking LS/OG forests should actually work toward a more representative system, however.

The degree to which strategies are or can be made spatially explicit varies widely (Table 2). "LS/OG Based:ALSEs" and "High-Quality LS/OG" strategies can be fully displayed spatially using the SNEP maps and data bases. The "Uneven-Aged Managed Mosaic" strategy is also spatially explicit since all of the landscape is managed in essentially identical fashion. The "Mixed LS/OG & Non-Commodity" strategy can be partially displayed but the land areas to be added to the high-ranked polygons are not currently identified except for the Eldorado National Forest (Sierra Nevada Ecosystem Project 1996). In the "Patch-Based" strategy patch locations can be identified to the scale of SNEP LS/OG polygons but not in greater detail except for polygons in which patches were mapped as part of the validation study (Langley 1996). Current and proposed policies for federal and non-federal lands do not provide for spatially explicit solutions; roadless areas are an exception for federal lands.

Essentially all of the conservation strategies do or could incorporate management of the matrix to provide for landscape connectivity and for retention of many elements of biological diversity (Table 2). Current federal policies do not explicitly provide for matrix management but the interim California spotted owl guidelines (Verner et al. 1992) are very heavily based on this strategy and generally utilize an upper diameter limit for harvest of 30 inches diameter at breast height (dbh). It can be argued that Alternative D of the California spotted owl EIS (USDA Forest Service 1995) would accomplish the goal of structurally complex forest conditions in the matrix but, if an upper diameter limit on harvest of 40 inches dbh is applied, large diameter tree densities may not be adequate to achieve ecological objectives. Current policy on non-federal lands provides for structural retention in the matrix but at very low levels; i.e., in the form of wildlife trees and snags.

Most strategies provide for restoration of LS/OG forests and structures (Table 2). The "Patch-Based" approach accepts the existing patches of high-quality LS/OG forest as the basis for its system and does not attempt to restore areas not meeting those standards. Current policies for federal and nonfederal lands has no explicit restoration goal where LS/OG conditions are currently absent. The proposed policy for national forests does increase the levels of late-successional forest structures in some areas.

Impacts on timber harvest are a consideration in all of the conservation designs but effects on ASQ are explicitly recognized in only two (Table 2). The "Mixed LS/OG & Non-Commodity" strategy was specifically designed to minimize impact on timber harvests while still retaining the best of the LS/OG polygons. The "Uneven-Aged Managed Mosaic" strategy is designed to keep the entire landscape available for management, including timber harvest. Timber harvest levels are, of course, major considerations in the current and proposed policies for both federal and non-federal forest lands.

CONCLUSIONS

The working group's conclusions are summarized in Table 2. None of the conservation strategies considered here is perfect from the standpoint of all important design elements.

The LS/OG-based strategies appear to come closest to addressing all of the important ecological elements. The "LS/OG Based: ALSE" and "High-Quality LS/OG" strategies trade off levels of retention of existing high-quality LS/OG forest against provision of larger blocks of habitat. The "Mixed LS/OG & Non-Commodity" strategy ranks significantly lower than the other LS/OG-based strategies with regards to several elements but does incorporate greater concern for timber harvest levels.

Other approaches have major deficiencies with regards to one or more elements. The "Patch-Based" strategy, while providing for retention of all existing high-quality LS/OG forest, fails in several other categories. The "Distributed Fine-Scale Patches" and "Uneven-Aged Managed Mosaic" fail at maintaining existing high-quality LS/OG forest and do not provide for large blocks of LS/OG habitat, among other deficiencies.

All of the strategies would require significant investments to produce and maintain LS/OG forest ecosystems in the Sierra Nevada (see, e.g., Johnson, Sessions, and Franklin). Furthermore, there will need to be some long-term stability in the commitment of financial and human resources; without a sustained investment no strategy for maintenance of late-successional forest ecosystems is likely to be successful. Although we have not analyzed differences in expected net receipts, any of the scenarios proposed here could generate significant revenues, some of which could be allocated to management activities.

Current and proposed policies for federal lands clearly do not give serious consideration to maintenance of high-quality LS/OG forest ecosystems. The circumstances on federal lands in the Sierra Nevada Range resembles the current and proposed policies for federal lands in the Pacific Northwest prior to FEMAT (1993) and adoption of the Northwest Forest Plan--i.e., attention to species utilizing LS/OG forests but not to intact LS/OG ecosystems.

Current policy for non-federal land does incorporate a concern for maintenance of LS/OG forests and structures but at very low levels and in only general terms. Clearly the brunt of any LS/OG strategy for the Sierra Nevada is going to have to be carried by the federal lands where the bulk of the remaining old-growth forests are located and policies could be adopted with existing legal structures.

Finally, we would like to emphasize the importance of scientific knowledge in developing and implementing any late-successional forest ecosystem strategy. Current knowledge concerning the structure and function of natural forest ecosystems in the Sierra Nevada is surprisingly limited in view of the extent and importance of these forests. There are some exceptions, such as the substantial information base that exists on fire regimes and the forest ecosystem studies which have been conducted in Sequoia-Kings Canyon National Park. Generally information on natural forest ecosystems is very limited for the Sierra Nevada, however.

Strategies to achieve a particular level of certainty or risk with regards to maintenance of late-successional forest ecosystems must, of necessity, reflect the level of available knowledge. A more conservative, less risk-prone strategy is required when scientific knowledge is limited, as in the case of the Sierra Nevada. **A substantial investment in research on the composition, structure, and function of forest ecosystems in the Sierra Nevada could provide the basis for less restrictive approaches to management which better integrate a variety of social objectives.**

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APPENDIX I.

An Application of the Concept of Areas of Late Successional Emphasis (ALSE)

Areas of Late-Successional Forest Emphasis (ALSE) are conceived as land units where the maintenance and restoration of high-quality late-successional and old-growth (LS/OG) forests is the primary management objective. Active management of ALSEs is considered to be implicit in the concept, including management to reduce the potential for catastrophic intense wildfires as well as restoration of moderate to low intensity fire as an important process.

ALSEs are typically larger areas, commonly ranging from 5,000 to 30,000. One reason for their relatively large size is to allow for flexibility in planning and carrying out various management activities such as prescribed burning and treatments which may reduce the potential for catastrophic fire, such as fuel breaks. Larger areas also allow incorporation of more of the environmental and forest complexity, including ecotones and gradients.

The proposed ALSEs in the Sierra Nevada (Franklin and Fites 1996) are centered on larger landscape units or polygons which currently have high LS/OG values (structural ratings of 4 or 5). Adjacent polygons have been added to provide logical management units as outlined in the previous paragraph.

A zoned approach to management of the ALSEs is proposed. Typically 1/2 to 2/3 of an ALSE would be maintained as a core area in which management would consist primarily of prescribed fire or managed wildflire with little or no mechanical treatment. Silvicultural manipulations, as well as prescribed fire, could be used on the remainder of the ALSE to create shaded fuel breaks, alter or remove fuels (such as by biomassing or thinning), etc., but always with the primary objective of protecting the LS/OG resource of the ALSE.

A management plan would be developed for each ALSE. This plan would include: a detailed evaluation of the LS/OG resource; a stratification of the ALSE for management purposes, including its historical development; and a detailed fire management plan including areas and priorities for fuel treatment, shaded fuel breaks, prescribed burning, and managed wildfire.

A proposed ALSE on the Eldorado National Forest provides an example of some of these concepts (Figure A1). This ALSE is located along lower Camp Creek on the Placerville District at the western boundary of the National Forest. Much of the area is very high quality (structurally complex) LS/OG forest based upon the LS/OG mapping and analysis (Franklin and Fites 1996) and subsequent field examinations. The high LS/OG quality of these forests is largely because relatively little timber harvest has occurred as a result of poor access in the steep-walled canyons of lower Camp Creek.

The Camp Creek ALSE is zoned primarily for management by prescribed fire and other natural processes (Figure A1). Some areas are identified as having a high priority for prescribed burning; most of these are south to western slopes which have undergone some of the most significant changes (e.g., in increased tree density) as the result of fire control programs.

Shaded fuel breaks are proposed both within and along some of the boundaries of the Camp Creek ALSE. The fuel breaks are viewed as important short- to midterm strategies to reduce the risk that intense wildfires will spread into the ALSE. These breaks also incorporate significant numbers of large-diameter trees which will reduce their ecological impact.

Locales for biomassing and other mechanical fuel reduction activities are also identified for the Camp Creek ALSE. It is anticipated that once such areas are treated silviculturally, they will be periodically subject to prescribed burning.

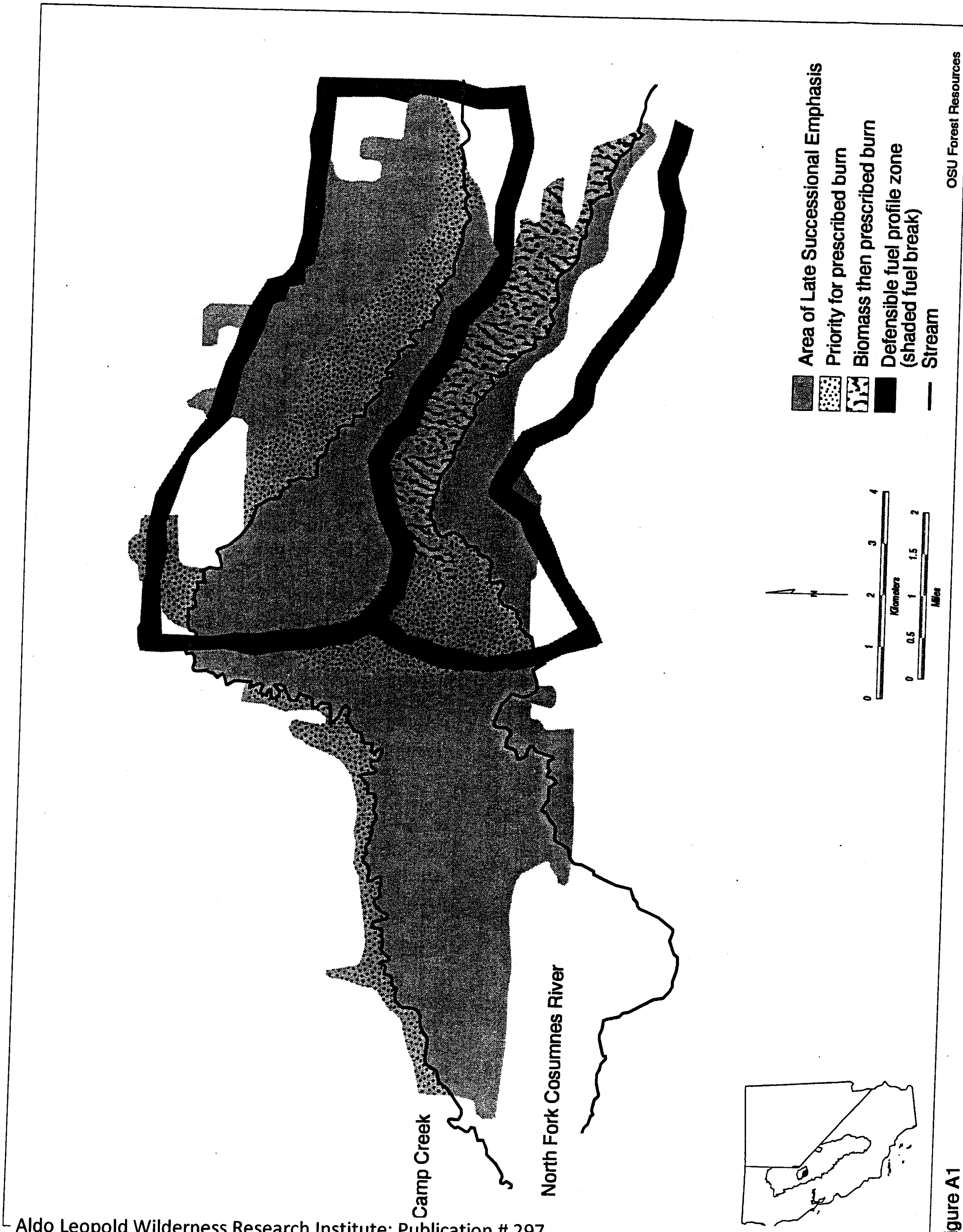

Figure A1

An example of ALSE management.

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