USING ECOLOGICAL RELATIONSHIPS OF WILDLIFE AS TEMPLATES FOR RESTORING SOUTHWESTERN FORESTS

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ABSTRACT. We demonstrate approaches to developing conservation strategies for two threatened, endangered, and sensitive predators, the northern goshawk (*Accipiter gentilis*) and the Mexican spotted owl (Strix *occidentalis lucida*), which incorporate knowledge of their habitats and those used by their major prey species. For each predator, a composite of prey habitats is constructed and then synthesized with the predator habitat. This synthesis results in a set of habitats for the predator's food web. Habitats are then projected onto a spatio-temporal scale by referencing them to historic forest conditions. These reference conditions include the composition, structure, and landscape patterns of relevant forest types that existed before intensive management. We focus on forest types because each contains plants and animals that are adapted to local environments; for example, different plant species compositions, structures, patterns, and natural disturbances.

Projection assures that the desired habitats and their mixes are attainable and sustainable; that is, that the desired conditions are within the biophysical capabilities of the vegetation comprising the forest type and that they are manageable. We show how the desired forest conditions, the templates, identified in this approach for Southwest ponderosa pine forests are similar to the natural species composition, structure, and landscape pattern in those forests.

INTRODUCTION

Species composition, structure, and landscape pattern of contemporary ponderosa pine (*Pinus ponderosa*) and mixed-conifer forests in the Southwest differ substantially from conditions that existed before European settlement primarily because of grazing, fire management, and logging. While some plant and animal species have benefited from these changes, populations of other species have seriously declined. Because changes have led to increased susceptibility to stand-replacing fires and increased losses to insects and disease, the persistence of the forests and the habitats they contain is of concern (Barrett 1988, Arno and Brown 1991, Reynolds et al. 1992, Wickman 1992, Mutch et al. 1993, USDI 1995).

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In response, recent management direction and recommendations emphasize treatments that are consistent with natural ecological processes (Overbay 1992, Reynolds et al. 1992, Risbrudt 1992, USDI 1995). The intent is to maintain a species composition. structure, and landscape pattern similar to that of presettlement forests. However, it is not always clear that managing forests toward natural conditions will conserve populations of species native to a forest type, and this uncertainty is heightened where the habitats of threatened, endangered, and sensitive (TES) species are involved.

We demonstrate approaches to developing conservation strategies for two TES predators, the northern goshawk (*Accipiter* gentilis) and Mexican spotted owl (Strix *occidentalis lucida*), which incorporate knowledge of their habitats and those used by their major prey species. For each predator, a composite of all prey habitats is constructed and then synthesized with the predator habitat. These. habitats are then projected at onto a spatio-temporal scale by referencing them against historic forest conditions. Reference conditions include the composition, structure, and landscape patterns of relevant forest types before intensive management. This projection is critical for verifying that habitats and their desired mixes are attainable and sustainable; that is, that the desired conditions are within the biophysical capabilities of the vegetation comprising the forest type. Our approach establishes a set of desired forest conditions that vary by forest type because each forest type contains plants and animals that are adapted to local species compositions, structures, landscape patterns, and natural disturbances. This process gives us confidence that species will be conserved.

Habitat provides the life needs of a species; a suitable microclimate, nest sites, food, escape cover, water, and mates. Thus, intrinsic and extrinsic relationships exist between a species and the physicgl and biological environment where it is found. These relationships partly underlay species evolution (Block and Brennen 1994). Native plants and animals of Southwestern forests were adapted to environmental conditions that existed before the beginning of intensive forest management. Management prescriptions that restore the composition, structure, and spatial patterns of these forests should improve the habitats of native species.

STRATEGIES

Conservation strategies should consider all of a species' requisite resources (nesting and foraging habitats, food) and ecological relationships (competition, predators, diseases) that might limit populations during any part their life histories. Furthermore, because habitats change through succession and natural and anthropogenic disturbances, conservation strategies should address the long-term sustainability of a species' habitat and the habitats of species in its food web. To sustain habitats and food resources, one must understand the habitat relationship of predator and prey and the dynamic physical, biological, and ecological processes that affect the sustainability of their forest habitats at large spatio-temporal scales. Our objective was to design a landscape of sustaining habitats so that long-term goshawk and spotted owl viability was assured.

The first step in developing our strategies was to review the life histories of goshawks and spotted owls including their resource-use, population biology, and habitat ecology. Specifically, we:

1. Reviewed how their populations might be limited by habitat, food, predators, competitors, and diseases;
2. Examined how environmental conditions, primarily vegetation, affect the distribution and abundance of their habitats and influence the types and intensities of their intra- and interspecific relationships;
3. Identified important prey for the goshawk and spotted owl within a forest type;
4. Reviewed current knowledge on the key habitats and foods of their prey;
5. Synthesized this information into qualitative models based on the desired abundance and spatial distribution of habitats of both predators and prey species; and
6. Overlayed information on the vegetation composition, structure, and landscape patterns of a forest type before intensive forest management to give these models a spatio-temporal context.

Incorporating the ecology of a forest, including its patterns of growth and development, allowed us to design a shifting mosaic of predator and prey habitats that simulated the natural shifting mosaic. Our rationale is that forests before Euro-American settlement were relatively stable in ecological time (Hansson 1977, Forman and Godran 1981, Romme and Knight 1982, Delcourt and Delcourt 1983). This stability allowed native plants and animals to adapt to local environments and to one another (Linhart 1989, Linhart et al. 1989). Managing these forests within their natural ranges of variation and ecological limits by using the natural compositions and abundances of fauna and flora and the processes that result in patterns of their assembly, is the best model for sustaining these predators and their food webs.

The shifting mosaic of habitats is achieved by matching, as closely as possible, the desired interspersion of habitats with natural forest patch dynamics. Patch dynamics are the interacting consequences of the life span of trees, stand development characteristics, successional processes and patterns, and natural disturbances that vary in space and time in a forest type. The planning horizons for our conservation strategies are, therefore, centuries.

Choosing the desired landscape

Conservation strategies must identify appropriate spatial scales for providing and assessing changes in the amount, quality, and intermixing of habitats to maximize probabilities for population viability of the target species. The appropriate scale depends on management objectiyes and can be site-specific or encompass the entire geographic range of the species. For example, if the objective is to maintain only known pairs of goshawks, then the scale should be based on the nesting home range, roughly 4,000 to 10,000 ac

(Eng and Gullion 1962, Reynolds 1983, Kennedy 1990, Hargis et al. 1994, Bright-Smith and Mannan 1994). However, if the objective is to provide for growth of a population by providing favorable habitats for dispersing goshawks, then the appropriate scale may be an entire national forest or ecoregion. Implementing a large scale strategy also allows for the expansion of a predator's home range when prey population are low during winter and lessens the need to determine the "correct" number, spatial configuration, and dispersal corridors between home ranges.

The Mexican spotted owl in pine-oak and mixed-conifer forests of the Southwest requires specific forest structures. Nest-stand structure typically includes large trees, closed-canopies, multiple-height strata, and log and snag decay (Zhou 1994, Ganey and Dick 1995, Seamans and Gutierrez 1995). Foraging habitats are more diverse; the consequence of foraging for prey species that have different habitat requirements (Reynolds et al. 1992, Ganey and Dick 1995). Foraging habitat includes multiple vegetation types and different seral stages (age classes) of those types. The size, shape, juxtaposition, and interspersion of habitat patches are as important to prey populations and to the foraging behavior of the goshawk or owl as the within-patch characteristics. Furthermore, landscape considerations must allow for both short- and long-range dispersal. Short-range dispersal occurs within contiguous landscapes of connected or nearly connected habitats. On the other hand, long-range dispersal occurs between isolated patches of habitat, such as in the Sky Island region of southeastern Arizona where the desired landscape may include stepping stone habitats that facilitate movement between these mountain islands. Conservation strategies must include nonbreeding and dispersal habitats because failure to do so may lead to decreased gene flow and genetic variation, and possibly to local extirpations.

Identifying pre-settlement forest conditions

Understanding the patterns and ecological processes that occurred in Southwestern ponderosa pine forests before the introduction of intensive forestry was central to our approach to developing conservation strategies. Sources of information concerning historical conditions include historical accounts and photographs, tree rings, fire scars, packrat middens, areas that have had minimal human disturbance, dendrochronology, palynology, and paleoecological and forest restoration studies (Kaufmann et al. 1993). Although numerous publications and reports describe the natural conditions of many North American forest types, the breadth and accuracy of the information is highly variable. The following is an abbreviated list of descriptions of the natural composition, structure, and landscape pattern of a variety of forest types: Cooper (1960, 1961), Pearson (1950), Billings (1969), Bormann and Likens (1979), Dieterich (1983), Critchfield (1985), Barbour (1988), Elliott-Fisk (1988), Franklin (1988), Greller (1988). Peet (1988). Laudenslayer et al. (1989), Betancourt et al. (1990), Covington and Moore (1992), McKelevy and Johnson 1992, Grissino-Meyer et al. (1994).

Limitations of pre-settlement data. Knowledge of presettlement forest conditions is largely based on correlative information. Conclusions of studies based on this information for ponderosa pine consistently describe presettlement forests as open, park-like areas composed of large trees that were strongly aggregated into groups. While much evidence supports this generalization, we are concerned with the degree that the results from these studies have been extrapolated. For example, Covington and Moore's (1992) study on the Bar-M canyon watershed of Arizona were on shallow slopes (0-15 percent) and included only one major soil type. We suspect that edaphic differences, topographic influences (especially aspect), and different fire regimes on steeper slopes (>15 percent) would have resulted in different densities, size-class distributions, and species compositions of presettlement trees than on shallow slopes. Many studies of presettlement forests provide few measures of dispersion, or information on distributional properties of the parameters estimated. Whether or not sample sizes in some studies were sufficient for unbiased estimates of the mean number of trees cannot be evaluated without information on sampling variances: sample sizes in most studies were small. While previous work has heuristic value in verifying certain forest conditions, we caution about the extrapolation of these results in complex landscapes.

Northern goshawk

Ponderosa pine in the Southwest (about 2.8 million ac) occurs between the dry pinyon-juniper or oak woodlands arid the cool, moist mixed-conifer forests at higher elevations, between 6,500 and 8,500 feet elevation. Within the ponderosa pine zone, the tree occurs either in pure stands where it typically is the climax species, or in mixed-species stands where it is often seral. At lower elevations it frequently mixes with pinyon pine, several species of juniper, and oak; at higher elevations it mixes with Douglas-fir, white fir, blue spruce, southwestern white pine, and quaking aspen (Barrett et al. 1980). Frequent (every 2-7 years) low-intensity ground fires maintained open, park-like forests visually dominated by large yellow-barked pines that occurred in small groups (< 0.3 ac) of trees(Covington and Moore 1992). Adjacent groups of trees typically differed in ages (Weaver 1951, Cooper 1961, Dieterich 1983, Swetnam and Dieterich 1985). Intensive livestock grazing since the late 19th century, and fire suppression and timber harvests since the early 1900s, have greatly altered the species composition of understory and overstory vegetation, soil characteristics, tree densities, fire fuel loadings, tree vigor, and wildlife habitat (Cooper 1960, Faulk 1970, Covington and Sackett 1984, White 1985, Covington and Moore 1992, Reynolds et al. 1992).

PREY AND HABITATS. The following is a summary of the current knowledge of goshawk and prey habitats historical composition, structure, pattern, and disturbance in Southwest ponderosa pine forests. The complete conservation strategy for the goshawk in this forest type is in Reynolds et al. (1992). Fourteen prey species (or groups of similar species), based on their numerical and biomass contribution to diets, were selected as important prey (Table 1). The majority of these prey reside on the ground or in the lower portions of the tree canopy. All of the mammals, and many of the avian prey, feed on seeds, berries, or the foliage of herbaceous and shrubby plants that occur in the forest understory or in small forest openings. Many feed on pollen and seeds of staminate and ovulate cones of conifers. Tree squirrels, for example, climb trees for cones, while chipmunks and ground squirrels scavenge cones or seeds from the ground or steal cones from caches of others. Other prey species eat arthropods that feed on understory plants or on trees, or that nest in downed logs or in the soil. Mycorrhizal soil fungi are important foods for many of the mammalian prey.

Snags (standing dead trees) provide critical resources for many birds, mammals, invertebrates, and plants. Among goshawk prey, all woodpeckers use snags for feeding, nesting, or both. Several other species of birds use snags for perches. Four mammals use snags with cavities for nesting and for caching cones.

Large, downed logs provide cover, feeding, and nest sites for a variety of vertebrates. Among goshawk prey, downed logs are important feeding sites for woodpeckers and as denning sites for chipmunks, mantled ground squirrels, and cottontail rabbits. Downed logs are also used by blue grouse during courtship.

The character, amount, and distribution of woody debris (material >3 in. and <12 in. in diameter) may affect the abundance of goshawk prey (Dimock 1974). Woody debris provides important denning sites for cottontail rabbits, cover for rabbits, chipmunks, and ground squirrels, and feeding sites for several woodpecker species.

Large trees (>18 in. in diameter) provide critical nesting, denning, feeding, and roosting sites for such goshawk prey as tassel-eared squirrels, large woodpeckers, and blue grouse. Large trees also are good cone producers, providing seed for many prey species. Large trees are the only source for large snags and downed logs, both important to all but one member of the suite of prey. Large trees also provide hunting perches and nest trees for goshawks.

Openings with their associated grassy, herbaceous, or shrubby vegetation, provide important food and cover for a number of goshawk prey. Three species require openings; blue grouse for nesting and brood-rearing, and band-tailed pigeons and mourning doves for feeding. Because pigeons and doves typically travel long distances to feed, large openings may not be necessary for them. Small to medium openings (<4 ac) benefit blue grouse, chipmunks, and mantled ground squirrels, and minimize the effects of larger openings on the more interior forest species.

Herbaceous and shrubby understories provide important foods (seeds and berries) and cover for many of the selected goshawk prey. Well developed understories occur in forests with canopies sufficiently open to allow adequate light to reach the forest floor. Herbaceous and shrubby understories are critical foods and cover for robins, doves, pigeons, grouse, chipmunks, rabbits, ground squirrels.

Interspersion is a measure of the degree of intermixing of vegetation structural stages (VSS). VSS describe forests on the basis of tree-size classes from seedlings to old trees: VSS 1 is open area dominated by grasses, forbs, and shrubs; VSS 2 is dominated by seedlings and saplings; VSS 3 is young forests; VSS 4 is mid-aged forests; VSS 5 is mature forests; and VSS 6 is old forests. Several prey require relatively high structural stage interspersion levels, others are affected little or not at all by interspersion. Tassel-eared squirrels, blue grouse, and cottontails need relatively high interspersion levels, while chipmunks are affected little by interspersion. Although some prey occur in each VSS, the mid-aged, mature, and old age-classes (VSS 4-6) are significant to most (11 of 14) important prey (Reynolds et al. 1992). Some species (American robin, mourning

TABLE 1. Suite of important northern goshawk prey in the Southwest (from Reynolds et al. 1992).

Birds	Mammals
American robin	Chipmunks (*Tamius* spp.)
Band-tailed pigeon	Cottontail (*Sylvilagus* spp.)
Blue grouse	Mantled ground squirrel
Hairy woodpecker	Red squirrel
Mourning dove	Tassel-eared squirrel
Northern flicker	
Red-naped sapsucker	
Steller's jay	
Williamson's sapsucker	

dove) are generalists and occur in most VSSs, while others, such as Williamson's sapsucker, occur in a limited number of structural stages. Blue grouse need older forests (VSS 4, 5, and 6) interspersed with openings (VSS 1), and tassel-eared squirrels need a mix of mid-aged and mature or old forests.

Many of the mammalian prey species depend on fungi during summer and fall; the physiological condition in which tree squirrels begin the winter depends on the amount of fungi eaten (Maser et al. 1978). In ponderosa pine forests, the best fungi-producers are mid-aged VSS with high canopy cover and shade to protect soil moisture (States 1985, States et al. 1988, Uphoff 1990).

Mexican spotted owl

The Mexican spotted owl was listed as a threatened species in 1993 under the Endangered Species Act (1973) and a team was formed to develop a recovery plan (USDI 1995). Summarized below are features of the recovery plan that characterize habitat needs for the owl and its prey.

PREY AND HABITATS. Seven groups of vertebrates, including more than 16 species, are important prey for owls based on comprising >10 percent of the diet by either frequency or biomass (Table 2). Although the owl's diet varies geographically, woodrats (Neotoma spp.) and peromyscid mice (Peromyscus spp.) usually dominate the diet. Even so, the species taken as prey represent a diverse array of habitats and ecological niches. Considered as a group, they demonstrate the importance of managing for a landscape mosaic consisting of habitat patches in various conditions and seral stages.

Although the owl is found predominantly in mixed-conifer forests, some reside in ponderosa pine-Gambel oak forests of northern Arizona. By biomass, the most common prey in these forests are woodrats (N. mexicana and N. *albigula*), peromyscid mice (P. maniculatus and P. *boylii*), cottontail (Sylvilagus *nuttalli*), and various sciurids (*Spermophilus* lateralis, S. variegatus, Tamias dorsalis, T. cinereicollus). Lesser components of the diet include various bird species, pocket gophers (*Thomomys* spp), Mexican voles (*Microtus* mexicanus), bats, and arthropods.

Habitat requirements for each of these species are unique. The deer mouse inhabits most areas, whereas the brush mouse and Mexican woodrat favor areas with rocky outcrops, high log volume, and a shrub understory. Such conditions occur frequently, but not exclusively, on poor timber producing sites. Cottontail, pocket gophers, and voles use more open areas where sparse canopy cover allows for a well-developed herbaceous understory. These areas typically occur within stands, along drainages and canyon bottoms, or in meadows adjacent to forests. Curiously, voles contributed little to the total diet of owls in the pine-oak forest, although they are a major diet component in other parts of the owl's range (Ward and Block 1995). The low number of voles

TABLE 2. Prey comprising >10% of relative frequency (X) or biomass (O) in the diet of Mexican spotted owls (from USDI 1995).

Prey group	Colorado Plateau	Southern Rocky Mountains Colorado	Southern Rocky Mountains New Mexico	Upper Gila Mts.	Basin & Range West	Basin & Range East	Sierra Madre Occidental Norte
Bats	X			X	X		
Rabbits	O	O	O	O	O	O	O
Pocket gophers				O			O
Peromycid mice							
Deer mouse	X O	X O	X	X O	X O	X O	X O
Brush mouse	X O	X O	X	X O	X O	X O	
Canyon mouse	? ?						
Woodrats							
Mexican woodrat	X O	X O	X O	X O	X O	X O	X O
Bushy-tailed woodrat	X O	X O	X O				
Desert woodrat	X O						
White-throated woodrat		X O	X O		X O		
Voles							
Mexican vole		X O		X O	X O		
Mountain vole		X O	X O				
Meadow vole		X O	X O				
Long-tailed vole		X O		X O	X O		
Birds			X O	X	X O	O	
Arthropods	X	-[a]	X	X	X X	X	

[a] *Undetermined.*

in the diet was corroborated by low numbers captured during live-trap sampling (Block and Ganey, **unpubl.** data). Possibly the unnaturally dense **conditions** of these forests (Covington and Moore 1992) have suppressed the growth of grasses and forbs decreasing habitat quality and quantity for species like voles, gophers, and rabbits.

Providing appropriate habitat conditions for prey species is critical for buffering predator populations against natural population declines in any prey species. Given the variety of prey taken and differences among prey species in habitat requirements, the desired landscape should be a mosaic consisting of vegetation in different conditions and seral stages. These prey species are adapted to natural conditions in Southwestern forests; thus, returning these forests to more natural conditions will help ensure an adequate prey base for the Mexican spotted owl.

Templates: Desired forest conditions

NORTHERN GOSHAWK. Our analysis showed that goshawk foraging habitat consisted of large trees and relatively open understories. Large trees have large limbs that are used as hunting perches, and relatively open understories provide flight room and opportunities for detecting and capturing prey. Habitat for goshawk prey in Southwestern ponderosa pine forests included small, scattered openings and a high interspersion of age classes to provide a diversity of habitats and foods. On average, canopy cover was relatively open, allowing sunlight and moisture to reach the forest floor so that grassy, herbaceous, or shrubby understories could develop. However, groups of trees within patches of VSS 5 & 6 had interlocking crowns and higher (60-80 percent) canopy cover. Interlocking crowns provided travel routes for squirrels (**Patton** 1984) and other prey, and shading to protect soil moisture and fungi populations (States 1985). Large tree components (live trees, snags, and downed logs) were abundant and scattered throughout the landscape. Large live trees provided many unique hiding, feeding, denning, and nesting sites used during some part of the annual cycle of all important goshawk prey species. Goshawk habitat in **ponderosa** pine should have abundant prey when at least 60 percent of the landscape is in the three older age classes (VSS **4, 5**, and 6).

The desired habitats of goshawks and their prey in ponderosa pine consisted of a mosaic of highly interspersed, small patches of different structural stages (**grass/forb/shrub** stage to old forest stage). This mosaic of forest patches and within-patch structure closely resembled the species composition, structure, and landscape pattern in historic Southwestern ponderosa pine forests. Mature and old trees in these pine forests were strongly aggregated into groups consisting of 3 to 44 trees and occupied from 0.5 to 0.7 ac (Cooper 1961, White 1985). Groups were typically separated by variably-sized openings. Although openings appeared unstocked, the roots of trees in the groups extended 50 feet or more into the openings (**Pearson** 1950). Tree reproduction (seedlings, saplings, poles) either occurred within a group, often when a mature tree **fell (Covington** and Moore **1992)**, or in openings between groups (**Pearson 1950**, Cooper **1961**). Seedlings were established in a year when fire exposed the mineral soil seed bed and when there was high seed production and rainfall (Cooper **1960, 1961**). The historical ponderosa pine forest landscape was composed of an all-aged forest (coarse scale) made **up** of small, either even-aged or multi-aged patches of trees (fine scale).

Interlocking tree crowns, large limbs in and below crowns, and extensive shading are important **within**-patch characteristics for goshawks and their prey. Yet trees in these patches should be vigorous enough to produce abundant symbiotic mycorrhizal fungi. Trees within groups of mature ponderosa pine display the characteristics of open-grown trees and trees grown in dense stands. Interior trees are under greater competition for soil moisture, nutrients, and light, whereas trees on group edges have more sunlight and openings to spread their roots (**Pearson** 1950). While interior trees have narrow and short crowns, trees on the edge have one-sided but long crowns. Further, the crowded conditions within groups result in an intermingling of adjacent trees limbs. The long crowns of the outside trees provide shading and maintain higher soil moisture within the group, which are conditions ideal for mycorrhizal fungi production (States **1985**, States et **al. 1988**, Uphoff **1990).**

Large diameter snags were historically abundant and well dispersed in Southwestern ponderosa forests because of the abundance and susceptibility of old trees to mortality factors such as wind, lightning, fire, mistletoe, fungal diseases, insects and other herbivores (**Pearson 1950**, Cooper 1961). Although frequent ground fires kept the forest floor relatively clear of woody debris, portions of large diameter logs often survived fires. These large trees and snags provided a continuing source of large-log habitats for goshawk prey.

The goshawk conservation strategy identified the proportions of managed landscapes that could be maintained in specified age classes so that the **availability** of those age classes would remain somewhat con-' **stant** through time. For the goshawk, this objective was met when a landscape had 20 percent in each **of the** older four age classes (VSS **3, 4, 5, 6**) and 10 percent each in VSS 1 and 2. The proportions that can be maintained in the differentage classes depends on the number of years required for seedling establishment, growth rate of trees (partly dependent on the intensity **of** management), and tree longevity.

MEXICAN SPOTTED OWL. Similar to the desired conditions for goshawks, the forested landscape for Mexican spotted owls and their prey in ponderosa pine-Gambel oak and mixed-conifer forests should emphasize a mosaic of different seral stages. Although the interspersion and juxtaposition of patches was unknown, a key consideration was the distribution of seral stages as they relate to topography, specifically slope and aspect. Presently, most owl nest and roost sites in this forest type are on steep slopes associated with cinder cones and drainages. Whether or not presettlement forest conditions on these slopes differed from those on flatter slopes is unknown. However, because of edaphic and microclimatic differences, and possibly differences in fire regimes, assuming that presettlement forest structure varied with slope and aspect is reasonable. Research is needed to describe the variations in presettlement forest structure as influenced by environmental differences.

The limiting factor for owls is adequate nest and roost habitat. Typically, such habitat exhibits high tree basal area, large trees, and a large oak component. Most nests in this forest type are in cavities of large Gambel oaks. Garnbel oak are shade intolerant, thus they require an open canopy structure to become established and achieve maximum growth potential. The size of nest stands is unknown but is currently under investigation (R. Gutiérrez, personal communication with W. Block). However, the Forest Service stand database indicates that 7 to 10 percent of pine-oak forests meet nest stand characteristics (USDI 1995). Whether or not stands exhibiting nest characteristics existed before European settlement and, if so, what proportion of the landscape contained these conditions, is unknown, but should be researched. The remainder of the landscape should include stands of various seral stages to meet the habitat requirements of the prey the owl requires. The distribution of seral stages and mosaic patterns required by the goshawk in pine forests appear compatible with spotted owl needs. We assume that species in both the owl and goshawk food webs are adapted to natural conditions; therefore, even partial restoration of those conditions will improve their habitats.

Implementation

A conservation strategy is not complete without area-specific guidelines for its implemention. Attainment of the desired conditions requires an understanding of the relationship between existing forest conditions, the desired conditions, and the landbase capability. The choice and intensity of management should be based on the direction and the distance the existing forest conditions must move to reach the desired conditions. Both Reynolds et al. (1992) and the USDI (1995) recognized that the capability of a landbase to produce certain forest conditions varies across sites and that this variation is associated with elevation, slope, aspect, soil, and moisture and nutrient availability. During implementation, we suggest the best reference conditions for sustaining habitats on sites are the historical species compositions, densities, and patterns on those sites.

Present forest conditions are moving away from històric conditions; many of the recommendations in our conservation strategies reverse that direction. Specific management prescriptions for Southwestern ponderosa pine were designed to improve predator and prey habitats by:

1. Increasing the abundance of old trees and forests, large snags, and large, downed logs;
2. Restoring the grouped nature of trees and the interspersion of small patches of different age classes;
3. Restoring the habitats and foods provided by a well-developed grass, forb, and shrub layer in understories; and
4. Protecting habitats from catastrophic loss from fire and insect epidemics by reducing fuel ladders and tree overstocking.

Some recommended tools to attain these goals are small group-selection (uneven-aged management), retention of large snags and logs, protection of the organic surface layer of soils during management activities, lengthening the harvest cycle, thinning from below, and the reintroduction of ground fires (Reynolds et al. 1992, USDI 1995).

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