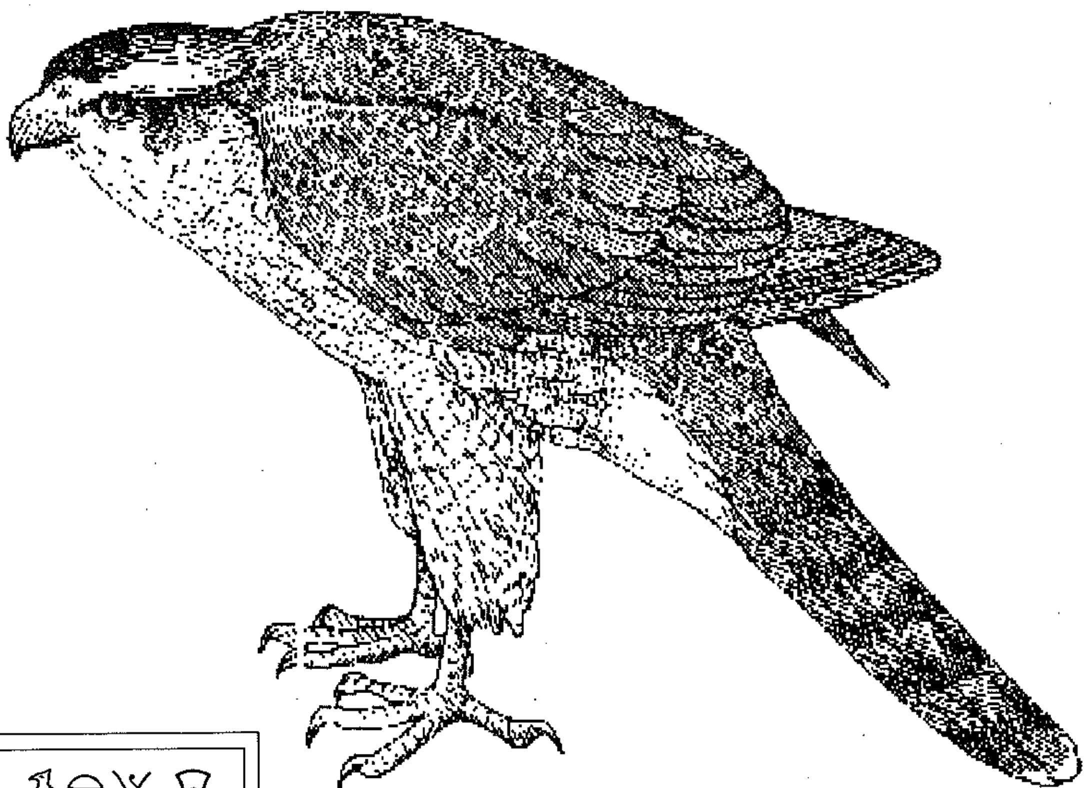
NORTHERN GOSHAWK AND FOREST MANAGEMENT IN THE SOUTHWESTERN UNITED STATES



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NORTHERN GOSHAWK AND FOREST MANAGEMENT IN THE SOUTHWESTERN UNITED STATES

The Wildlife Society
and
American Ornithologists' Union
Technical Review Team on Northern Goshawks

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Foreword

Presidents of The Wildlife Society occasionally appoint ad hoc committees to study and report on selected conservation issues. The reports ordinarily appear as either a Technical Review or a Position Statement. Review papers present technical information and the views of the appointed committee members, but not necessarily the views of their employers. Position statements are based on the review papers, and the preliminary versions are published in **The Wildlifer** for comment by Society members. Following the comment period, revision, and Council's approval, the statements are published as official positions of The Wildlife Society.

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SYNOPSIS

The Northern Goshawk/Southwestern Forest Management Review Team analyzed the scientific basis of the interim management guidelines resulting from the *Management Recommendations for the Northern Goshawk in the Southwestern United States* developed by the Northern Goshawk Scientific Committee of the U.S. Forest Service. The Review Team evaluated regional Forest Service policy implementing the interim guidelines and field application of those guidelines.

Two related issues emerged: management to create northern goshawk (Accipiter gentilis) habitats and to benefit goshawk populations, and management of southwestern forests, especially ponderosa pine (Pinus ponderosa) forests. These aspects were inextricably linked. Finally, public misconceptions about pre-settlement condition of ponderosa pine forests and the desire by some individuals and groups for different forest conditions confounded these issues.

The scientific basis for the *Management Recommendations*, and the recommendations themselves are sound. Implementation of the *Management Recommendations* should benefit the northern goshawk and many other animal and plant species. Implementation will change the structure of the forest and the relative abundance of many plant and animal species.

Pre-settlement ponderosa pine forests were mostly open and park-like with sparse canopies. Because of fire prevention, overgrazing, timber management, and other cultural activities, the character of southwestern ponderosa pine forests has been modified. Implementation of the interim guidelines for northern goshawks may reverse the trend to younger age classes of ponderosa pine, but recommended densities of large old trees are sometimes less than one-half that documented in certain pre-settlement periods.

The U.S. Forest Service has interim policy that implements the *Management Recommendations*. Implementation is recent and objective evaluation of effects has not been conducted. Further, no evaluation is recommended in the guidelines or implementation policy. Our brief visits to the field and discussions with forest managers revealed no consensus upon how to apply interim guidelines. Some local managers are making changes in their practices based on experience. Some managers are thought to emphasize minimal, not maximal, retention of old large ponderosa pines. Use of the interim guidelines appears varied because of different interpretations. Most training for implementation has been in northern Arizona, and much implementation has been on the North Kaibab plateau, where the forest differs from most national forests in the Southwest. The heterogeneity of stand conditions and growth rates in the Southwest are diverse, therefore blanket application of methods tested on the North Kaibab is inappropriate. Implementations on the North Kaibab should be evaluated to understand why certain practices were implemented, and if the desired effects were achieved.

Review of northern goshawk biology and habitat use by the Northern Goshawk Scientific Committee was excellent. No evidence was presented to indicate that northern goshawk populations are declining, threatened or endangered in the Southwest or anywhere within its range, and we found no evidence of a long-term decline in goshawk breeding populations. However, the U.S. Forest Service has taken a proactive position to reduce the loss of mature and old tree habitat that usually is associated with goshawk nesting. Furthermore, the *Management Recommendations* and the interim policies for implementing *Management Recommendations* are designed to manage for a variety of plant and animal species. Management for a goshawk food web is an important step toward ecosystem management, as well as an important step to keep goshawks from becoming threatened or endangered. The Forest Service must be sensitive to the concerns for other species in the forest systems. Further, the complexity of forest management prescriptions for the *Management Recommendations* requires precision that takes considerable effort. This effort should benefit as many species as possible. National forests should be managed for a diversity of species and habitat types with retention of large areas, at least at the watershed level, characterized by large, old trees. Pre-settlement conditions or the desired forest conditions of the *Management Recommendations* are uncommon on national forests but can be managed for by manipulation of forests over significant areas of national forest lands in the long term. These manipulations include mechanical thinning of younger trees and use of ground fires. *Management Recommendations for the Northern Goshawk in the Southwestern United States* provides the basis for adaptive management that strives for a naturally functioning ecosystem.

INTRODUCTION

Aggressive management of public lands is increasingly contentious because users articulate and promote different values. These conflicts are very evident in the western United States where issues range from costs of grazing fees to intensity of forest management. Protection of long-term timber supplies on public forest lands was a primary management objective for creation of the National Forest System. Timber harvest in the United States generally exceeded annual growth before 1950; since 1950 growth has consistently exceeded harvest (Powell et al. 1993). However, most growth is in younger age classes of trees and there is no large reserve of high quality, old trees for harvest (Powell et al. 1993). Because of the shortage of large old trees, further cutting of remaining old trees is increasingly opposed by some agency personnel and much of the public in the Southwest and elsewhere.

Opposition to the harvest of old trees in the Southwest rests on potential negative effects on certain species of wildlife and interest in restoring pre-settlement forest conditions (Dodd 1992, Ariz. Game and Fish Dep. 1993). Research conducted in the Kaibab National Forest in northern Arizona identified negative effects of timber harvest on northern goshawk breeding success (Crocker-Bedford 1990), which in turn led to an increased interest in reducing timber harvest in the North Kaibab. Later in the year, the U.S. Forest Service responded to the findings and established the Northern Goshawk Scientific Committee (Scientific Committee) "to develop a credible management strategy to conserve the goshawk in the United States" (Reynolds et al. 1992). The committee's report, *Management Recommendations for the Northern Goshawk in the Southwestern United States* (Reynolds et al. 1992) and the subsequent U.S. Forest Service policies for "Interim Management Guidelines for the Northern Goshawk in the Southwest" have received wide publicity and been critiqued by resource management agencies and environmental groups.

Out of concern for the remaining mature forests in the Southwest and a fear that implementation of the Forest Service's management guidelines for the northern goshawk might be ineffective or even detrimental to some wildlife habitats, the Arizona Chapter of The Wildlife Society requested the formation of a panel of scientists to review the interim guidelines and related forest management activities in the Southwest. The Northern Goshawk/Southwestern Forest Management Review Team was formed jointly by The Wildlife Society and the American Ornithologists' Union and asked to review the scientific basis of the goshawk interim management guidelines; to determine whether appropriate regional Forest Service policy is in effect for guideline implementation, and to determine whether the interim guidelines are being applied appropriately in the field. Specific charges were to: (1) review the scientific literature concerning northern goshawk biology and management in the Southwest; (2) evaluate the scientific basis and policy guidance for the interim guidelines; (3) perform an on-the-ground inspection of forest management conditions in the Southwest relative to implementation of the interim guidelines; and (4) prepare a report outlining the Review Team's findings and recommendations.

METHODS

The Review Team was formed in November 1993 by action of The Wildlife Society and the American Ornithologists' Union. A public meeting was held in Phoenix, Arizona on 11 December 1993 where issues were identified and discussed. The team visited sites in the Coconino and Kaibab National forests, including the Gus Pearson Natural Area and the North Kaibab Ranger District,on 12-13 December 1993. The Team reviewed scientific literature, non-peer-reviewed publications, correspondence, and bibliographic information on northern goshawks and southwestern forests, especially ponderosa pine forests.

NORTHERN GOSHAWK

Distribution --- The goshawk has a circumpolar distribution north of 30° north latitude (AOU 1957, 1983) in deciduous and coniferous forest habitats including woodlands interspersed with cultivated areas. In North America, it occurs from central California, Arizona, northern Mexico, north and northeast through New Mexico, Colorado, and South Dakota east across the southern Lake States and south into the Appalachian Mountains to North Carolina. This range includes suitable habitats through Alaska and Canada. In Eurasia, the species occurs from the United Kingdom east through Scandinavia, northern Russia, and south to the Mediterranean region, Asia Minor, Iran, and east into China and Japan. Goshawks breed and winter throughout much of the same region (AOU 1957, 1983). Because of its position as a top predator, the goshawk is not numerous, but it occurs in many forest and forest edge communities.

Habitats --- In North America, goshawks nest from the northern limit of the boreal forest south to the mountain woodlands of Mexico. Nesting habitats are diverse, including expanses of contiguous boreal forest, coastal temperate forests, the mixed deciduous-coniferous forests and woodlots of New England, pine and aspen forests (*Populus* spp.) in the Great Lakes Region, ponderosa pine and mixed coniferous forests of the Rockies and Sierra Nevada, and aspen stands of less than 1 ha in the Great Basin (Younk and Bechard 1994). Goshawks are secretive and special methods are required to find these birds or their nests. However, the species is not rare in major portions of its distribution. In central Europe it appears to have adapted to the rural mix of woodlands and agricultural areas and appears to be doing the same in the northeastern United States. In northern Europe goshawks are common in forests in Finland and Sweden, where the species has been considered a pest because of predation on domestic-reared ring-necked pheasants (*Phasianus colchicus*), and a bounty was offered, resulting in thousands being killed each year (Kenward et al. 1981).

Status --- The northern goshawk in the United States is not designated as threatened or endangered by the U.S. Fish and Wildlife Service (USFWS). The goshawk has Category 2 status under the Endangered Species Act indicating that more information is required to make a final status assignment. Nowhere in North America are there long-term indices of trends or estimates of goshawk breeding population size derived from standardized, widespread surveys. Because of this lack of data and its poorly known biology, the goshawk has been described as a "sensitive species" (in the Southwest Region of the U.S. Forest Service). Because there is evidence that some forestry practices could have detrimental effects on goshawk nesting habitat, the U.S. Forest Service (USFS), state natural resource agencies, and concerned public groups have initiated research on the biology of goshawks and evaluation of forest management practices on goshawks. Most prominently, the USFS developed and initiated implementation of *Management Recommendations For The Northern Goshawk In The Southwestern United States* (Reynolds et al. 1992).

Foraging Strategy and Diet --- Goshawks are fast and maneuverable and often hunt by perching in cover followed by short, sudden attacks on prey or by fast flights through forest openings or along forest edges (Palmer 1988, Johnsgard 1990). The perch-hunting method is the most commonly observed technique (Kenward 1982, Widén 1984), but Kenward (1982) stressed that this is not sit-and-wait hunting. The hawks quickly scan an area and move to another perch if no prey is detected. Widén (1989) found that goshawks in Sweden preferred large patches of mature forest for hunting and showed no hunting habitat segregation by sex.

Goshawks feed almost exclusively on birds and mammals (Sutton 1927, Schnell 1958, Meng 1959, Grzybowski and Eaton 1976, Reynolds and Meslow 1984, Kennedy 1991, Bosakowski and Smith 1992). Goshawk diets in North America contain 21-59% mammals and 18-69% birds by number (summarized by Sherrod 1978). Most prey is moderate to large in size; geometric mean prey weight was 248 g and ranged from 10 to 3,000 g in a compilation of North American diet studies (Marti et al. 1993). Goshawks are opportunistic, taking an extremely wide variety of birds and mammals (Johnsgard 1990). Dietary diversity of goshawks (measured by a standardized index) in western North America ranked fourth highest among 30 raptor species and second highest continent-wide among 34 species (Marti et al. 1993). Some individuals appear to specialize on 1-2 kinds of prey (Palmer 1988); Lindén and Wikman (1983) observed a functional response by goshawks in Finland with respect to their main prey, hazel grouse (*Bonasa bonasia*).

Population Dynamics --- Goshawk population densities usually have been estimated on the basis of number of breeding pairs because non-breeding birds are difficult to count. Reproductive activity depends on prey availability, weather, nest site quality, ages of the adults, and other factors. Mortality of immatures, fledglings, and older birds depends on weather, food, cover, and human activities. Much of the annual mortality occurs during non-breeding seasons and is not easily detected. Predictions of population increases or declines based on reproductive activity alone, or survivorship alone, have little validity. Although attempts to model population changes based on inadequate data do not represent reliable predictions of population trends, they can indicate which components of reproduction, mortality, and dispersal are effective in causing changes in numbers.

Reproduction --- Goshawk studies report about 3.3 - 3.8 eggs per clutch on average, but several factors cause variation (Huhtala and Sulkava 1981, Thissen et al. 1982). Huhtala and Sulkava (1981) reported small clutches were produced when the laying period was delayed by cold weather. Further, not all territorial pairs produce eggs in a given year. In Fennoscandia, about half of the territorial pairs produced no eggs the year following a deep low in hazel grouse numbers, a favorite prey (Lindén and Wikman 1983).

The most commonly available statistic quantifying reproduction is the number of young fledged per territorial pair (Newton 1979). Records of fledglings for goshawks vary between means of 1.5 and 2.5 young per pair, the former for Finland (Huhtala and Sulkava 1981), the latter for Alaska during a high in hare abundance (McGowan 1975). In general, 1.7 young per pair is average for this species, but annual variation is great among some populations and among sites (Reynolds and Wight 1978, Huhtala and Sulkava 1981). A strong positive correlation between this statistic and the percentage of food remains containing grouse was found in Finland (Wikman and Lindén 1981).

<u>Survivorship</u> --- Like most hawks, survivorship of goshawks is lowest in the first year of life and increases markedly in the next. Haukioja and Haukioja (1970) analyzed band recoveries and estimated mortality of 63, 33, and 19% for years 1-3, respectively, in Finland. These estimates are probably high because young birds are more vulnerable to death from shooting (Haukioja and Haukioja 1970). These authors reported a 52% first-year mortality for a much smaller sample of birds found dead from non-shooting causes. Newton (1979) estimated that adult goshawks would have an annual mortality rate of 15-40% based on body size. In Holland, annual adult turnover at nests, based on feather color-pattern analysis, varied between 21 and 51% (Thissen et al. 1982). High turnover, presumably the result of mortality, perhaps was caused by pesticide contamination and, more recently, by increased human persecution or increased competition for food or nests at high population levels. In this study, as in others, annual changes in mortality were masked as the result of combining data for several years.

Failure of adults to return to a territory can be assumed to be caused by mortality if the birds are faithful to their territory as long as they live. However, some individuals nest undetected at alternate sites causing mortality estimates determined by the return rates of marked birds to be biased high. Woodbridge and Detrich (1994) found that adult goshawks in California usually moved to new nests within their territory from one year to the next. Detrich and Woodbridge (1994) reported that 18.2% of females and 23.1% of males were in new territories (4-13 km from where marked) in subsequent years. Recently, a mortality rate of 14% was estimated for the North Kaibab plateau based on return of banded adults in 1991-92 (Reynolds et al. 1994). This rate may represent a high estimate of mortality because adults that were not reobserved were assumed dead. This estimate is similar to that for peregrine falcons (<u>*Falco peregrinus*</u>), of roughly the same body weight, using a similar method (Enderson and Craig 1988).

<u>Population Modeling and Viability Analysis</u> --- A recent attempt to model the North Kaibab plateau goshawk "population" demonstrated the lack of adequate information on survivorship and dispersal (Maguire 1993). This analysis suggested that 2 factors are most critical for predicting population change. First, if mortality is about 40, 25, and 15% for the first 3 years, and if breeding begins by the third year at rates observed on the North Kaibab plateau, the population should remain viable. Second, immigration could be powerful in offsetting any negative influence of other factors within the area. Immigration of 5 pairs of adults per year could prevent a rapid decline simulated by grossly unfavorable values of reproduction and survivorship.

<u>Population Performance and Stability</u> --- Data available for factors relating to goshawk population size are few and come from quite disjunct regions of North America and Europe. Breeding pairs may vary greatly in number over a few years in northern regions (Höglund 1964, McGowan 1975) due to dependence on 1-2 prey species whose populations vary markedly. Southern populations of goshawks are clearly more stable (Pielowski 1968). On the North Kaibab, reproduction and survivorship data for goshawks do not indicate a failing population. Discovery of previously unknown occupied goshawk nests in that area occurred at high rates in 1991-92 (Fletcher and Sheppard 1994) suggesting the full extent and size of the population remains unknown.

Goshawks are capable of dramatic population increases. In 1970, the Dutch population was estimated at about 30 pairs; by 1980 it was probably over 400 pairs (Thissen et al. 1982). This change followed bans on certain pesticides and, perhaps, reduction of human persecution. The evidence also suggests this species is not especially sensitive to changes in reproductive activity or first-year survivorship. At least 5,000 goshawks, mostly first-year birds, were killed annually in Finland without apparent long-term negative impacts on the number of breeding pairs (Saurola 1976). Reproduction is less important than other factors governing population dynamics (I. Newton, pers. commun.). The far more important aspects of mortality and dispersal occur mainly outside the nesting period. Further insights into goshawk population dynamics will require additional study because "the most important things are happening in winter" (Wikman and Lindén 1981:113).

<u>Synthesis of Available Information About Northern Goshawks</u> --- The Scientific Committee drafted a reasonable set of management recommendations that should enhance northern goshawk habitat and population size if numbers of goshawks were reduced by previous forest management. The Scientific Committee, in effect, assumed such a reduction had occurred. There is evidence that harvest of some mature and old-growth forest stands has destroyed nesting habitats of goshawks (Reynolds et al. 1992.) Nowhere in the *Management*

Recommendations or in the other material we reviewed is there presentation of data or a substantive discussion of the rationale for assuming the northern goshawk population(s), in the context of the Endangered Species Act, is declining. Therefore, our review of the *Management Recommendations* and the associated issues and concerns about its implementation proceeded on the basis that data are not available to indicate that the long-term trend in the northern goshawk breeding population in the Southwest or elsewhere in North America is decreasing or that the species has been demonstrated to be threatened or endangered. This finding influenced our conclusions about how the *Management Recommendations* should be implemented.

We are impressed by the magnitude of the effort that has been devoted to developing a relatively broad, comprehensive strategy for southwestern forest management on behalf of the northern goshawk. We also are impressed by the scientific quality and scope of the *Management Recommendations*, and by the contributions, reviews, and critiques of the development and implementation of the USFS guidelines by interested parties. We liked the perspective that a simultaneous focus on the goshawk, its prey, and the plants upon which they depend permits forest managers to recognize the importance of ecological processes at the community and ecosystem scales. However, we found little detailed, data-based evidence for the assumption that recent forest management threatens the northern goshawk population. The evidence that harvesting mature and old forest stands destroys nesting habitat created interest and momentum to conduct specific research upon the biology of goshawks, prey species, and management issues associated with these species.

The bulk of the *Management Recommendations* deals with goshawk and goshawk prey biology, habitat descriptions, and habitat management recommendations. We found that authors of the *Management Recommendations* have thoroughly reviewed the literature about goshawk habitat, and indeed, the prevailing expertise on North American goshawk habitat was well represented on the Northern Goshawk Scientific Committee. There is a lack of information about winter habitats in the *Management Recommendations*. This period especially needs additional research. The focus of the *Management Recommendations* is on nest area and foraging area habitat for individual goshawk pairs. It is assumed that management that enhances habitat for pairs will be beneficial for the population. We encourage evaluation of this assumption.

We were impressed by the integration of goshawk habitat information and prey habitat information into innovative recommendations for goshawk management in the *Management Recommendations*. However, we found that many questions have been raised by other agencies and public groups about the ultimate effects of implementation of the *Management Recommendations* on goshawks, on other wildlife, and on the forest systems. These questions should be addressed by the USFS so that other agencies and interested public groups understand the purpose and goals of the *Management Recommendations*. The recommendations for habitat management for the purpose of creating certain conditions for goshawks and their prey are useful as a basis for tests of treatments among areas. We hesitate to advocate the widespread implementation of the recommendations when they might be differently interpreted by managers, or implemented without evaluation of their effects on goshawks and other components of the forest system. Because the *Management Recommendations* have far-reaching implications for forest conservation and management, and because the recommendations likely will be implemented on a broad scale, they must be carefully evaluated.

In summary, because the goshawk is the impetus for an ambitious management strategy that can have far-reaching effects on other plant and wildlife populations and other uses of forests, there is need for (1) inventory and long-term monitoring to establish the status of the goshawk and other selected species; (2) research to learn key population parameters (e.g., prey availability in managed forests, survival and dispersal of goshawks) in the Southwest; and (3) experimental designs to carefully evaluate the consequences of the options in the *Management Recommendations* strategy on the status and population dynamics of goshawks, their prey, and other selected species.

FORESTS OF THE SOUTHWEST

Reynolds et al. (1992) were asked to develop management recommendations for the northern goshawk. To achieve this goal, they also considered general forest health as a requisite for managing forest habitats to benefit goshawks and their prey. They were not asked to address forest management for pre-settlement conditions. However, our review of the critiques of the *Management Recommendations* indicated that desired future conditions of southwestern forests were linked with forest management for goshawks. Consequently we reviewed the available literature on pre- and post-settlement structure of southwestern forests focusing on ponderosa pine forests.

The forests of this region show a strong zonation, affected primarily by elevation, precipitation, and slope aspect. The overall patterns of this zonation were described by C.

Hart Merriam (1890, 1899) when he studied the vegetation of the San Francisco Mountains, Arizona. Four primary zones of woodland and forest are relevant to this discussion: (1) the subalpine conifer forest in which dominant trees are subalpine fir (*Abies lasiocarpa*)and Engelmann spruce (*Picea engelmanni*); (2) an upper montane mixed-conifer forest that consists primarily of Douglas-fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*); (3) a lower montane forest in which the dominant species is ponderosa pine (*Pinus ponderosa var. scopulorum*); and (4) the pinyon-juniper woodland composed primarily of pinyon pine (*Pinus edulis*) and Rocky Mountain juniper (*Juniperus scopulorum*). Descriptions of 3 of these forest zones (described by Brown 1982a) are in the appendix, but ponderosa pine forests will be discussed in detail because the *Management Recommendations* focuses on them, and because 74% of southwestern forests are dominated by ponderosa pine (Reynolds et al. 1992).

Ponderosa Pine Forest

Importance of Ponderosa Pine --- Ponderosa pine is the most important commercial tree species of western North America. Its geographic range extends from Nebraska, South Dakota, and Texas to the west coast from California to British Columbia. It extends well into Canada in the north and into Mexico in the south. In many parts of its range, ponderosa pine constitutes either the major or the sole tree component of forests extending over thousands of meters of elevation. It provides the physical and biological framework to the biological communities inhabiting these forests. Its wood is excellent for a variety of uses from furniture to dimension lumber; consequently it has formed the base of extensive logging, house building, and manufacturing industries, and many homes have been framed with and contain objects made from ponderosa pine. Any number of books, films, and stories are set in ponderosa pine habitats. For all these reasons, it can truly be said that, in many ways, ponderosa pine "defines the American West" (Benedict 1990:272) and is worthy of special care and concern.

Early Impressions of Ponderosa Pine Forests --- Several accounts describe, often in lyrical terms, the ponderosa pine forests of the Southwest and the central Rocky Mountains. These descriptions are available for a number of locations in Arizona and New Mexico; north into Colorado, Idaho, and Washington; and west into California. It is significant that these forests, regardless of location, were usually open, consisting of groups of large ponderosa pine, with few (or at least unremarkable) saplings, and a forest floor thick with a mixture of grasses and wildflowers.

When we read these early accounts, special effort was made to look for evidence of dense patches of seedlings or saplings within the region. Only 3 such accounts mention them. The Gila River Forest Reserve stand near Spring Creek was described as having a "phenomenal growth of young pines, approximately 30 feet in height and 6 inches in diameter" (Rixon 1905). Rixon noted that such regeneration was present in some areas and absent in others. Dense reproduction also was noted in certain areas within the Black Mesa Forest Reserve (Plummer 1904). Finally, in the Prescott National Forest, reproduction was noted to be good and, in places, so dense that it was almost impenetrable (Pearson 1910).

In addition to providing descriptions of forest structure, early travelers, botanists, and land managers were witness to the impressively rapid impact of overgrazing on these forest communities. The most dramatic of these reports was by Holsinger (1902), who provided an example of changes around Fort Whipple: "where hundreds of tons of hay were cut under the actual spread of the forest trees during the sixties and seventies, there is not now enough grass on a thousand acres to keep in condition a family cow. Where were then running streams are now only arroyos, and where were then living springs are now beds of silt and sand." Other detailed descriptions of overgrazing and its impacts upon streams and water in general were given by Cooper (1960) and Bahre (1991).

Scientific Evidence About Forest Conditions --- It is possible, although difficult, to identify past forest conditions because of the longevity of ponderosa pine. This species routinely reaches many hundreds of years of age, and stumps and snags can remain *in situ* for many decades after logging as a result of the arid climate of the region. The study of old stumps and large old trees allows approximation of 2 important features of these forests: their density and dispersion patterns, and their fire history. Pearson (1950) was the first forest scientist to take careful measurements on ponderosa pine forests. Research on the biology and management of ponderosa pine began in 1908 at Fort Valley, near Flagstaff, Arizona. Pearson noted that as early as 1909, it was recognized that certain areas should be protected from logging to permit their description and to follow their fate through time. Such research is continuing today. For example, detailed stand analyses have entailed repeated measurements and observations on more than 3,300 tagged trees. The resulting record, thanks to the foresight of G. A. Pearson and his collaborators, and to the dedication of current forest scientists such as C. C. Avery (Avery et al. 1976) and W. W. Covington (Covington and Moore 1994), constitutes one of the most detailed and ambitious data sets about forest biology anywhere in the world, since it spans an 80-year period with repeated measurements every 5 - 10 years.

The overall pattern that Pearson described shows the forest in this area consisted of clusters of mature "yellow pines" over 200 years of age interspersed with younger clusters. When and if fire was kept out of an area, seedlings and saplings invaded the open spaces between clusters and also grew under the old trees where the canopy was "not dense."

The economic and biological importance of ponderosa pine as a species and as a forest association have continued to provide an important impetus for research. Several recent book-length treatments dealing wholly or in part with ponderosa pine are available (e.g., Baumgartner and Lotan 1988, Tecle et al. 1989, Kaufmann et al. 1992). The most detailed recent analyses of stand structure in the Southwest were done by Covington and Moore (e.g., 1994). These analyses, in combination with the work of Cooper (1960, 1961) and White (1985), all in Arizona, provide a well-documented picture of both pre-settlement stand densities and post-settlement changes.

Pre-settlement Ponderosa Pine Forests --- These forests consisted of large trees, aggregated into clusters of varying sizes, usually 0.05 to 0.3 ha per cluster (Cooper 1960, 1961; White 1985; Moore et al. 1993). These clusters typically consisted of relatively few trees (3-44 reported by White [1985]) whose ages within a group spanned ranges of 33 years in relatively homogenous groups to 268 years in heterogeneous stands. As a result of the patchy structure of these stands, canopy closure was highly irregular: it was probably close to 100% within clumps and 0% outside. On a large scale, canopy closure values were reported to be about 20% (White 1985, Covington and Sackett 1986), 25%, and seldom over 30% (Pearson 1923). The number of trees per hectare was variable. Stand densities varied from site to site, depending upon heterogeneity of climatic, elevational, and ecological conditions. However, regardless of these conditions, current data clearly support the observation that pre-settlement forests were irregularly stocked and open canopied. This was true both in the Southwest and in other parts of the Rocky Mountains and California (Covington and Moore 1994).

The primary factor contributing to the open nature of these forests was the occurrence of frequent ground fires. Exact frequencies cannot be ascertained for many sites, but it is probable that frequency varied as a function of terrain, temperature, rainfall, and grazing. However, precise estimates are available in certain stands based on fire scars dated by growth rings on stumps, snags, and live trees. Research findings indicate that fire frequencies have varied throughout the ponderosa pine range with 2-3 years reported in northcentral Arizona (Dieterich 1980), 5-6 years in southwestern New Mexico (Swetnam and Dieterich 1985) and 6-7 years in eastcentral Arizona. Additional research confirmed these findings showing the presence of fire scars on the most frequently burned individual stumps occurred on average every 4.8 years, with the longest interval between fires being 11.8 years (Weaver 1951). Individual trees provided the basis for estimates; thus, the collection process focused on single sites and provided estimates of fire occurrence at those sites. Some estimates may be conservative because fires that were light enough to create no scarring were undetectable. These frequent fires in open forest were ground fires, and were fueled primarily by grasses and seedlings that had grown since the passing of a previous fire. Thus, fuel loads were relatively light and fires were not intense. Over the past several centuries, there is also some evidence of intervals of 15 - 20 years without fires. These were usually associated with abnormally wet periods (Swetnam and Dieterich 1985).

Post-settlement Changes --- These changes have involved many activities and form the basis of many problems faced by these forests and their inhabitants today. The most important change in many parts of the Southwest was the advent of large-scale logging. Intensive logging was initiated in the context of railroad building, but it continued until recently because of the high demand for pine lumber and the accessibility of the forests. Intensive timber harvest, often coupled with controversial economic policies associated with below-cost timber sales on national forest lands (e.g., O'Toole 1988), has led to a current climate of public mistrust about any forestry activity that involves logging and tree removal.

Even in areas that are currently forested dramatic changes have occurred that have drastically modified stand structure and forest characteristics. Heavy grazing in the early 1900's removed the dense herbaceous vegetation in many areas, thereby removing the potential for competition between grasses and newly germinated seedlings, a competition that young ponderosa pine cannot tolerate (Pearson 1950). An unusually wet period over several years at about the same time allowed for large-scale dense seedling establishment, often at the rate of dozens of seedlings per square meter. Finally, aggressive fire suppression prevented frequent (but low intensity) fires from sweeping through the forests, thereby allowing large proportions of seedlings to survive to sapling stages. In 1994, Covington and Moore simulated the overall impacts of these changes on the forest structure based on data from actual stands. The impacts are clear: forest density has increased, the herbaceous layer has almost disappeared, and stream flow has been reduced significantly. In addition, fire data show that fire suppression is actually counterproductive. Fires now burn over larger areas, are more intense, and more devastating than in earlier times. Crown fires, practically unheard of before 1940, are now common because of fire ladders provided by dense stands of saplings below the large trees, and increasing canopy closure in these forests (Covington and Moore 1994). Among lightning-caused fires, the area burned per year went from 4,100 ha in the 1940's to 6,100 ha in the 1980's, and the fire character changed from surface fires averaging 1,200 ha to crown fires reaching 4,000-8,000 ha (Swetnam and Dieterich 1985, Swetnam 1990).

Additional changes in these forests include increased incidence and intensity of diseases, parasites, and insect outbreaks, including dwarf mistletoe and bark beetles, and shifts in tree species composition from ponderosa pine to (primarily) white fir. During our field visit in December 1993, we noted that invasion of white fir into ponderosa pine is especially well illustrated on the Kaibab Plateau, within Grand Canyon National Park.

Health of Ponderosa Pine And Its Importance To Forest Residents --- Ponderosa pines are moisture-sensitive, and show significant physiological stress in response to low soil moisture availability. Under stressful conditions induced either by drought or by high tree density, ponderosa pine close their stomata and reduce their photosynthetic rates drastically (Bassman 1988). Under these conditions, low photosythetic rates mean there is little carbohydrate production and, as a result, the trees produce few or no cones. This association between moisture stress and low cone production is known for a variety of pines including ponderosa (Baumgartner and Lotan 1988, Linhart 1988). Impacts on cone production can be dramatic: an uncrowded adult tree will routinely produce 100-1,000 or more cones in a good year. Densely-grown trees, even if they are the same height and age, will produce 1/10 of that or less, and young trees in dense stands often produce no cones for years on end (Linhart and Mitton 1985). Ponderosa pine seeds are a critical food base for seed-eating mammals such as deer mice (*Peromyscus maniculatus*), chipmunks (*Tamias spp.*), tree squirrels (*Sciurus aberti* and *Tamiasciurus hudsonicus*) and golden-mantled ground squirrels (*Spermophilus lateralis*); birds such as juncos (*Junco spp.*), Cassin's finch (*Carpodacus cassinii*), pine siskin (*Carduelis pinus*), evening grosbeak (*Coccothraustes vespertinus*), chickadees (*Parus spp.*), crossbills (*Loxia spp.*), nuthatches (*Sitta spp.*), Stellers' jay (*Cyanocitta stelleri*), and Clark's nutcracker (*Nucifraga columbiana*); as well as cone and seed insects including beetles (*Conophthorus spp.*), bugs (*Conotrachelus spp.*), and moths (*Dioryctria spp.*). These species, in turn, are potential prey for a variety of carnivorous mammals and birds of prey. The dependence of these and other species on cone crops in turn means that dense, closed ponderosa pine forests that produce a small fraction of the cone crops of open-canopied forests will also support a fraction of the individuals of these animal species.

Synthesis of Available Information About Ponderosa Pine Forests --- Pre-settlement ponderosa pine forests were park-like, had open canopies, and consisted of clusters of trees, scattered irregularly over the landscape. Young seedlings and saplings also were scattered, and seldom did young trees form dense thickets of any notable size. The evidence for this perspective is solid, and consists of a combination of eyewitness reports and recent, careful studies conducted in Arizona, New Mexico, and other states where ponderosa pine forests are common.

The understory of these forests usually consisted of dense herbaceous vegetation, dominated by bunch grasses, but also contained many species of wildflowers. This profuse growth provides indirect but strong evidence there was abundant sunlight reaching the forest floor, which provides additional testimony to the open-canopied nature of this forest.

This open forest has been replaced by a much denser forest, dominated in many places by dense thickets of saplings and pole-size trees of ponderosa pine and, in other places, by a dense understory of white fir. This shift is attributed to a combination of climatic changes along with human activities, especially logging of large trees, overgrazing, and fire prevention.

Those parties involved in forest management and forest protection must agree on their vision of the structure of future ponderosa pine forests. If, as one possibility, everyone agrees these forests should be managed so as to return to some semblance of their former structure, then human manipulations will be necessary. The primary goal of such manipulation will need to involve large-scale thinning and removal of dense stands of young ponderosa pine and white fir that presently choke the understory. This thinning will have to be done by a combination of fire and mechanical manipulations. In some places, present fuel loads are so high that fire is no longer a viable option, and tree removal must be done by logging (Covington and Moore 1992, 1994).

We must learn to read the southwestern landscape as it once existed and as it exists today, and attempt not to have preconceptions about what the landscape "ought to be" like. Many of us, when asked to conjure up "forest primeval" or "old-growth forests" automatically think of close-canopied, densely shaded places. This vision may be applicable to the Pacific Northwest, the eastern United States, or to Europe but it is not appropriate for ponderosa pine forests. If we insist on thinking of them as close-canopied, and demand that current forests remain that way, we will commit the same error committed by the first European and eastern settlers and foresters in the area. For example, these people viewed fire as an all-consuming savage, scary, and wasteful beast that had to be stopped at all costs. The quotes from Gifford Pinchot (Appendix), who was trained as a forester in France where wild fires are uncommon but devastating when they occur, are typical.

Heterogeneity in this landscape also must be recognized. In some areas, past forests had 20% canopy closure, in others 40%, and numbers of trees undoubtedly varied from 25 to 100/ha.

The *Management Recommendations* present an accurate, well-researched description of forest communities in the Southwest. We concur that thinning from below seems appropriate (Reynolds et al. 1992:22). We also caution that while even proportions of 20% Vegetation Structural State (VSS) 3-6 and 10% of the other 2 VSS seem reasonable to provide heterogeneity of forest stands (page 23), these recommendations must not be used to justify logging of large trees. The recommended minima of 7-12 mature trees/ha (pages 24, 28) are low in the context of known densities of large trees or old-growth forests which ranged from 25 to 74 or more trees/ha. For example, densities of 7-12/ha are insufficient to provide the interlocking crowns needed by Abert's squirrels (Sciurus aberti).

We disagree with the concept of a "pathological age" (Reynolds et al. 1992, table 4) as ponderosa pine can remain healthy for 250+ years. The values presented appear to be incorrect and irrelevant. Further, they can be misinterpreted to justify logging of large trees.

OTHER ISSUES

Single Species Management vs. Ecosystem Management --- Management practices recommended by Reynolds et al. (1992) are designed to benefit numerous species besides the northern goshawk, but their effects on other species (e.g., certain passerine birds, owls, and mammals) must also be considered (Ariz. Game and Fish Dep. 1993). Ideally, national forests should be managed for a diversity of species. For this reason, an ecosystem management strategy is needed. The *Management Recommendations* are a step in that direction.

Secondary cavity-nesting birds constitute 40-55% of the breeding bird population in ponderosa pine forests (Balda 1975) and have exhibited 53% declines in density following snag removal during timber harvesting (Scott and Oldemeyer 1983). For this reason, care must be taken to prevent lack of snag recruitment associated with intensive silvicultural management (Brawn and Balda 1988).

Three other forest raptor species whose status is uncertain also could be affected by intensive management for goshawks. The flammulated owl (Otus flammeolus) and sharp-shinned hawk (Accipiter striatus) are also Forest Service sensitive species (U.S. Dep. Agric. 1989). The flammulated owl is associated with old-growth ponderosa pine forest (Reynolds and Linkhart 1992) and is a secondary cavity nester. A reduction of snag recruitment trees could be detrimental to this species. The sharp-shinned hawk may also incur negative impacts from forest thinning treatments recommended in the *Management Recommendations*. The Mexican spotted owl (Strix occidentalis lucida), a subspecies listed as threatened (U.S. Dep. Inter. 1993), requires habitat characteristics (e.g., relatively dense canopy cover) that may not be compatible with some recommendations of the *Management Recommendations* (McDonald et al. 1991). However, prime habitat for the spotted owl in the Southwest may not overlap completely with that of the goshawk (Ganey and Balda 1989, 1994), so this may not be an issue. The potential effects of the *Management Recommendations* on other species should be explored more thoroughly.

Wild turkey (Meleagris gallopavo) could benefit from some forest characteristics recommended in the *Management Recommendations*, but the early effects of some vegetative treatments could be detrimental until cover regenerates.

Black bears (Ursus americanus) also may be adversely affected by intensive forest management for goshawks. Black bears select habitat primarily because of its cover, preferring areas with low horizontal visibility (LeCount and Yarchin 1990). Widespread application of the *Management Recommendations* could make certain areas unattractive to black bears.

Tassel-eared squirrels are prey for goshawks and important components of ponderosa pine forests. Several studies (Patton 1984; Patton et al. 1985; Snyder 1992, 1993; Snyder and Linhart 1993, 1994) have clearly demonstrated that these squirrels depend on large, cone-producing ponderosa pines and, at least for certain activities, prefer large ponderosa pine in clumps with some continuity to the canopy. Other species should benefit from forest conditions resulting from application of the *Management Recommendations*. Habitat requirements of 14 species of birds and mammals identified as important prey were used to help designate forest conditions that would result in sustainable populations of the prey (Reynolds et al. 1992).

Disturbance --- Knight and Skagen (1988) compiled many examples of how human recreational uses can alter activities of certain raptors. They found these activities can alter the distribution of raptors, disrupt nest attentiveness, cause abandonment of breeding territories, reduce productivity, and alter foraging behavior. Suggested mitigation of such disturbance included total restriction of human access to critical raptor areas, and tailoring management plans to specific cases (e.g., identifying critical nesting areas and prohibiting human access during the raptors' breeding season).

We know of no studies of human disturbance on breeding goshawks, but the *Management Recommendations* recommendation to minimize human activity in the nest area during the breeding season seems to be a reasonable, conservative approach.

Esthetics --- Bird watching is the second most popular passive sport in North America, with 30 million participants (Ehrlich et al. 1988). Birds of prey, because of their array of fascinating adaptations and scarcity, are of particular interest to birders. Species difficult to see are especially valued, and northern goshawks, because of habitats used and their secrecy, are difficult to see. The public also places a high esthetic value on the idea of pristine forests with pre-settlement-like characteristics. To the extent that good goshawk habitat and old-growth forests are the same, the support for conservation of both is strengthened.

MONITORING OF GOSHAWKS AND FOREST MANAGEMENT

Further inventory and monitoring are necessary to provide a basis for identifying trends in populations of the northern goshawk. Presently, there are several untested estimates of statewide numbers of nest areas or nesting pairs (e.g., Herron et al. 1985 for Nevada, Bloom et al. 1986 for California) and there are some counts or estimates for local areas such as a portion of a national forest. Many of these latter estimates are from reports cited by Marshall (1992). However, most of these studies use different survey designs and field methods and many lack information about effort and detection rates. The data cannot be combined or compared to give a clear indication of the status of the species. A recent analysis of counts of migrating hawks in the western United States suggests that counts of northern goshawks have declined (S.W. Hoffman, J.C. Bednarz, and W.R. DeRagon, pers. commun.). Recent and ongoing breeding season surveys using more standardized methods will contribute to a better determination of status (DeStefano et al. 1994; Woodbridge and Detrich 1994; R.T. Reynolds, pers. commun).

The determination of status requires some basis for comparison with measurements taken to detect changes such as those expected from landscape-scale management practices prescribed by the *Management Recommendations*. The USFS, USFWS, and others must complete sufficient basic inventory to make an initial determination of status. Population status usually is based on a scale encompassing the species or subspecies distribution, or on an isolated group or population that constitutes a signigicant portion of the subspecies or species. Most of the concern for the status of northern goshawk that we encountered were based on threats to some number of pairs of a local breeding assemblage. Results such as those of Crocker-Bedford (1990) and Patla (1990) should be analyzed in the context of populations and metapopulations as well as individual pairs. Based on results of the 2 petitions to list southwestern northern goshawks (T.J. Tibbits, pers. commun.) and from the population viability analysis by Maguire (1993), there are too few data to biologically delineate a southwestern "population." Clearly, population status is yet to be determined, although the work of Whaley and White (1994) suggests that identifiable geographic populations may exist.

Most inventories conducted to date have been inadequate to estimate the numbers of northern goshawks on a given southwestern national forest or even most ranger districts. The report by Fletcher and Sheppard (1994) indicates that in recent years, with more and more search effort, more and more goshawk nests were found. Until the number of nests found, or some estimate of nests, or pairs, or birds stabilizes for a known amount of search effort, we cannot know the status of local northern goshawks.

Standardized survey and monitoring designs and field protocols should be established to ascertain the status of northern goshawks. Managers must use the protocols to monitor changes in status that result from current timber harvest procedures and from implementation of the *Management Recommendations*. Similar efforts should be made throughout the breeding range of the goshawk in the United States. Further, managers should design their surveys and monitoring to complement research on the demography and population dynamics of northern goshawks.

The information we reviewed from southwestern forests suggests monitoring to date has involved locating nests or nest areas, and assigning an activity status (e.g., Fletcher and Sheppard 1994). We note that determining distribution and monitoring population status need not involve finding nests. More area probably can be sampled by surveying for the presence of goshawks, rather than counting nests *per se*. For example, repeated surveys could be used along transects through representative habitats, on which a biologist records sight or sound detections of goshawks. The study design could use the Kennedy and Stahlecker (1993) broadcast field method to establish an area occupied index (Geissler and Fuller 1986, Iverson and Fuller 1991). Regardless of what (birds or nests or occupied areas) is being surveyed, it is imperative that similar methods be used, that the effort and areas surveyed be carefully recorded, and that there is an estimate of detection rate for each of the general circumstances or situations that are to be compared, or from which results are to be pooled for analyses (Geissler and Fuller 1986).

When nests must be found for demographic studies, monitoring for specific objectives, or for evaluating management, it is important to survey representative habitats, not just the "best" or the "most likely" habitat (stratification of effort can be used). Also, it is important to search for new nests or alternative nests because if only historical nests are surveyed, a perceived decrease in nesting is assured; goshawks do not always use the same nest (e.g., Detrich and Woodbridge 1994, Reynolds et al. 1994). The protocols (e.g., for the Coronado and Coconino National forests) and Interim Directives (e.g., No. R32670-93-1) we have seen for nest surveys allow for modifications to the Kennedy and Stahlecker (1993) survey method. Modifications should not be made to a basic survey design unless the effects of these modifications are known and can be quantified and accounted for in an estimate. Joy et al. (1994) have results suggesting useful modifications for a basic survey design. These should be implemented wherever applicable, and "corrections" or adjustments made whenever possible to data gathered under the previous protocol. The terminology relevant to the survey should be defined, and preferably follow some established usage (e.g., Ralph and Scott 1981, Verner 1985, Fuller and Mosher 1987, Steenhof 1987).

It is our impression that the recommendations, the minimum and maximum values, the VSS categories, etc., and the scope of implementation are not uniformly interpreted and applied. If there is no systematic procedure for evaluating compliance with the recommendations or measuring the outcome of implementation, hypotheses cannot be tested, questions about effects on non-target species and forestry practices cannot be answered, and the concerns of persons, groups, and agencies cannot be clearly addressed. We are not familiar with the usefulness of the Biological Evaluation process (FSM 2672.4, cited in the Interim Guidelines), and cannot speculate on how well this process meets the needs of testing the hypotheses or providing information for addressing questions and concerns. However, we found little mention of it or other criteria for evaluating the usefulness of the *Management Recommendations*.

The USFS should conduct training to ensure standardized interpretation and careful implementation of the *Management Recommendations* wherever it is used. It would be most expedient to select a number of areas for initial implementation and testing. An adequate sample of areas could be designated to receive treatments based on the extremes of the range of values presented in the *Management Recommendations*. Other areas should be left as controls of either routine forestry practices, or "hands-off" as on National Park Service lands. Measures of goshawk demography and trends in other wildlife species, plant community changes, forest products, etc. could be made through time to understand the implications and effectiveness of the *Management Recommendations*. Planning an evaluation such as this should cause all interested parties to think more about the type(s) of forest they want in the Southwest in the future, and to have a better understanding of each other's objectives and concerns.

CONCLUSIONS

1. The scope and the review of the biology of northern goshawks in the *Management Recommendations* are excellent.

2. The *Management Recommendations* represent an innovative approach to forest management because they encourage forest managers to consider forest ecosystems as assemblages of interacting species of plants and animals.

3. The *Management Recommendations* and related USFS policy lack substantive considerations for evaluating the effectiveness, and testing the consequences of implementing these practices.

4. No evidence was presented to indicate that northern goshawk populations are declining, threatened or endangered in the Southwest or anywhere within its range, and we found no evidence of a long-term decline in goshawk breeding populations. There is a need to conduct additional research of goshawk demographics and additional inventory and monitoring of goshawk populations.

5. The complexity of detail for silvicultural treatments in the *Management Recommendations* indicates a preciseness of management that cannot and probably need not uniformly be achieved over large areas. Further, the impacts of the prescriptions on other species resident in ponderosa pine ecosystems are difficult to predict at this time. Therefore, we conclude that the *Management Recomendations* should be implemented as experiments in adaptive management to learn about the practicality and the effects of managing by these methods in a variety of landscapes and forest types.

6. Surveys of goshawks should be standardized and conducted in all southwestern forests to establish baseline data on population status and trends in all seasons, and to monitor the status of goshawks.

7. Northern goshawks use a variety of forested habitats during the nesting period (Apr-Aug). Throughout its distribution it is considered a forest and prey generalist. However, populations are adapted to local conditions and are, therefore, considered specialized concerning nest-use sites, foraging habitats, and prey selection. We conclude that current forest management practices will not have the same effect on goshawk breeding populations in different regions. Administrators, managers, and other interested public groups must recognize that the *Management Recommendations* were not designed to and may not provide the same results everywhere. Application of specific prescriptions developed on the North Kaibab elsewhere in the Southwest and generally in North America would be inappropriate and may be detrimental to northern goshawks and their preferred nesting areas and prey. Prescriptions for habitat management to benefit northern goshawks will need to be ecosystem-specific with the realization that prescriptions may need to be tailored to the watershed scale.

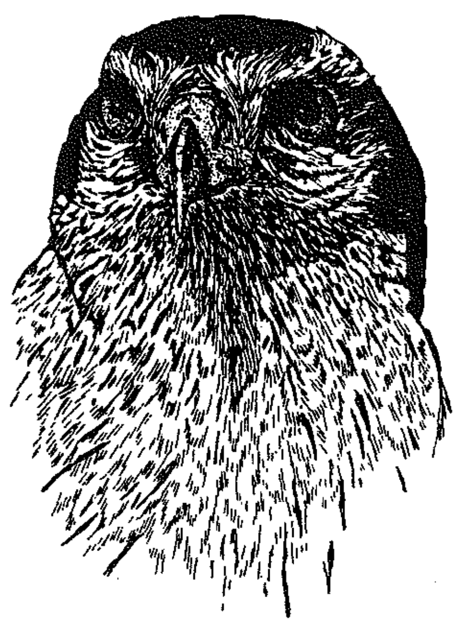
8. Significant research should be conducted on habitat and prey requirements during the non-nesting period (Sep-Mar).

9. Implementation of prescriptions in the *Management Recommendations* must be carefully considered and recognize the diverse growing conditions and inherent heterogeneity of southwestern forests.

10. In the absence of frequent ground fire, healthy southwestern ponderosa pine forests need management (e.g., removal of small trees) to enhance forest stand variability necessary to maintain diverse assemblages of animals and to ensure that significant areas (at least at the watershed level) will attain and sustain the successional stages and character of pre-settlement forests. The *Management Recommendations* should contribute to a healthy, heterogenous forest.

11. Proper management of southwestern forests must involve an ecosystem/landscape approach and should not be narrowly focused on one species. We believe the *Management Recommendations* represent a major step toward research and management of ecosystems at a landscape scale. We recognize that insufficient data are available for many species to adequately understand their needs and roles in southwestern forests.

12. The public needs to learn that ponderosa pine forests in the Southwest were open and park-like in the pre-settlement period. Information must be made available to all interested public groups about the actual condition of ponderosa pine forests prior to settlement in the 1800's. A goal for future desired conditions must be set as a basis for forest management.



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APPENDIX

Descriptions of Southwestern Forests

Subalpine Conifer Forests --- Subalpine forests consist primarily of Engelmann spruce and subalpine fir. Other dominant species can include corkbark fir (A. lasiocarpa var. arizonica) and periodically, white fir and blue spruce (P. pungens). In rocky, steep scree areas, limber pine (Pinus flexilis) and bristlecone pine (P. aristata) dominate.

Spruce-fir forests tend to be dense, and canopy closure can be almost complete. Old-growth stands can exceed 25 m in height, and all species can reach several hundred years at maturity. For example, average longevities of trees in old-growth stands in the Southwest are about 200 years for both Abies, 500 to 600 years for both Picea, with maxima recorded of 450 years for A. lasiocarpa and 1,670 years for Pinus flexilis (Moir 1992, Swetnam and Brown 1992).

The primary shrub species in spruce-fir forests include several willows (Salix bebbiana, S. scouleriana), maple (Acer glabrum), elders (Sambucus glauca, S. microbotrys), alder (Alnus tenuifolia), bitter cherry (Prunus emarginata), Mahonia (Berberis repens), several species of raspberries (Rubus), snowberries (Symphoricarpos spp.), and the ubiquitous common juniper (Juniperus communis), kinnikinnik (Arctostaphylos uva-ursi), honeysuckle (Lonicera involucrata), and shrubby cinquefoil (Potentilla fruticosa). Wherever there has been recent disturbance (e.g., fire or landslides), quaking aspen (Populus tremuloides) can occur in dense and extensive stands. Clonal growth and resprouting from underground rhizomes allows this species to regrow quickly after disturbance, but individual stems seldom live to 100 years, so that fire suppression often leads to aspen stands being overgrown in a few decades by conifers. At high elevations these forests become sparse, trees become low growing shrubs and the alpine zone begins. At lower elevations, usually between 2,400 and 2,900 m, these forests intergrade into the mixed-conifer forest.

Mixed-conifer Forest --- This is the most complex forest in terms of tree diversity, because it can contain the spruces and firs, especially white fir, plus Douglas-fir, ponderosa pine, and southwestern white pine (P. strobiformis). The mixed-conifer forest defines a zone intermediate in elevation, density, and moisture between the moist, often snowy, relatively dense and close-canopied spruce-fir forests with a short growing season, and the open, warm, and much drier ponderosa pine forests below. The mixed-conifer association is especially common in cool canyons and on north-facing slopes. Many of the understory shrubs are the same genera, and often the same species as those in the subalpine forest. Aspen defines seral stands, and Gambel oak (Quercus gambelii) is locally common (Pase and Brown 1982).

Pinyon-Juniper Woodland --- These open woodlands are characterized by trees of short, broad, often multi-stemmed stature, seldom over 10 m tall. The primary pinyon pine is P. edulis, while a variety of junipers occur in the region including J. deppeana and J. scopulorum, although J. monosperma is an occasional member of the association. Shrubs are also common in these woodlands, especially cliffrose (Cowania mexicana), Apache-plume (Fallugia paradoxa), Mormon tea (Ephedra spp.), barberries (Berberis fremontii and B haematocarpa), and soapweed (Yucca glauca and Y. baccata) (Brown 1982b). Variations of the major forest types are common. One of the more striking is provided by Marshall (1957) who noted that the head of Florida Canyon in the Santa Rita Mountains contains a forest of Douglas-fir with an understory of walnut (Juglans arizonica) while at the same elevation and slope in the nearby Madre Canyon, the forest is pure ponderosa pine. Also, certain canyons are so steep and narrow, that the canyon floors are moister (and colder because of temperature inversions); therefore, one can find inversions of forest associations with Douglas-fir dominated stands below ponderosa pine.

Views of Early Foresters

When forestry operations were initiated in the Southwest at the turn of the century, foresters were impressed by the big trees, covering millions of hectares of land, and representing an important resource. They decided these stands could be made to grow at higher densities to yield more timber, but that higher densities were only possible if fire was kept out of the forest. For example, Leiberg et al. (1904:23) noted that, in the San Francisco Mountain Forest Reserve, "It is very evident that the yellow pine stands, even when entirely untouched by the ax, do not carry an average crop of more than 40 percent of the timber they are capable of producing ..." This attitude seemed to be prevalent throughout the west: in California, Show and Kotok (1924) noted that fire exclusion would allow nature "...to utilize the full growing power of the land, and to restore the broken and understocked forest to a more normal condition." The logic or the biological evidence behind the arguments that these forest stands were "capable" of producing more wood, if only nature's "full growing power" was used are not mentioned. Thus, fire prevention became the stated goal and duty of these foresters, encouraged from the start by John Wesley Powell's (1879) early call to action "Can these forests be saved from fire?" This attitude about the need to extract the bounties of nature with maximal efficiency, and to prevent the wasting of these bounties by wild fires was strongly supported by Gifford Pinchot, who was the Chief Forester of the Division of Forestry within the U.S. Department of Agriculture. Pinchot had strong opinions about conservation, development,and fires. For example, in his book *The Fight for Conservation* (1910:42-46) he wrote: "The first great fact about conservation is that it stands for development...In the second place, conservation stands for the prevention of waste...waste is not a good thing and...the attack on waste is an industrial necessity...Today we understand that forest fires are wholly within the control of men. So we are coming...to understand that the prevention of waste...is a simple matter of good business. We are in a position... to say how far the waste and destruction of natural resources are to be allowed to go on and where they are to stop."

Impressions of Pre-settlement Ponderosa Pine Forests

Descriptions	**Area**	**Source**
Arizona - New Mexico		
"Pines tall...grass luxuriant...profusion of...flowers...the wildrose...among them."	Chuska Mtns., Washington Pass	Simpson 1850
"Towering pines and firs...flowers of rich profusion...upwards of 90 varieties..."	Chuska Mtns., Rio Negro	Simpson 1850
"Bright green sward...open groves [of pines] dispersed gracefully..."	Bill Williams Mtn.	Ives 1861
"Pine, aspen, park-like region with a large growth of yellow pine (*P. ponderosa*) and fir...a diversified herbaceous vegetation."	South of Gallup	Rothrock 1875
Noted open canopy structure	N AZ (35°N)	Whipple 1856 (cited in Cooper 1960)
"The forest was perfectly open and unencumbered with brush."	Chuska Mtns.	Beale 1858
"Vast forest of gigantic pines, intersected frequently with green glades, sprinkled all over with...meadows and wide savannas filled with the richest grasses, were traversed by our party for many days."		
"Plateau at 2130 m. covered throughout with beautiful forest of stately pines (*P. ponderosa*)...There is no undergrowth to obstruct the view...grass after rainy season...is knee-deep in places."	San Francisco Mtns.	Merriam 1890
"trees are...noble in aspect and stand widely apart, exception the highest part of the plateau where spruces predominate. Instead of dense thicket...we can...see tree trunks vanishing away like and infinite colonnade...From June until September there is a display of wild flowers."	Kaibab Plateau	Dutton 1887
"Pine trees are widely spaced and in close groves of oak and grass-floored parks."	Chuska, Carrizo, and Navajo Mtn.	Rothrock 1887
"...scarcely any undergrowth, but a dense mat of grass and flowers in these forests, and beautiful mountain parks..."	Springerville, AZ	Nelson 1884
"The first day we were fatiqued by the difficulty of getting through the high grass which covered the heavily timbered bottom."	Gila R.	Pattie 1905
"The bottoms of the Blue River were in 1885...stirrup high in gramma grass and covered with groves of mixed hardwoods and pine."	Blue R. (tributary of upper Gila)	Leopold 1921
"The forests of Arizona...were green, devoid of undergrowth, and consisted in the main mature trees. Instead of...undergrowth, the ground was well set with perennial grasses and other herbage."	Arizona Overview	Holsinger 1902
"The typical western yellow pine forest of the Southwest is a pure parklike stand made up of scattered groups from 2 to 20 trees...openings are frequent and vary greatly in size."	AZ & NM	Woolsey 1911

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