Associations between Forest Fire and Mexican Spotted Owls

Jeffrey S. Jenness, Paul Beier, and Joseph L. Ganey

ABSTRACT. In 1993, the US Fish and Wildlife Service listed the Mexican spotted owl (*Strix occidentalis lucida*) as threatened, in part because of the rising threat to its habitat from stand-replacing wildfires. In 1997, we surveyed 33 owl sites that, in the previous four years, had burned at various levels ranging from light controlled burns to stand-replacing fires. We compared owl occupancy and reproduction in these burned sites to 31 unburned owl sites with similar habitat and topography. Although unburned sites showed higher proportions of both occupancy and reproduction, the negative relationship observed between recent fire occurrence and owl occupancy rank was statistically weak (Test for Marginal Homogeneity, $P = 0.110$). Owls tended not to be present where pure pine stands (*Pinus* spp.) comprised a large proportion (38–85%) of burned sites, but no other factors relating to habitat or fire severity had a significant, biologically interpretable influence on occupancy rank. We suspect that relatively low-intensity ground fires, including most prescribed fires, probably have little or no short-term impact on Mexican spotted owl presence or reproduction, but we have no data on long-term effects of fire. We recommend proactive fuels-management treatments in areas not currently occupied by owls as a means of reducing fire risk in areas occupied by owls. Within areas occupied by owls, judicious treatments may be appropriate after case-by-case evaluations of potential benefits and risks within those sites. FOR. SCI. 50(6): 765–772.

Key Words: Prescribed burn, occupancy, reproduction, stand-replacement, stand-maintenance.

Wildfire historically has been a major disturbance agent important in structuring southwestern forests (Swetnam 1990, Covington and Moore 1994a). Fire suppression, timber harvesting, and grazing have altered southwestern forests greatly over the past century, however (Marshall 1963, Covington and Moore 1994a, 1994b, Kolb et al. 1994). These activities have markedly increased litter and combustible debris on the ground, and density of understory shrubs and small trees (Leopold 1924, Madany and West 1983, Savage and Swetnam 1990). In turn, these conditions increase the potential for larger and hotter fires (Moody et al. 1992, Covington et al. 1994). Thus, management actions have altered the fire regime in some southwestern forest types, such as ponderosa pine (*Pinus ponderosa*) and mixed-conifer forests, from one characterized by frequent, low-intensity

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fires, to one characterized more by infrequent, high-intensity fires.

The Mexican spotted owl (*Strix occidentalis lucida*) inhabits mixed-conifer and pine-oak (*Quercus* spp.) forests and rocky canyonlands in the southwestern United States and Mexico (Gutiérrez et al. 1995, USDI Fish and Wildlife Service 1995). This owl thus has a long evolutionary history in forests structured by frequent, low-intensity fires. The Mexican spotted owl was listed as a threatened species in 1993, based on historical and ongoing habitat alteration resulting from timber-management practices and the threat of additional habitat loss from stand-replacing wildfires (USDI Fish and Wildlife Service 1993). Large-scale stand-replacing fires occurring throughout the owl's range could harm the owl by reducing or eliminating roosting, nesting, and foraging habitat (Sheppard and Farnsworth 1997). The indirect effects of high-intensity wildfire on Mexican spotted owls are not known, unfortunately, and descriptive data are lacking on fire behavior at sites used by owls and how owls respond to fire-induced changes to their habitat (but see Sheppard and Farnsworth 1997).

Fire may affect spotted owls either directly or indirectly. Mexican spotted owls typically nest and roost in structurally-complex, diverse forests with a variety of age and size classes, a component of large trees, often with many snags and down logs and relatively high basal areas and canopy closures (Ganey and Dick 1995, Ganey et al. 1999). Fire directly affects these habitat components either by destroying them, as is typical in a stand-replacing fire, or enhancing them by creating snags, thinning densely packed stands, and reducing competition for water and nutrients. Fire may indirectly affect these habitat components by reducing fuel loads and thereby reducing the chance for stand-replacing fires.

Spotted owls may select habitats partially based on prey availability (Verner et al. 1992, Ward and Block 1995), so fire can affect owls indirectly by altering habitat conditions for their prey. Ward and Block (1995) summarized data suggesting that reproductive success of Mexican spotted owls was influenced by total prey biomass rather than the relative abundance of any particular species.

Some Mexican spotted-owl prey species show a decline or mixed response after fire, but many species, especially deer mice (*Peromyscus maniculatus*), increase in abundance after fire (Tevis 1956, Buech et al. 1977, Wirtz et al. 1988). Early successional specialists (such as the deer mouse) and species that require open habitats with well-developed herbaceous understories (such as pocket gophers [*Thomomys* spp.] or microtine voles [*Microtus* spp.]) benefit from intense stand-replacing fires, whereas species that require dense canopies or ground cover decline (McGee 1982, Ward and Block 1995). Seed-eating species would find a sudden increase in their food supply when annual grasses come in.

The effects of fire on prey biomass are varied, but generally appear to be short-lived (Bock and Bock 1983, Martell 1984, Kirkland et al. 1996). Deer mouse populations appear to universally increase after fire (Wirtz 1982, Kaufman et al. 1988, Schwilk and Keeley 1998). Total prey biomass after fire appears to increase in some areas and decrease in others. Thus, overall effects of fire on prey biomass also are equivocal. The reduction in ground cover caused by fire could benefit the owl by leaving the prey more exposed, however, thus increasing prey availability.

To assess potential impacts of fire on Mexican spotted owls, we compared the presence and reproductive success of owls between recently burned sites and similar unburned sites (we use "sites" to refer to areas with a history of recent occupancy by owls, loosely analogous to owl territories). We also collected data on severity and extent of burn, topographic characteristics, and dominant forest cover types in burned sites to compare the importance of fire to other possible predictor variables. Our research questions were: (1) Does fire in an owl site influence spotted owl occupancy and reproduction 1–4 years after the fire, compared to unburned sites; and (2) Given a fire within an owl site, does severity and extent of fire, dominant cover type, or topography within the burned site influence spotted owl occupancy and reproduction? We also briefly describe fire extent (percent of forest cover types burned) for recent fires in owl sites.

Methods

Study Area and Site Selection

Using information gathered from USDA Forest Service (USFS) offices, we selected owl sites in Arizona and New Mexico that burned during 1993–1996. These included sites burned by prescribed and prescribed-natural fire (naturally occurring fires that burn in preplanned locations, which are allowed to burn while they meet management objectives), and wildfire. For each burned site, we selected a paired unburned site (i.e., no evidence of recent burn) within 12 km that had similar topography and forest cover types. We selected paired sites based on recommendations from local USFS and other research biologists, drawing on their experience and knowledge of the area. We initially selected 32 pairs of burned and unburned sites. Ground surveys revealed no evidence of recent fire in one of the "burned" sites, however, and extensive burned areas in two "unburned" sites. Thus, our sample consisted of 33 burned sites and 31 unburned sites, including 29 pairs of burned/unburned sites, distributed among nine geographic areas and four national forests (Fig. 1).

Prior knowledge of occupancy patterns on these sites varied greatly in quality and quantity, but all sites had a record of, at minimum, either a pair of owls in a single year or a single owl in at least two years, between 1990 and 1996. USFS survey histories were available for 53 of the 64 sites. Historic occupancy rates for these sites are calculated as the number of years of occupancy recorded divided by the number of years the site was observed. On average, burned sites (n = 29) were surveyed 5.1 $\pm$ 2.2 (SD) years, with an occupancy rate of 0.88 $\pm$ 0.21. Unburned sites (n = 24) were surveyed 5.3 $\pm$ 3.3 years with an average occupancy rate of 0.96 $\pm$ 0.08. Of the remaining sites, eight were surveyed numerous years as part of a study on

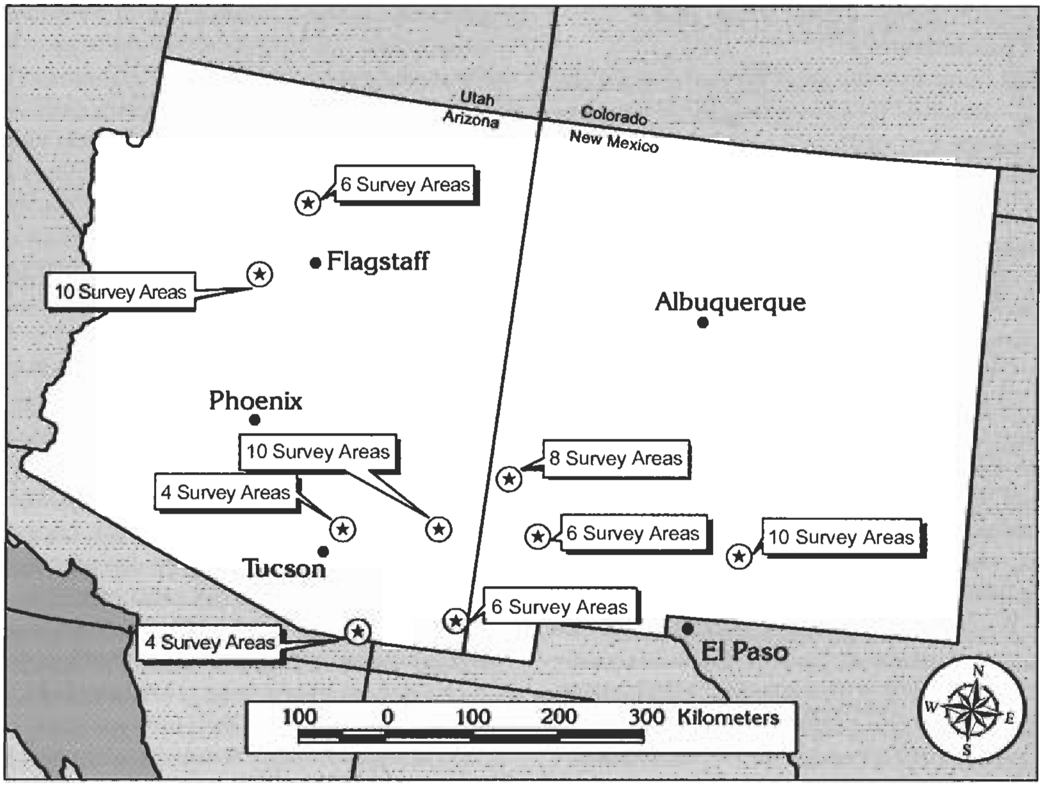

Figure 1. Distribution of Mexican spotted owl survey areas in Arizona and New Mexico, 1997. Forty survey areas were located in Arizona (16 in the Coconino National Forest and 24 in the Coronado National Forest [Catalina, Pinaleno, Chiricahua, and Huachuca mountain ranges]), and 24 were in New Mexico (14 in the Gila National Forest and 10 in the Lincoln National Forest). All locations have an equal number of burned and unburned survey areas.

demography of Mexican spotted owls (Seamans et al. 1999), but actual survey histories were not available. For the remaining three sites, the records did not show survey history but indicated only owl locations and dates.

We conducted owl surveys within each site using three delineations of the site boundary. These were: (1) activity centers delineated by USFS biologists, based on historical use patterns and professional judgment; (2) a 400-m radius circle centered on the nest site or cluster of owl detections for each site; and (3) a 1-km radius circle centered on the nest site or cluster of owl detections for each site. The 1-km radius circle (314.2 ha) was chosen because it was a convenient number that approximated the current guidelines for size and extent of Mexican spotted owl Protected Activity Centers (243 ha with irregular boundary; USDI Fish and Wildlife Service 1995). Because results differed little among the three types of boundary delineation and because the 1-km circles had a more uniform size and shape than delineated activity centers and contained more grid points (see below) than the 400-m circles, we will restrict our discussion here to results from the 1-km circles and hereafter refer to them as "survey areas." Results of analyses involving the other two survey-area delineations are available in Jenness (2000).

Owl Surveys

We conducted nocturnal calling surveys from 1 Mar. to 31 Aug. 1997, following established protocols (Forsman 1983, USDA Forest Service 1988). All surveys occurred between 30 min after sunset and 30 min before sunrise. Calling was discontinued in windy and stormy conditions. We called for owls from either fixed points or while walking along continuous transects, located so that calls were audible over the entire survey area. Each area was surveyed four times unless young spotted owls were observed outside the nest, confirming successful reproduction, before the fourth survey. If we heard a spotted owl at night, we returned to the area within 48 h to conduct a daytime follow-up survey to search for evidence of nesting. We searched for nests visually and, if unsuccessful, offered mice to the owls to attempt to locate the nest. In all cases, the same individuals surveyed both burned areas and their unburned counterparts. We assigned each survey area to one of four Owl Occupancy Ranks on completion of surveys. These were: (1) no owls detected; (2) one owl detected, but no conclusive evidence of pair occupancy; (3) a pair of owls detected, but no evidence of successful reproduction; and (4) young spotted owls observed outside the nest. This four-level ordinal categorization provides a reasonable basis for comparing occupancy or successful reproduction within established owl territories because each increasing level reflects increasing fitness. Quantitative measures of fecundity and survival over several years would better describe potential impacts on spotted owls (see Burnham et al. 1996, Gutiérrez et al. 1996, Raphael et al. 1996), but we did not have such data.

Determining Fire Severity, Cover Type, and Topographic Characteristics

We sampled all burned survey areas for fire severity and dominant prefire vegetation type by systematically surveying a grid (186-m spacing, with an average of 91 ± 2.9 points per survey area) randomly overlaid on each survey area map. Using each point as the center of a 10-m radius circle, we assigned the plot to one of four fire severity classes and one of four prefire vegetative cover types.

We used criteria described by Wenger (1984) to distinguish between stand-replacing and stand-maintaining fires. Stand-replacing ("catastrophic") fires kill most vegetation within the fire boundary. Depending on the fire intensity and the vegetation density, stand-replacing fires may leave large amounts of dead vegetative material that increases the risk and intensity of future fires. Stand-maintaining fires generally burn close to the ground, killing the aboveground parts of grasses, shrubs, forbs, small trees, and burning accumulated ground fuels, without killing larger trees (Wenger 1984). We subdivided stand-maintaining fires into canopy-level and surface-level fires. Our fire severity classes were: (1) no evidence of fire within plot (unburned); (2) no evidence of canopy fire within the plot, but evidence of ground fire (ground fire); (3) evidence of patchy canopy fire within the plot (canopy fire); and (4) all canopy vegetation within the plot killed by fire (stand-replacement fire).

We classified each site into one of four vegetation cover types (mixed-conifer, pine, pine/oak, other) based on the primary species composition of overstory and understory vegetation. Mixed-conifer sites were primarily Douglas-fir (*Pseudotsuga menziesii*), spruce (*Picea* spp.), or true fir (*Abies* spp.). Pine sites were characterized by forests of long-needled pines (*Pinus* spp.). Pine/oak sites included mixed species stands of pine and oak (*Quercus* spp., primarily *Q. gambelii*).

We also used 7.5′ Digital Elevation Models (DEMs; Arizona State Land Department 1997, USDA Forest Service Geometronics Center 1997) to derive slope and aspect data and a crude index of topographic roughness within survey areas. We estimated topographic roughness by generating 20-m contour lines over the survey area, clipping them to the survey area boundary, summing the total length of the clipped contour lines, and dividing by the survey area to yield a density of 20-m contour lines in meters per hectare.

Statistical Analysis

We analyzed our data in two steps. First, we compared occupancy rank between paired burned and unburned sites. Second, for burned sites only, we evaluated potential relationships between site characteristics and occupancy rank.

We used a Test of Marginal Homogeneity (Mehta and Patel 2001) to compare occupancy rank among the 29 pairs of burned and unburned survey areas. We used a two-tailed test because fire could potentially degrade or improve owl habitat.

We used the Multiple Response Permutation Procedure (MRPP [Mielke and Berry 1995]) as implemented in program BLOSSOM (Slauson et al. 1994) to examine the associations between occupancy ranking at burned sites and the severity and extent of fire, dominant cover type, and topographic characteristics in those sites. MRPP uses permutations of the actual data to calculate the probability that the observed grouping of observations could be due to chance, and thus can be used even when underlying distributions are non-normal. After a significant omnibus MRPP, we used univariate MRPP tests to identify specific variables associated with occupancy rank.

Results

Description of Fire Extent in Owl Survey Areas

On average, fires affected 55% of the area in burned sites (range 1–99%). This included 25% burned only by understory fire (range 1–73%) and 30% of the survey area burned by canopy-level fire (range 0–91%). On average, 14% of a survey area burned only partially into the canopy (range 0–44%), and 16% of the area burned at stand-replacing level (range 0–55%). Within the combined area of all our burned survey areas, fires burned 56% of the mixed-conifer type (24% at ground level, 17% in canopy, and 16% stand-replacement), 66% of the pine type (26% at ground level, 18% in canopy, and 22% stand-replacement) and 54% of the pine/oak type (34% at ground level, 8% in canopy, and 13% stand-replacement). Thirty-three percent of the burned portions were in mixed-conifer, 44% were in pine, and 14% were in pine/oak.

Associations Between Fire Presence and Owl Occupancy Rank

Unburned survey areas tended to have more pairs and more reproductive pairs than did burned survey areas (Fig. 2). Compared to the 33 burned sites, the 31 unburned sites had a higher proportion of occupied sites (84% versus 70%) and reproduction (16% versus 9%) in 1997. Of the 29 paired sites, 6 cases had a higher occupancy rank in the burned survey areas, 9 pairs resulted in ties, and 14 cases had a

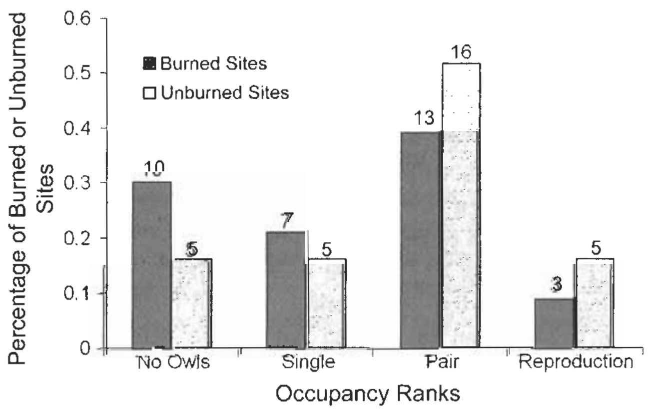

Figure 2. Relative proportions of burned and unburned Mexican spotted owl survey areas that had either no owls, a single bird, a pair, or confirmed reproduction. The numbers above the bars represent the actual numbers of survey areas at each response level, whereas the Y-axis represents the proportion of either burned or unburned survey areas at each response level.

higher occupancy rank in the unburned survey areas. These differences were not statistically strong ($P = 0.110$).

There was no marked difference in occupancy rank in relation to time since fire. Of the survey areas that burned in 1996 (one year before our surveys), six of eight were occupied, compared to 17 of 25 survey areas that burned 2–4 years before our surveys.

Owls were present and reproducing at several sites that experienced severe fires. Fires burned >50% of each of the three burned survey areas with successful nests in 1997 (including stand-replacement-level percentages of 8, 31, and 32%), and the most severely burned survey area had a single owl in 1997. Thirty of the survey areas burned only once in the 4 years before our surveys, but three burned multiple times. At the latter sites, we found single owls at two sites and a nonreproducing pair at the other site.

Associations Between Fire Severity/Habitat Variables and Owl Occupancy Rank

The omnibus MRPP test indicated that occupancy rank was significantly influenced by some variable or combination of variables ($P = 0.040$). Subsequent univariate tests identified three variables as showing the most significant differences among the occupancy ranks: percent pine ($P = 0.003$), percent mixed conifer ($P = 0.038$), and percent of survey area unburned ($P = 0.075$) (Table 1, Fig. 3). Owl sites where we detected no owls in 1997 contained more pine than sites where owls were present, and successful reproduction was associated with a higher proportion of mixed conifer (Fig. 3). The differences in percent of area burned relative to occupancy rank did not follow a biologically interpretable pattern (Fig. 3).

Discussion

Our results were equivocal regarding the potential impact of fire on Mexican spotted owls. Although statistical significance was weak, our sample size was small, resulting in low power to detect a significant association between occupancy rank and fire. Further, we lack information on spatial and temporal variability in owl occupancy rates, and our burned areas encompassed a wide range in both burn extent and severity. These factors further complicate interpretation of our data. However, point estimates of effect size (e.g., probability of occupancy 14% higher and probability of successful reproduction 7% higher in unburned sites) were suggestive of a biologically significant impact. Consequently, we caution against interpreting our results as indicative that fires do not affect spotted owls.

Our MRPP tests suggested that the percentage of pure pine in a survey area was most strongly associated with occupancy rank. Because fires burned greater proportions of the pine type in our survey areas, there may have been an interaction between fire effects and cover type.

Previous evidence also is equivocal with respect to the effects of fire on Mexican spotted owls. Willey (1998) radiotracked three pairs of Mexican spotted owls before and after relatively low-intensity prescribed burns in Saguaro National Park, southern Arizona, finding that, at least in the short term, the owls tended to stay in the same general area after the fires. Bond et al. (2002) documented survival, site and mate fidelity, and reproductive success after large fires for 21 owls in 11 territories in California, Arizona, and New Mexico, finding high survival, site and mate fidelity, and reproductive success. Several Mexican spotted owls in the Gila National Forest continued to occupy territories after prescribed natural fires that minimally altered stand structure (USDA Forest Service 1995), and there are numerous anecdotal observations of Mexican spotted owls occupying areas after wildfires and prescribed burns (Paul Boucher, Gila National Forest, 1997; Peter Stacey, Univ. New Mexico, July 8, 2001).

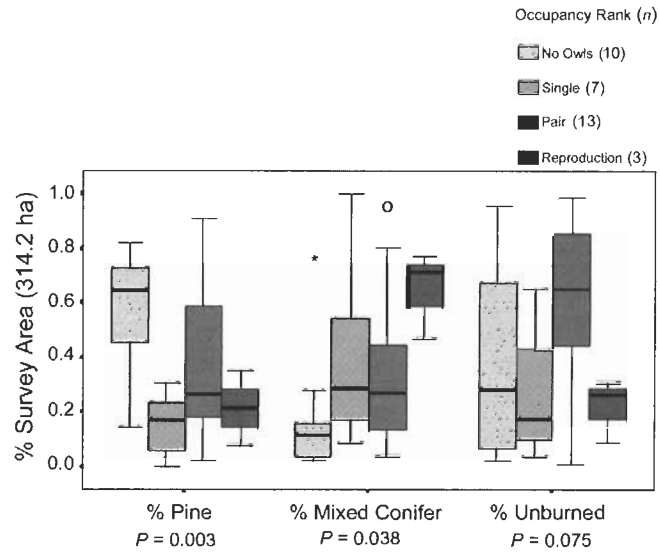

Figure 3. Percent pine, mixed-conifer, and unburned predictor variables in 33 burned areas (314.2 ha each). Horizontal bars within boxes represent the median, the tops and bottoms of the boxes represent the 75th and 25th quantiles, and the whiskers represent the range excluding outliers and extremes. Outliers (values >1.5 box lengths from box) are displayed with the symbol "○" and extremes (values >3 box lengths from the box) are displayed with the symbol "*".

Table 1. For 33 burned sites, the probability that each fire severity and habitat variable did not differ among the four levels of occupancy rank (no owls, single owl, pair, reproduction) as determined by MRPP.

Variable	*P*-value
Average slope in degrees	0.524
% North-facing slope	0.224
% East-facing slope	0.716
% South-facing slope	0.103
% West-facing slope	0.923
% Unburned	0.075
% Ground fire	0.712
% Canopy fire	0.178
% Stand-replacement fire	0.263
% Pine	0.003
% Pine/Oak	0.226
% Mixed-conifer	0.038
Topographic roughness	0.597

The omnibus MRPP test using all predictor variables suggested that at least one variable differed among owl occupancy types ($P = 0.04$).

Other anecdotal evidence demonstrates possible negative response to fire, such as Elliot's (1985) observation that at least one California spotted owl (*S. o. occidentalis*) territory apparently was abandoned for several years after a highly destructive fire in 1977. Gaines et al. (1997) described impacts of 1994 wildfires on six northern spotted owl (*S. o. caurina*) activity centers in eastern Washington, noting a small decrease in the number of reproductive pairs on these sites, and an increase in the number of unoccupied sites the year after the fires. Bevis et al. (1997) discussed two pairs of radio-tagged northern spotted owls in south-central Washington that stayed near their territories after a 1994 wildfire but shifted their primary activity to lightly burned or unburned areas. One female owl in that study was found dead in an emaciated condition 2.5 months after the fire, leading to speculation that the fire may have reduced prey availability, and her mate disappeared over the winter. Two new owls occupied the territory one year after the fire, suggesting that, by then, the territory could support owls despite the fire.

The potential for widespread stand-replacing fire, identified as a leading factor endangering the Mexican spotted owl by USDI Fish and Wildlife Service (1993, 1995), has not abated during the last decade. For example, Sheppard and Farnsworth (1997) estimated that at least 10 Mexican spotted owl territories were affected by fire in Arizona and New Mexico during the 1994 fire season alone. They further estimated that >20,234 ha of owl habitat experienced stand-replacing wildfire from 1989–1994. Severe wildfires have occurred in virtually every year since 1994, with peaks in 1996 and 2002. Thus, stand-replacing wildfire remains a significant threat to owls and their habitat in both the short and long-term. We recognize that most wildfires burn in a patchy nature and leave pockets of useable habitat for owls. We further recognize that some owls locate and use these patches and thus are relatively resilient to wildfire, at least in the short term. Nevertheless, we continue to view the potential cumulative loss of habitat to wildfire as a major threat to the owl, especially given lack of data on long-term responses of owls to fire.

Our concern over loss of owl habitat to wildfire is exacerbated by several factors. One is the current structure of southwestern forests. Although owl habitat as we know it today is inherently fire prone, with high tree densities, canopy cover, and fuel loadings (Ganey and Dick 1995), we suspect that those conditions were not continuous on the landscape under natural fire regimes (Marshall 1963, Covington et al. 1994). Such conditions now are relatively continuous on the landscape, raising the specter of more, larger, and more intense wildfires. This creates greater potential for widespread loss of owl habitat.

Further, much of the currently occupied owl habitat occurs in canyons featuring cool microsites and rock outcrops. These areas may have functioned as fire refugia (*sensu* Camp et al. 1997) in historic times, escaping some of the frequent fires and allowing longer fire-free periods for stand development. With increasing intensity of wildfires (Moody et al. 1992) and greater continuity of heavy fuels, the potential for fire to spread into these refugia would appear to be higher as well. This problem is further exacerbated by the fact that the southwest is currently experiencing a severe drought of unknown duration, further increasing the potential for large and intense wildfires (Swetnam 1990, Swetnam and Betancourt 1990).

Finally, the seasonality of fire in the southwest has changed. Most naturally occurring fires in Arizona and New Mexico occur during the monsoon season between July and September as a result of lightning strikes during thunderstorms (Sackett et al. 1994, Fulé et al. 1997, Brown et al. 2001). This is a rainy season in the southwest when fuel moistures are often high and precipitation is likely to fall concurrent with or soon after the lightning strikes, both factors which can moderate fire behavior and extent.

In contrast, many large wildfires in recent years have been human-caused, and have occurred in May and June (historical data on timing, size, and cause of large fires, www.fs.fed.us/r3/fire/swainfo/swainfo.htm, Sept., 2003). This is a dry period in the southwest, falling between periods of winter precipitation and summer thunderstorms. This season is characterized by low fuel moistures, high winds, and little chance of precipitation to moderate fire behavior. These conditions, coupled with high and relatively continuous fuel loadings as a result of fire suppression, favor extreme fire behavior and large fires.

We also suspect that fire may affect owls differently based on whether it burns in core/nest areas where it may cause changes in the microclimate and cover necessary for raising young, or foraging areas where it may affect prey availability and diversity. We were unable to analyze this possibility because of a lack of sufficient historical nesting locations in our dataset, but we feel it could have important management implications and should be considered in future research or management actions.

Management Implications

The recovery plan for the Mexican spotted owl (USDI Fish and Wildlife Service 1995) recommended proactive fuels management to reduce continuity of fuels on the landscape. We support that recommendation. The plan further recommended that initial fuels-reduction efforts focus on areas not currently occupied by owls (Protected Activity Centers or PACs) because of uncertainty over the effects of those treatments on owls. We also believe this recommendation is appropriate. We agree with the plan's conclusion that treatment of areas outside of PACs can provide considerable protection to those PACs by allowing managers to reduce continuity of fuels on the landscape, thus reducing the potential for fires to start elsewhere and spread into PACs. Because owl PACs comprise only approximately 2.1% of National Forest lands in Arizona and New Mexico (USDA Forest Service, unpublished data), we further believe that this approach leaves open to management more area than land management agencies can reasonably treat in the near future, and thus should not prevent managers from addressing fuels-management issues in most areas. We recognize, however, that unique situations may exist requiring treatments to proceed in PACs. One example is cases where owls occur in the wildland–urban interface, and treatment of those areas is necessary to reduce fire risk to rural and urban areas of human settlement. Other examples undoubtedly exist. We recommend that managers evaluate these situations on a case-by-case basis. Ideally, where fuels reduction treatments proceed in PACs, associated effects on Mexican spotted owls and key ecological linkages (e.g., prey and important habitat variables) should be determined by incorporating those treatments in a management experiment using a credible scientific design, examining long-term survival and fecundity, and including a rigorous multiyear monitoring program. However, such an effort may prove prohibitively expensive. Therefore, as an alternative, we suggest that response of owls be monitored using systematic and standardized research designs that will allow results from various areas to be included in a meta-analysis evaluating effects of fuels treatments on owls, their habitat, and important prey species.

Literature Cited

ARIZONA STATE LAND DEPARTMENT. 1997. Arizona digital elevation models [7.5′ Quads]. Arizona State Land Dept., Phoenix, AZ.

BEVIS, K.R., G.M. KING, AND E.E. HANSON. 1997. Spotted owls and 1994 fires on the Yakama Indian reservation. P. 112–116 *in* Proc. First Conf. on fire effects on rare and endangered species and their habitats: J.M. Greenlee (eds.). Internat. Assoc. Wildland Fire, Coeur d'Alene, ID.

BOCK, C.E., AND J.H. BOCK. 1983. Responses of birds and deer mice to prescribed burning in ponderosa pine. J. Wild. Manage. 47(3):836–840.

BOND, M.L., R.J. GUTIERREZ, A.B. FRANKLIN, W.S. LAHAYE, C.A. MAY, AND M.E. SEAMANS. 2002. Short-term effects of wildfires on spotted owl survival, site fidelity, mate fidelity, and reproductive success. Wild. Soc. Bull. 30(4):1022–1028.

BROWN, P.M., M.W. KAYE, L.S. HUCKABY, AND C.H. BAISAN. 2001. Fire history along environmental gradients in the Sacramento Mountains, New Mexico: Influences of local patterns and regional processes. Ecoscience 8(1):115–126.

BUECH, R.R., K. SIDERITS, R.E. RADTKE, H.L. SHELDON, AND D. ELSING. 1977. Small mammal populations after a wildfire in northeast Minnesota. USDA For. Serv., Nor. Cent. For. Exp. Stn., St. Paul, MN. NC-151. 8 p.

BURNHAM, K.P., D.R. ANDERSON, AND G.C. WHITE. 1996. Meta-analysis of vital rates of the northern spotted owl. P. 92–101 *in* Studies in avian biology, Vol. 17. Demography of the northern spotted owl, Forsman, E.D., S. DeStefano, M.G. Raphael, and R.J. Gutiérrez (eds.). Cooper Ornithological Society. Allen Press, Inc., Lawrence, KS.

CAMP, A., C. OLIVER, P. HESSBURG, AND R. EVERETT. 1997. Predicting late-successional fire refugia pre-dating European settlement in the Wenatchee Mountains. For. Ecol. Manage. 95:63–77.

COVINGTON, W.W., AND M.M. MOORE. 1994a. Postsettlement changes in natural fire regimes and forest structure: Ecological restoration of old-growth ponderosa pine forests. J. Sust. For. 2:153–181.

COVINGTON, W.W., AND M.M. MOORE. 1994b. Southwestern ponderosa forest structure. J. For. 92(1):39–47.

COVINGTON, W.W., R.L. EVERETT, R. STEELE, L.L. IRWIN, T.A. DAER, AND A.N.D. AUCLAIR. 1994. Historical and anticipated changes in forest ecosystems of the inland west of the United States. J. Sust. For. 2:13–63.

ELLIOTT, B. 1985. Changes in distribution of owl species subsequent to habitat alteration by fire. West. Birds 16:25–28.

FORSMAN, E.D. 1983. Methods and materials for locating and studying spotted owls. USDA For. Serv. Gen. Tech. Rep. PNW-GTR-162. 8 p.

FULE, P.Z., W.W. COVINGTON, AND M.M. MOORE. 1997. Determining reference conditions for ecosystem management of southwestern ponderosa pine forests. Ecol. App. 7:895–908.

GAINES, W.L., R.A. STRAND, AND S.D. PIPER. 1997. Effects of the hatchery complex fires on northern spotted owls in the eastern Washington cascades. P. 123–129 *in* Proc. First Conf. on fire effects on rare and endangered species and their habitats. Greenlee, J.M. (eds.). Internat. Assoc. Wildland Fire, Coeur d'Alene, ID.

GANEY, J.L, W.M. BLOCK, J.S. JENNESS, AND R.A WILSON. 1999. Mexican spotted owl home range and habitat use in pine-oak forest: Implications for forest management. For. Sci. 45(1)1:127–135.

GANEY, J.L., AND J.L. DICK JR. 1995. Habitat relationships of the Mexican spotted owl: Current knowledge. Vol. II, Chap. 4 *in* Recovery plan for the mexican spotted owl, USDI Fish and Wildlife Ser., Albuquerque, NM.

GUTIERREZ, R.J., FRANKLIN, A.B., AND LAHAYE, W.S. 1995. Spotted owl (*Strix occidentalis*). P. 1–28 *in* The birds of North America, No. 179. Poole, A, and F. Gill (eds.). The Academy of Natural Sciences, Philadelphia, and The American Ornithologists Union, Washington, DC.

GUTIERREZ, R.J., E.D. FORSMAN, A.B. FRANKLIN, AND E.C. MESLOW. 1996. History of demographic studies in the management of the northern spotted owl. P. 6–11 *in* Studies in avian biology, Vol. 17. Demography of the northern spotted owl, Forsman, E.D., S. DeStefano, M.G. Raphael, and R.J. Gutiérrez (eds.). Cooper Ornithological Society, Allen Press, Inc., Lawrence, KS.

JENNESS, J.S. 2000. The effects of fire on Mexican spotted owls in Arizona and New Mexico. M.Sc. thesis, North. Az. Univ., Flagstaff, AZ. 131 p. Available online at www.jennessent.com/Literature/Thesis/

KAUFMAN, G.A., D.W. KAUFMAN, AND E.J. FINCK. 1988. Influence of fire and topography on habitat selection by *Peromyscus maniculatus* and *Reithrodontomys megalotis* in ungrazed tallgrass prairie. J. Mamm. 69(2):342–352.

KIRKLAND G.L. JR., H.W. SNODDY, AND T.L. AMSLER. 1996. Impact of fire on small mammals and amphibians in a central Appalachian deciduous forest. Am. Midl. Nat. 135(2):253–260.

KOLB, T.E., M.R. WAGNER, AND W.W. COVINGTON. 1994. Concepts of forest health: Utilitarian and ecosystem perspectives. J. For. 92(7):10–15.

LEOPOLD, A. 1924. Grass, brush, timber and fire in southern Arizona. J. For. 22(6):1–10.

MADANY, M.H., AND N.E. WEST. 1983. Livestock grazing—Fire regime interactions within montane forests of Zion National Park, Utah. Ecol. 64:661–667.

MARSHALL, J.T. JR. 1963. Fire and birds in the mountains of southern Arizona. P. 135–141 *in* Proceedings—Tall timbers fire ecology conference, 1963. Komarek, E.V. Sr. (ed.). Tall Timbers Res. Sta., Tallahassee, FL.

MARTELL, A.M. 1984. Changes in small mammal communities after fire in northcentral Ontario. Can. Field Nat. 98(2): 223–226.

MCGEE, J.M. 1982. Small mammal populations in an unburned and early fire successional sagebrush community. J. Range Manage. 35(2):177–180.

MEHTA, C., AND N. PATEL. 2001. StatXact5: Statistical software for exact nonparametric inference user manual, Vol 1. CYTEL Software Corporation, Cambridge, MA.

MIELKE, P.W., AND K.J. BERRY. 1995. BLOSSOM Statistical Package. Version Beta EVMB 0898.L4.5d.S3. US Geol. Surv. Midcontinent Ecological Sci. Ctr., Fort Collins, CO.

MOODY, R., L. BUCHANAN, R. MELCHER, AND H. WISTRAND. 1992. Fire and forest health: Southwestern region. USDA For. Serv. SW Region, Albuquerque, NM. 23 p.

RAPHAEL, M.G., R.G. ANTHONY, S. DESTEFANO, E.D. FORSMAN, A.B. FRANKLIN, R. HOLTHAUSEN, E.C. MESLOW, AND B.R. NOON. 1996. Use, interpretation, and implications of demographic analyses of northern spotted owl populations. P. 102–112 *in* Studies in avian biology, Vol. 17. Demography of the northern spotted owl, Forsman, E.D., S. DeStefano, M.G. Raphael, and R.J. Gutiérrez (eds.). Cooper Ornithological Society, Allen Press, Inc., Lawrence, KS.

SACKETT, S., S. HAASE, AND M.G. HARRINGTON. 1994. Restoration of southwestern ponderosa pine ecosystems with fire. P. 115–121 *in* Proceedings—Sustainable ecological systems: Implementing an ecological approach to land management, July 12–15, 1993. Covington, W.W. and L.F. DeBano (tech. coords.) USDA For. Serv. Gen. Tech. Rep. GTR-RM-247.

SAVAGE, M., AND T.W. SWETNAM. 1990. Early 19th-century fire decline following sheep pasturing in a Navajo ponderosa pine forest. Ecology 71:2374–2378.

SCHWILK, D.W., AND J.E. KEELEY. 1998. Rodent populations after a large wildfire in California chaparral and coastal sage scrub. The Southwestern Nat. 43(4):480–483.

SEAMANS, M.E., R.J. GUTIERREZ, C.A. MAY, AND M.Z. PEERY. 1999. Demography of two Mexican spotted owl populations. Cons. Biol. 13:744–754.

SHEPPARD, G., AND A. FARNSWORTH. 1997. Fire effects and the use of prescribed fire in Mexican spotted owl habitat. P. 131–135 *in* Conf. Proc.—Fire effects on rare and endangered species and habitats. Nov. 13–16, 1995, Int. Assoc. Wildland Fire, Coeur d'Alene, ID.

SLAUSON, W.L., B.S. CADE, AND J.D. RICHARDS. 1994. User manual for BLOSSOM statistical software. National Biological Survey, Midcontinental Ecological Sci. Ctr., Fort Collins, CO. 59 p.

SWETNAM, T.W. 1990. Fire history and climate in the southwestern United States. P. 617 *in* Effects of fire management of southwestern natural resources. Krammes, J.S., L.F. DeBano, and M.J. Zwolinski (tech. coords). Rocky. Mtn. For. and Range Exper. Stn. Ft. Collins, CO. USDA For. Serv. Gen. Tech. Rept. RM-191.

SWETNAM, T.W., AND J.L. BETANCOURT. 1990. Fire-southern oscillation relations in the southwestern United States. Sci. 249:1017–1020.

TEVIS, L. JR. 1956. Effect of a slash burn on forest mice. J. Wild. Manage. 20(4):405–409.

USDA FOREST SERVICE. 1988. Spotted owl inventory and monitoring handbook. USDA For. Serv. Pacific Northwest Region, Portland, OR. 13 p.

USDA FOREST SERVICE. 1995. Final environmental impact statement for amendment of forest plans. USDA For. Serv. SW Region, Albuquerque, NM. 262 p.

USDA FOREST SERVICE GEOMETRONICS CENTER. 1997. Arizona and New Mexico Digital Elevation Models [7.5′ quads]. USDA For. Serv. Geometronics Ctr. Salt Lake City, UT.

USDI FISH AND WILDLIFE SERVICE. 1993. Endangered and threatened wildlife and plants: Final rule to list the Mexican spotted owl as a threatened species. Fed. Reg. 58:14248–14271.

USDI FISH AND WILDLIFE SERVICE. 1995. Recovery plan for the Mexican spotted owl, Vol I. USDI Fish and Wildlife Serv., Albuquerque, NM. 347 p.

VERNER J., K.S. MCKELVEY, B.R. NOON, R.J. GUTIERREZ., G.I. GOULD JR., AND T.W. BECK. 1992. The California spotted owl: A technical assessment of its current status. USDA For. Serv., Pacific SW Res. Sta. Gen. Tech. Rep. PSW-133.

WARD J.P. JR., AND W.M. BLOCK. 1995. Mexican spotted owl prey ecology. Vol. II, Chap. 5 *in* Recovery plan for the Mexican spotted owl. Vol. II. USDI Fish and Wildlife Serv., Albuquerque, NM.

WENGER, K.F. (ED.). 1984. Forestry handbook, 2nd Ed. John Wiley & Sons, New York, NY. 1,335 p.

WILLEY, D.W. 1998. Influence of fire on Mexican spotted owls in Saguaro National Park. Final Report. Heritage Fund Program, Arizona Game and Fish Dept. Phoenix, AZ. 38 p.

WIRTZ, W.O., D. HOEKMAN, J.R. MUHM, AND S.L. SOUZA. 1988. Postfire rodent succession following prescribed fire in southern California chaparral. P. 333–339 *in* Proc. of Conf. on management of amphibians, reptiles and small mammals in North America, Szaro, R.C., K.E. Severson, and D.R. Patton (tech. coords.). USDA For. Serv. Rock. Mt. For. and Range Exp. Stn., Ft. Collins, CO, Gen. Tech. Rep. RM-166.

WIRTZ, W.O. II. 1982. Postfire community structure of birds and rodents in southern California chaparral. P. 241–246 *in* Proc. of conf. on dynamics and management of Mediterranean-type ecosystems. USDA For. Serv. Pac. SW For. and Rang. Exp. Stn. Gen. Tech. Rep. PSW-58.