Short-term effects of wildfires on spotted owl survival, site fidelity, mate fidelity, and reproductive success

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Abstract The effects of wildfire on wildlife are important considerations for resource managers because of recent interest in the role of fire in shaping forested landscapes in the western United States. This is particularly true of wildfire effects on spotted owls (*Strix occidentalis*) because of the uncertainty of impacts of controlled burning within spotted owl habitat. Therefore, we documented minimum survival, site fidelity, mate fidelity, and reproductive success for 21 spotted owls after large (>540 ha) wildfires occurred within 11 owl territories in California, Arizona, and New Mexico. In each territory, fire burned through the nest and primary roost sites. Eighteen owls (86%) were known to be alive at least 1 year after the fires, which was similar to reported annual adult survival probabilities for the species. Of 7 pairs of which both members were later resighted, all were located together on the same territories during the breeding season following fires, and 4 pairs produced a total of 7 fledglings. No pair separations were observed after fire. On 8 territories where fire severities were mapped, 50% experienced predominantly low- to moderate-severity fires while 50% experienced high-severity fires that burned large (>30%) areas of the territories. We hypothesize that wildfires may have little short-term impact on survival, site fidelity, mate fidelity, and reproductive success of spotted owls. Further, prescribed burning could be an effective tool in restoring habitat to natural conditions with minimal short-term impact on resident spotted owls. While we do not advocate wholesale prescribed burning in spotted owl territories at this time, we believe our observations justify large-scale experiments on effects of prescribed burning on spotted owls to corroborate our observations and to establish cause-and-effect relationships.

Key words prescribed burning, spotted owl, *Strix occidentalis*, wildfire

Wildfire is a natural process that has shaped the character of western forests (Agee 1990). In many areas, pre-settlement fire regimes consisted of frequent low-severity fires at 5–30-year intervals (Kilgore 1973, Horton and Mannan 1988, Weatherspoon et al. 1992, MacCracken et al. 1996). In central and southern California, the Southwest, and eastern slopes of the Cascades, low-severity fires created a mosaic of uneven- and even-aged forest stands (Kilgore 1973, Horton and Mannan 1988,

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MacCracken et al. 1996). In northwestern California, the xeric end of the Pacific Northwest rainforest, fire frequency occurred at about 20-year intervals and the fire regime was more similar to southwestern than other northwestern regions (Agee 1990, 1993). However, western forests were not immune to higher-severity wildfires, which occurred infrequently and were patchy in nature (Stephenson et al. 1991, MacCracken et al. 1996). Therefore, both low- and high-severity fires have had significant impacts on forest structure, composition, and distribution. Risk of high-severity wildfires associated with drought, insect and disease epidemics, and global warming has increased significantly in the western United States following decades of fire suppression (Agee 1993).

Many studies have been conducted on indirect impacts of wildfire on bird populations (e.g., Marshall 1963, Biswell 1989). Indirect impacts include changes in vegetation type, canopy closure, and relative food abundance, which influence local densities of birds (Kilgore 1973, Horton and Mannan 1988). In addition to indirect effects, direct mortality of birds due to fire has been assumed or suspected (Robbins and Myers 1992, Smith 2000). Further, avian lungs may be more susceptible to damage from smoke exposure than mammalian lungs because of an apparent inability of the avian respiratory tract to repair itself (Rombout et al. 1991). While nest destruction caused by fires has been reported for some ground-nesting birds in North Dakota (Robbins and Myers 1992), few studies have examined avian mortality and behavior directly following fire (McMahon and deCalesta 1990).

Some biologists assume that large wildfires negatively impact long-term survival of the spotted owl (*Strix occidentalis*; e.g., Weatherspoon et al. 1992, MacCracken et al. 1996), and believe catastrophic or "stand-replacement" fires, which kill all vegetation within the fire boundary, pose the greatest natural risk to spotted owl habitat (United States Fish and Wildlife Service [USFWS] 1992, 1995; Verner et al. 1992). Management plans generally recommend reducing risk of catastrophic fire in forests occupied by spotted owls (e.g., Verner et al. 1992). One method of reducing risk of wildfire is the use of prescribed fire to remove fuels that can facilitate surface fires becoming crown fires (Biswell 1989). Because northern (*S. o. caurina*) and Mexican spotted owls (*S. o. lucida*) are federally listed as threatened subspecies, prescribed fires within owl areas require consultation with the USFWS. USFWS smoke and wildlife guidelines for prescribed burning currently exist for site-preparation of clearcut units located near northern spotted owl Habitat Conservation Areas (HCAs), but some agency biologists have proposed prescribed burns within northern spotted owl HCAs (J. Perkins, United States Forest Service [USFS], Klamath National Forest, unpublished report). Because of uncertainty over fire effects on owls, controlled burning as a habitat management tool is not conducted routinely within areas reserved for spotted owls. For example, researchers have examined occupancy of spotted owl territories in years following a wildfire (Elliot 1985, MacCracken et al. 1996, Gaines et al. 1997, Scott 1998, Jenness 2000), but short-term impacts on individuals could not be assessed because owls were not color-marked.

We describe minimum survival, site fidelity, mate fidelity, and reproductive success of color-marked spotted owls after wildfires burned nest and roost areas in northwestern California, southern California, Arizona, and New Mexico. After a fire occurred within an owl territory, we posed 4 questions:

1. Did the owl(s) survive the fire (minimum survival)?
2. If an owl survived, was it found in the same territory after the fire (site fidelity)?
3. If both members of a pair survived a fire, did they retain the same mates (mate fidelity)?
4. If both members of a pair survived a fire, did they nest successfully the year after the fire (reproductive success)?

Direct observations of fire effects on spotted owls are difficult to obtain because of the patchy and infrequent (due to fire suppression) nature of fire, and logistical or political limitations associated with conducting fire experiments on a meaningful scale. Nevertheless, we provide insight on short-term effects of fire on spotted owls by presenting observations gathered during 15 years of study throughout a large portion of the species' range.

Study areas

We recorded spotted owl responses to fires >540 ha that occurred on 4 long-term demographic study areas, representing all 3 subspecies of the owl. Study areas were located in northwestern California (292 km^2, 1985–2000, northern spotted owl);

San Bernardino Mountains, southern California (1,890 km^2, 1987-2000, California spotted owl [*S. o. occidentalis*]); Tularosa Mountains, New Mexico (323 km^2, 1991-2000, Mexican spotted owl); and Coconino Plateau, Arizona (585 km^2, 1991-2000, Mexican spotted owl).

Forests in northwestern California were primarily mixed evergreen (Sawyer et al. 1988), dominated by Douglas-fir (*Pseudotsuga menziesii*) with a hardwood subcanopy of madrone (*Arbutus menziesii*), tanoak (*Lithocarpus densiflora*), and canyon live oak (*Quercus chrysolepis*) below 1,200 m elevation. Above 1,200 m, forests were mainly subalpine forests (Sawyer and Thornburgh 1988) dominated by white fir (*Abies concolor*) and pines (*Pinus* spp.). Forests in the San Bernardino Mountains consisted of mixed evergreens (Sawyer et al. 1988) below 1,500 m, and ponderosa pine (*P. ponderosa*) and white fir-sugar pine (*P. lambertiana*) forests (Thorne 1988) above 1,500 m. Forests consisted of various combinations of white fir, ponderosa pine, sugar pine, incense-cedar (*Calocedrus decurrens*), and black oak (*Q. kelloggii*) at higher elevations, and canyon live oak and bigcone Douglas-fir (*Pseudotsuga macrocarpa*) at lower elevations. Forests in the Tularosa Mountains were primarily mixed-conifer and pine-oak. Douglas-fir and white fir were the dominant species in mixed-conifer forests. Pine-oak forest was dominated by ponderosa pine and Gambel oak (*Q. gambelii*). Piñon-juniper woodland, dominated by piñon pine (*P. edulis*) and alligator juniper (*Juniperus deppeana*), was an extensive community within the mountain range. Forests on the Coconino Plateau were pine-oak dominated by ponderosa pine and Gambel oak (Peet 2000). Other communities on the plateau included mixed-conifer forest having Douglas-fir, ponderosa pine, and white fir in the overstory and quaking aspen (*Populus tremuloides*) and Gambel oak in the understory; and piñon-juniper woodland dominated by piñon pine and junipers (*Juniperus* spp.; Peet 2000).

Methods

Owl surveys

We surveyed each study area annually for spotted owls during the breeding season from 1985-2001 following methods described by Forsman (1983) and Franklin et al. (1996). We captured adult and juvenile owls using snare poles, noose poles, and mist nets. All captured birds were marked with a locking aluminum USFWS band on 1 leg and a plastic band and tab with a unique color combination on the other leg (Forsman et al. 1996). We determined the sex of owls by calls and behavior (Franklin et al. 1996). Rate of band loss for spotted owls was negligible (Franklin et al. 1996). This project was approved by the University of Minnesota's Animal Care and Use Committee (Animal Subjects Code Number: 0003A42461).

Impacts of fire

We used USFS records of severity, extent, and duration of all fires >540 ha occurring within territories of individually color-marked spotted owls. We limited our study to fires at least this large because home-range sizes of spotted owls range from 422-591 ha in northwestern California (northern spotted owl; Zabel et al. 1995), 415-810 ha in the San Bernardino Mountains (California spotted owl; Zimmerman et al. 2001), and 648 ha in Arizona (Mexican spotted owl; Ganey and Balda 1989). In each case, nest and roost areas were located within the fire perimeter, and all were burned. Detailed information about conditions (e.g., weather condition, fuel moisture, humidity, and fuel load) at owl nests and roosts was unavailable. We used available USFS data to describe the extent of each fire at the landscape and territory scales. At the landscape scale, we obtained the name, season, and year of the fire, as well as total size and duration of each fire. We addressed fire at the territory scale by estimating percent of each individual owl territory that burned, and percent of the fire-affected area in the territory that burned at high, moderate, or low severity. We defined an owl territory as a circle, with a radius of one-half the average nearest neighbor distance for each study area (see Bingham and Noon 1998) around the nest or roost site during the breeding season, at the time of or prior to the fire (northern spotted owl=710 m [Franklin et al. 2000]; California spotted owl=748.5 m [Smith et al. 2002]; Mexican spotted owl, AZ=1,178 m [May 2000]; and NM=1,060 m [Peery et al. 1999]). To estimate percent of each territory that burned and nest or roost area location within the fire, we overlaid owl territories onto digitized fire maps obtained from the USFS using ArcView GIS 3.2 (Environmental Systems Research Institute 1996).

Fire-severity classifications for each coverage were conducted by each USFS district within which the fire occurred. Coverages were classified as follows: 1987 autumn King Titus fire (24,282 ha) in northwestern California (3 owl territories) into low (<30% canopy kill), moderate (31-70% canopy kill), and high severity (>70% canopy kill); 1995 summer HB fire (5,261 ha) in New Mexico (3 owl territories) into low (≤35% canopy kill) and high (>35% canopy kill) severity; 1987 autumn Cold fire (4,876 ha) in northwestern California (1 owl territory) into high (small and subcanopy trees killed, and many to most overstory trees killed) and moderate (most small trees killed, some subcanopy trees killed or heavily damaged, and occasional mortality of overstory trees) severity; and 1996 spring Pot fire (2,833 ha) in Arizona (1 owl territory) into crown ("standing black sticks" with no live trees), high (>70% crown scorch of standing overstory trees), medium (30-70% crown scorch of standing overstory trees), and low/underburn (<30% scorch of standing overstory trees or generally on flanks or heel of fire area). Severity on the King Titus and HB fires was estimated using aerial photography; satellite imagery was also used on the HB fire. The Cold fire severity was estimated from ground surveys. The Pot fire map was developed using satellite imagery followed by ground verification. Unfortunately, USFS GIS data for the remaining 3 summer fires in southern California (Verbena, 1995 [9,308 ha], Mill, 1997 [541 ha], Willow, 1999 [25,091 ha]) portrayed only boundaries. We recognized that a boundary may be over-simplified, but severity maps for these fires were unavailable. We did not include more detailed pre- and post-fire habitat information in our analysis because our study focused on short-term effects of fire on survival and movements of owls rather than long-term habitat changes. No salvage logging or other major anthropogenic changes to vegetation within owl territories occurred between the time of the fire and the time we surveyed owls the following year.

We qualitatively described impacts of fire on survival, site fidelity, mate fidelity, and reproductive success of individuals and pairs because these were opportunistic observations taken over a long period of time. We pooled data across subspecies because sample sizes for each subspecies were small (≤4 territories) and we were describing observational responses rather than conducting comparative statistical analyses. We defined minimum survival rate as percent of individuals resighted alive at least 1 year after the fire ($n=21$ owls). We defined site fidelity as percent of individuals resighted alive within the same territory before the fire occurred and 1 year after the fire occurred ($n=18$ owls). We defined mate fidelity as percent of pairs that survived the fire ($n=7$ owl pairs) and both original pair members remained together (i.e., resighted in same territory as a social pair) 1 year after the fire occurred. Our evaluation of mate fidelity does not imply cause and effect if a pair-bond was broken. Rather, we interpreted it to mean only that a fire did not mediate a pair dissolution if they remained together. Reproductive success was defined as average number of fledglings per pair of owls that survived ($n=7$ owl pairs) 1 year after the fire occurred.

We compared overall estimates of annual adult spotted owl survival and reproductive success for each study area from our previous research (W. S. LaHaye, unpublished data; Seamans et al. 1999, Franklin et al. 2000) with qualitative findings from this study. Our previous survival estimates were based on mark-recapture estimators, whereas fire survival estimates were empirical estimates from a small sample size. Therefore, confidence limits for empirical estimates did not reflect uncertainty due to recapture probability. We compared short-term (1-year) reproductive success of owls surviving fires with general rates of owl reproduction. However, caution must be used when drawing conclusions about reproduction because spotted owl reproduction was more variable than survival and differences from overall averages could have been due to annual variation rather than effects of fire.

We also estimated overall annual site fidelity for each study area based on long-term data. We calculated annual site fidelity by dividing number of owls remaining on territories from year t to year t+1 by total number of owls surviving from year t to year t+1. Only banded, adult owls were used in site-fidelity calculations.

Results

Data were gathered from 4 study areas representing 38 observation years, >2,000 banded owls, >300 owl territories, and 7 wildfires. Wildfires occurred in 11 spotted owl territories (10 pairs and 1 single owl) during the period of investigation (1985-2001). Fires occurred in 4 northern, 3 California, and 4 Mexican spotted owl territories. All territories were >80% burned (83-100%). In all cases, nest and roost areas were burned. Four of 8 territories where fire severities were mapped burned primarily at low to moderate severity. However, the remaining 4 territories experienced fires that burned 36–88% of the territory at high-severity levels.

Eighteen of 21 (86%) individual owls affected by fires were resighted at least 1 year after the fires, and 16 of the 18 (89%) resighted owls were located in the same territories in the breeding season after the fire. Among 7 owl pairs in which both members were resighted after a fire, all were site- and mate-faithful. Among 3 individuals whose mates were never resighted, 2 females were resighted after the fire on different territories with different males, and 1 male exhibited site fidelity after the fire but was found paired with a different female. Four of 7 surviving owl pairs (57%) produced 7 fledglings the year following fire.

Minimum survival of spotted owls experiencing fires was similar to overall annual survival rates reported for the 3 subspecies (Table 1). Site fidelity among fire-impacted birds was also similar to overall estimates from the 4 demographic studies (Table 1). Reproductive success of spotted owls 1 year after fire occurred was higher than overall annual rates of reproduction (Table 1).

Table 1. Estimates (95% confidence intervals) of minimum post-fire survival, site fidelity, and average number of fledglings per pair for 21 spotted owls (*Strix occidentalis*) that experienced fire in their territories in northwestern California, southern California, Arizona, and New Mexico, compared with overall average annual survival, site fidelity, and average number of fledglings per pair for the 4 populations at the above locations, 1987–2001.

		Estimates			
		S.o. caurina	*S.o. occidentalis*	*S.o. lucida*	
Parameter	Post-fire estimates	NWC[a]	SC[b]	NM[c]	AZ[d]
Survival	0.86 (0.71–1.00) *n*=21	0.876 (0.84–0.91)	0.79 (0.76–0.81)	0.832 (0.78–0.89)	0.814 (0.72–0.91)
Site Fidelity	0.89 (0.74–1.00) *n*=18	0.88 (0.85–0.92)	0.91 (0.88–0.94)	0.90 (0.85–0.95)	0.92 (0.85–0.99)
Average no. fledglings/pair	1.0 (0.62–1.38) *n*=7 pairs	0.62 (0.56–0.68)	0.643 (0.59–0.69)	0.77 (0.70–0.84)	0.93 (0.86–1.0)

[a] Northwestern California: survival estimate from 1985–1998 (source: Franklin et al. 2000). Site fidelity estimate from 1985–2000; *n* = 42–68 owls per year for 15 years. Reproduction estimate from 1985–2001; *n* = 1019 pair observations.

[b] Southern California: survival estimate from 1987–1998 (source: W. S. LaHaye, unpublished data). Site fidelity estimate from 1987–1998; *n* = 35–93 owls per year for 11 years. Reproduction estimate from 1987–1998; *n* = 840 pair observations.

[c] New Mexico: survival estimate from 1991–1997 (source: Seamans et al. 1999). Site fidelity estimate from 1991–2000; *n* = 21–41 owls per year for 10 years. Reproduction estimate from 1991–2001; *n* = 203 pair observations.

[d] Arizona: survival estimate from 1991–1997 (source: Seamans et al. 1999). Site fidelity estimate from 1991–2000; *n* = 19–36 owls per year for 10 years. Reproduction estimate from 1991–2001; *n* = 241 pair observations.

Discussion

Results from previous studies on impacts of wildfires on spotted owls have been equivocal. In some cases, large stand-replacing wildfires appeared to have a negative impact on owl occupancy (Elliot 1985, MacCracken et al. 1996, Gaines et al. 1997). Other reports have suggested that low- to moderate-severity wildfires did not adversely impact spotted owls (Yasuda 1997, Scott 1998, Jenness 2000). Although high-severity fires may displace some owls from territories (Elliot 1985, Gaines et al. 1997), it was unknown whether birds moved or died because owls in these studies were not marked. Since we monitored fates of color-marked owls, we could derive modest inference on effects of fire on individual survival, site fidelity, mate fidelity, and reproductive success. In our study, fates of only 3 of 21 owls exposed to fire were unknown. Relatively large wildfires that burned nest and roost areas appeared to have little short-term effect on survival, site fidelity, mate fidelity, and reproductive success of spotted owls, as rates were similar to estimates independent of fire. While post-fire reproductive rates were higher than background rates for these populations, they were well within the range of variation seen in these populations. Most (6 of 8) territories burned $\geq$50% at low to moderate severity. Therefore, we hypothesize that spotted owls may have the ability to withstand the immediate, short-term (1-year) effects of fire occurring at primarily low to moderate severities within their territory.

Horton and Mannan (1988) noted that animals that occupied forests having frequent fire intervals should be adapted to repeated fires. While pre-settlement fire regimes of western forests consisted of frequent low-intensity burns, infrequent high-severity fires also occurred and were important determinants of forest structure, composition, and distribution (Agee 1990, Stephenson et al. 1991). Given historical fire regimes within its range, the spotted owl may be adapted to survive wildfires of various sizes and severities. Therefore, prescribed burning could be an effective tool in reducing current fire risk and restoring forests to natural conditions with minimal short-term impact to owls. However, we believe that programmatic prescribed burning in spotted owl territories cannot be justified solely on the observations we report here. Experiments testing effects of fire on spotted owls are still needed to corroborate the effects we observed, establish cause-and-effect relationships, and determine long-term impacts on spotted owls.

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Literature cited

AGEE, J. K. 1990. Natural and prescribed fire in Pacific Northwest forests. Oregon State University, Corvallis, USA.

AGEE, J. K. 1993. Fire ecology of Pacific Northwest forests. Island Press, Washington, D. C., USA.

BINGHAM, B.B., AND B. R. NOON. 1998. The use of core areas in comprehensive mitigation strategies. Conservation Biology 12:241-243.

BISWELL, H. H. 1989. Prescribed burning in California wildlands vegetation management. University of California, Berkeley, USA.

ELLIOT, B. 1985. Changes in distribution of owl species subsequent to habitat alteration by fire. Western Birds 16:25-28.

ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE. 1996. ArcView GIS, Version 3.2. Environmental Systems Research Institute, Redlands, California, USA.

FORSMAN, E. D. 1983. Methods and materials for locating and studying spotted owls. United States Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-162, Portland, Oregon, USA.

FORSMAN, E. D., A. B. FRANKLIN, F. M. OLIVER, AND J. P. WARD. 1996. A color band for spotted owls. Journal of Field Ornithology 67:507-510.

FRANKLIN, A. B., D. R. ANDERSON, E. D. FORSMAN, K. P. BURNHAM, AND F. W. WAGNER. 1996. Methods for collecting and analyzing demographic data on the northern spotted owl. Studies in Avian Biology 17:12-20.

FRANKLIN, A. B., D. R. ANDERSON, R. J. GUTIÉRREZ, AND K. P. BURNHAM. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California. Ecological Monographs 70:539-590.

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. Pages 123-129 *in* J. N. Greenlee, editor. Proceedings of the Fire Effects on Rare and Endangered Species and Habitats Conference, International Association of Wildfire and Forestry, Coeur D'Alene, Idaho, USA.

GANEY, J. L., AND R. P. BALDA. 1989. Home-range characteristics of spotted owls in northern Arizona. Journal of Wildlife Management 53:1159-1165.

HORTON, S. P., AND R. W. MANNAN. 1988. Effects of prescribed fire on snags and cavity-nesting birds in southeastern Arizona pine forests. Wildlife Society Bulletin 16:37-44.

JENNESS, J. S. 2000. The effects of fire on Mexican spotted owls in Arizona and New Mexico. Thesis, Northern Arizona University, Flagstaff, USA.

KILGORE, B. M. 1973. The ecological role of fire in Sierran conifer forests: its application to National Park management. Quaternary Research 3:496-513.

MACCRACKEN, J. G., W. C. BOYD, AND B. S. ROWE. 1996. Forest health and spotted owls in the eastern cascades of Washington. Pages 519-527 *in* K.G. Wadsworth and R. E. McCabe, editors. Facing realities in resource management. Transactions of the North American Wildlife and Natural Resources Conference, Special Session 7 Number 61.

MARSHALL, J. T. 1963. Fire and birds in the mountains of southern Arizona. Proceedings of the Tall Timbers Fire Ecology Conference 2:135-141.

MAY, C. A. 2000. Landscape scale analysis of Mexican spotted owl nest and roost habitat in central Arizona. Thesis, Humboldt State University, Arcata, California, USA.

MCMAHON T. E., AND D. S. DECALESTA. 1990. Effects of fire on fish and wildlife. Pages 233-248 *in* J. K. Agee, editor. Natural and prescribed fire in Pacific Northwest forests. Oregon State University, Corvallis, USA.

PEERY, M. Z., R. J. GUTIÉRREZ, AND M. E. SEAMANS. 1999. Habitat composition and configuration around spotted owl nest and roost sites in the Tularosa Mountains, New Mexico. Journal of Wildlife Management 63:36-43.

PEET, R. K. 2000. Forests and meadows of the Rocky Mountains. Pages 75-121 *in* M. B. Barbour and W. D. Billings, editors. North American Terrestrial Vegetation. Second edition. Cambridge University, New York, New York, USA.

ROBBINS, L. E., AND R. L. MYERS. 1992. Seasonal effects of prescribed burning in Florida: a review. Miscellaneous Publication No. 8, Tall Timbers Research, Inc., Tallahassee, Florida, USA.

ROMBOUT, P. J. A., J. A. M. A. DORMANS, L. VAN BREE, AND M. MARRA. 1991. Structural and biochemical effects in lungs of Japanese quail following a 1-week exposure to ozone. Environmental Research 54:39-51.

SAWYER, J. O., AND D. A. THORNBURGH. 1988. Montane and subalpine vegetation of the Klamath Mountains. Pages 699-732 *in* M. G. Barbour and J. Major, editors. Terrestrial vegetation of California. Second edition. California Native Plant Society, Sacramento, USA.

SAWYER, J. O., D. A. THORNBURGH, AND J. R. GRIFFIN. 1988. Mixed evergreen forest. Pages 359-382 *in* M. G. Barbour and J. Major, editors. Terrestrial vegetation of California. Second edition. California Native Plant Society, Sacramento, USA.

SEAMANS, M. E., R. J .GUTIÉRREZ, C. A. MAY, AND M. Z. PEERY. 1999. Demography of two Mexican spotted owl populations. Conservation Biology 13:744-754.

SCOTT, J. E. 1998. The Clark Peak fire. Arizona Wildlife Views 41: 13-15.

SMITH, J. K., editor. 2000. Wildland fire in ecosystems: effects of fire on fauna. United States Forest Service, Rocky Mountain Research Station, General Technical Report RM-42, Ogden, Utah, USA.

SMITH, R. B., W. S. LAHAYE, R. J. GUTIÉRREZ, AND G. S. ZIMMERMAN. 2002. Spatial habitat characteristics of an insular spotted owl population in southern California. Pages 137-147 *in* I. Newton, R. Kavanagh, J. Olson, and I. Taylor, editors. Ecology and conservation of owls. CSIRO Publishing, Victoria, Australia.

STEPHENSON, N. L., D. J. PARSONS, AND T. W. SWETNAM. 1991. Restoring natural fire to the Sequoia-mixed conifer forest: should intense fire play a role? Proceedings of the Tall Timbers Fire Ecology Conference 17:321-337.

THORNE, R. F. 1988. Montane and subalpine forests of the Transverse and Peninsular Ranges. Pages 537-558 *in* M. G. Barbour and J. Major, editors. Terrestrial vegetation of California. Second edition. California Native Plant Society, Sacramento, USA.

UNITED STATES FISH AND WILDLIFE SERVICE. 1992. Recovery plan for the northern spotted owl: draft. United States Department of Interior, Fish and Wildlife Service, Portland, Oregon, USA.

UNITED STATES FISH AND WILDLIFE SERVICE. 1995. Recovery plan for the Mexican spotted owl. Volume I. United States Department of Interior, Fish and Wildlife Service, Albuquerque, New Mexico, USA.

VERNER, J. K., S. MCKELVEY, B. R. NOON, R. J. GUTIÉRREZ, G. I. GOULD, T. W. BECK, TECHNICAL COORDINATORS. 1992. The California spotted owl: a technical assessment of its current status. United States Department of Agriculture, Forest Service, Pacific Southwest Research Station, General Technical Report PSW-133, Albany, California, USA.

WEATHERSPOON, C. P., S. J. HUSARI, AND J. W. VAN WAGTENDONK. 1992. Fire and fuels management in relation to owl habitat in forests of the Sierra Nevada and Southern California. Pages 247-260 *in* J. K Verner, S. McKelvey, B. R. Noon, R. J. Gutiérrez, G. I. Gould, T. W. Beck, technical coordinators. The California spotted owl: a technical assessment of its current status. United States Department of Agriculture, Forest Service, Pacific Southwest Research Station, General Technical Report PSW-133, Albany, California, USA.

YASUDA, D. 1997. Report on prescribed burning and spotted owls. Page 4 *in* L. Larson and T. Locker, editors. Resource management: the fire element newsletter. California Fuels Committee, United States Department of Agriculture, Forest Service, Pacific Southwest, San Francisco, California, USA.

ZABEL, C. J., K. MCKELVEY, AND J. P. WARD, JR. 1995. Influence of primary prey on home-range size and habitat-use patterns of northern spotted owls (*Strix occidentalis caurina*). Canadian Journal of Zoology 73:433-439.

ZIMMERMAN, G. S., W. S. LAHAYE, AND R. J. GUTIÉRREZ. 2001. Breeding season home ranges of spotted owls (*Strix occidentalis occidentalis*) in the San Bernardino Mountains, California. Western Birds 32:83-87.

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