WINTER MOVEMENTS BY CALIFORNIA SPOTTED OWLS IN A BURNED LANDSCAPE

MONICA L. BOND, DEREK E. LEE, and RODNEY B. SIEGEL, The Institute for Bird Populations, P. O. Box 1346, Point Reyes Station, California 94956; monibond@gmail.com

ABSTRACT: The movements and habitat requirements of the California Spotted Owl (*Strix occidentalis occidentalis*) during the nonbreeding season remain poorly understood in comparison with those during the breeding season, and no data are available on the subspecies' use of burned landscapes in fall and winter. From October 2006 to March 2007, we estimated the locations of daytime roosts of five radio-marked California Spotted Owls in an area of the southern Sierra Nevada that burned in a 60,985-ha wildfire 4 years previously. Our objectives were to determine whether these owls expanded their movements during the nonbreeding season and whether they roosted in the area burned. During the nonbreeding season, two males increased the distance between locations of successive roosts while still remaining within their breeding-season ranges. One pair migrated from its breeding territory for the winter but returned by 1 March. One female dispersed to a new breeding territory. Three of the five owls roosted in burned landscapes during the nonbreeding season, and 30% of all roost locations were within the fire's perimeter. Burned forests may therefore represent important winter habitat for the California Spotted Owl.

The California Spotted Owl (*Strix occidentalis occidentalis*) is an important species for management in the Sierra Nevada and southern California because it is strongly associated with older coniferous forests for nesting, roosting, and foraging (Gutiérrez et al. 1992, Blakesley et al. 2005, Seamans 2005). Spotted Owl populations are highly sensitive to reductions in adult survival (Noon et al. 1992), and mortality of adults is greatest in winter (Franklin et al. 2000, Seamans and Gutiérrez 2007), yet the species' needs for winter habitat are seldom considered in efforts at management (Laymon 1989). Severe fire is invoked as one of the primary threats to the Spotted Owl because of its potential to eliminate suitable habitat (Weatherspoon et al. 1992, SEI 2004). Bond et al. (2009), however, found that during the breeding season California Spotted Owls with burned areas in their home ranges forage preferentially in severely burned forest, suggesting that severe fire may enhance short-term habitat suitability under certain circumstances, possibly by increasing the abundance of prey or the owls' access to it.

Only three studies in the Sierra Nevada have documented habitat use of the California Spotted Owl with radio-telemetry during the nonbreeding season (Laymon 1989, Zabel et al. 1992, Call et al. 1992), but none of these studies took place in a burned landscape. Management of burned forests to conserve the Spotted Owl requires understanding how individuals use such habitat year round because in fall and winter home ranges sometimes expand to incorporate habitats different from those within the breeding range (Laymon 1989, Zabel et al. 1992). Yet the winter habits and habitat requirements of the Spotted Owl in the Sierra Nevada remain poorly understood in comparison to those in the breeding season, and in burned landscapes they are virtually unstudied.

From the air, we estimated the locations of the daytime roosts of five

radio-marked California Spotted Owls biweekly during the nonbreeding season (Oct–Mar) in an area that burned in a large wildfire 4 years prior to our study. Our specific objectives were to determine if during the nonbreeding season these owls (1) remained in their breeding ranges, enlarged or shifted their home ranges, or migrated to new areas and (2) whether they roosted in burned landscapes.

METHODS

Study Area

Our study took place in the Greenhorn Mountains, Sequoia National Forest, southern Sierra Nevada, California, at elevations from 1500 to 2500 m. From 1971 to 2000, annual precipitation at the nearest National Weather Service weather station, at Johnsondale (1427 m), averaged 57 cm. The vegetation is Sierran mixed conifer forest (Allen 1988), dominated by ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*P. jeffreyi*), and white fir (*Abies concolor*). Above 2100 m, a transition zone is dominated by red fir (*A. magnifica*). Other common trees include the sugar pine (*P. lambertiana*), incense cedar (*Calocedrus decurrens*), canyon live oak (*Quercus chrysolepis*), and California black oak (*Q. kelloggii*). In July and August of 2002, the McNally Fire burned approximately 60,985 ha in the Sequoia and Inyo national forests, including 33,704 ha of conifer-dominated forests (Odion and Hanson 2006). Like most forest fires, the McNally Fire burned with variable severity, leaving a mosaic of disturbance in the study area.

Capturing and Tracking Owls

Using techniques described by Bond et al. (2009), we captured and radio-marked three male and two female Spotted Owls in three burned territories. These birds were a subsample of the Spotted Owls that had been radio-tracked from May to September 2006 as part of a study of selection of foraging habitat during the breeding season (Bond et al. 2009). We affixed backpack-style radio transmitters designed to minimize contact with the owl's back (AVM Instrument Company, Ltd., Colfax, CA) with Kevlar ribbon (0.63 cm wide; Bally Ribbon Mills, Bally, PA). We sewed the transmitter in place with cotton thread to allow it to be lost within 12–24 months, if we failed to recapture a marked owl and remove the transmitter. With the harness, our transmitter units weighed <20 g, or <4% of each owl's body mass.

Verner et al. (1992) reported that some adult Spotted Owls begin their fall migration early in October. Therefore, we defined the nonbreeding season as beginning on 1 October. During the breeding season (May–September 2006), we visually located Spotted Owls at roosts or nests every 7–10 days by following the strongest signal to the owl's roost or nest site. We used hand-held three-element collapsible directional Yagi antennas and portable receivers supplied by AVM Instrument Company and Telonics (Mesa, AZ) for deciphering signal strength and direction. During the nonbreeding season from 11 October 2006 to 23 March 2007 (January excluded for logistical reasons), we used a Cessna 182 fixed-wing aircraft with an ATS 1000/4

Element Yagi receiver and antennae to locate radio-marked owls every other week. We estimated the error of the telemetry by placing three transmitters at known locations and having a naïve observer estimate their locations from the aircraft on five separate occasions. The average error was 673 m (standard error 118 m, range 79–1585 m, $n = 15$). We recaptured all five owls and removed their backpack transmitters at the end of the study (May 2007).

Data Analysis

We compared the dispersion of locations of successive Spotted Owl roosts in the breeding and nonbreeding seasons to determine whether owls remained in their breeding ranges, enlarged or shifted their ranges, or migrated during the nonbreeding season. We calculated dispersion as the mean of the linear distances between each owl's successive roosts; larger values indicate greater dispersion (Conner and Leopold 2001). We used a one-tailed repeated-measures t test to compare dispersion by season because we expected nonbreeding-season movements to be greater on the basis of previous studies (Laymon 1989, Zabel et al. 1992). If an owl moved significantly farther from roost to roost during the nonbreeding season than during the breeding season, we presumed that it had enlarged or shifted its breeding-season range. If during the nonbreeding season an owl moved >10 km from the center of its breeding-season territory, we considered it to have migrated.

Because of substantial radio-telemetry error during the nonbreeding season, we could not describe use of roosting habitat at a fine scale. Therefore, we described whether each Spotted Owl roost was inside, on the edge, or outside the fire's perimeter. To define the fire's perimeter, we used digital maps of the severity with which vegetation burned, generated by the U.S. Forest Service (Region 5 Remote Sensing Lab, Sacramento, CA; see Bond et al. 2009). We plotted roosting owls' estimated locations with ArcMap 9.1 (ESRI, Redlands, CA). The overall accuracy of the fire-severity map was 93% correct, as determined by vegetation sampling at 80 randomly located sites within the breeding-season ranges of foraging Spotted Owls (Bond et al. 2009).

We identified breeding-season roosts by visually locating the owl, so we plotted the exact locations as either outside or inside the fire's perimeter without the need to incorporate any telemetry error. On the basis of our average telemetry error during the nonbreeding season, we defined an error circle with a radius of 673 m around each estimated roost location to categorize the location as either outside or inside the fire's perimeter. We categorized locations where the error circle included the perimeter as "edge" roosts. Thus each location was categorized as (1) within the fire perimeter (>673 m inside), (2) at the edge of the fire (within 673 m of the edge, either outside or inside), (3) outside the fire (>673 m from the perimeter but within 10 km of the center of the breeding-season territory), or (4) that the owl had migrated (moved >10 km from the center of the breeding-season territory). We defined the center of an owl's breeding-season territory as the tree in which it nested in 2006 (all pairs attempted to nest, as determined by behavior and evidence of brood patches on females).

RESULTS

During the breeding season (May–September 2006) we identified 7 to 11 daytime roost locations per Spotted Owl (mean = 9), for a total of 45 roosting locations. One male owl's (Mill Creek) nest tree and all daytime roost locations were outside the perimeter of the fire but within 1 km of it, giving this owl access to burned habitat (Bond et al. 2009). The nest tree and roost locations of the other two pairs (Speas Ridge and Burnt Ridge) were located primarily within the fire's perimeter (Bond et al. 2009). During the nonbreeding season, we estimated nine roost locations per owl from 11 October 2006 to 23 March 2007, excluding two fall locations for the Speas Ridge male (pilot had the incorrect radio frequency), for a total of 43 locations.

Our sample of five Spotted Owls moved a mean of 625 m (SE [standard error] 136 m) between successive roost locations during the breeding season and 2468 m (SE 613 m) during the nonbreeding season. For all five, movements between successive roost locations were significantly greater during the nonbreeding season than during the breeding season ($t = -2.78$, df = 4, $P = 0.02$).

One female (Burnt Ridge) moved 2.6 km from the center of her breeding-season territory on 12 September, roosted >1800 m apart from her mate of 2006 for the duration of the nonbreeding season, and was relocated the following spring in a different territory >4 km from the 2006 breeding territory. Two males (Burnt Ridge and Mill Creek) expanded their movements during the nonbreeding season while still remaining within 10 km of their nests of 2006. One pair (Speas Ridge) migrated approximately 13 km southeast of the center of their breeding-season territory from mid-December to mid-February before returning to their previous breeding territory. During the breeding season, the mean distance between same-day roosts of the male and female of the Speas Ridge pair was 406 m (SE 255, range 0–1582 m, $n = 7$). This distance was strongly influenced by one instance on 29 August when the pair roosted 1582 m apart; from May through July these owls roosted in the same tree on three occasions and 35 and 51 m apart on two occasions. During the nonbreeding season, the mean distance between same-day roosts of the male and female was 2801 m (SE 1350, range 116–9852 m, $n = 7$), suggesting that this pair roosted separately more often in the nonbreeding season than during the breeding season.

Of the 45 locations of breeding-season roosts, 29 (64%) were inside the fire perimeter and 16 were outside. During the breeding season, when ground-based telemetry allowed us to identify actual roost trees, we found that all roosts within the fire's perimeter were in burned stands. Of 43 error circles for roosts in the nonbreeding season, 13 (30%) were located entirely within the burned area, 8 (19%) were near the fire's perimeter, and 22 (51%) were completely outside the burned area (Table 1). Two of the five owls roosted mostly inside the fire's perimeter (Speas Ridge male and female), and two roosted mostly outside the perimeter (Burnt Ridge female and Mill Creek male), while 1 owl's roost locations were equally distributed between sites inside and on the edge of the perimeter (Burnt Ridge male). Because of the substantial error associated with aerially based estimates,

Table 1 Dates and Roosting Locations of Five Radio-Marked California Spotted Owls with Respect to the 2002 McNally Fire, Sequoia National Forest, Sierra Nevada, during the Nonbreeding Season, 2006–2007[a]

Date	Mill Creek male	Speas Ridge male	Speas Ridge female	Burnt Ridge male	Burnt Ridge female
11 Oct 2006	Out	—	Edge	Edge	Edge
25 Oct 2006	Out	—	Edge	Edge	Out
22 Nov 2006	Out	In	In	Out	Out
7 Dec 2006	Edge	In	In	In	Out
20 Dec 2006	Out	Migrated	Migrated	Edge	Out
3 Feb 2007	Out	Migrated	Migrated	In	Out
14 Feb 2007	Out	Migrated	In	Edge	Out
1 Mar 2007	Out	In	In	In	Out
23 Mar 2007	Out	In	In	In	Out

[a]In, >673 m inside fire's perimeter; edge, ≤673 m from perimeter, either outside or inside; out, >673 m outside of perimeter but ≤10 km from center of breeding-season territory; migrated, >10 km from center of breeding-season territory.

during the nonbreeding season we were unable to assess the severity of the fire at locations where the owls roosted within the perimeter.

DISCUSSION

During the winter, these five radio-tracked Spotted Owls either increased their movements or migrated fully out of their breeding-season territory. One female moved permanently in an apparent instance of dispersal. In the spring following this study, this female was resighted in a new territory, while her former mate remained on their 2006 breeding territory and was paired with a new, unbanded female.

Our results from a burned study area are similar to those reported from unburned sites. In the Eldorado National Forest of the central Sierra Nevada, Laymon (1989) found that 8 of 10 California Spotted Owls migrated downslope during the winter, whereas none of the 4 owls in the adjacent Tahoe National Forest monitored by Call et al. (1992) migrated. In the Sierra National Forest of the southern Sierra Nevada, Zabel et al. (1992) reported that 7 of 21 owls enlarged or shifted their home ranges and 5 migrated during the nonbreeding season. It remains unknown why some individual owls migrate, shift, or enlarge their ranges and others do not, as no correlation between migration patterns and habitat quality or quantity as defined by vegetation has been found (Verner et al. 1992). Zabel et al. (1992) suspected that the size of the California Spotted Owl's home range may be correlated with variation in its prey, with larger ranges associated with a greater proportion of the northern flying squirrel (*Glaucomys sabrinus*) and smaller ranges associated with a greater proportion of the dusky-footed or big-eared woodrats (*Neotoma fuscipes* and *N. macrotis*). Owls may be enlarging ranges or migrating in response to availability of prey. Patterns of the California Spotted Owl's movement in burned areas in the nonbreeding season appear to be as varied as those in unburned areas. Nonetheless, the

expansion of movements, as attested by greater distances between successive roost locations during the nonbreeding season in postfire landscapes, underscores the importance of identifying and conserving winter habitat in addition to that used during the breeding season.

During the nonbreeding season, three of five Spotted Owls roosted within the burned landscape to some degree (Table 1). During the breeding season, this sample of Spotted Owls typically roosted in unburned or lightly burned forest but foraged selectively in severely burned areas close to the territory center (Bond et al. 2009). Spotted Owls often roost near where they foraged the previous night (Guetterman et al. 1991), which may be particularly true during the nonbreeding season when adults are not required to return to a nest to provision young. Thus Spotted Owls that roost in the burned landscape during the nonbreeding season may be continuing to forage in the burned areas throughout the fall and winter. These burned forests may represent important habitat for the California Spotted Owl during both the breeding and nonbreeding seasons.

Further studies of the Spotted Owl's habitat use during the nonbreeding season, as well as research on the population dynamics of key prey species, are needed in both burned and unburned landscapes for a better understanding of how patterns of landscape disturbance affect the owl's pattern of movement in fall and winter.

ACKNOWLEDGMENTS

We thank R. van Wagenen of Ecoscan Resources, Watsonville, California, for obtaining roost locations for this study. W. Rannals and R. Galloway of the Sequoia National Forest provided Spotted Owl locations prior to our field work and offered valuable input and field support during our study. The U.S. Forest Service's Region 5 Remote Sensing Lab supplied GIS data. P. Carlson and D. Wiens provided valuable suggestions for improving the manuscript. This study was funded by a grant from the Resources Legacy Fund Foundation awarded to The Institute for Bird Populations (IBP) and was conducted by IBP's Sierra Nevada Bird Observatory. This is contribution 367 of The Institute for Bird Populations.

LITERATURE CITED

Allen, B. 1988. Sierran mixed conifer, in A Guide to Wildlife Habitat Relationships (K. E. Mayer and W. F. Laudenslayer, eds.), pp. 46–47. California Dept. Fish and Game, Sacramento.

Blakesley, J. A., Noon, B. R., and Anderson, D. R. 2005. Site occupancy, apparent survival, and reproduction of California Spotted Owls in relation to forest stand characteristics. J. Wildlife Mgmt. 69:1554–1564.

Bond, M. B., Lee, D. L., Siegel, R. S., and Ward, J. P. 2009. Habitat use and selection by California Spotted Owls in a postfire landscape. J. Wildlife Mgmt. 73:1116–1124.

Call, D. R., Gutiérrez, R. J., and Verner, J. 1992. Foraging habitat and home-range characteristics of California Spotted Owls in the Sierra Nevada. Condor 94:880–888.

Conner, L. M., and Leopold, B. D. 2001. A Euclidean distance metric to index dispersion from radiotelemetry data. Wildlife Soc. Bull. 29:783–786.

Franklin, A. B., Anderson, D. R., Gutiérrez, R. J., and Burnham, K. P. 2000. Climate, habitat quality, and fitness in Northern Spotted Owl populations in northwestern California. Ecol. Monogr. 70:539–590.

Guetterman, J. H., Burns, J. A., Reid, J. A., Horn, R. B., and Foster, C. C. 1991. Radio telemetry methods for studying Spotted Owls in the Pacific Northwest. U. S. Forest Service Gen. Tech. Rep. PNW-GTR-272.

Gutiérrez, R. J., Verner, J., McKelvey, K. S., Noon, B. R., Steger, G. N., Call, D. R., LaHaye, W. S., Gingham, B. B., and Senser, J. S. 1992. Habitat relations of the California Spotted Owl, in The California Spotted Owl: a technical assessment of its current status (J. Verner, K. S. McKelvey, B. R. Noon, R. J. Gutiérrez, G. I. Gould, Jr., and T. W. Beck, eds.), pp. 79–99. U. S. Forest Service, Pacific Southwest Res. Sta. PSW-GTR-133.

Laymon, S. A. 1989. Altitudinal migration movements of Spotted Owls in the Sierra Nevada, California. Condor 91:837–841.

Noon, B. R., McKelvey, K. S., Lutz, D. W., LaHaye, W. S., Gutiérrez, R. J., and Moen, C. A. 1992. Estimates of demographic parameters and rates of population change, in The California Spotted Owl: a technical assessment of its current status (J. Verner, K. S. McKelvey, B. R. Noon, R. J. Gutiérrez, G. I. Gould, and T. W. Beck, eds.), pp. 175–186. U. S. Forest Service, Pacific Southwest Res. Sta. PSW-GTR-133.

Odion, D. C., and Hanson, C. T. 2006. Fire severity in conifer forests of the Sierra Nevada, California. Ecosystems 9:1177–1189.

Seamans, M. E. 2005. Population biology of the California Spotted Owl in the central Sierra Nevada. Ph.D. dissertation, Univ. of Minn., St. Paul.

Seamans, M. E., and R. J. Gutiérrez. 2007. Sources of variability in Spotted Owl population growth rate: testing predictions using long-term mark–recapture data. Oecologia 152:57–70.

SEI (Sustainable Ecosystems Institute). 2004. Scientific evaluation of the status of the northern Spotted Owl. Sustainable Ecosystems Inst., Portland, OR.

Verner, J., Gutiérrez, R. J., and Gould, G. I., Jr. 1992. The California Spotted Owl: General biology and ecological relations, in The California Spotted Owl: a technical assessment of its current status (J. Verner, K. S. McKelvey, B. R. Noon, R. J. Gutiérrez, G. I. Gould, and T. W. Beck, eds.), pp. 55–77. U. S. Forest Service, Pacific Southwest Res. Sta. PSW-GTR-133.

Weatherspoon, C. P, Husari, S. J., and van Wagtendonk, J. W. 1992. Fire and fuels management in relation to owl habitat in forests of the Sierra Nevada and southern California, in The California Spotted Owl: a technical assessment of its current status (J. Verner, K. S. McKelvey, B. R. Noon, R. J. Gutiérrez, G. I. Gould, and T. W. Beck, eds.), pp. 247–260. U. S. Forest Service, Pacific Southwest Res. Sta. PSW-GTR-133.

Zabel, C. J., Steger, G. N., McKelvey, K. S., Eberlein, G. P., Noon, B. R., and Verner, J. 1992. Home-range size and habitat-use patterns of California Spotted Owls in the Sierra Nevada, in The California Spotted Owl: a technical assessment of its current status (J. Verner, K. S. McKelvey, B. R. Noon, R. J. Gutiérrez, G. I. Gould, and T. W. Beck, eds.), pp. 149–163. U. S. Forest Service, Pacific Southwest Res. Sta. PSW-GTR-133.

Accepted 21 July 2010