Spotted Owls and forest fire: A systematic review and meta-analysis of the evidence

DEREK E. LEE, 1 Wild Nature Institute, 15 North Main Street, Concord, NH 03302, USA

Appendix S1

Figure S1. Funnel plot of all reported effects of mixed-severity fire on Spotted Owl (Strix occidentalis) parameters illustrating no publication bias or unusual heterogeneity exists.

Descriptions of papers

1. Bond et al. (2002) was an examination of survival, reproduction, and site and mate fidelity of northern (S. o. caurina), California (S. o. occidentalis), and Mexican Spotted Owls (S. o. lucida) 1 year after fire. Short-term (1-year) postfire survival of 21 color-banded Spotted Owls was reported from four separate study areas encompassing all subspecies: in northwestern California, southern California, New Mexico, and Arizona. All nest and roost areas were burned, and no post-fire logging had occurred before owls were surveyed the year after fire. Vegetation burn severity maps were available for 8 of the 11 breeding sites, with each breeding site defined as a circle approximately 150–400 ha, depending on study area. Half of the breeding sites where fire severities were mapped burned at low to moderate severity, and the other half burned 36–88% at high severity. The authors found that 18 of 21 (86%) individual owls were resighted after fire. These survival rates are higher (+0.03) than the mean from unburned sites. Sixteen of 18 (89%) surviving owls (of all subspecies) were in the same breeding sites after fire (-0.01),

1 Email: derek@wildnatureinstitute.org
and all pairs were faithful to their pre-fire breeding site and mate. Productivity of burned Spotted Owl sites was higher (+0.26) than mean annual rates of reproduction for long-unburned sites.

2. Jenness et al. (2004) reported pre- and post-fire occupancy of 64 Mexican Spotted Owl sites in four national forests in New Mexico and Arizona. The authors selected owl breeding sites in fires that burned from 1993 to 1996 and compared levels of occupancy (single, pair, failed reproduction, and successful reproduction) in 1997 in 33 burned and 31 unburned sites, including 29 paired burned and long-unburned sites within 12 km of each other. Post-fire logging was minor in most of the fires. Post-fire occupancy rates were not significantly different between burned and unburned sites and did not statistically differ with time since fire. The percent of high-severity fire in a burned site had no significant influence on whether the site was occupied. The number of successfully reproducing Mexican Spotted Owl sites did not differ between burned and unburned forests. Non-significant effects included lower occupancy (-0.14) and lower reproduction (-0.07) in burned sites.

3. Bond et al. (2009) quantified roosting and foraging habitat selection by Spotted Owls in a burned landscape. The authors banded and radiomarked 7 California Spotted Owls occupying the McNally Fire in the southern Sierra Nevada, California 4 years after fire. Effects of high-severity fire were not confounded with post-fire logging because <3% of the foraging ranges of these owls had been post-fire logged. The probability of an owl using a site for foraging was significantly greater in low- (+0.33), moderate- (+0.42), and high-severity (+0.42) burned forests than unburned forest. In this study, California Spotted Owls roosted in all fire intensity classes. Owls selected roost sites burned at low severity (+0.29) and avoided unburned sites and sites burned at moderate (-0.13) and high severity (-0.28).

4. Bond et al. (2010) documented 3 of 5 radiomarked California Spotted Owls that occupied the McNally Fire in the southern Sierra Nevada during the breeding season 4 years post-fire, roosted within the burned landscape during the following winter.

5. Clark et al. (2011) examined the survival rates of northern Spotted Owls 3–4 years after fire and postfire logging in two fire areas in southwestern Oregon. Twelve (12) owls were radiomarked in unburned forest and 11 owls were radiomarked inside the burn perimeter where much of the forest (20–23%) had been post-fire logged. The authors found no significant effect of fire severity or quantity of forested habitat on Spotted Owl survival. Six of the owls monitored in unburned forest were known to have moved outside the fire perimeter after fire and salvage logging, but before survival monitoring took place. In the original paper, the authors considered the owls that moved similar to the owls inside the fire perimeter. I combined all outside-the-burn owls to compare with inside-the-burn owls. Non-significant effects: owls that resided within the post-fire logged landscape had lower survival rates (-0.07) than those residing in unburned unlogged forest.

6. Roberts et al. (2011) compared effects of wildfire and prescribed burns on occupancy of California Spotted Owls residing in burned (1 to 15 years since fire) and long-unburned forests in Yosemite National Park, central Sierra Nevada, California. This study compared occupancy in 16 randomly selected burned and 16 unburned ‘owl survey areas,’ each 3.75 km². A total of 19 owl pairs were monitored for a single year, and vegetation at owl sites was compared with sites that yielded no owl response to build detectability and occupancy models. The mean ‘owl survey area’ that burned at high severity was 14%, with the greatest amount of high-severity burn in a survey area being 52%. Because this study was conducted in a national park, no post-fire or recent pre-fire logging had occurred to confound results.
The authors found no support for a model of occupancy rates that distinguished between burned and unburned sites. Non-significant effects: occupancy from model based on canopy cover and basal area was lower at burned versus unburned sites (-0.26).

7. Lee et al. (2012) published an 11-year longitudinal study of California Spotted Owl occupancy on national forest lands in the Sierra Nevada, California. The authors used data collected by the U.S. Forest Service to compile occupancy survey histories at 41 breeding sites within six large mixed-severity fires that occurred from 2000 to 2007 throughout the Sierra Nevada and at 145 long-unburned control sites. Fires had no significant effect on occupancy probability. Non-significant effects: occupancy probability was higher in burned sites (+0.041) relative to unburned. Post-fire logging occurred in an unknown number of territories.

8. Bond et al. (2013) found Spotted Owls in the McNally Fire area, southern Sierra Nevada, California fed primarily on pocket gophers (*Thomomys* spp., 40.3% by biomass) and northern flying squirrels (*Glaucomys sabrinus*, 25.9% by biomass), whereas owls fed primarily on flying squirrel and woodrats (*Neotoma* spp.) in long-unburned study areas. The mean home-range sizes of the McNally Fire owls were 12% smaller than those recorded in unburned forests using similar time periods and methodology.

9. Clark et al. (2013) investigated the occupancy dynamics of northern Spotted Owls in burned and salvage-logged landscapes in three fire areas and an adjacent long-unburned demographic study area in the southern Oregon Cascade Mountains. The three fires all burned within 1 year of each other. Modeled occupancy rates of 103 Spotted Owl sites in the long-unburned area were compared with 40 burned sites before and after fire and post-fire logging occurred. Post-fire logging was prevalent, thus it was not possible to quantify the influence of fire alone on occupancy dynamics and survival. Occupancy probability declined more steeply after post-fire logging than in the unburned area (-0.39).

10. Lee et al. (2013) used Spotted Owl survey data from 97 long-unburned and 71 burned breeding sites over 8 years to examine the influence of fire and post-fire logging on local rates of extinction, colonization, and occupancy probability. Post-fire logging occurred on 21 of the burned sites. None of the fire and logging coefficients were statistically significant. Non-significant effects: model-averaged effect sizes suggested that high-severity fire that burned >50% of forest in the 203-ha core area was correlated with lower occupancy relative to unburned sites. Post-fire logging further increased extinction probability. The majority (75%) of sites burned below the 50% threshold. Non-significant effects: burned site occupancy -0.062 lower than unburned sites. Post-fire-logged sites occupancy -0.05 lower than unlogged burned sites.

11. Ganey et al. (2014) reported a sample of 4 radiomarked Mexican Spotted Owls in the Sacramento Mountains, New Mexico, moved to wintering areas that had burned 4–6 years earlier and that had 2–6 times greater abundance and biomass of small mammal prey than nest core areas associated with those owls.

12. Tempel et al. (2014) used data from a long-term (>20 years) demographic study of California Spotted Owls in the Eldorado and Tahoe national forests of the central Sierra Nevada, California to examine the influence of timber harvest and wildfire on reproduction, survival, and occupancy over a 6-year timescale using data from 74 breeding sites. Twelve (12) breeding sites experienced fire during the course of the study. Fire did not significantly affect survival, reproduction, or site extinction. The coefficient for the effect of fire on site colonization was negative, but the standard error of the
coefﬁcient could not be estimated making this parameter estimate of low quality. The authors reported lower occupancy (-0.06) when fire frequency was doubled in simulations that assumed zero post-ﬁre colonization. Post-ﬁre logging occurred on public and private lands in the study territories, but was not reported.

13. Lee and Bond (2015a) examined California Spotted Owl site occupancy in the 2013 Rim Fire near Yosemite National Park, which was the largest ﬁre in recent recorded Sierra Nevada history, burning more than 100,000 ha. The ﬁres burned through 45 known Spotted Owl breeding sites in the Stanislaus National Forest and all sites were surveyed by U.S. Forest Service personnel the following year. For all detections, 100% severe ﬁre surrounding nest and roost sites decreased occupancy probability (-0.04), but did not affect occupancy by pairs of owls. Single-season modeled occupancy rates 1 year after the Rim Fire were signiﬁcantly higher (+0.175) than other previously published occupancy rates in long-unburned forests.

14. Lee and Bond (2015b) examined how the quality of a site inﬂuenced California Spotted Owl occupancy and reproduction after ﬁre in southern California (using the same dataset as Lee et al. 2013). Site quality was measured by whether the site supported a single owl, pair of owls, or pair of owls with offspring the previous year. Amount of severe ﬁre in a core use area was not a signiﬁcant variable inﬂuencing reproduction. The inﬂuence of severe ﬁre on occupancy was minor in sites that had been occupied and reproductive the previous year (high quality), and if a site remained occupied, severe ﬁre did not affect the probability of reproduction compared with unburned sites. Occupancy of high-quality sites (previously reproductive) that burned was -0.02 lower than unburned sites. Occupancy of high-quality sites that were post-ﬁre logged was -0.03 lower. Occupancy of low-quality sites (previously non-reproductive) was -0.19 lower in burned versus unburned sites, and -0.26 lower after post-ﬁre logging.

15. Bond et al. (2016) analyzed foraging habitat selection by 8 radiomarked California Spotted Owls in the Slide Fire in the San Bernardino National Forest of southern California 3 and 4 years after ﬁre. Habitat selection with sensitivity analysis at three spatial extents of available habitat showed owls used forests burned at all severities in proportion to their availability (no signiﬁcant effects), with the exception of signiﬁcant selection for moderately burned forest (+0.03) farther from core areas.

16. Comfort et al. (2016) examined foraging habitat selection by 23 radiomarked Northern Spotted Owls in the Timbered Rock Fire in southwest Oregon in relation to edges created by ﬁre and post-ﬁre logging. Because post-ﬁre logging occurred immediately following ﬁre on extensive private lands in the study area, and their remote-sensing methodology could not distinguish between ﬁre and post-ﬁre logged areas, the authors created a combined burned–logged variable called the ‘disturbance severity.’ The edges between forested habitats and burned–logged areas were deﬁned as ‘hard’ edges. At smaller spatial scales (3.2 and 51.8 ha surrounding telemetry locations), increases in disturbance severity decreased the probability of use, but at larger spatial scales (829 ha), the opposite was true. The use of a location for foraging was maximized when about 20% of a 3.2-ha area surrounding the location was composed of hard edge. Owls avoided areas with larger amounts of hard edge, but selected smaller amounts of edge. Larger, more contiguous hard edges were described as intensively managed edges created by post-ﬁre logging.

17. Jones et al. (2016) reported on breeding site occupancy dynamics from 15 unburned and 30 burned sites (14 of which burned >50% high severity), and foraging habitat selection for 9 owls, in the Eldorado National Forest, central Sierra Nevada, California after the King Fire of 2014. Occupancy declined in
burned sites relative to unburned, and >50% high-severity burn further reduced occupancy. Foraging habitat selection showed owls significantly avoided high-severity burn and a non-significant preference for low-severity burn.

I included the results from this paper in my review, however methodological difficulties in this study make their results unreliable. First, the Eldorado owl population that provided the data for Jones et al. (2016) has documented long-term trends of decreasing site colonization and increasing site extinction probabilities, as reported before the King Fire (Tempel and Gutiérrez 2013). However, Jones et al. did not account for these pre-fire trends in their site occupancy analyses. This omission of temporal trends means their results for 2015 could be due to the fact that this single year of post-fire data was the last year in the dataset, and should not be attributed unequivocally to the King Fire. Fig. 3f shows that the 2015 post-fire year of decrease in occupancy was not significantly different from the 10 previous instances of documented declines that occurred in the absence of fire. Second, Jones et al. (2016) used compositional analysis of foraging habitat selection, a method that is inappropriate for central place foragers like Spotted Owls (Rosenberg and McKelvey 1999). Compositional analysis relies upon an assumption of no spatial correlation among foraging locations (Rosenberg and McKelvey 1999, Manly et al. 2002). Central place foraging behaviour results in a clustered distribution of foraging points near the center of a territory which violates the assumption of no spatial correlation among foraging locations, a pattern that was apparent for most of the Spotted Owls in Web Figure 3 of Jones et al. (2016). The appropriate habitat selection analysis is a ‘resource selection function’, a mathematical function that accounts for the fact that Spotted Owls, as central place foragers, will return to their nest or roost trees many times during the night, so their probability of using habitats near the nest or roost core is much higher than the probability of using habitats farther away (Bond et al. 2009, Bond et al. 2016, Eyes et al. 2017). Third, Jones et al. (2016) reported extinction for a territory in Web Figure 4 when the owls shifted their location by a distance that was less than the diameter of a territory as defined by the authors, and less than mean foraging distance reported by the authors. This decision inflated their ‘burned site’ extinction probability by classifying a normal within-territory movement as site extinction. These methodological difficulties in their data analyses limit the utility of Jones et al. (2016) for guiding forest management, particularly when weighing the risks from management actions relative to risks from fire.

18. Tempel et al. (2016) examined occupancy dynamics in 43 burned breeding sites and 232 unburned sites in four study areas across the Sierra Nevada using 19 years of data. The authors found no significant effects of fire on occupancy, but their top ranked model for one study area (Sequoia Kings Canyon) included a covariate for proportion of the core area where canopy cover was reduced by >10% by wildfire. This covariate was negatively correlated with territory extinction probability, meaning more area burned reduced the site extinction probability, thereby increasing occupancy probability (+0.01).

19. Eyes et al. (2017) radiotracked 13 California Spotted Owls over 3 years and collected data on foraging habitat selection in Yosemite National Park, Sierra Nevada, California. The authors analyzed foraging by a sample of owls nesting in and near forest burned 1–14 years previously from a mix of wildfires and prescribed burns. Eyes et al. (2017) found no significant effect of burn severity on foraging habitat selection, but non-significant effects were reported that showed a decrease in probability of use for the most severely burned locations (-0.06), and moderately burned locations (-0.03), relative to unburned locations.
20. Rockweit et al. (2017) examined survival and recruitment rates of northern Spotted Owls in 70 unburned sites and 28 sites burned in four fires. The authors reported wildfires with different mixtures of burn severity resulted in different effects on survival and recruitment. Ten owl territory cores that were burned at mostly low severity (1987 and 1999 fires) were associated with no significant effects on survival or recruitment. When 14 territory cores burned with moderate amounts of high- and low-severity fire (2008 fire), the result was a significant reduction in survival (-0.17) and a significant increase in recruitment (+0.22). When 4 territory cores burned at predominantly high severity (2004 fire), there was a significant reduction in survival (-0.30). The burned territories were partially post-fire logged, although that was not reported by the authors (C. Hanson, pers. comm.).

21. Hanson et al. (2018) examined naïve site occupancy of California Spotted Owls in 54 sites that burned in one of 8 large fires between 2012 and 2015. All sites were occupied in the year immediately prior to the site burning, and comparisons were before-after fire and logging. Sites were classified into 4 groups based on amount of high-severity burn (20–49% or 50–80%) and amount of post-fire logging (<5% and ≥5%) in a 1500m-radius circle around the nesting roosting core area. Hanson et al. (2018) found no significant effect of fire severity on occupancy, but significant effects of post-fire logging. Mean amount of core areas burned at high severity was 63%. Results were: 80% occupancy in sites with 20–49% high-severity fire and <5% post-fire logging, 33% occupancy in sites with 20–49% high-severity fire and ≥5% post-fire logging; and 77% occupancy in sites with 50–80% high-severity fire and <5% post-fire logging, 20% occupancy in sites with 50–80% high-severity fire and ≥5% post-fire logging. Amongst the sites with ≥5% post-fire logging, the mean amount of such logging of the area within a 1500 m radius of site centers was 16.7% (SD = 8.7%).

LITERATURE CITED

Bond, M. L., R. J. Gutierrez, A. B. Franklin, W. S. LaHaye, C. A. May, and M. E. Seamsans. 2002. Short–term effects of wildfires on Spotted Owl survival, site fidelity, mate fidelity, and reproductive success. Wildlife Society Bulletin 30:1022–1028.

Bond, M. L., D. E. Lee, and R. B. Siegel. 2010. Winter movements by California Spotted Owls in a burned landscape. Western Birds 41:174–180.

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

Bond, M. L., C. Bradley, and D. E. Lee. 2016. Foraging habitat selection by California Spotted Owls after forest fire in southern California. Journal of Wildlife Management http://dx.doi.org/10.1002/jwmg.21112.

Bond, M. L., D. E. Lee, R. B. Siegel, and M. W. Tingley. 2013. Diet and home–range size of California Spotted Owls in a burned forest. Western Birds 44:114–126.

Clark, D. A., R. G. Anthony, and L. S. Andrews. 2011. Survival rates of northern Spotted Owls in post–fire landscapes of southwest Oregon. Journal of Raptor Research 45:38–47.

Clark, D. A., R. G. Anthony, and L. S. Andrews. 2013. Relationship between wildfire, salvage logging, and occupancy of nesting territories by northern Spotted Owls. Journal of Wildlife Management 77:672–688.
Comfort, E. J., D. A. Clark, R. G. Anthony, J. Bailey, and M. G. Betts. 2016. Quantifying edges as gradients at multiple scales improves habitat selection models for northern Spotted Owl. Landscape Ecology http://dx.doi.org/10.1007/s10980–015–0330–1.

Eyes, S. A., S. L. Roberts, and M. D. Johnson. 2017. California Spotted Owl (Strix occidentalis occidentalis) habitat use patterns in a burned landscape. The Condor 119:375–388.

Ganey, J. L., S. C. Kyle, T. A. Rawlinson, D. L. Apprill, and J. P. Ward Jr. 2014. Relative abundance of small mammals in nest core areas and burned wintering areas of Mexican Spotted Owls in the Sacramento Mountains, New Mexico. Wilson Journal of Ornithology 126:47–52.

Hanson, C. T., M. L. Bond, and D. E. Lee. 2018. Effects of post-fire logging on California Spotted Owl occupancy. Nature Conservation 24:93–105. doi: 10.3897/natureconservation.24.20538.

Jenness, J. J., P. Beier, and J. L. Ganey. 2004. Associations between forest fire and Mexican Spotted Owls. Forestry Sciences 50:765–772.

Jones, G. M., R. J. Gutiérrez, D. J. Tempel, S. A. Whitmore, W. L. Berigan, and M. Z. Peery. 2016. Megafires: an emerging threat to old-forest species. Frontiers in Ecology and the Environment 14:300–306.

Lee, D. E., and M. L. Bond. 2015a. Occupancy of California Spotted Owl sites following a large fire in the Sierra Nevada. Condor 117:228–236.

Lee, D. E., and M. L. Bond. 2015b. Previous year’s reproductive state affects Spotted Owl site occupancy and reproduction responses to natural and anthropogenic disturbances. Condor 117:307–319.

Lee, D. E., M. L. Bond, and R. B. Siegel. 2012. Dynamics of breeding-season site occupancy of the California Spotted Owl in burned forests. Condor 114:792–802.

Lee, D. E., M. L. Bond, M. I. Borchert, and R. Tanner. 2013. Influence of fire and salvage logging on site occupancy of Spotted Owls in the San Bernardino and San Jacinto mountains of southern California. The Journal of Wildlife Management 77:1327–1341.

Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Second edition. Kluwer Academic, Dordrecht, The Netherlands.

Roberts, S. L., J. W. Van Wagtendonk, A. K. Miles, and D. A. Kelt. 2011. Effects of fire on Spotted Owl site occupancy in a late-successional forest. Biological Conservation 144:610–619.

Rosenberg, D. K., and K. S. McKelvey. 1999. Estimation of habitat selection for central-place foraging animals. Journal of Wildlife Management 63:1028–1038.

Rockweit, J. T., A. B. Franklin, and P. C. Carlson. 2017. Differential impacts of wildfire on the population dynamics of an old-forest species. Ecology doi:10.1002/ecy.1805.

Tempel, D. J., R. J. Gutiérrez, S. A. Whitmore, M. J. Reetz, R. E. Stoelting, W. J. Berigan, M. A. Seamans, and M. Z. Peery. 2014. Effects of forest management on California Spotted Owls: implications for reducing wildfire risk in fire-prone forests. Ecological Applications 24:2089–2106.
Tempel, D. J., J. J. Keane, R. J. Gutiérrez, J. D. Wolfe, G. M. Jones, A. Koltunov, C. M. Ramirez, W. J. Berijan, C. V. Gallagher, T. E. Munton, P. A. Shaklee, S. A. Whitmore, and M. Z. Peery. 2016. Meta-analysis of California Spotted Owl (Strix occidentalis occidentalis) territory occupancy in the Sierra Nevada: Habitat associations and their implications for forest management. The Condor 118:747–765.