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Effects of post-fire logging on California spotted owl occupancy

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Abstract

In fire-adapted forest ecosystems around the world, there has been growing concern about adverse impacts of post-fire logging on native biodiversity and ecological processes. This is also true in conifer forests of California, U.S.A. which are home to a rare and declining owl subspecies, the California spotted owl (*Strix occidentalis occidentalis*). While there has been recent concern about the California spotted owl occupancy in large fire areas where some territories have substantial high-severity fire effects, the influence of post-fire logging on the California spotted owl occupancy has been investigated very little, leading to some uncertainty about interpretation of conflicting results in different large fires. Research has found these owls preferentially select high-severity fire areas, characterised by high levels of snags and native shrubs, for foraging in forests that were not logged after fire, suggesting that removal of this foraging habitat might impact occupancy. The authors assessed the effect of post-fire logging and high-severity fire, on occupancy of this subspecies in eight large fire areas, within spotted owl sites with two different levels of high-severity fire effects. They found a significant adverse effect of such logging and no effect of high-severity fire alone. These results indicate it is post-fire logging, not large fires themselves, that poses a conservation threat to this imperilled species.

Keywords

wildland fire, spotted owl, forests, logging, post-fire logging, fire severity

Introduction

In fire-adapted forests around the world, a growing body of research indicates reasons for conservation concerns about the impacts of post-fire logging on native biodiversity and ecological processes (Lindenmayer and Noss 2006, Lindenmayer and Ough 2006, DellaSala et al. 2015, Heneberg 2015). The conifer forests of western North America are no exception (Hutto 2006, Swanson et al. 2011, DellaSala et al. 2015).

For a rare owl subspecies, the California spotted owl (*Strix occidentalis occidentalis*) which lives in the low/middle-montane conifer forests of the Sierra Nevada mountains of California, U.S.A. and the mountains of southern California, the effects of post-fire logging have been little studied. Some research suggests reduced site occupancy which has been observed in at least one large recent fire, the King fire of 2014 in the central Sierra Nevada, may occur due to predominantly high-severity fire effects (Jones et al. 2016). However, distinguishing the effects of fire alone from those of post-fire logging remains a challenge.

Populations of this subspecies are declining (Conner et al. 2013) and a petition for listing under the U.S. Endangered Species Act is pending (Bond and Hanson 2014). Thus, it is important to understand the extent to which forest management activities such as post-fire logging may be affecting spotted owl populations.

California spotted owls have been found to preferentially select unlogged high-severity fire areas characterised by high snag basal area and shrub cover for foraging (Bond et al. 2009) or to forage in this forest type in proportion to its availability (Bond et al. 2016, Eyes et al. 2017). This is likely due to the small mammal prey base found in this "complex early seral forest" habitat (DellaSala and Hanson 2015). One study, conducted in the San Bernardino mountains of southern California, found that removal of burned foraging habitat due to post-fire logging adversely impacted spotted owl site occupancy (Lee et al. 2013). However, this issue has not been addressed in the Sierra Nevada, where most California spotted owls live.

In this study, this issue was investigated by analysing the effect of post-fire logging on occupancy of California spotted owl sites, burned in large fires throughout the range of the subspecies, as well as the effect of high-severity fires.

Methods

First, to address how large fires affect California spotted owl site occupancy, fires with the following characteristics were analysed: (1) over 10,000 hectares in size, (2) occurring primarily on U.S. Forest Service lands post-2000, (3) included multiple spotted owl sites burned in the fire and (4) occupancy data were gathered by or for the U.S. Forest Service on national forest lands within the fire's perimeter. The sampling unit was the site (1500 m radius around the historical centre of the territory). Locations of historical site centres come from U.S. Forest Service survey data, as described below.

All sites analysed in this study were located in mature mixed-conifer forest that had recently burned. This forest type is comprised of yellow pine (*Pinus ponderosa* or *Pinus jeffreyi*) mixed with sugar pine (*Pinus lambertiana*), white fir (*Abies concolor*), incense-cedar (*Calocedrus decurrens*), Douglas-fir (*Psuedotsuga menziesii*) and California black oak (*Quercus kelloggi*).

High-severity fires were defined as forest with RdNBR (Relativised differenced Normalised Burn Ratio) values >572 (Jones et al. 2016), equating to a median level of basal area mortality of trees of ~80% (Miller et al. 2009, Miller and Quayle 2015). RdNBR values are based on satellite imagery and pertain to the difference between pre-fire and post-fire reflectance of green foliage (Miller and Thode 2007). The Rapid Assessment of Vegetation Condition (RAVG) satellite imagery database employed by the U.S. Forest Service was used to assess fire severity (https://www.fs.fed.us/postfirevegcondition/whatis.shtml). The RAVG database did not include the four oldest fires, the McNally fire, the Old fire, the Butler2-Slide fire and the Moonlight-Antelope fire, so the Monitoring Trends in Burn Severity (MTBS) satellite imagery database (www.mtbs.gov) was used for these fires, adjusting the 572 threshold value in the RAVG system by multiplying it by 0.875 (i.e. yielding an RdNBR value of 500) to obtain the equivalent percentage of high-severity fire in the MTBS system as was used in RAVG (Miller and Quayle 2015).

The U.S. Forest Service's Region 5 biologists conducted or oversaw surveys for California spotted owls at known sites using an established protocol (USFS 1995). Protocol for a given visit to a site involved trained observers playing calls to elicit responses from territorial spotted owls at night at multiple call points at fixed locations, with each call point surveyed for >10 minutes. At each site, to infer non-occupancy, the protocol required six visits with no detections during one breeding season (this was the case for all but one of the owl sites), or three visits with no detections in each of two consecutive breeding seasons (this was the case for site TUO027). Protocol further required that surveyors temporarily discontinue or reschedule surveys during inclement weather, such as high wind or rain. The authors excluded sites that otherwise met these study criteria but did not have a sufficient number of visits (possibly due to access issues) to meet protocol requirements.

Occupancy data from these surveys were obtained both before and after post-fire logging from the U.S. Forest Service for the following fires that met the above criteria: the McNally fire of 2002 (Sequoia National Forest); the Old fire of 2003 (San Bernardino National Forest); the Moonlight-Antelope fire of 2007 (Plumas National Forest); the Butler2-Slide fire of 2007 (San Bernardino National Forest); the Chips fire of 2012 (Plumas National Forest), not including the western half of the fire area which re-burned the Storrie fire of 2000 and that had extensive post-fire logging more than a decade ago, a fact which could confound these results; the Rim fire of 2013 (Stanislaus National Forest); the King fire of 2014 (Eldorado National Forest); and the Lake fire of 2015 (San Bernardino National Forest) (Figure 1).

Sites that were occupied in the most recent spotted owl survey year prior to post-fire logging were analysed. For example, the most recent surveys on the San Bernardino

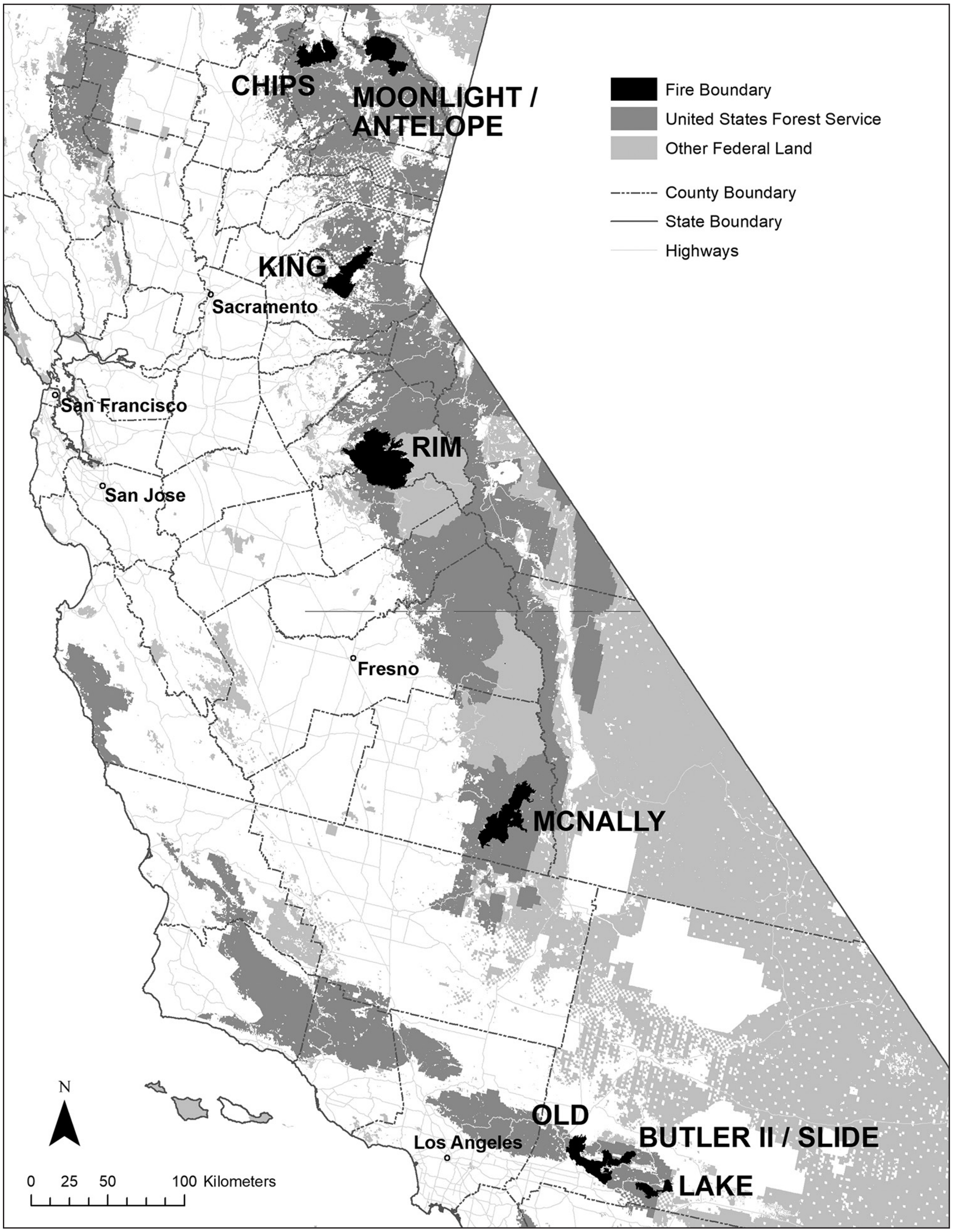

Figure 1. Large fires, in occupied California spotted owl habitat that were studied in this analysis.

National Forest (prior to the Lake fire of 2015) occurred in 2011, whereas in the Rim fire of 2013, surveys were sporadic prior to the fire, but were extensive beginning in the spring of 2014, prior to post-fire logging on national forest lands. The dates of fires, pre-logging and post-logging surveys and logging are shown in Table 1.

Table 1. Years in which the fires, pre-logging and post-logging surveys and logging occurred in each of the fires in this analysis.

Fire Name	Fire Year	Pre-/Post-Logging Surveys[1]	Logging
McNally	2002	2001/2004	Not applicable
Old	2003	2003/2005	Late 2003 through 2004
Moonlight-Antelope	2007	2006/2009	Late 2007 through 2008
Chips	2012	2012/2014	Late 2012 through early 2014
Rim	2013	2014/2016	Late 2014 through 2015
King	2014	2014/2015	Late 2014 through early 2015
Lake	2015	2011/2016	Not applicable
Butler2-Slide	2007	2007/2011	Late 2007 through 2010

[1] In the McNally and Lake fires, there was no post-fire logging in any of the spotted owl sites analysed in this study.

The authors considered a site to be occupied in a given year when at least one owl was detected (Lee et al. 2012, Lee and Bond 2015a, b, Jones et al. 2016). Detection indicated an owl utilised the site for any component of its life history, including foraging, roosting, nesting or territorial defence (Jones et al. 2016). Given the concern indicated in Jones et al. (2016) regarding lost occupancy in sites with substantial high-severity fire effects, the authors analysed naïve occupancy (detections versus no detections as recorded by surveyors, without extrapolating to adjust for probability of detection) of California spotted owl sites with 20–49% and 50–80% high-severity fire (as defined below). Occupancy of such sites was analysed within a 1500 m radius around site centres (nest or core roost locations at the centre of the site; Lee et al. 2012) at two different levels of post-fire logging, <5% and ≥5%, pertaining to the percentage of the total area within the 1500 m radius around the site's centre that was post-fire logged.

The radius distance of 1500 m around site centres was used as it has been found to be important to this subspecies for foraging (Bond et al. 2009). The authors chose 5% as the threshold for analysis of post-fire logging because this threshold, for logging in general, has previously been found to be associated with reduced California spotted owl occupancy (Seamans and Gutiérrez 2007). The effects of post-fire logging was not analysed for spotted owl sites with <20% high-severity fire because post-fire logging often does not occur in such sites. Conversely, the effects of post-fire logging were not analysed for sites with >80% high-severity fire because nearly all of these sites have ≥5% post-fire logging and there was not a sufficient number of such sites with <5% post-fire logging for the analysis.

To determine post-fire-logged areas, the U.S. Forest Service's FACTS database (http://www.fs.usda.gov/detail/r5/landmanagement/gis/?cid=STELPRDB5327833) was used which contains spatially explicit GIS data of post-fire logging activity in any given fire during any time period. The authors also used GIS data on fire severity (https://www.fs.fed.us/postfirevegcondition/whatis.shtml) and land ownership, where forested moderate- and high-severity fire areas on private lands are consistently post-fire logged, with rare exceptions. Post-fire logging in California's forests is a slightly modified form of clear-cutting, wherein nearly all fire-killed/scorched trees are removed (generally retaining ~10 snags/ha), except in low-severity fire areas which are typically not post-fire logged. Low-severity fire areas were excluded from post-fire logging polygons, with low-severity defined as RdNBR values <316 (Miller and Thode 2007). Google Earth was used, as well as physical inspections of the sites, to confirm post-fire logging. A remote private inholding in a large unroaded area in the Lake fire, which would otherwise have met the criteria described above and a private recreation inholding in the Rim fire were excluded, as no logging had occurred in either area. Similarly, some moderate/high-severity fire areas on larger private residential/recreational parcels had no post-fire logging in the Old fire and Butler2-Slide fire and such areas were not included in post-fire logging percentages.

In each of the two high-severity fire categories, the authors analysed whether post-fire logging affected spotted owl site occupancy using Chi-square tests for change in binomial proportions (Rosner 2000). A Chi-square test for change in binomial proportions was also used to analyse whether high-severity fire, without the influence of post-fire logging, affects site occupancy, restricting the analysis to sites with <5% post-fire logging and comparing occupancy of such sites with 20–49% high-severity fire to those with 50–80% high-severity fire.

Results

In sites with 20–49% high-severity fire (in terms of the percentage of the total area within a 1500 m radius around site centres with high-severity fire) and which were all occupied prior to post-fire logging, with <5% post-fire logging of the total area within a 1500 m radius of site centres, 12 of 15 spotted owl sites were occupied (80% occupancy). With 20–49% high-severity fire and ≥5% post-fire logging, 2 of 6 sites were occupied (33% occupancy) (Table 2). This difference was statistically significant ($c^2 = 4.23$, $P = 0.040$, DF = 1, $N = 21$ sites). To verify that this effect on site occupancy did not result from differences in high-severity fire, an *a posteriori* t-test for two independent means was conducted. In terms of percent high-severity fire, there were no differences between the <5% post-fire logging category (mean = 34.9%, SD = 7.7%, $N = 15$) and the ≥5% post-fire logging category (mean = 35.7%, SD = 11.0%, $N = 6$). This indicates that the difference in site occupancy was not due to different levels of high-severity fire ($t = -0.175$, $P = 0.863$). Amongst the sites with ≥5% post-fire logging, the mean amount of such logging of the area within a 1500 m radius of site centres was 17.5% (SD = 8.3%).

In sites with 50–80% high-severity fire and which were all occupied prior to post-fire logging, with <5% post-fire logging of the total area within a 1500 m radius of site centres, 10 of 13 spotted owl sites were occupied (77% occupancy). With 50–80% high-severity fire and ≥5% post-fire logging, only 4 of 20 sites were occupied (20% occupancy) (Table 3). This difference was statistically significant ($c^2 = 10.40$, $P = 0.001$, DF = 1, $N = 33$ sites). In terms of percent high-severity fire, there were no differences

Table 2. Occupancy of California spotted owl sites with 20-49% high-severity fire. Sites have varying levels of post-fire logging, within a 1500 m radius of territory centres, in large fires >10,000 ha in size since 2001. Within each fire, all sites were occupied in a single survey year prior to post-fire logging.

Fire	Site	% Post-fire Logging Category	% Post-fire Logging	% High-Severity Fire	Occupied?
Old	SB116	≥5%	24	49	N
Moonlight-Antelope	PL253	≥5%	26	40	N
Chips	Sta. 221/222	≥5%	8	26	Y
Chips	Sta. 223	<5%	0	27	Y
Chips	Sta. 207	≥5%	25	31	N
Rim	TUO010	<5%	3	40	Y
Rim	TUO011	<5%	4	39	Y
Rim	TUO024	<5%	2	36	Y
Rim	TUO026	<5%	4	25	Y
Rim	TUO039	<5%	4	33	Y
Rim	TUO040	<5%	2	44	Y
Rim	TUO078	<5%	2	30	Y
Rim	TUO085	<5%	3	45	Y
King	ELD009	<5%	4	23	N
King	PLA080	<5%	2	43	Y
King	S. Fork	<5%	4	24	N
King	PLA016	≥5%	10	22	Y
Lake	SB123	<5%	0	38	Y
Butler2-Slide	SB013	<5%	3	34	Y
Butler2-Slide	SB003	≥5%	12	46	N
Butler2-Slide	SB074	<5%	4	43	N

Table 3. Occupancy of California spotted owl sites with 50-80% high-severity fire. Sites have varying levels of post-fire logging, within a 1500 m radius of territory centres, in large fires >10,000 ha in size since 2001. Within each fire, all sites were occupied in a single survey year prior to post-fire logging.

Fire	Site	% Post-fire Logging Category	% Post-fire Logging	% High-Severity Fire	Occupied?
McNally	TU045	<5%	0	57	Y
McNally	TU047	<5%	0	59	Y
Old	SB084	≥5%	7	61	N
Old	SB089	≥5%	7	69	N
Old	SB065	≥5%	10	50	Y
Old	SB026	≥5%	27	79	N
Old	SB053	≥5%	12	66	N
Old	SB066	≥5%	18	53	N
Moonlight-Antelope	PL122	≥5%	15	53	N
Moonlight-Antelope	PL006	≥5%	17	65	N
Moonlight-Antelope	PL229	≥5%	11	66	N
Moonlight-Antelope	PL284	≥5%	23	71	N
Moonlight-Antelope	PL107	<5%	0	51	Y
Moonlight-Antelope	PL123	≥5%	11	59	N
Moonlight-Antelope	PL042	≥5%	8	71	N
Moonlight-Antelope	PL073	≥5%	10	57	N

Fire	Site	% Post-fire Logging Category	% Post-fire Logging	% High-Severity Fire	Occupied?
Moonlight-Antelope	PL125	≥5%	17	72	N
Chips	Mosquito	<5%	4	60	Y
Rim	TUO027	≥5%	39	59	N
Rim	TUO028	≥5%	24	77	Y
Rim	TUO177	≥5%	25	64	Y
King	ELD051	<5%	2	50	Y
King	PLA039	<5%	0	60	Y
King	ELD085	<5%	4	75	Y
King	ELD058	<5%	0	67	N
King	ELD057	<5%	1	63	N
King	Rd. 12N46	≥5%	30	52	N
Lake	SB021	<5%	0	77	Y
Lake	SB041	<5%	0	78	N
Lake	SB138	<5%	0	65	Y
Butler2-Slide	SB137	≥5%	9	55	Y
Butler2-Slide	SB060	<5%	2	57	Y
Butler2-Slide	SB014	≥5%	14	57	N

between the <5% post-fire logging category (mean = 63.0%, SD = 9.2%, N = 13) and the ≥5% post-fire logging category (mean = 62.8%, SD = 8.5%, N = 20), as determined *a posteriori* using a t-test for two independent means (t = 0.064, P = 0.949). This indicates that the difference in site occupancy did not result from different levels of high-severity fire. Amongst the sites with ≥5% post-fire logging, the mean amount of such logging of the area within a 1500 m radius of site centres was 16.7% (SD = 8.7%).

For sites with <5% post-fire logging within a 1500 m radius of site centres, there was no difference in occupancy between such sites with 20–49% high-severity fire and those with 50–80% high-severity fire (c^2 = 0.034, P = 0.854, DF = 1, N = 28 sites).

Discussion

These results indicate that substantial declines in California spotted owl occupancy following large fires are primarily driven by post-fire logging of complex early seral forest—a forest habitat type created by high-severity fire effects in mature conifer forests and which this subspecies has been found to select for foraging (Bond et al. 2009). Spotted owls likely forage in complex early seral forests because abundant dead trees for perch sites are available for this sit-and-wait predator (Carey and Peeler 1995) and the small mammal prey base can increase in such habitat, particularly deer mice (*Peromyscus maniculatus*; Zwolak 2009, Fontaine and Kennedy 2012, Borchert et al. 2014). Under this study design, all spotted owl sites were confirmed occupied prior to post-fire logging. While none of the categories analysed had 100% occupancy following post-fire logging, this is expected given that spotted owls often temporarily abandon sites occupied in the previous year, even where no logging or fire has occurred (USDA 1995). Thus, a portion of sites occupied in one year will not be occupied in the next. Conversely, a portion of sites not occupied in a given year may be re-colonised and occupied in the next year.

Concern has recently been expressed regarding the effect of large forest fires in the central Sierra Nevada on occupancy of the California spotted owl, particularly in sites with predominantly high-severity fire effects (Jones et al. 2016). Jones et al. (2016), who analysed the northern half of the 39,311 ha King fire of 2014, dismissed post-fire logging as a factor in the reduced spotted owl occupancy that they reported one year after the fire.

These results differ from those of Jones et al. (2016) in the King fire. There are some likely reasons for this difference. First, Jones et al. (2016) reported that a median of only 2% of the area within 1100 m circles around the site centres experienced post-fire logging based upon data obtained from privately owned forest management companies (Sierra Pacific Industries and Mason, Bruce & Girard Inc.). A mean of 6% post-fire logging within 1500 m circles was found (and a mean of 12% post-fire logging when sites with >80% high-severity fire are added), based on the methods described above, the FACTS database, Google Earth and physical inspection of the areas. This indicates a more pronounced role of post-fire logging when a larger portion of spotted owls' biological home range (Bond et al. 2009) is analysed. Second, Jones et al. (2016) reported that 8 sites, out of a total of 13 (Jones et al. 2016: figure 2) with >50% high-severity fire, experienced "site extinction" (i.e. were rendered unoccupied) due to the King fire. In fact these sites (PLA007, PLA065, PLA015, PLA109, PLA012, ELD060, PLA049 and PLA043) had not been occupied prior to the fire (based on spotted owl surveys conducted for the Forest Service, which were obtained from the agency). Many spotted owl sites have lost occupancy in recent years in this area likely due to extensive logging (Tempel et al. 2014). Thus, the conclusion by Jones et al. (2016), that the King fire caused the loss of occupancy in these sites, is not sound.

Jones et al. (2016) also reported that, for the foraging behaviour component of their study, spotted owls avoided high-severity fire areas, contrary to the findings of Bond et al. (2009). Jones et al. (2016) suggested that avoidance of high-severity fire areas may have explained reduced occupancy in sites with high levels of high-severity fire. However, Jones et al. (2016) did not account for distance from site centres for this central-place forager (Carey and Peeler 1995, Rosenberg and McKelvey 2009). They also included recent pre- and post-fire clearcut areas in their analysis of selection/avoidance of high-severity fire areas for foraging, rather than analysing foraging of intact, unlogged high-severity fire areas, as in Bond et al. (2009). Thus, the foraging behaviour results of Bond et al. (2009) and Jones et al. (2016) can be reconciled, given the owls' tendency to avoid clearcut areas (Call et al. 1992, Comfort et al. 2016), while selecting intact, unlogged high-severity fire areas dominated by an abundance of snags (standing dead trees) and shrubs (Bond et al. 2009).

Tempel et al. (2014) also reported an adverse effect of high-severity fires on California spotted owl site occupancy, mostly due to four sites that generally became unoccupied, or infrequently occupied, following the Star fire of 2001 on the Eldorado and Tahoe National Forests, amongst a sample size of 12 sites inside wildland fire areas.

However, these sites were heavily post-fire logged on both private timberlands and National Forest lands (Bond and Hanson 2014: Appendix C), a fact that was not reported by Tempel et al. (2014).

A common assumption has been that the occurrence of high-severity fires is increasing and is a major threat to the owl. This assumption is accompanied by recommendations for increased logging—especially "mechanical thinning"—on National Forest lands, intended to create low-density forests and reduce the potential for high-severity fires (Jones et al. 2016, Stephens et al. 2016). Post-fire logging and tree plantation establishment have also been promoted by the U.S. Forest Service in high-severity fire areas in an attempt to recover and restore mature, green forest cover (Peterson et al. 2015). However, these results and other research (Lee et al. 2013), indicate that post-fire logging of complex early seral forests is not consistent with California spotted owl conservation and mechanical thinning has been associated with dramatic and rapid population declines for this subspecies in the Sierra Nevada (Stephens et al. 2014). Further, multiple studies have indicated that there is no long-term increasing trend in high-severity fires in the Sierra Nevada (Hanson and Odion 2015, Keyser and Westerling 2017), or in the vast majority of the western U.S. (Keyser and Westerling 2017) since 1984.

The authors' finding, that spotted owl sites with predominantly high-severity fire effects had 77% occupancy when <5% of the area within a 1500 m radius of territory centres was subjected to post-fire logging, is notable in the sense that it compares favourably with current California spotted owl occupancy levels in unburned, mature forest (Lee et al. 2012). More post-fire research is needed pertaining to spotted owls, including investigations of time-since-fire. This is especially true for spotted owl sites with higher levels of fire severity, such as those with >80% high-severity fire within a 1500 m radius of site centres, which are uncommon compared to those with lower levels of high-severity fire. However, most of the relatively few owl sites with such high-severity fire levels in larger fires are subjected to substantial post-fire logging on both private and public lands, undermining potential for scientific understanding of the owl's relationship with such fire events. This will need to change in the future if one is to have sufficient data to analyse the effects of fire, versus the effects of post-fire logging, in sites with such levels of high-severity fire.

Conclusions

Adverse impacts to California spotted owl occupancy in large fires appear to be strongly influenced by post-fire logging, rather than fire alone. Increased logging of unburned forests has been proposed as a measure to curb fire behaviour (Jones et al. 2016), but such logging has been associated with a substantial and rapid loss of site occupancy (Stephens et al. 2014). Based on these results here and other research, it is suggested that such increased logging and the weakening of environmental protections that would be needed to facilitate it, are not a scientifically sound path forward towards recovery and conservation of declining California spotted owl populations.

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