

Is “Fuel Reduction” Justified as Fire Management in Spotted Owl Habitat?

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Simple Summary: The California Spotted Owl is an imperiled species that selects mature conifer forests for nesting and roosting while actively foraging in the “snag forest habitat” created when fire or drought kills most of the trees in patches. Federal agencies believe there are excess surface fuels in both of these habitat conditions in many of California’s forests due to fuel accumulation from decades of fire suppression and recent drought-related tree mortality. Accordingly, land management agencies are conducting widespread “fuel reduction” logging in Spotted Owl territories under the expectation that this will reduce high-severity fire occurrence and, therefore, promote nesting/roosting habitat. Such logging has been found to adversely affect Spotted Owl occupancy. Therefore, it is important for the conservation of this species to understand whether fuel-reduction logging is effectively accomplishing its stated fire management objective. In an initial investigation, I analyzed this issue in a large 2020 fire, the Creek Fire (153,738 ha), in the southern Sierra Nevada mountains of California. I found that pre-fire snag density was not correlated with burn severity, but fuel-reduction logging was associated with higher fire severity. My results suggest the fuel reduction approach is not justified and provide indirect evidence that such management represents a threat to Spotted Owls.



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Abstract: The California Spotted Owl is an imperiled species that selects mature conifer forests for nesting and roosting while actively foraging in the “snag forest habitat” created when fire or drought kills most of the trees in patches. Federal agencies believe there are excess surface fuels in both of these habitat conditions in many of California’s forests due to fuel accumulation from decades of fire suppression and recent drought-related tree mortality. Accordingly, agencies such as the U.S. Forest Service are implementing widespread logging in Spotted Owl territories. While they acknowledge habitat degradation from such logging, and risks to the conservation of declining Spotted Owl populations, agencies hypothesize that such active forest management equates to effective fuel reduction that is needed to curb fire severity for the overall benefit of this at-risk species. In an initial investigation, I analyzed this issue in a large 2020 fire, the Creek Fire (153,738 ha), in the southern Sierra Nevada mountains of California. I found that pre-fire snag density was not correlated with burn severity. I also found that more intensive forest management was correlated to higher fire severity. My results suggest the fuel reduction approach is not justified and provide indirect evidence that such management represents a threat to Spotted Owls.

Keywords: Spotted Owl; high-severity fire; fuel reduction; fuel accumulation; logging

1. Introduction

The current dominant fire management approach of agencies managing western U.S. federal forestlands is to implement widespread active management for the stated purpose of reducing fuels, primarily to curb fire severity. Such management includes commercial thinning, which involves substantial removal of small and mature live trees along with removal of many snags. It also includes pre-commercial thinning of small trees [1]. “Salvage” logging of patches of snags, created by fire or drought, is another common type of fuel-reduction management [1]. Mixed-severity wildfires are often viewed as events that increase combustible fuel by creating many new snags [1]. These forest

management activities occur frequently within forests occupied by the imperiled California Spotted Owl (*Strix occidentalis*) [1], which nests and roosts in dense, mature/old forest that is unburned or has experienced low/moderate-severity fire [2,3]. However, the Spotted Owl actively forages and hunts in areas of snag forest habitat, also known as “complex early seral forest”, where natural disturbance processes have turned many or most live trees into snags [4–6], and small mammal prey populations can be 2–6 times higher in such post-fire habitats compared to unburned old forest [2,7]. In the absence of post-fire logging, high-severity fire patches within Spotted Owl home ranges are associated with increased reproduction [8]. The home ranges of Spotted Owls within mixed-severity fire areas have a mean of 402 ha in the Sierra Nevada [4].

The types of logging activities that are conducted for fuel reduction degrade both the nesting/roosting and foraging habitat for this species, posing a risk to the conservation of Spotted Owl populations [8–12]. However, federal land agencies hypothesize that there are currently excess surface fuels in the spotted-owl-inhabited conifer forests of the Sierra Nevada, California, USA, and that such logging is needed to reduce fuels and curb future fire severity to avert greater harm to Spotted Owls [1]. In this context, it is important to understand whether the fuel-reduction management approach is accomplishing its stated objective.

Fire regimes in the ponderosa pine and mixed conifer forest types in which Spotted Owls live were historically characterized by mixed-severity fires that were dominated by low/moderate-severity effects but included a substantial component (often 22–39%) of high-severity fire where most or all trees were killed in both small and large patches [13,14]. These forests generally have less area burned now than they did before fire suppression policies, though the annual area burned has been increasing in the most recent decades since the 1980s [15]. Some authors have expressed concern about imperiled species where large fires occur and propose increasing the pace and scale of fuel-reduction logging as a landscape-scale fire management and conservation approach [1,16,17].

A core assumption of the fuel reduction hypothesis is that forests with little or no fuel-reduction logging and unmanaged forests that are long unburned or have many snags from past drought or mixed-severity fire will burn more severely due to fuel accumulation when wildland fires occur [1,18]. Some have also hypothesized that within the range of the Spotted Owl in the southern Sierra Nevada, forests with the highest densities of snags from heightened drought-driven snag recruitment in 2014–2017 would burn more severely due to accumulating dead branches and downed logs on the forest floor [18].

Large-scale logging operations are being conducted in California Spotted Owl habitat based on the fuel reduction hypothesis, which raises significant conservation concerns. Such logging has been found to adversely impact Spotted Owl occupancy and/or foraging activity [5,9,11,12,19]. Moreover, California Spotted Owl populations are small and vulnerable. The California Spotted Owl population is estimated to be comprised of <2500 individuals [20] and has been declining for more than two decades in every demographic study area [16,20] except for the one in Sequoia and Kings Canyon National Park, where wildfires are common but no logging is allowed [21]. One meta-analysis indicates that the minimum viable population for bird species is 3742 individuals [22]. While specific population thresholds may vary by genus and species, California Spotted Owl populations are small, underscoring the importance of understanding the effects of fuel-reduction logging in order to facilitate conservation of the species.

Here, I present an initial investigation of the fuel reduction hypothesis and fire severity in a large 2020 fire, the Creek Fire (153,738 ha), in the southern Sierra Nevada mountains of California, USA. This fire occurred in a landscape with a mix of past fuel-reduction logging and forest protections along with numerous areas of high tree mortality from past wildfires and an intense drought and resulting snag recruitment in 2014–2017. The fire area is inhabited by California Spotted Owls. I address three specific questions regarding (1) whether fire severity is correlated with increasing time since the previous fire;

(2) whether fire severity is correlated with higher snag densities; and (3) whether more intensive fuel-reduction management is correlated with lower, or higher, fire severity.

2. Materials and Methods

My object of study was the Creek Fire of 2020 (Figure 1), which occurred primarily in the Sierra National Forest but also included some private forestlands. The Creek Fire began on 4 September 2020 in the Big Creek drainage north of the town of Shaver Lake, California, with lightning identified by the U.S. Forest Service as the most likely cause. During the first four full days, during extreme fire weather, the Creek Fire grew rapidly, reaching a size of 65,890 ha by 8 September 2020, after which the fire slowed, reaching a final size of 153,738 ha by early December of 2020. The fire was largely composed of lower/middle montane forest types inhabited by Spotted Owls and consisting of ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*P. jeffreyi*), sugar pine (*P. lambertiana*), white fir (*Abies concolor*), incense cedar (*Calocedrus decurrens*), Douglas fir (*Pseudotsuga menziesii*), and California black oak (*Quercus kelloggii*), with shrubs mainly consisting of mountain whitethorn (*Ceanothus cordulatus*), deer brush (*C. integerrimus*), and greenleaf manzanita (*Arctostaphylos patula*).

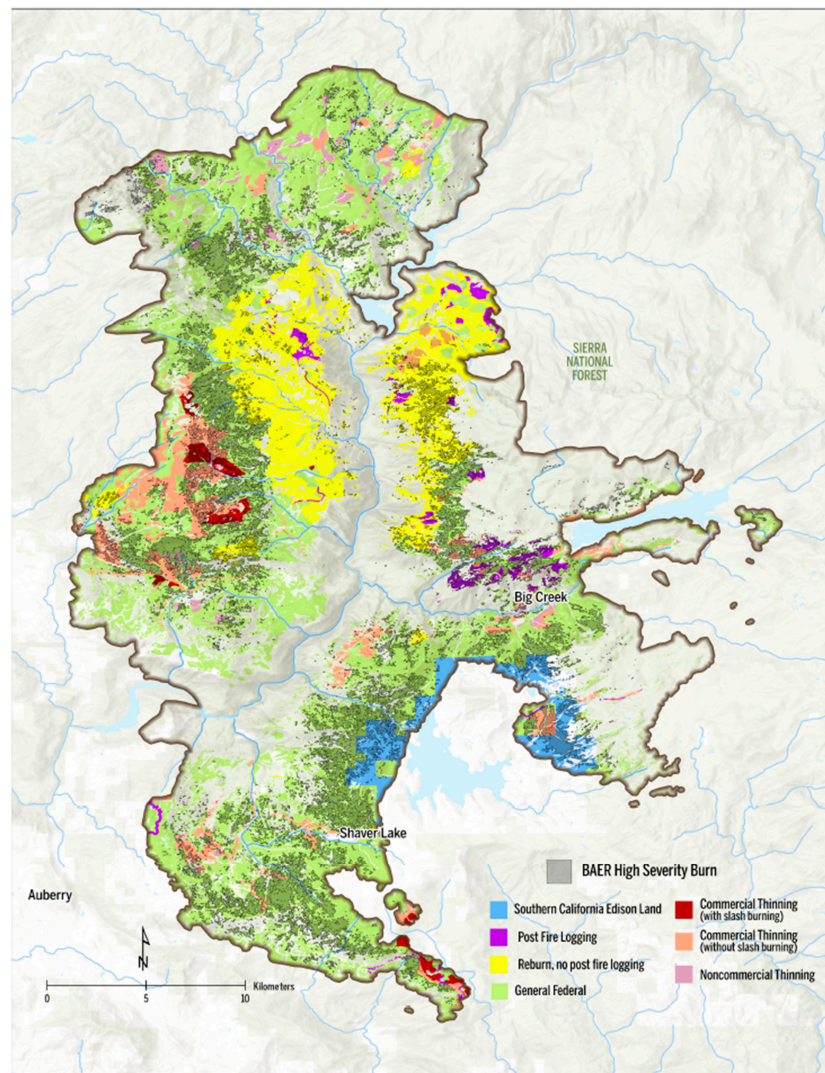


Figure 1. The Creek Fire study area, showing management categories and high-severity fire during the first four days when the most extreme fire behavior occurred.

To determine percent high-severity fire (percentage of the total area in a given category that experienced high-severity fire), I used the U.S. Forest Service's Burned Area Emergency Rehabilitation (BAER) fire severity data (released in November 2020) for this fire area (<https://fsapps.nwcg.gov/baer/baer-imagery-support-data-download>, accessed on 18 February 2021). As the BAER severity data are focused on soil burn severity, they tend to be somewhat conservative relative to vegetation severity data that are based on the difference between pre-fire satellite imagery and one-year post-fire imagery [23]. This makes BAER severity data useful for spatial assessments of high-severity fire since BAER data most consistently represent high-severity fire areas, whereas vegetation severity assessments of high-severity fire tend to contain relatively more surviving trees. I did not use vegetation severity data from the U.S. Forest Service's "Rapid Assessment of Vegetation Condition after Wildfire" ("RAVG") satellite imagery system because the satellite imagery is taken only 30 to 60 days after fires and therefore cannot account for "flushing" of conifers that initially appear dead (due to little or no remaining green foliage) but which are often alive and healthy and produce new green crowns in the summer of the year following the fire due to surviving terminal buds [24]. The inability of the RAVG system to account for post-fire flushing can often lead to serious inaccuracies and large overestimations of high-severity fire [2]. More reliable vegetation severity data, based on one-year post-fire satellite imagery under the Monitoring Trends in Burn Severity (MTBS) system (<https://www.mtbs.gov>, accessed on 10 November 2021), are not generally processed and made available until approximately two years post-fire—typically well after forest management decisions regarding post-fire logging are already made and such logging is underway.

I restricted my analyses to the ponderosa pine and mixed conifer forest types that are inhabited by Spotted Owls, using Landfire BpS data (<https://www.landfire.gov>, accessed on 18 February 2021) for the following forest type categories: Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland, Mediterranean California Mesic Mixed Conifer Forest and Woodland, Mediterranean California Lower Montane Black Oak—Conifer Forest and Woodland, and California Montane Jeffrey Pine(-Ponderosa Pine) Woodland.

For forest management and fire history on federal lands, I used U.S. Forest Service data on the date, spatial location and boundaries, and type of past logging (<https://data.fs.usda.gov/geodata/edw/datasets.php>; <https://data.fs.usda.gov/geodata/edw/datasets.php?xmlKeyword=Hazardous+Fuel+Treatment>; both accessed on 18 February 2021), eliminating any redundant data entries in these datasets, and the state of California's FRAP database for previous fire perimeters (<https://frap.fire.ca.gov/frap-projects/fire-perimeters/>, accessed on 18 February 2021). For drought-induced snag density, I used the U.S. Forest Service's aerial tree mortality survey data for 2014–2017 (<https://map.dfg.ca.gov/metadata/ds2783.html>, accessed on 18 February 2021).

The resolution (pixel size) of the datasets used was 30 m.

I used Spearman's rank correlation test [25,26] (two-tailed) to determine whether increasing snag density was associated with fire severity, with percent high-severity fire as the dependent variable. I arranged the snag density data into the following snags/ha categories: (1) <25, (2) 26–50, (3) 51–75, (4) 76–100, (5) 101–125, and (6) >125. I restricted this analysis to protected federal forests with no logging history in order to avoid the potentially confounding effect of past logging. These forests burned after the first four days of the Creek Fire. For this analysis, each category had a minimum of 400 ha of total burned area.

The snag density data were provided as continuous data. However, it would not have been optimal to attempt to analyze these data as continuous in this circumstance because many of the areas with a particular numerical snags/ha density were in patches of only 1 ha or smaller, and the percent high-severity fire at such a spatial scale becomes extremely variable, or "noisy". Moreover, attempting to delineate the experimental unit for such continuous data using all of the data would be infeasible and subject to many arbitrary choices. My approach used all of the available data in each snag density category for the Creek Fire within protected federal forests.

To assess whether there was a correlation between more intensive fuel-reduction management and percent high-severity fire, I restricted this analysis to the first four full days of the Creek Fire, from 5 September 2020 through 8 September 2020, during which extreme fire weather and plume-dominated fire behavior occurred. This was associated with a rapid daily rate of spread on these days of 14,643 to 18,240 ha, which was approximately twice the next closest daily rates of spread during subsequent days. I used Spearman's rank correlation test (two-tailed), ranking categories such that the most intensive fuel-reduction logging received the lowest rank, as follows: (1) post-fire "salvage" logging on federal lands, 1995–present; (2) Southern California Edison private timberlands (40-year history of commercial thinning and prescribed burning); (3) commercial thinning, with slash burning, on federal lands, 1995–present; (4) commercial thinning, with no slash burning, on federal lands, 1995–present; (5) noncommercial thinning on federal lands, 1995–present (cutting of seedlings and sapling-sized trees); (6) re-burn, no post-fire logging ("re-burn" of previous mixed-severity fires, 1995–present, on federal lands with no subsequent post-fire logging); and (7) general federal forestlands (no forest management or wildfire between 1995 and the occurrence of the Creek Fire). Each category had a minimum of 400 ha of total burned area. Percent high-severity fire was the dependent variable.

I assigned federal lands with post-fire logging the lowest rank (most intensive fuel-reduction logging) because under the existing forest plan, such logging is focused in areas of high-severity fire, where most or all trees were killed, and is characterized by clearcutting, with retention of small clumps of snags, averaging 10/ha [1]. This category involves the most intensive tree removal and, under the fuel reduction hypothesis, would be expected to have the lowest fire severity. I assigned the second ranking to the Edison private timberlands, which have been commercially thinned and prescription burned for approximately 40 years. I assigned the third and fourth rankings to commercial thinning on federal lands, with and without subsequent burning of logging "slash" debris, respectively, because the current forest plan allows many small trees and some mature trees to be removed (up to 75 cm in diameter at breast height) but also includes some limits on canopy cover reduction in Spotted Owl habitat (limits that do not exist for the Edison private lands), generally requiring retention of at least 50% canopy cover [1]. I assigned noncommercial thinning on federal lands to the fifth ranking because it is a less intensive form of thinning that does not include removal of mature trees, making it a less intensive form of fuel-reduction management. Re-burn of federal lands with mixed-severity wildfire, 1995–present, and no post-fire logging, occupied the sixth ranking because such areas represent only wildfire, with no fuel management. General federal forestlands occupied the last ranking since these areas have no forest management or fire history between 1995 and the Creek Fire of 2020 and would be expected to have high fire severity under the fuel reduction hypothesis.

3. Results

There was no correlation between snag density and percent high-severity fire ($r_s = 0.143$, $p = 0.787$; Table 1).

Table 1. Snag density and percent high-severity fire in unmanaged forests.

Snags (ha)	Rank	High-Severity %	Area (ha)
<25	1	1.1	3632
26–50	2	2.2	5161
51–75	3	6.2	4178
76–100	4	6.4	405
101–125	5	0.4	693
>125	6	4.3	973

There was a significant inverse correlation between intensity of fuel-reduction management and percent high-severity fire, with the fuel-reduction logging categories experiencing

the highest fire severity and the lowest fire severity occurring in forests that had previous prescribed fire (with no pre-fire thinning or post-fire logging) or wildfire (with no post-fire logging) ($r_s = -0.893$, $p = 0.007$; Table 2). General federal forests with no recent (since 1995) fire or forest management prior to the Creek Fire had intermediate levels of high-severity fire.

Table 2. Forest management categories and percent high-severity fire for the first four days of the Creek Fire.

Category	Rank	High-Severity %	Area (ha)
Post-fire logging	1	29.2	985
Edison (private)	2	28.6	1496
Commercial thin, burn	3	24.7	432
Commercial thin, no burn	4	21.7	2624
Noncommercial thin	5	14.1	647
Re-burn, no post-fire logging	6	9.1	5935
General federal forestlands	7	21.4	23,260

4. Discussion

Within the forest types inhabited by California Spotted Owls, high-severity fire occurrence was not higher overall in unmanaged forests and was not associated with the density of pre-fire snags from recent drought in the Creek Fire, contrary to expectations under the fuel reduction hypothesis. Moreover, fuel-reduction logging in California Spotted Owl habitats was associated with higher fire severity in most cases. The highest levels of high-severity fire were in the categories with commercial logging (post-fire logging, private commercial timberlands, and commercial thinning), while the three categories with lower levels of high-severity fire were in forests with no recent forest management or wildfire, less intensive noncommercial management, and unmanaged forests with re-burning of mixed-severity wildfire, respectively. These initial results, which provide indirect but important information regarding fuel-reduction management in Spotted Owl habitats, do not support the fuel reduction hypothesis. Other recent research indicates that forests with less environmental protection and more tree removal tend to burn more severely [27], and there is research concluding that forests with post-fire logging and artificial tree planting burn more severely than burned forests with no post-fire logging and no tree planting [28].

The scientific conclusion that logging is associated with increased fire severity is not new. In 1996, a large team of university and agency scientists, commissioned by the U.S. Congress, released the conclusions of the Sierra Nevada Ecosystem Project Report, finding the following: “Timber harvest, through its effects on forest structure, local microclimate, and fuel accumulation, has increased fire severity more than any other recent human activity” [29]. Logging, conducted under the rubric of fuel reduction, reduces the cooling shade of the forest canopy, creating a hotter, drier microclimate and reducing the buffering effect that denser stands have against the winds that drive flames, while leaving behind some amount of kindling-like slash debris and spreading combustible invasive grasses such as cheatgrass [27,30]. Post-fire logging also reduces shade and nearly eliminates large, downed logs that retain soil moisture [31] while spreading slash debris and ignitable invasive grasses [27], and the homogenous tree plantations that are planted after post-fire logging may often burn more severely [28].

Moreover, contrary to the hypothesis proposed by proponents of fuel-reduction logging of snag forest habitats [18], forests with the highest densities of pre-fire snags in the Creek Fire did not have higher fire severity. This result is broadly consistent with region-wide, field-based research finding overall lower fire severity in forests with high levels of snags from previous drought and bark beetle occurrence [32].

My results are based on one fire, the Creek Fire of 2020. Though this was a very large fire, similar research in other large fires will be important in the future, especially where the spatial area comprising certain snag density and/or fuel-reduction management categories

may be more extensive than in my Creek Fire analysis. Moreover, topography was beyond the scope of my analysis here, but future research in other large fires could incorporate this variable.

My findings are good news for conservation efforts of imperiled Spotted Owls since they indicate that the acknowledged degradation of dense, mature/old forests that is caused by commercial thinning, which removes trees up to 76 cm in diameter in the National Forests of the Sierra Nevada [1], is not a necessary or warranted impact to Spotted Owl nesting/roosting habitat. My results suggest that it does not reliably accomplish its stated goal of reducing fire severity. Similarly, my finding that earlier unlogged wildfires re-burned at >90% low/moderate severity in the Creek Fire is also good news for Spotted Owl conservation. High-severity fire levels were three times higher where post-fire logging had occurred in earlier fires. Snag forest habitat is actively used, and even selected, for foraging by Spotted Owls due to an enhanced small mammal prey base in this habitat [2]. Given that post-fire logging was not associated with lower fire severity and, in fact, had much higher fire severity than unlogged fire areas, the well-documented adverse impacts to Spotted Owls from this forest management practice [9] are also unwarranted. Notably, other research has found that in the absence of post-fire logging, re-burns tend to be heavily dominated by lower-severity effects [33,34], similar to my results here.

These results are good news in particular for the Spotted Owls inhabiting the Creek Fire area in the Sierra National Forest. There are an estimated 226 Spotted Owl territories in the Sierra National Forest, ~40% of which are within the Creek Fire perimeter [3,20]. Spotted Owl populations in the Sierra National Forest have been suffering ongoing population declines in recent decades due to habitat degradation and loss, largely from commercial thinning and post-fire logging [20]. Notably, Spotted Owl populations have been declining by ~1–2% per year since the 1990s in the Sierra Nevada demographic study areas where fuel-reduction logging occurs, while Spotted Owl populations have been increasing by ~1% per year in the minor portion of the landscape that is protected from logging [20,35]. Moving away from such logging activities following the Creek Fire, as my results suggest is warranted, would benefit the recovery of Spotted Owl populations.

My findings in the Creek Fire, based on the U.S. Forest Service's own forest management and fire severity data, and the at-risk status of the Spotted Owl, suggest a need to change the management direction and shift away from fuel-reduction logging in forests inhabited by this species.

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