Article

Forest Management, Barred Owls, and Wildfire in Northern Spotted Owl Territories

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Abstract: The Northern Spotted Owl (*Strix occidentalis caurina*) (NSO) was listed as federally threatened in 1992 due to widespread logging of its old-growth forest habitat. The NSO recovery plan in 2011 elevated competition with Barred Owls (*Strix varia*) (BO) and wildfires as primary NSO threats based partly on the assumption that severely burned forests were no longer NSO nesting and roosting habitat. We quantified amount of logging before and/or after wildfire and opportunistic detections of BOs within two home range scales (0.8 and 2.09 km) at 105 NSO sites that experienced severe wildfire from 2000–2017. Logging affected 87% of severely burned NSO sites, with BO recorded at 22% of burned-and-logged sites. Most (60%) severely burned NSO sites had evidence of logging both before and after fires while only 12% of severely burned sites had no logging or BO detections, indicating rarity of NSO territories subjected to severe fire without the compounding stressors of logging and invasive BOs. We recommend changes to NSO habitat modeling that assume nesting and roosting habitat is no longer viable if severely burned, and to the US Fish and Wildlife Service's practice of granting incidental take permits for NSOs in logging operations within severely burned owl sites.

Keywords: logging; severe fire; *Strix occidentalis*; thinning; threatened species

1. Introduction

The U.S Endangered Species Act (ESA) developed a formal process for listing a species at risk of extinction based on "listing factors." Listing factors may act individually or in concert and are difficult to untangle when multiple interacting factors are involved in population declines, as often the case with imperiled species. The Northern Spotted Owl (NSO; *Strix occidentalis caurina*; Figure 1) is a territorial, monogamous, nocturnal raptor that primarily inhabits late-successional coniferous forests in the Pacific Northwest of the U.S. and southwest British Columbia [1]. Adults are territorial, have large home ranges, and have high fidelity to roosting and breeding sites [1,2]. Spotted Owls select forests that contain a high density of large conifers, high canopy cover, multiple canopy layers, numerous large snags, understory shrubs and hardwoods, and downed woody debris [1–3]. These conditions provide the owl with shade for hiding and thermoregulating, structures for nesting and roosting, and habitat for its primary prey, including northern flying squirrels (*Glaucomys sabrinus*), dusky-footed woodrats (*Neotoma fuscipes*), mice (*Peromyscus* spp.), pocket gophers (*Thomomys* spp.), and red tree voles (*Phenacomys longicaudus*) [1–3]. Elimination or degradation of older, structurally complex forests is associated with reduced site occupancy and reproduction failures of NSO [4].

Figure 1. Northern Spotted Owl (NSO) nest site with young in a severely burned undisclosed location (photograph Courtesy of Maya Khosla with permission).

The NSO was listed under the ESA as a federally threatened species in 1992 due primarily to adverse modification of older forest habitat by logging and inadequate regulatory mechanisms to prevent the owl's extinction [5–7]. The 2011 NSO recovery plan expanded on the primary listing factors by including threats from competitive exclusion by Barred Owls (BO; *Strix varia*) and habitat alteration by severe wildfires [4].

There is evidence that ongoing old forest habitat loss together with BOs are the main factors behind continued NSO declines [8–11]. However, whether wildfire is also a driver of NSO population declines is equivocal [12–14] because the few empirical wildfire studies of this subspecies are confounded by the additional stressor of logging (e.g., [15,16]). Spotted Owl territories are often compromised by pre- and post-fire logging that can obscure effects of severe fire on site occupancy [17,18]. Recent large-scale analyses of NSO demography and occupancy dynamics have used habitat covariates that made no distinction between logging and wildfire [9–11], rather these factors are lumped together as hectares of 'disturbance' and reductions in the amount of 'nesting-roosting habitat'.

Studies of wildfire effects on the related California Spotted Owl (*S. o. occidentalis*) have found that the presence of relatively large severely burned patches in a breeding site that was not consistently inhabited, was occupied mostly by single owls, and/or was unproductive before fire was associated with the loss of occupancy in that site after fire, but this was not evident in sites that were consistently occupied by pairs and reproductive owls before fire [19–21]. Formal meta-analyses that combined effect sizes of different studies showed no statistically significant negative influence of severe fire on site occupancy by Spotted Owls and in some cases significant positive effects on foraging and reproduction [12,13], whereas post-fire salvage logging has a demonstrated negative effect on occupancy [17,18]. Additionally, older forests where Spotted Owls live, as well as unmanaged forests in general, were less likely to burn severely [22,23]. Nevertheless, logging (before and after fire) continues to be proposed in wildfire risk reduction efforts and for "restoring forests" in NSO habitat [24] despite: (1) documented adverse effects of logging on NSO site occupancy and habitat use [4,25]; (2) questionable efficacy of logging on reducing severe fires driven mainly by extreme fire weather [26,27]; and (3) damage that post-fire salvage logging causes to post-fire tree regrowth [28] and forest ecosystems generally [29].

The main objective of our study was to determine the extent to which logging activities before and/or after wildfire routinely compound the stresses of wildfire and BO on the

federally threatened NSO. We assessed the annual amount of pre- and post-fire logging, and whether BOs were detected within 105 NSO sites affected by severe wildfire in forests managed by the USDA Forest Service (USFS) throughout the range of the subspecies over an 18-year period (2000–2017). We quantified the cumulative site- and year-specific amount of logging in the USFS-designated core home range area of 0.8 km radius and provincial home range area of 2.09 km radius around each site center [4]. We also quantified the cumulative amount of severe fire at both spatial scales, as well as whether BOs were opportunistically detected during surveys for NSOs. Our findings may help managers understand the extent of forest management activities in NSO sites that were affected by wildfire and BOs. This information is useful when quantifying anthropogenic disturbances and adjusting recovery actions for the NSO.

## 2. Materials and Methods

2.1. Study Area

Our study area incorporated portions of five national forests throughout the geographic range of the NSO (Okanagan-Wenatchee in Washington, Deschutes and Umpqua in Oregon, and Klamath and Six Rivers in California; Figure 2). On National Forest System lands, the USFS establishes a permanent alpha-numeric 'activity center' to represent a known NSO territory and delineates for management purposes a 'core home range' of 0.8 km radius and a 'provincial home range' of 2.09 km radius around the center of NSO detections, as per the interim guidelines of the U.S. Fish and Wildlife Service (USFWS) [4]. We requested field survey data from the USFS Region 6 for all historical NSO activity centers (hereafter, 'sites') that had experienced fire from 2000–2017. Our final sample included data from all the NSO sites having core or provincial home range areas that intersected with severe fire and logging (or no logging) either before or after fire, or both. We also quantified whether BOs had been opportunistically detected at the site during NSO surveys at any point during the 18-year study period. This offered contrasting gradients of stressors, enabling us to quantify the relative prevalence of the three effects in known NSO sites that experienced severe wildfire.

2.2. NSO Survey Data and Site Characteristics

We used a combination of the original NSO field survey forms, summary reports, and the California Natural Diversity DataBase (CNDDB: https://wildlife.ca.gov/Data/CNDDB/Spotted-Owl-Info; accessed on 10 August 2022) to plot geographic locations of nests, young, daytime roosts, and nighttime detections. The detections were then used to determine the 'center' of the site each year and to quantify forest attributes around that center.

NSO locations were digitized from the records provided for each year of the study and assembled into a GIS database. For each year that an NSO site was surveyed, the site was assigned a single core location at the geographic mean of all observations, around which we drew the core and provincial home ranges for geospatial analysis and quantification of environmental covariates. We based the center of the site on the highest status and most biologically significant NSO detection, in the following descending order of importance: (1) location of active nest; (2) location of juvenile owlets; (3) centroid of daytime roosts of adult pairs; (4) centroid of daytime roosts of single adults; (5) centroid of nighttime detections; and finally, (6) old site center location. For sites without a known nest location and where NSOs were recorded in multiple locations within one year, we assigned a point at the geographic mean of the locations. This geospatial analysis was repeated for each year of the study as the amount of severe wildfire and logging within the home range circles changed over time, and as the owls might have shifted their location(s) within the site. We quantified covariate values for each year for each NSO site as: (1) area of initial conifer forest cover in 2001; (2) year-specific area of logging in conifer forest (including commercial thinning, clearcuts, and post-fire salvage); and (3) year-specific area of severe wildfire in

conifer forest. We presented annual estimates of logging and severe fire within each spatial scale (0.8 km radius and 2.09 km radius) cumulatively.
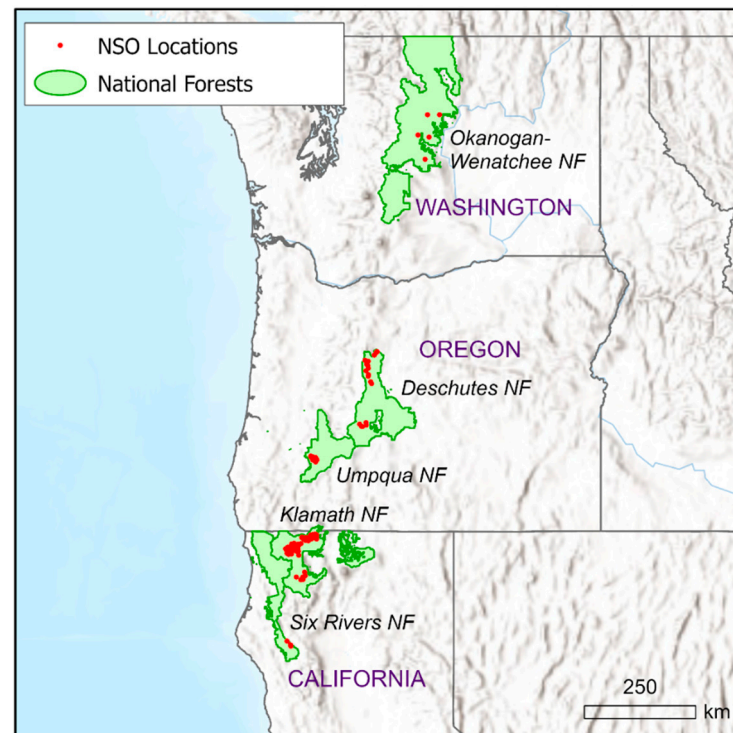
Figure 2. Study area showing the location of severely burned Northern Spotted Owl sites in five national forests where information on logging, wildfires, and Barred Owls was available from 2000–2017.

To define initial forest cover, we used the Existing Vegetation Type dataset from LANDFIRE version 1.0.5 (LANDFIRE, *public communication*, http://www.landfire.gov; accessed on 10 August 2022). We chose this version of LANDFIRE because it employed satellite imagery from 2001, which is nearest to the beginning of our study period. The EVT data layer represents the current distribution of the terrestrial ecological systems classification developed by NatureServe for the western hemisphere. EVT cover was reclassified into conifer and non-conifer using the "System Group Physiology" attribute and intersected with our home range circles for each year.

2.3. Logging Type and Severe Wildfire

We used three datasets to determine severely burned NSO sites that underwent some type of logging during the study period via the Forest Service Activity System (FACTS) (https://data.fs.usda.gov/geodata/edw/datasets.php; accessed on 10 August 2022): 'Timber Harvests' dataset, representing areas clearcut and thinned; pre-commercial thinning activities within the 'Silviculture Timber Stand Improvement' dataset; and thinning and cutting activities within the 'Hazardous Fuel Treatment Reduction' dataset. These logged areas were combined for each specific year of the study and then intersected with our home range circles for the year of the logging.

For determining high severity fire in conifer forests for each year of our study, we used the Monitoring Trends in Burn Severity project (MTBS, public communication, http://www.mtbs.gov; accessed on 10 August 2022). MTBS is a U.S. Department of Interior and USDA-sponsored program designed to consistently map burn severity and perimeters using satellite imagery across all lands of the United States. We used the burn severity mosaics that represented a composite of all the individual fires that occurred in each year of our study and are classified by a MTBS analyst into 5 different categories: unburned

and unburned to low burn severity, low burn severity, moderate burn severity, high burn severity, and increased greenness. These categories are typically based on values of the Differenced Normalized Burn Ratio (dNBR). The fires in our study were reclassified into two categories: high burn severity and not high burn severity. High severity areas were then intersected with the home range circles for the year of the fire. Figure 3 provides two examples of NSO provincial home range areas and the intersecting conifer forest, severe fire, and logging covariates.
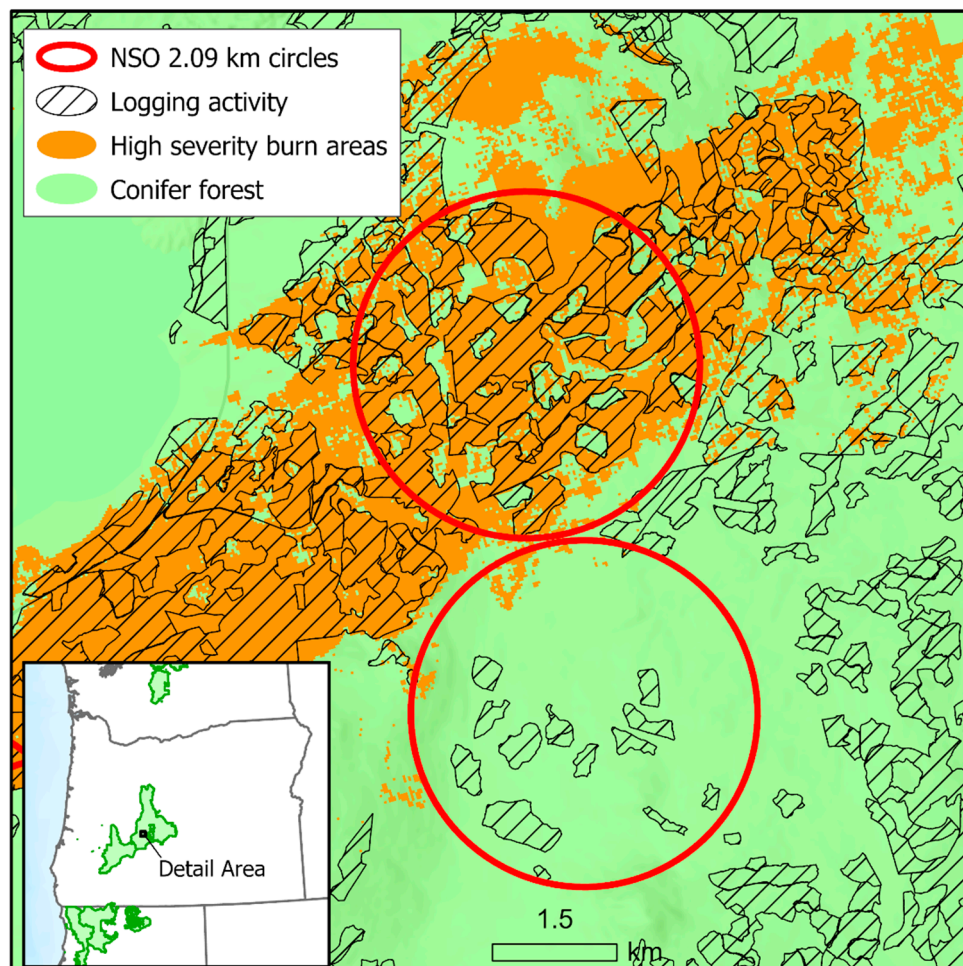
Figure 3. Examples of two Northern Spotted Owl provincial home range areas and the intersecting conifer forest, severe fire, and logging covariates.

3. Results

3.1. NSO Sample Size and Distribution

We identified 105 severely burned NSO sites obtained from the Okanagan-Wenatchee National Forest (n = 5); the Deschutes (n = 18) and the Umpqua National Forests (n = 14); and the Six Rivers (n = 3) and the Klamath National Forests (n = 65) (Figure 2). Data for all 105 NSO sites included national forest location, proportion of conifer forest and cumulative logged area, amount of severe wildfire in the core and provincial home ranges, whether the site was logged and/or BOs detected, the number of times the site was logged, and the type of logging (pre-fire and/or post-fire) (Online Supplemental Table S1).

3.2. NSO Site Characteristics and Degree of Logging

The mean proportion of the NSO core home range comprised of conifer forest was 0.89 (SD = 0.14, range = 0.28–1.00, n = 105) and the mean proportion of the provincial home range that was conifer forest was 0.86 (SE = 0.14, range = 0.34–1.00, n = 105). The

vast majority (87%) of burned sites (91 of 105) were affected by logging, while only 12% of burned sites (13 of 105) had no logging or BO detections during the 18-year period (Figure 4). That is, just 13 NSO sites experienced severe fire only; 1 severely burned site had BO detections and no logging; 68 sites had both severe fire and logging; and all three effects (BO, logging, severe fire) were present in 23 NSO sites.
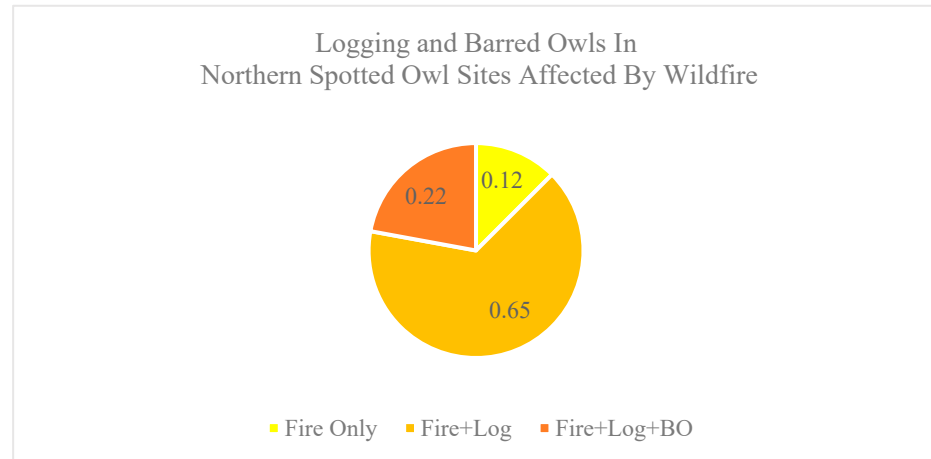
Figure 4. Proportion of Northern Spotted Owl sites that experienced severe wildfire and were not logged (fire only); that were also logged (fire + log), and that were logged and Barred Owls were detected (fire + log + BO).

We further quantified whether the 91 logged sites were subjected to pre-fire logging only, post-fire logging only, or both pre- and post-fire logging. The majority ($n = 63$, 60%) of NSO sites were logged both before and after fire, followed by those logged only after fire ($n = 15$, 14%) and sites logged only before fire ($n = 13$, 12%) (Online Supplemental Table S1). At both the core and provincial home range scales, most NSO sites were logged multiple times. Within the 0.8 km circle logged sites, NSO experienced a mean of 2.3 logging entries (SD = 1.3, maximum = 8 times). Within the 2.09 km circle sites, logged NSO sites experienced a mean of 4.9 logging entries (SD = 2.7, maximum = 14 times). The mean amount of conifer forest in the 0.8 km home range cores that was logged within our sample of NSO sites (including sites that were not logged) was 27 ha (SD = 32.8 ha) with a maximum of 174.8 ha logged within the core area. The mean amount of logging in conifer forests within the 2.09 km provincial home range (including unlogged sites) was 171.8 ha (SD = 152.1 ha) with a maximum of 965 ha logged in the provincial area.

Examples of actual (pre- and post-fire) and proposed logging activities within NSO sites are provided in Figure 5.
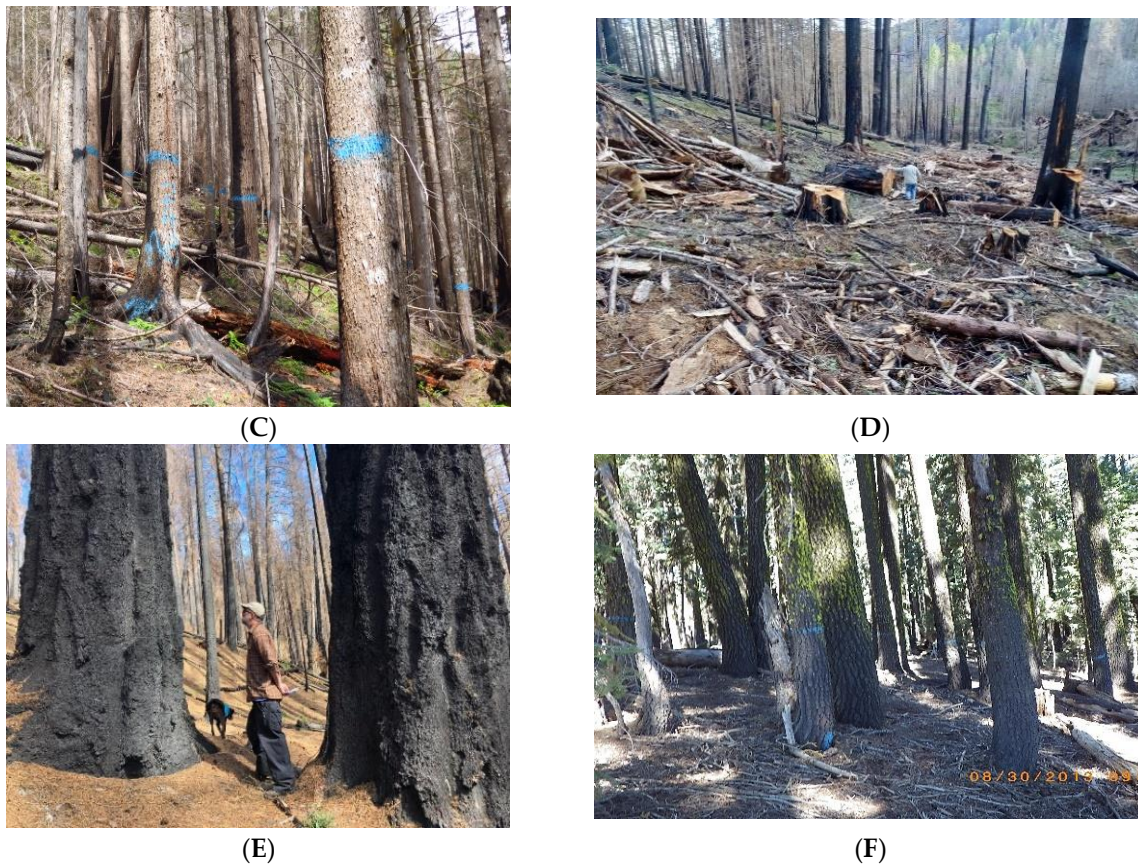

(**A**)

(**B**)

Figure 5. *Cont*.

Figure 5. (**A**) Bureau of Land Management's Picket West timber sale in NSO Critical Habitat in Oregon where fuel treatments will reduce overstory canopy closure to 40% (photograph Courtesy of Luke Ruediger). (**B**) Trees marked for logging in the Pilgrim project on California's Shasta-Trinity National Forest in NSO occupied territories (photograph Courtesy of Doug Bevington). (**C**) Downey Creek timber sale in the Darrington Ranger District of the Mt. Baker-Snoqualmie National Forest in California showing large trees to be removed within a Late Successional Reserve (LSR) where fire occurred (photograph Courtesy of Kathy Johnson). (**D**) Post-fire logging within NSO core areas on the Bureau of Land Management's Roseburg District in Oregon (photograph Courtesy of Francis Eatherington). (**E**) Seiad-Horse post-fire timber sale within an LSR on the Klamath National Forest in California (photograph Courtesy of George Sexton). (**F**) Trees marked for logging in an occupied NSO activity center in the Smokey project on the Mendocino National Forest in California (photograph Courtesy of Monica Bond). All photographs are with permission from their copyright owners.

4. Discussion

We enumerated the amount of logging and severe fire at two spatial scales, the NSO core home range and the provincial home range, as well as the presence of BOs, in 105 NSO sites that had experienced severe wildfire in conifer forests on USFS lands from 2000–2017. By quantifying the simultaneous extent of these three primary stressors (logging, severe fire, BO) within NSO core and provincial home ranges, we showed that logging was the predominant stressor in 87% of NSO sites that also experienced severe fire, with the additional stressor of BO at 22% of the burned-and-logged sites. Most (60%) of the NSO sites had evidence of logging (clearcuts, commercial thin, fuels reduction) both before and after severe fires. Only 12% of severely burned sites had no logging or BO detections during the 18-year study period, indicating the rarity of NSO territories subjected to severe fire without the compounding effects of multiple logging entries and invasive BOs.

An interesting finding was that of 14 sites that experienced wildfire but were not logged at any point during the 18-year period, only 1 site (8%) also had BOs recorded. Of the sites that were logged either before or after fire, or both before and after, 23 sites

(34%) had BOs detected. This result agrees with previous research demonstrating low use of severely burned forests by BOs [30] and offers some support for the hypothesis that logging facilitates invasions of BOs into NSO sites [31,32]. Conversely, NSO territories with relatively high proportions of suitable NSO habitat (unlogged) may be better capable of withstanding BO competition [32]. However, one caveat to our study is that BOs were only recorded opportunistically when detected during NSO surveys, so true prevalence of BOs may be underestimated.

The USFS claims that severe wildfire is a major cause of NSO territory abandonment and has constructed habitat suitability models that assume severely burned areas are no longer nesting or roosting habitat [33] (also see https://www.fs.usda.gov/rmrs/science-spotlights/severe-fire-good-or-bad-spotted-owls; accessed on 26 April 2022). Based on this assumption, the agency applies for 'incidental take' permits under section 7 of the ESA to log and presumably kill or harass any NSOs in designated Critical Habitat, Late-Successional Reserves, and NSO activity centers (known territories) following severe fires where logging is most often proposed [14]. Take permits are routinely granted by the USFWS, who also assumes severely burned sites are no longer nesting or roosting habitat. In these situations, competing hypotheses are seldom addressed nor are habitat suitability models validated. We note that despite assertions by federal agencies and some researchers that logging for fire risk reduction is mostly about small trees (e.g., [34]) in Spotted Owl territories and elsewhere [27], fuels reduction logging most often removes large trees to pay for the costs of thinning (see Figure 5A–F). This can impact critical NSO habitat by reducing canopy closure below recommended thresholds (e.g., 60% canopy overstory; Figure 5) while altering ground cover that supports NSO prey species [35].

Logging, and to some extent BOs, are stressors that are can be managed [36]. It remains an area of active research and debate as to whether severe fires can be reduced through certain forms of logging (e.g., thinning), particularly as the recent increase in megafires is attributed to extreme fire weather associated with climate change that is overriding efforts to reduce flammable vegetation via thinning [26,27,37,38]. Further, the extent to which severe fire is a major threat to Spotted Owls is often biased by the tendency for federal agencies and some researchers to falsely attribute abandonment by Spotted Owls in severely burned sites to fire alone [39] even though logging is usually present on those sites [12,13,17,18].

Our findings support the need to validate NSO habitat modeling assumptions and adjust incidental take permits that are routinely granted by the USFWS based on the assumption that severe fire is no longer NSO habitat. For instance, the Klamath National Forest in 2016 proposed to clearcut 2720 ha of severely burned NSO sites within Late-Successional Reserves under the Northwest Forest Plan based on the assumption that they were no longer suitable NSO habitat. The USFWS [40] proceeded to grant the USFS an incidental take permit to harm, kill, or harass 74 adult NSOs and 12–29 juveniles, concluding that logging would not trigger a range-wide jeopardy decision because the sites were assumed to no longer provide suitable habitat. With the recent uptick in wildfires within the range of the NSO [41], ongoing NSO incidental take under the assumption that severely burned forest patches are no longer NSO habitat could indeed trigger cumulative effects resulting in a future jeopardy decision. This could otherwise be avoided by validating NSO habitat models based on our findings and prohibiting incidental take permits in severely burned NSO sites.

5. Conclusions and Management Recommendations

Recovery Action 8 in the NSO Recovery Plan [4] (p. III-40) suggests "analyz[ing] exiting data on [NSO] occupancy pre- and post-fire and establish a consistent database to track owl occupancy response to fires across the dry Cascades provinces". We note that in our study NSO survey forms lacked a standardized data reporting protocol, resulting in many survey forms where activity center numbers or specific site coordinates were missing; hence the need for consistency in reporting. Moreover, our findings point to the need for

federal agencies responsible for the recovery of the NSO (USFWS) and the management of its habitat (USFS) to adjust recovery actions to better quantify and address two of the principal interacting NSO stressors—logging and BOs—that complicate severe fire effects on NSOs as well as agency efforts (e.g., thinning) to reduce fire intensity based on this assumption. Odion et al. [35] used a transition state model to conclude thinning at the scale proposed in the 2011 NSO recovery plan would result in 3.4 to 6.0 times more NSO habitat loss than severe wildfire over a 40-year timeline that was similarly demonstrated by Raphael et al. [42]. That is to say, the main treatment type on National Forest lands to lower fire intensity in NSO sites may actually be causing more habitat degradation than severe wildfires, especially when results of NSO site occupancy are conflicted by pre- and post-fire logging.

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