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Original Article

Use of Higher Severity Fire Areas by Female Pacific Fishers on the Kern Plateau, Sierra Nevada, California, USA

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ABSTRACT The Pacific fisher (*Pekania pennanti*) is a rare and imperiled forest carnivore, with a genetically distinct and isolated population living in the southern Sierra Nevada mountains of California, USA. Female fishers are of special interest and concern, given their very small numbers and their disproportionately important role in the potential recovery of the population. Using fisher scat detection to assess patterns of habitat use, I conducted analyses regarding use by fishers of unlogged higher severity fire areas at 10–11 years postfire in the 2002 McNally fire area. Contrary to the prevailing current hypothesis regarding fisher postfire habitat use, fishers did not use higher severity fire areas less than low–moderate-severity areas or unburned forest ($n = 77$ scats), and female fishers used the large, intense McNally fire area significantly more than unburned forest ($n = 12$ scats). Female fishers were detected at multiple locations >250 m into the interior of a very large (>5,000 ha), unlogged higher severity fire patch. These results indicate unlogged higher severity fire areas are suitable habitat for fishers, especially female fishers, and suggest a need to revisit current management direction, which emphasizes extensive commercial thinning and postfire logging to reduce fuels and control fire.

KEY WORDS California, higher severity fire, mixed-conifer forests, Pacific fisher, *Pekania pennanti*, Sierra Nevada.

There is notable conservation concern regarding the southern Sierra Nevada, California, USA, population of the Pacific fisher (*Pekania pennanti*); this is a rare forest carnivore that is strongly associated with dense, mature–old, mixed-conifer forest with high canopy cover and tree densities for resting and denning habitat (Zielinski et al. 2006, Purcell et al. 2009, Zhao et al. 2012). Suitable foraging habitat is less well-understood. The Sierra Nevada fisher population, which is genetically distinct (Tucker et al. 2012), is very small and isolated, and there is particular interest in and concern about female fishers, given their very low numbers (only 73–147 ad F) and their disproportionate importance to the recovery of the population (Spencer et al. 2011). On account of important concerns regarding population persistence, the U.S. Fish and Wildlife Service had designated this species as a Candidate for listing under the Federal Endangered Species Act.

Current forest-management direction in Sierra Nevada forests inhabited by Pacific fishers emphasizes aggressive fire suppression, as well as landscape-level mechanical thinning for the stated purpose of reducing forest density and fuels and preventing occurrence of higher severity fire (USDA 2004, 2014)—patches of approximately 50–100% tree mortality (by basal area). Such fire effects are hypothesized to eliminate suitable fisher habitat (USDA 2004, 2014; Scheller et al. 2011), and are described as a "deforested condition" by the U.S. Forest Service (http://www.fs.fed.us/r5/rsl/projects/postfirecondition/methods/). In guidance for the upcoming forest plan revisions for Sierra Nevada national forests, the U.S. Forest Service has expressed its intention to implement commercial logging at an "unprecedented scale" to advance the stated goal of saving species such as the Pacific fisher from the effects of higher severity fire (http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5351674.pdf).

However, such forest management activities themselves degrade fisher habitat, and fishers tend to avoid mechanically thinned areas when near them (Garner 2013, Truex and Zielinski 2013). Moreover, logging of snags, and conversion of fir-dominated forests to pine-dominated forests through mechanical thinning, are recognized as threats to fishers (Bull et al. 2001). Thus, forest management of fisher habitat, at present, is predicated on the belief that mechanical thinning, though not ideal for Pacific fishers, is better than allowing mixed-severity wildland fire. However, until recently, no empirical studies had been conducted on the relationship between Pacific fishers and postfire forest.

Investigating the McNally fire of 2002 at 10–11 years postfire, and adjacent unburned forest, my objectives in this study were to 1) test the prevailing hypothesis that fishers avoided higher severity fire areas; 2) determine whether

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female fishers used the large, intense McNally fire area less than unburned mature forest, consistent with current hypotheses; and 3) determine whether female fishers used higher severity fire areas proportionally more or less than males.

STUDY AREA

The study area was a 38,400-ha area in the northern Kern Plateau, southeastern Sequoia National Forest (CA, USA), which included the 2002 McNally fire area and adjacent unburned, mature forest (Fig. 1). The particular emphasis of this study was the 2002 McNally fire, including a very large (approx. 5,422 ha) higher severity fire patch, and unburned forest adjacent to the McNally fire area (Fig. 1).

Over 99% of the postfire habitat in this area of the McNally fire was unmanaged, and did not experience either postfire logging or artificial planting following fire. This landscape included Sierran mixed-conifer forest, which tended to be dominated by white fir (*Abies concolor*; http://www.dfg.ca.gov/biogeodata/Cwhr/pdfs/SMC.pdf), as well as Jeffrey pine (*Pinus jeffreyi*), red (*A. magnifica*) fir, and lodgepole pine (*P. contorta*) forests. The study area consisted of 44% Sierran mixed-conifer, 18% Jeffrey pine, 13% lodgepole pine, 13% red fir, and 12% other vegetation–cover (chaparral, meadows, rock outcroppings). Seventy-nine percent of the study area, prefire, consisted of dense, mature conifer forest (CWHR 4M, 4D, 5M, 5D, and 6; see http://frap.cdf.ca.gov/projects/frap_veg/classification.html). Elevation of forests in the study area ranged from approximately 1,600 m to 2,900 m.

METHODS

Two scat dog teams conducted random transects across all vegetation types and structures in unburned forest and in the McNally fire area (all fire severities) in the study area in July and November of 2012, and November of 2013, and detections were defined as presence of fisher scat, as confirmed by later genetic analysis (the genetic integrity of scat degrades rapidly, with exposure to weather and bacteria; thus, detections were assumed to coincide with the calendar year of surveys). Transects were not conducted to coincide with roads or trails. Rather, transect routes were determined randomly by scat dog teams on a moment-to-moment basis each day within the study area, and included slopes, ridges, riparian zones, and occasional crossing of meadows and rock outcroppings (Fig. 1). Each team consisted of a dog specially trained to detect fisher scat, and a professional human handler, from Conservation Canines at the University of Washington's Center for Conservation Biology (Wasser et al. 2004). DNA testing of all scat samples was conducted by the genetics lab at the Center for Conservation Biology to

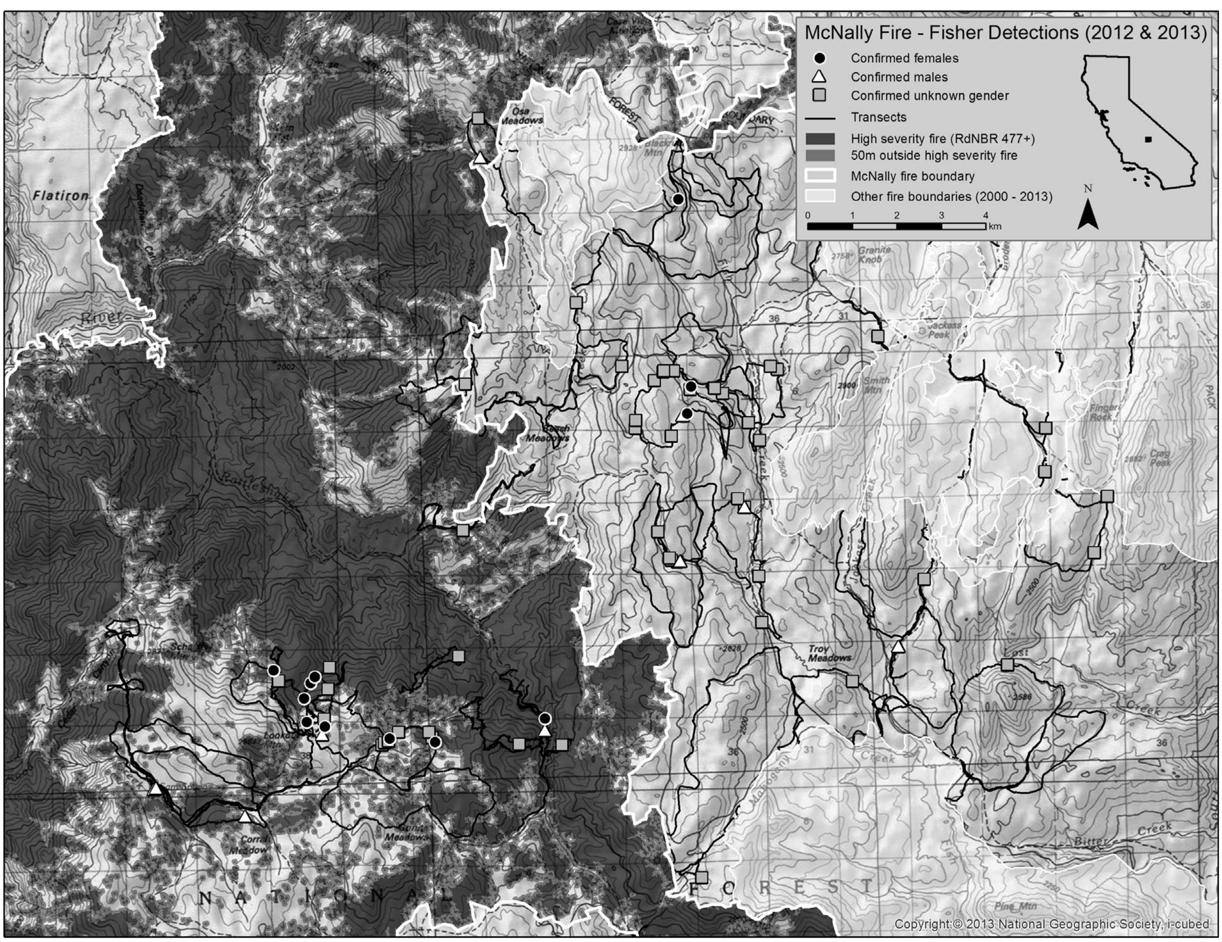

Figure 1. Fisher scat survey transects conducted in 2012 and 2013 in the McNally fire area and adjacent unburned forests, showing confirmed female and male fisher detections, and unknown gender detections, Sequoia National Forest, southeastern Sierra Nevada, California, USA.

confirm that samples were from fishers, and to identify gender (Wasser et al. 2004). Specific methods of genetic analysis for species and gender identification of fisher scat samples are described in Hanson (2013).

For the postfire habitat portion of the study area, I chose to focus on the McNally fire area in order to avoid potential for a confounding influence of time-since-fire in other nearby, but more recent, fires (e.g., Clover fire of 2008, Granite fire of 2009, and Lion fire of 2009) wherein I detected fishers at 3–4 years postfire in a previous study, conducted in 2012 (Hanson 2013). Further, I chose to focus on the McNally fire area because large, intense fires, such as McNally, are at the center of forest management discussions and concerns with regard to the Pacific fisher (USDA 2004, 2014; Scheller et al. 2011). Because this study includes, on the one hand, data from an additional field season (2013) while, on the other hand, it does not include more recent fires that were included in the 2012 field season (Hanson 2013), sample sizes are not simply additive with regard to Hanson (2013) and this study.

I assessed the amount of available vegetation types by measuring the length (km) of transects in unburned forest and within the categories in the McNally fire area, as described below. For fire severity, I used satellite imagery (www.mtbs.gov), based on RdNBR (relative differenced normalized burn ratio), which compares prefire conditions to those at 1 year postfire (Miller and Thode 2007). Higher severity fire was defined as RdNBR $\geq$477, equating to approximately 50–100% basal area mortality of trees, and low–moderate-severity areas were defined as RdNBR $<$477, equating to 1–49% basal area mortality (Hanson 2013). Higher severity fire patches $>$0.1 ha in size were included. I use the term "higher-severity fire" to describe fire effects through which half or more of the live tree basal area was killed by fire, in order to evaluate a key current management metric described by the Forest Service as a "deforested condition" (http://www.fs.fed.us/r5/rsl/projects/postfirecondition/methods/), and to distinguish these effects from the narrower definition of "high-severity fire" as, generally, 75–100% mortality (http://www.mtbs.gov/files/MTBS_pnw-psw_final.pdf).

I used a χ^2 goodness-of-fit test (Rosner 2000) to determine whether fishers avoid higher severity fire areas (USDA 2004, 2014, Scheller et al. 2011), analyzing use of 5 categories: higher severity fire areas $>$100 m inside higher severity patch boundaries; higher severity fire areas 1–100 m inside patch boundaries; edges (1–50 m outside higher severity fire patch boundaries); low–moderate-severity areas $>$50 m outside higher severity fire patch boundaries; and unburned forest. Expected values were based on the relative proportions of transect length in each category.

Second, I used a χ^2 goodness-of-fit test (Rosner 2000) to determine whether female fisher use of burned forest was lower than female detections in unburned forest adjacent to the McNally fire area (USDA 2004, 2014; Scheller et al. 2011). Expected values were based on the relative proportion of transect length in the McNally fire area and in unburned forest. For the burned forest detections in this analysis, I included all female fisher detections within the perimeter of the McNally fire area. As noted in Hanson (2013), there were 3 female detections outside of fire perimeters, and 2 within the McNally fire perimeter in an area mapped as unchanged–unburned by the fire. During the 2013 field season, evidence of light fire effects were found in this inclusion; thus, the 2 female detections in the inclusion were analyzed as part of the McNally fire area, rather than as unburned forest.

Third, I used a χ^2 trend test of proportions (Rosner 2000) to assess whether the female fisher detections, relative to detections of males, differed over 4 categories: higher severity fire patches; higher severity fire edges (1–50 m outside of higher severity fire patch boundaries); low–moderate-severity areas ($>$50 m outside of higher severity fire patch boundaries); and adjacent unburned forest.

RESULTS

A total of 239 km of transects were conducted in unburned forest. A total of 67 km of transects were conducted in higher severity fire areas in the McNally fire area and 110 km were conducted outside of the higher severity fire patch boundaries within this fire area (Table 1).

Overall, Pacific fishers did not avoid higher severity fire areas. I found no statistically significant difference between fisher use of higher severity fire areas compared with low–moderate-severity areas or unburned forest ($\chi^2 = 1.78$, $P = 0.776$, $df = 4$, $n = 77$; Table 1).

For female fishers, use of the McNally fire area was significantly higher than that of adjacent unburned forest, based on availability ($\chi^2 = 5.18$, $P = 0.023$, $df = 1$, $n = 12$; Table 2). Detections deep into the very large higher severity fire patch ($>$250 m inside the approx. 5,422-ha higher severity fire patch) equated to 0.293/km, while detections/km were 0.192 in adjacent unburned forest (Fig. 2). The proportional use of higher severity fire patches and higher severity patch edges by female fishers, relative to males, did not significantly differ with the proportion in low–moderate-

Table 1. Fisher use (observed vs. expected detections during scat-transect surveys conducted in 2012 and 2013) of higher severity fire areas (interior areas $>$100 m inside higher severity fire patches, and areas 1–100 m inside such patches), edges (1–50 m outside higher severity fire patches), low–moderate-severity areas ($>$50 m outside higher severity fire patches) in the McNally fire area, and unburned forest within the Sequoia National Forest, southeastern Sierra Nevada, California, USA.

Detections	Higher severity ($>$100 m inside)	Higher severity (1–100 m inside)	Edges	Low–moderate	Unburned
Observed	9	5	10	7	46
Expected	7.5	4.8	9.4	11.0	44.3
Transect km	41	26	51	59	239

Table 2. Female fisher use (observed vs. expected detections during scat-transect surveys conducted in 2012 and 2013) of the McNally fire area compared with adjacent unburned forests within the Sequoia National Forest, southeastern Sierra Nevada, California, USA.

Detections	McNally fire	Unburned forest
Observed	9	3
Expected	5.1	6.9
Transect km	177	239

severity areas >50 m from higher severity fire patches and unburned forest ($\chi^2 = 3.08$, $P = 0.380$, $df = 3$, $n = 24$; Table 3). All of the female fisher detections in higher severity fire areas within the McNally fire area were in the 5,422-ha higher severity fire patch, and most of these were >250 m inside this very large higher severity fire patch.

DISCUSSION

The results of this analysis indicate that female Pacific fishers actively use patches of higher severity fire in conifer forest, including edges and interior areas of large higher severity fire patches, in the southern Sierra Nevada. Therefore, the hypothesis that higher severity fire areas are not fisher habitat, and that female fishers would avoid mixed-severity fire areas, including higher severity fire patches, was rejected.

Overall, fishers did not avoid higher severity fire areas in general, or the interior of large high-severity fire patches in particular. Thus, the hypothesis that Pacific fishers would avoid higher severity fire areas, and that such areas represent a categorical loss of habitat (USDA 2004, Scheller et al. 2011), was rejected. Although fishers were detected in burned areas at varying postfire periods, including 3–4 years postfire, in Hanson (2013), the results of this study indicate that such use is not merely temporary. In this study, at 10–11 years postfire in the area of the large, intense McNally fire, fishers continued to actively use postfire habitat.

Differences in landscape characteristics between the burned and unburned portions of my study area, along the surveyed transects, are unlikely to explain the results here. Mean elevation of the burned portion was 2,454 m (SD = 158 m), and mean elevation of the unburned portion was 2,481 m (SD = 144 m). Mean distance to riparian areas (streams) was 346 m (SD = 362 m) for the burned portion and 369 m (SD = 298 m) for the unburned portion. With regard to the combination of forest type (Sierran mixed-conifer) and structure (dense, mature forest: CWHR 4M, 4D, 5M, 5D, and 6) most selected by fishers (Hanson 2013), such conditions comprised 28.9% of the prefire condition in the burned portion of the study area, and 25.9% of the unburned portion. In a *post hoc* analysis of these 3 factors (elevation, distance to riparian, preferred forest type-structure), there were no significant differences between the burned and unburned portions of the study area.

Figure 2. Photograph of a representative confirmed female fisher foraging location (based on Global Positioning System coordinates of a scat detection during transect surveys conducted in 2012 and 2013) 305 m into the interior of the largest higher severity fire patch in the McNally fire area of Sequoia National Forest, southeastern Sierra Nevada, California, USA.

Future research might investigate fisher use of postfire habitat explicitly with regard to time-since-fire across multiple fire areas. Additionally, future investigations could explore population size in and adjacent to fire areas. This was beyond the scope of this study. However, given the mean size of 528 ha for female fisher home ranges in the southern Sierra Nevada (Zielinski et al. 2004), which equates approximately to a radius of 1.0–1.5 km (if home ranges are roughly circular), there were likely 3 or more different females using the large higher severity fire patch in the McNally fire area in my study area.

Current forest management focuses on fisher resting and denning habitat, which is well-described in the scientific literature as dense, mature–old conifer forest (Zielinski et al. 2006, Purcell et al. 2009, Zhao et al. 2012). My results indicate that fishers also actively use conifer forests that have experienced higher severity fire. Given that such areas are distinctly different from resting–denning habitat (Zielinski et al. 2006, Purcell et al. 2009, Zhao et al. 2012), my results are consistent with higher severity fire areas being used as foraging habitat by fishers, similar to findings regarding the California spotted owl (*Strix occidentalis occidentalis*) in the McNally fire area (Bond et al. 2009, 2013). In a recent radiotelemetry study of Mexican spotted owls (*S. o. lucida*), researchers found that the owls tended to leave unburned old forest nest cores, traveling up to 14 km to spend the winter in mixed-severity fire areas, where small mammal prey biomass was found to be 2–6 times higher (Ganey et al. 2014). Future research on the Pacific fisher could similarly explore prey type and abundance in burned versus unburned forest.

My results suggest that efforts to restore mixed-severity fire to Sierra Nevada forests (DellaSala et al. 2014, Odion et al. 2014) would not be inconsistent with Pacific fisher conservation. Increased managed wildland fire activities (i.e., allowing lightning fires to burn in more remote areas) could be used more frequently in these forests, while focusing fuel reduction in defensible space areas adjacent to homes (Gibbons et al. 2012, Calkin et al. 2014). This should be operationally feasible, given that even the most fire-suppressed forests are burning mostly at low- and moderate-severity (Odion and Hanson 2006, 2008; van Wagtendonk et al. 2012), and the most comprehensive current analysis of fire severity patterns shows no trend of increasing

Table 3. Female fisher use (detected during scat-transect surveys conducted in 2012 and 2013) of higher severity fire patches, higher severity fire edges (1–50 m outside higher severity patches), low–moderate-severity areas (>50 m outside higher severity patches) in the McNally fire area, and adjacent unburned forest within the Sequoia National Forest, southeastern Sierra Nevada, California (USA), relative to males.

Detections	Higher severity	Edges	Low–moderate	Unburned	Total
Female	4	3	2	3	12
Male	1	2	3	6	12
Total	5	5	5	9	24
Proportion female	0.80	0.60	0.40	0.33	0.50

severity in Sierra Nevada forests (Hanson and Odion 2014). Such restoration of mixed-severity fire would also have benefits for overall forest biodiversity, given that complex early seral forest created by higher severity fire supports very high levels of species richness and wildlife abundance, and numerous rare and imperiled plant and animal species are primarily associated with such habitat (Swanson et al. 2011, Buchalski et al. 2013, DellaSala et al. 2014). Meanwhile, habitat connectivity models for the Pacific fisher could begin to incorporate unlogged high-severity fire areas into landscape-level conservation planning (Carroll et al. 2012).

Higher severity fire, including large patches, is a natural part of fire regimes in ponderosa pine (*Pinus ponderosa*) and mixed-conifer forests of the western Sierra Nevada (Baker 2014, Hanson and Odion 2015), and has declined severely since the onset of fire suppression policies in the early 20th century (Odion and Hanson 2013, Odion et al. 2014), reducing landscape heterogeneity.

MANAGEMENT IMPLICATIONS

The results of this study indicate that current forest management direction, which is focused on large mechanical thinning projects designed to create open forests and preclude higher severity fire, as well as postfire logging, is likely to unnecessarily degrade and homogenize existing suitable fisher denning and resting habitat and also hinder development of suitable foraging habitat from mixed-severity fire, exacerbating threats to fisher populations. My results also indicate that existing management assumptions about threats posed to Pacific fishers by mixed-severity wildland fires, including large fires, are not well-founded, and that expansion of managed wildland fire activities may benefit fishers.

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