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An assessment of fisher (*Pekania pennanti*) tolerance to forest management intensity on the landscape

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ABSTRACT

Forest restoration intended to reduce the overabundance of dense vegetation can be at odds with wildlife habitat conservation, particularly for species of wildlife that are strongly associated with structurally diverse forests with dense canopies. The fisher (*Pekania pennanti*), a mesopredator that occurs in mid-elevation forests of the southern Sierra Nevada, is such a species and managers are challenged to address fuel accumulations while at the same time maintaining sufficient habitat. We were interested in whether fishers tolerate the amount of management-related disturbance that fire ecologists predict will be sufficient to reduce the severity and spread rate of fires. To address this question we related an index of relative fisher abundance to data on the amount of each sample area that has been affected by one or more forms of disturbance. These are forms of forest management associated with either restoration activities (e.g., thinning, prescribed fire) or timber harvest (e.g., clear cutting, selection harvest). We used scat detection dogs to determine the relative abundance of scats in each of 15, 14 km^2 hexagonal sample areas that were sampled twice a year for 4 years. These data were used to classify each sample area as either low, moderate or high relative abundance of fishers. We also summarized for each of the sample areas the total number of hectares (including overlap) affected by management activities each year, and generated a 3-year running average. The areas exhibiting the highest use by fishers had an average of 36.7 hectares per year affected by ground-disturbing activities. Given that each sample area was 1400 hectares, this suggests that fishers consistently occupy – at the highest rate of use – places where an average of 2.6% of the area has been disturbed per year. This translates to an average of 7.4 ha of disturbance/year/km^2 (47.1 acres of disturbance/year/mi^2). This is more disturbance than was predicted to be necessary to treat forests to reduce fire spread rate and severity in the southern Sierra Nevada, but less than predicted to be necessary by fire models for other geographic locations. Our work suggests that it may be possible to implement restorative treatments at an extent and rate that achieves fire modeling goals and does not affect occupancy by fishers. Implementation of such an approach, however, should also consider protection of large trees (conifers and hardwoods) used as resting and denning sites and account for the maintenance of habitat connectivity.

1. Introduction

The fisher (*Pekania pennanti*, formerly *Martes pennanti* [see Sato et al., 2012]) is an intermediate-sized mammalian carnivore that is associated with late-successional, mixed hardwood-conifer forests in western North America (Lofroth et al., 2010). The population in the Pacific states has been considered warranted for federal listing under the Endangered Species Act (USFWS, 2004) and, as such, it is necessary to understand how sensitive the fisher is to the types of disturbances that characterize forest management. The fisher in the Sierra Nevada of California occurs in a forest environment that is characterized by a frequent fire regime (Van de Water and Safford, 2011) but the 20th century era of fire suppression has resulted in an altered ecosystem characterized by an accumulation of fuels that increase the risk of severe and widespread fires (Collins et al., 2011; Miller et al., 2009; Miller and Safford, 2012; Scholl and Taylor, 2010; van Wagtendonk and Fites-Kaufman, 2006). Uncharacteristically severe fires threaten human habitations as well as important wildlife habitats. Consequently the USDA Forest Service and other land managers seek options to reduce the surface and ladder fuels that can lead to large crown fires. Crown thinning and underburning, using prescribed fire, are the most frequently applied treatments for this purpose (Martinson and Omi, 2013). In addition, ecologists have increasingly recog-

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nized the important role of fire in the forest ecosystems of the Sierra Nevada, for its role in nutrient cycling, forest development and the generation of structural heterogeneity that fosters a diversity of wildlife habitats (Long et al., 2013; North et al., 2009, 2012). Thus, there is a great deal of motivation to reduce accumulated fuels to the point that forests can sustain regular low-intensity fires that will restore important ecological processes.

The goal of restoring forests to conditions that will sustain regular low-intensity fire is a difficult one to achieve, especially in the face of warm and dry conditions expected in future climates (Collins and Skinner, 2013). The prevailing philosophy, at least in the Sierra Nevada, suggests that a combination of mechanical thinning and prescribed fire – distributed in a strategic arrangement designed to retard fire spread rate (Finney et al., 2007) – will address the fuel accumulation problem and also make suppression easier in situations where it is necessary. This philosophy, however, has not often considered the effects of these changes in forest structure on wildlife, especially species like the fisher that are strongly associated with spatially connected dense forests that include a significant amount of dead and downed woody material (Aubry et al., 2013; Lofroth et al., 2010; Raley et al., 2012). These habitat conditions are precisely the conditions that fire managers seek to reduce, in their effort to decrease fuels and apply treatments in spatial configurations that slow fire spread rates.

Reconciling the need to protect vulnerable fisher habitat while reducing unnatural accumulations of forest fuels has been an issue that has stymied fuels reduction actions for well over a decade in the southern Sierra. Until recently, there has been little opportunity to gather empirical evidence regarding fisher reaction to management efforts. Instead, efforts to fill this information void have been largely limited to informed inference. Truex and Zielinski (2013) explored the effects of small scale treatments (mechanical and prescribed fire) on predicted fisher resting habitat value and reported that the combination of both treatments significantly reduced resting habitat compared to controls. Scheller et al. (2011) modeled the regional effects of fuels treatments on the distribution of fisher habitat. Although the benefits of fuel treatments varied by elevation and treatment location, and there was considerable uncertainty in their projections, they found that indirect benefits to fishers of forest thinning exceeded the negative effects of treatments on habitat quality. Neither of these studies, however, evaluated the direct effects of management disturbances on fisher use of habitats. Garner (2013) used radio-tracking data to analyze second-order and third-order (Johnson, 1980) fisher habitat selection relative to treatment areas. He reported that while fishers tend to avoid treated areas when resting or foraging, they will tolerate treatments within their home range but use primarily the untreated areas. What remains unclear is the extent of the tolerance that fishers have to disturbance that occurs within the areas they use. We estimate the amount of forest management (e.g., timber harvest, vegetation management, prescribed burning) that occurs in areas regularly used by fishers. We compare these estimates with predictions by fire ecologists as to the amount (area and rate) of fuel treatment predicted to be necessary to significantly reduce fire severity and spread rate. Our goal is to help managers understand how the extent and frequency of treatments necessary to reduce the negative effects of fire compares with the proportions of areas occupied by fishers that have been subjected to some form of vegetation management.

2. Materials and methods

We used scat detection dogs (MacKay et al., 2008; Thompson et al., 2012) to conduct surveys for fisher scats on 210 km^2 of suitable habitat on the High Sierra District of the Sierra National Forest (SNF) in the southern Sierra Nevada, California. The survey area was divided into 15, 14-km^2 hexagonal shaped sample areas each roughly the size of a female fisher's home range (Fig. 1). These sample areas occurred between 1000 and 2000 m elevation and within an area where an empirically based model (Davis et al., 2007) predicted uniformly high habitat suitability, with the exception of one sample area (Fig. 1). Scat detector dog teams, provided by the University of Washington's Center for Conservation Biology (UWCCB) and trained to locate fisher scat, surveyed the area twice a year, in June and October, for 4 years (2007–2010). During a month-long survey, each sample area was surveyed 3 times on different days by alternating dog teams in order to account for the variation associated with weather conditions and individual dog ability. Surveys began in the early morning hours and lasted 5–7 h, capitalizing on morning moisture and air movement. Teams carried GPS receivers that logged the team's location at 60-second intervals, generating a tracklog of the survey route. Tracklogs were consulted to aid in complete coverage of the sample area. Because of the diversity of mesocarnivore species in the area and the risk of misidentification, all scats were genetically verified as fisher by UWCCB or the USFS Wildlife Genetics Laboratory, Missoula, Montana.

Intensity of use by fishers was indexed by calculating the total number of fisher scats collected across all sampling periods, then calculating the percent of total scats collected that were found in each of the 15 sample areas. Each area was classified as high use (>10%, $n = 5$), moderate use (5–10%, $n = 3$) or low use (<5%, $n = 7$) based on the ranked average scat detection rates. Although this was a relatively arbitrary definition, we recognize that fishers do not use all parts of the landscape equally for reasons that can have nothing to do with management actions. Instead, we simply wanted to identify those areas of the landscape that were used more often than others. It was in these areas that we were most interested in assessing the amounts of previous disturbance by forest management activities.

We related the fisher use indices to the proportion of each sample area that had been subjected to any of a selected set of forest management activities that are reported in a USDA Forest Service database referred to as FACTS (Forest Service Activity Tracking System), and a smaller database of the locations of prescribed burns maintained by the SNF. Only those 22 activities in the FACTS database that were assumed to have significant effects on fisher habitat structure or were substantial ground-disturbing activities were included (Table 1). For example, we included forms of harvest (e.g., code 4152 *Group Selection Cut*) and vegetation management (e.g., code 4220 *Commercial Thinning*) that would have direct effects on the basis of their disturbance and their alteration of forest structure. We excluded activities that did not meet this criterion or which very rarely occurred (e.g., code 4290 *Administrative Changes*, code 4314 *Pretreatment Exam for Reforestation*; code 4552 *Area Fertilizing*, code 4980 *Other Tree Improvement*; code 1250 *Rearrangement of Activity Fuels*). The smaller, prescribed fire database from the SNF is an internal database maintained by the High Sierra Ranger District that documents the ignition dates and extent of prescribed fires ignited on the district since 1994. All entries in this, second, database were included in the set of activities we considered affecting fisher habitat.

The extent of management activity for each sample area was quantified using a 3-year running average (calculated from 2000 to 2011) of the area (hectares) of management activities. For example, the 2005 value was calculated as the sum of 2003, 2004 and 2005 divided by 3. The running averages were based on three years to represent the average amount of disturbance experienced during a fisher generation time and to smooth the effect of year-to-year variation in amount of area treated. The 12 years of data resulted in 10, 3-year running averages for each sample area. The fisher scat data were compared to the annual area of treatments

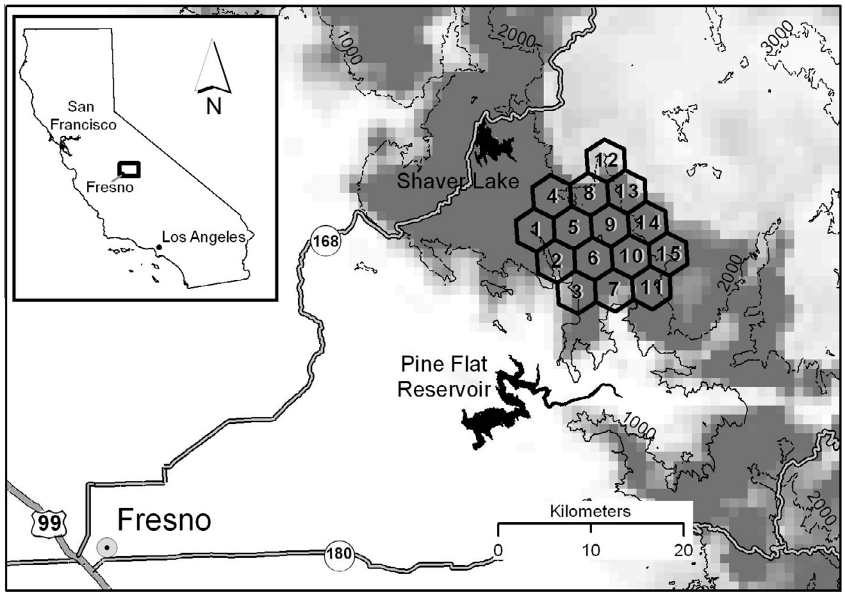

Fig. 1. Location of sample areas (cluster of hexagons) on the Sierra National Forest, California. Shading represents the results of modeling predicted fisher habitat, at the landscape scale, by Davis et al. (2007) and illustrates that all but one sample area fall within the areas of highest suitability. Also illustrated are selected elevation contours to demonstrate that all sample areas fall within the general band between 1000 and 2000 m.

Table 1
List of forest management activities in FACTS database that were considered to have significant effect on fishers or fisher habitat structure. Extractive activities are those related to the harvest and production of wood, usually for economic gain; restorative activities are designed to address the overabundance of small-diameter trees, surface fuel and forest density.

Activity code	Activity	Extractive	Restorative
1160	Thin of natural fuels		X
4111	Patch clearcutting	X	
4113	Stand clearcutting	X	
4114	Stand clearcutting – salvage mortality	X	
4117	Stand clearcutting	X	
4121	Shelterwood preparation cut	X	
4132	Seed-tree seed cut	X	
4142	Seed-tree final removal cut	X	
4143	Overstory removal cut	X	
4151	Single-tree selection cut	X	
4152	Group selection cut	X	
4220	Commercial thinning		X
4230	Sanitation (salvage)	X	
4231	Salvage cut (intermediate treatment, not regeneration)	X	
4232	Sanitation cut	X	
4431	Full planting without concurrent site preparation	X	
4432	Fill-in planting without concurrent site preparation	X	
4470	Site preparation for planting	X	
4511	Individual tree release and weeding		X
4521	Precommercial thinning – individual or selected trees		X
4522	Precommercial thinning – strip		X
4530	Pruning		X

in each sample area, assessed in blocks of 3-year running averages.

We were also interested in distinguishing two general categories of forest management activities: (1) those conducted with the relatively new objective of reducing fuels and restoring ecosystems (e.g., thinnings and prescribed fire-related activities, the two most common restorative treatments in western forests [Martinson and Omi, 2013]) and, (2) those conducted for other more traditional extractive purposes (e.g., clear cutting, sanitation and salvage harvests). Forest management is evolving, and we wanted to understand the proportion of activities that fishers were subjected to in our study area that were intended for each of these two different purposes. Typically, the extractive activities have greater impact than restorative activities on the habitat features associated with fisher use, such as canopy cover and density of large live and dead woody material (Zielinski et al., 2004; Purcell et al., 2009). We were also interested in identifying the dominant forest management activity in each sample area. To conduct this analysis, we identified 6 of the activity codes in the FACTS data base that were associated with restoration activities (e.g., code 4521 *Precommercial thinning – Individual or Selected Trees*; Table 1). We added to this total, the area treated with prescribed fire (i.e., underburning) that was recorded in the SNF database, since these were also conducted for restorative purposes. These two sets of activities constituted the *restoration* activities. The balance of the activities constituted the *extractive* activities. This analysis would allow us the opportunity to consider whether the fishers in our study were exposed primarily to forest management activities emphasized today on public lands, and likely in the near future (i.e., the restorative ones), as compared to the forest management activities more typical of the past (i.e., the extractive ones).

A forest management activity from either source, the FACTS or the SNF prescribed fire database, could spatially overlap any other activity. Thus, the same area could be tallied more than once if a second, but different, activity occurred there. This can occur, for example, when one or more activities are part of a sequence of silvicultural actions, such as when a precommercial thinning precedes a commercial thinning that occurs a few years later in the same stand. Both activities have potential impacts on fishers and their habitat, despite the fact that they occurred in the same area, since they occurred at different times and represent independent disturbance events. One shortcoming of the FACTS database is that some entries in the database represented the general perimeter surrounding a number of smaller subunits that were treated at the same time. These entries included some areas within the boundary that were unaffected by the treatment applied to the subunits. We could not review the thousands of entries to investigate the magnitude of this issue but specialists familiar with the FACTS database suggested that, when this occurred, the boundaries were drawn to minimize the inclusion of unaffected areas (J. Sherlock, Regional Silviculturist, Pacific Southwest Region, USDA Forest Service, pers. comm.). Furthermore, considering the small scale of most treated areas such spatial discrepancies are probably insignificant relative to an individual fisher home range size (mean = 2298 ha, min = 551 ha; Garner (2013)).

3. Results

The areas exhibiting the highest use by fishers had an average (SD) of 36.7 (46.3) ha/yr affected by ground-disturbing activities (Table 2). Given that each sample area was 14 km^2 (1400 ha) this suggests that fishers occupy – at the highest rate of use – places where an average of 2.6% of the area had been disturbed per year. This translates to an average of 7.4 ha of disturbance/year/km^2 (47.1 acres/year/mi^2). The areas we categorized as moderate use had about the same amount of area affected as the high use areas (37.8 ha/year; Table 2). The sample areas with the lowest fisher use had somewhat higher amount of area affected by treatment per year (49.3 ha/year; Table 2), but none of the categories of fisher use differed in terms of mean hectares of treatment/year ($F = 0.31$, df = 2, $p = 0.088$).

The dominant activities in the sample areas were, in decreasing rank order: underburning, sanitation (salvage) harvest, individual tree release and weeding, and thinning (Table 2). Four of the 5 sample areas with the *highest* use had dominant activities over the 12-year period that were largely restorative in nature (underburning, thinning or individual tree release); only one had a dominant activity that was extractive (sample area 7: sanitation [salvage]). In most of the sample areas (11 of 15; 73.3%) the majority of affected area was by restorative treatments (Table 2). Interestingly, 3 of the 4 sample areas that were primarily affected by extractive activities were in the low use category (Table 2).

4. Discussion

As indexed by scat deposition rates, places where fishers are most common had an average of 2.6% of the area affected by land management activities per year. This includes all relevant forms of disturbance, ranging from timber harvest to methods of fuels reduction, including thinning and prescribed fire. Each of the activities included in this assessment are likely to continue, to varying degrees, in the forests of the southern Sierra Nevada. For this reason, we believe it is pertinent to fisher conservation to represent in this analysis all significant forms of forest management that are likely to affect fisher habitat. However, the most relevant activities are those associated with reducing surface and ladder fuels because these are directly prescribed to address the backlog of areas in need of restoration. A number of authors have proposed methods of spatial optimization to locate and prioritize fuel management activities (e.g., Ager et al., 2013; Finney et al., 2007; Kim et al., 2009; Loehle, 1999). These approaches suggest that non-random (strategic) placement of fuels treatments on the landscape can reduce fire spread rates. The approaches vary, however, in their estimates of the *proportion of an area* that should be treated with a spatially optimized array of treatments before fire spread rate or ecological goals are achieved. Variation in the amount of area treated is necessary to consider when determining whether fuels treatments applied in this manner need to be applied on more, or less, land than was affected by management within the fisher study areas.

The estimates, by fire modelers, of the necessary amount of area to be treated vary considerably depending on the methods used, the forest type and geographic area, and other factors. Most relevant to our study, however, is the work by Syphard et al. (2011)

Table 2
Use of 15 sample areas by fishers, as indexed by scat detections, and hectares of each area affected by one or more of the selected forest management activities (see Table 1 for a list of the activities and codes). Fisher relative use was indexed by percent of scat total, from 2007 to 2010, and hectares affected by management were summarized during the period 2000–2011 and derived from the FACTS database and a local database of prescribed burning perimeters from the Sierra National Forest. Percent restorative treatments reflects the percent of the area of each sample area that was affected by treatments that are either prescribed fire or some form of thinning (see Table 1).

Sample Area	Category of use by fishers														
	Low use[a]							Moderate use[b]			High use[c]				
	1	3	8	9	12	14	15	2	6	13	4	5	7	10	11
Percent relative use by fishers	3.14	2.48	2.48	1.98	0.33	0.7	3.8	7.93	9.59	7.11	11.9	10.74	13.72	13.88	10.25
Mean hectares/yr affected by management	134.7	107.0	5.0	14.7	51.2	6.0	26.5	91.2	14.0	8.1	11.0	7.9	48.3	22.3	93.9
Dominant Activity Code	UB[d]	4230[e]	4230	4230	UB	4521[f]	4511[g]	UB	UB	UB	1160[h]	4511	4230	UB	UB
Percent Restorative Treatments	81.9	2.8	13.0	35.1	92.9	96.1	60.7	100	55.9	100	100	100	66.8	61.2	81.9
Mean (SD) hectares/yr affected, by category of use	Low = 49.3 (51.9)							Moderate = 37.8 (46.3)			High = 36.7 (35.7)				

[a] Less than 5% use as indexed by scat dog detections.
[b] Between 5% and 10% use as indexed by scat dog detections.
[c] Greater than 10% use as indexed by scat dog detections.
[d] Underburn (from Sierra NF database; no FACTS code).
[e] Sanitation (salvage).
[f] Precommercial thinning.
[g] Individual tree release.
[h] Thinning natural fuels.

who simulated the long-term (50 year) effects of fuels treatments in the same region and forest types where we conducted our fisher surveys. Using spatially dynamic modeling of wildfire, succession and fuels treatments they found that treating 8% of the landscape every 5 years was sufficient to minimize the ecological effects of high-severity fire. This is a smaller percent of area disturbed than we discovered had occurred in our fisher high use areas which, when evaluated over a 5-year period (i.e., 13.0% [2.6% × 5]). This suggests that fishers may tolerate the amount of treatments that Syphard et al. (2011) predicted were necessary to reduce fire spread rates in fire-suppressed forests. Other fire modelers, however, report that a larger proportion of the landscape must be treated to reduce fire severity. For example, Schmidt et al. (2008), simulating fire in the California Cascades, estimated that strategically placed fuels treatments are best at reducing fire spread rate and fire intensity when at least 20–27% of the landscape is treated. If we assume that this can be implemented in 5 years, this higher estimate represents about twice the area that fishers in the high use areas were exposed to and appeared to tolerate. In sum, if the fire modeling results of Syphard et al. (2011) are realistic, then fishers may tolerate the extent of restorative activities necessary to address the threat of uncharacteristically severe fire. If, however, it is necessary to treat much more than 13% of the landscape in 5 years, as suggested by the work of Schmidt et al. (2008), this may put fisher habitat and fisher use of these areas at risk. We emphasize that our results, in terms of fisher tolerance of treatments, very much depend on the rate at which treatments are applied.

Importantly, in most of the sample areas (11 of 15) the dominant treatments were restorative (i.e., underburning or some form of thinning) rather than extractive. And, when averaged over all sample areas, restorative treatments comprised 69.9% of all affected acres. This suggests that, over the period that treatments were quantified (2000–2011), the landscapes were being affected by – and fishers were primarily exposed to – the types of treatments that will characterize future forest management. Had the majority of treatments instead been largely extractive in nature (e.g., clear cutting, shelterwood harvest, sanitation harvest) they would have been less representative of the treatments we expect in the future. Future treatments, especially on public lands, will more likely be restorative than extractive. We were particularly encouraged by the fact that in 4 of 5 of the high use areas either thinning or underburning were the dominant activities, often representing more than 60% of the affected area. That fishers occupy at the highest rates the areas where restorative forestry activities have been applied suggests that if these activities are applied at rates that do not exceed about 13% of an area in 5 years – and individual, critical structures are identified and retained on the landscape – fishers should occupy areas with this extent and rate of disturbance.

The index of fisher use was lowest in sample areas that had somewhat greater average area treated each year (49.3 ha/year) compared to areas with moderate or high use (37.8 and 36.7 ha, respectively). This suggests that as the area treated increases, fishers may respond by using these areas less frequently. In addition, 3 of the 7 low use sample areas were dominated by an extractive activity (i.e., sanitation [salvage] harvest), which typically has more intensive effects on habitat elements of importance to fishers, whereas almost all (7 of 8) of the sample areas with moderate or high use by fishers had restorative activities as the dominant treatments, which are typically less intensive. These lines of evidence suggest that fishers may spend less time, or at least deposit fewer scats, in areas that have received more treatment and where the treatment is more intensive. Garner (2013), also working in our study area, found that although fishers avoided using treated areas when resting and foraging, they showed no aversion to including treated areas within their home ranges. More work is necessary to explore whether there is a threshold of area of treatment, above which discourages fisher use, and how the type of treatment (extractive or restorative), and the spatial and temporal extent of treatment affect the use by fishers. We also recommend that future work explore the interaction of measures of habitat quality with the amount of area treated, as areas with higher quality habitat may be able to sustain more treatment before they become unsuitable. We note, however, that variation in modeled habitat suitability was unlikely to explain variation in our indices of fisher use, given that most sample areas were predicted to be of high suitability (Fig. 1).

This was a post-hoc analysis, using data not specifically collected for this purpose and we only addressed one part of a full analysis of treatment effects on fishers. A more thorough evaluation of management impacts would include assessing the variable intensity of disturbance associated with different management actions, the potential variation in the application of treatments (e.g., topographic placement of treatments, seasonal variation in the effects of prescribed fire), and the importance of retaining functional habitat connectivity among treated patches. Future studies could take advantage of the efficiency of sampling for scats using dogs but expand the sampling or use other designs (e.g., before/after, control treatment). Additional steps would be necessary before we would establish standards or guidelines for the maximum area of treatment that is consistent with fisher conservation. For example, low intensity underburns are, technically, a disturbance but they appear to have minimal effects on fisher behavior outside the denning (reproductive) period (C. Thompson, pers. obs.) and may improve long-term habitat viability by promoting regrowth and forest heterogeneity (Hessburg et al., 2005, 2007; Taylor and Skinner, 2003; Zald et al., 2008). However, smoke in den cavities during critical denning periods may be a potential hazard to the development of neonatal fishers (C. Thompson, unpubl. data), suggesting that the timing of restorative activities may be important. It is also critical to identify and retain essential habitat features, such as large decadent trees, that are rare across the landscape and known to be of high value (Weir et al., 2012). The numbers presented here, however, represent a starting point for future research, and indicate that effective fuel management and the conservation of closed-canopy species such as the fisher may be compatible.

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