Southern Sierra Nevada

Fisher Conservation Strategy

DRAFT Interim Recommendations

Prepared By:

Craig Thompson
Wayne Spencer
Heather Romsos
Sarah Sawyer

Prepared For:

USDA Forest Service, Region 5

December, 2019

Produced by the Conservation Biology Institute. CBI is a 501©3 tax-exempt organization that works collaboratively to conserve biological diversity in its natural state through applied research, education, planning, and community service.

Contents

DRAFT

DRAFT

1. Background

The Southern Sierra Nevada Fisher Conservation Strategy (SSNFCS, Version 1.0, Spencer et al. 2016) was developed during 2012-16 based on fisher population and vegetation data up to that period. Unfortunately, this coincided with major environmental changes in the Sierra Nevada, including the effects of unprecedented drought (2012-16), bark beetle outbreaks, large severe wildfires, and associated tree mortality in fisher habitat. Implementing the fisher conservation strategy was immediately derailed by this dramatic shift in habitat conditions as well as by the lack of an updateable vegetation database for planning conservation actions and monitoring habitat changes due to forest management and other factors. Due to the extensive changes in the fisher's forest habitat, many recommendations in the Strategy became extremely difficult or even undesirable to implement, especially as they hindered attempts to restore more resilient fisher habitat conditions. The SSNFCS will be comprehensively updated based on the new conditions currently on the landscape and using a new, updateable vegetation database. In the meantime, there is urgent need for guidance for forest restoration projects to increase resilience and benefit fishers within the SSN Fisher Conservation Area (Figure 1). This interim fisher conservation guidance document applies the concept of natural range of variation (NRV; Safford and Stevens 2017) as a framework for pursuing multi-scale habitat heterogeneity to provide for the habitat needs of the fisher, a complex structure-obligate species, while also increasing forest resiliency. These guidelines apply within the SSN Fisher Conservation Area outlined in Figure 1.

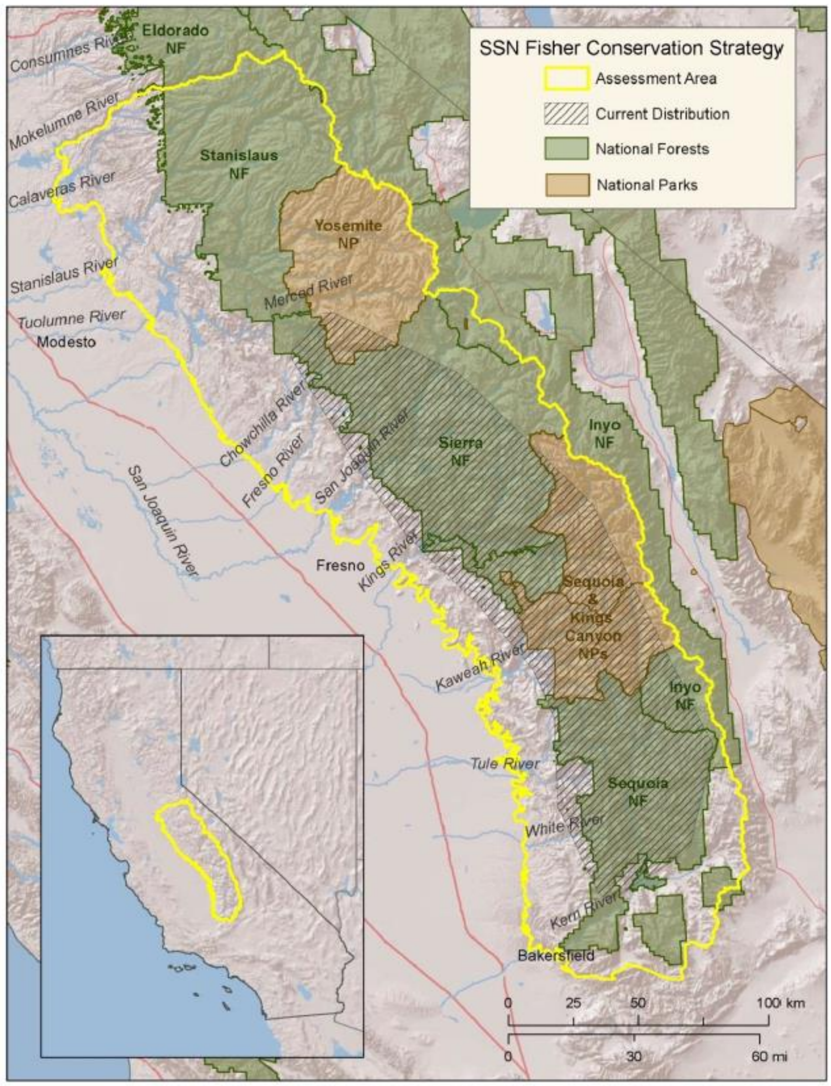

Figure 1. Assessment area used for the 2016 Southern Sierra Nevada Fisher Conservation Assessment and Strategy.

The need for updated, interim recommendations was further highlighted by the U.S. Fish and Wildlife Service's proposal to list the West Coast Distinct Population Segment of fisher as threatened (USFWS 2019) under a special Endangered Species Act (ESA) Section 4(d) rule. The 4(d) rule provides "specific exemptions from prohibitions [which] include forestry management activities for the purposes of reducing the risk or severity of wildfires, forestry management activities pursuant to an approved fisher conservation plan or strategy, forestry management activities that are consistent with the conservation needs of the fisher but are not specifically designed as fisher conservation plans or strategies, and management activities designed to identify and clean-up toxicant-contaminated sites." Thus, the 4(d) rule guiding fisher conservation under the ESA specifically recognizes the need to balance resiliency-based management with habitat conservation.

It is important to recognize that there is the potential for a perceived conflict between desirable management objectives such as maintaining habitat connectivity and promoting landscape heterogeneity. Promoting habitat connectivity at the expense of heterogeneity may result in catastrophic habitat loss through large-scale disturbances or changing ecological conditions. At the same time, pursuit of landscape heterogeneity and resilience without careful consideration of connectivity can lead to exceeding a habitat fragmentation threshold beyond which a species such as fisher cannot persist. Balancing these objectives is a question of scale; the fine-scale heterogeneity consistent with the natural range of variation in Sierra Nevada vegetation occurs within stands or patches, at the scale of square meters. Habitat connectivity, on the other hand, is best evaluated at larger scales, from multi-stand project areas to landscapes. To balance these objectives, managers ***must*** consider multiple spatial scales and work with the existing landscape template. Therefore, while whenever possible this document provides examples of metrics such as gap size or how many trees define a 'clump', these values are not meant as management targets or thresholds. They are representative of the values a manager should consider; a starting point from which thoughtful deviations can be made but should be explained and justified.

This document provides up-to-date interim recommendations for forest management and restoration projects until a new, comprehensive fisher conservation strategy can be completed with updated habitat information. Due to changed circumstances, these interim recommendations replace the recommendations and conservation measures in the 2016 SSNCFS and are intended to meet the needs of multiple agencies with an interest in fisher conservation and land management in the Sierra Nevada until an updated strategy can be completed. Though the sole focus of these interim recommendations is fisher conservation, they are intended to be compatible with the missions, objectives, and legal requirements of multiple agencies.

2. Goals and Objectives

Developing an updated Conservation Strategy will require additional analyses of fisher habitat conditions following the recent massive tree mortality event, as well as an assessment of new fisher data concerning how the population has been responding to these changed habitat conditions. Comprehensively updating the SSNFCS with these new analyses will take time, and it is clear that time is of the essence for providing clear guidance to forest management actions that cannot wait. Fisher persistence in the southern Sierra Nevada is now at elevated risk due to the recent habitat changes and increased population fragmentation that appears evident following the recent drought-related tree mortality and high-intensity wildfires. This interim guidance was therefore developed with the following objectives to inform forest management activities while the more comprehensive fisher conservation strategy is being updated:

1. Update information on the status of fishers and fisher habitat in the Southern Sierra Nevada, including changes in habitat distribution, quality, and configuration.

DRAFT

2. Summarize new science relevant to the modified landscapes of the Southern Sierra Nevada, which were not available for the 2015 Conservation Assessment or the 2016 Conservation Strategy.
3. Provide near-term recommendations for identifying, retaining, and enhancing key habitat elements (e.g. natal and maternal den sites) and components (e.g. connectivity) in the new environment.
4. Provide near-term recommendations for increasing resilience of remaining fisher habitat by aligning habitat composition and configuration with select reference NRV conditions...
5. Provide suggestions for mitigating potential negative effects of other necessary management actions (e.g. hazard tree removal).
6. Identify new recommendations for managing forest conditions to support fisher conservation in the Southern Sierra Nevada, given changed conditions

3. Current Status of Fisher Habitat

3.1 Habitat identification

Existing fisher habitat models, based on vegetation data collected in 2012 or earlier, do not accurately portray current (post-drought) habitat conditions in the southern Sierra Nevada. Until these models can be updated with post-drought vegetation and fisher data it is critical that forest biologists and resource managers become proficient at recognizing suitable fisher habitat conditions in the field.

For the purpose of this document, modeled habitat is described as:

> **Modeled Denning Habitat –** In the 2016 SSFNCS, denning habitat was modeled based on 350 den locations on the Sierra National Forest spanning 2008 through 2013. The final model included CWHR habitat type, area with > 60% canopy cover, the presence of hardwoods, low to moderate slope, and maximum summer temperature as predictors (see Appendix A of the 2016 SSNFCS for details).
>
> At this time, canopy cover is the only variable in the denning habitat model for which updated data are available. We therefore created an updated denning habitat model for this interim document by inserting updated (post-drought) canopy cover data for 2018 into the model while keeping previous values for all other variables. No new fisher den locations were used to create this model, which simply reflects how changing canopy cover due to tree mortality may have affected denning habitat. Until an updated denning model can be created with new (post-2016) fisher and vegetation data, the results of this interim model should be used with caution.
>
> **Modeled Foraging Habitat –** In 2014, CBI modeled foraging habitat (or landscape-scale fisher habitat) using a dataset of verified fisher locations from the USFS fisher monitoring program spanning 1991-2011. Twenty-one biotic and abiotic variables, representing vegetation data spanning 2000-2008, were tested in the modeling process. The final best model used canopy height, minimum winter temperature, tassle-cap greenness (an index of above-ground biomass), and the proportion of the surrounding area classified as dense forest as predictors (see Appendix A of the 2016 SSNFCS for details).

In 2019, we created a new foraging habitat model using fisher location data from 2017-2018 and a similar suite of potential predictor variables, using 2016 vegetation data The final model used canopy height, average winter precipitation (1981-2010), snags larger than 10" DBH, stand age, slope, maximum summer temperature (1981-2010), and distance to drainage as predictors. Again, results of this model should be used with caution until a more complete modeling assessment can be made with additional fisher and vegetation data.

For the purpose of identifying fisher habitat in the field and applying these interim conservation measures before updated habitat maps are available, fisher habitat is defined as:

High quality denning habitat is defined as**:** *habitat types* - Douglas Fir, Eastside Pine, Jeffrey Pine, Lodgepole Pine, Montane Hardwood-Conifer, Montane Hardwood, Montane Riparian, Ponderosa Pine, Red Fir, Subalpine Conifer, Sierran Mixed Conifer, or White Fir; *CWHR size and density classes* - 4D, 5M, 5D, and 6; *Elevational range* - 3300-8000 ft.; *Stand characteristics* - > 60% canopy cover and > 20 inch QMD. Given the importance of these habitat conditions to fisher persistence in the southern Sierra Nevada and the recent loss of these area, stands meeting these characteristics should be assumed to be occupied.

Potential reproductive habitat is defined as areas meeting the habitat and CWHR requirements of denning habitat and located in areas with suitable site potential, but not yet developed enough to meet the canopy cover and tree size thresholds. These are areas with the potential to provide denning habitat in the future given continued stand development

Suitable hábitat includes all of the high value reproductive habitat (and denning habitat) described above, as well as additional foraging habitat in the form of the 4M size and density class in the same habitat types. Where modeled suitable habitat is available with up-to-date vegetation information, a more detailed footprint of can be mapped.

DRAFT

3.2 Comparison to original SSFCS conditions

While a lack of updated and complete vegetation information continues to hamper our ability to meet objective 1 (Provide updated information on the status of fisher and its habitat in the Southern Sierra Nevada, including changes in habitat availability and/or configuration), early indicators suggest some general patterns described below.

3.1.1 Landscape-scale habitat availability

While we do not yet have complete post-drought vegetation information, the limited sources available suggest that almost 40% of the foraging habitat in the fisher conservation area has been lost through the cascading effects of drought, insect infestation, fire, and subsequent tree mortality (Figure 2). Habitat mapping for the 2016 SSFCA estimated that 2.3 million acres (9,300 km²) of suitable habitat existed in 2014. The revised foraging habitat model, using similar ecological parameters applied to vegetation data from 2016 and fisher detections from 2017-18, estimated that approximately 1.4 million acres (5,700 km²) remained (a 39% loss). Possibly more significant than simple acreage, the number of habitat patches went from 74 to 558 and the average patch size went from over 31,500 acres to 2,600 acres (127 to 10.5 km²), indicating severe fragmentation. In 2014, fisher foraging habitat occurred primarily in 2

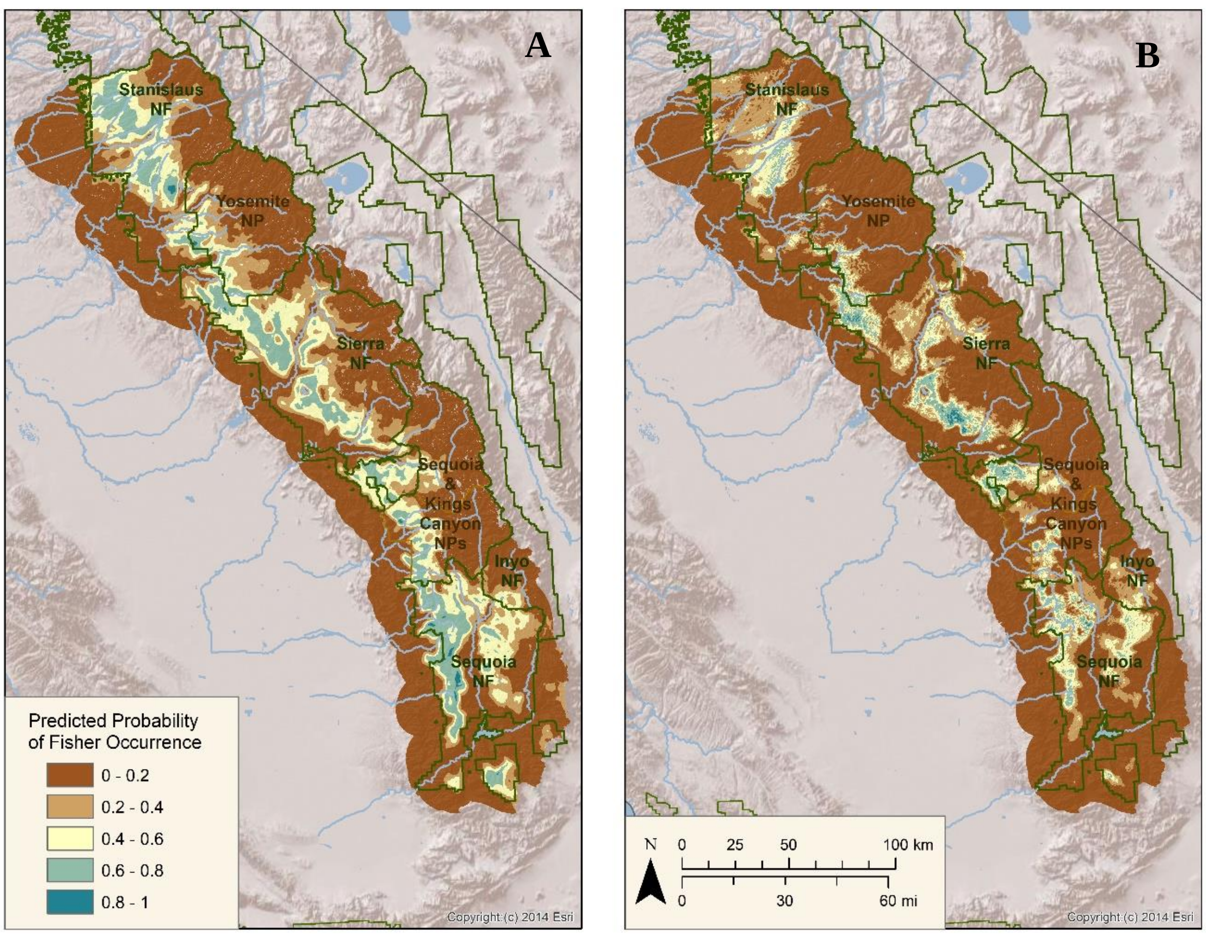

Figure 2. Pre- and post-drought probability of fisher occurrence across the Southern Sierra Nevada. Left panel (A) shows habitat based on 2012 vegetation data and pre-2014 fisher locations. Right panel (B) shows habitat based on 2016 vegetation data and 2017-2018 fisher locations.

contiguous patches with a combined acreage of 2.2 million acres. The remaining 100,000 acres occurred in patches ranging from 1 to 50,000 ac. In 2019, the bulk of fisher foraging habitat was split into 7 patches between 100,000 and 300,000 acres, with an additional 552 isolated patches ranging from 1 to 50,000 acres in size. These estimates do not include fires or other disturbances that occurred after 2016, such as the Railroad Fire.

A similarly dramatic loss has likely occurred in the highest quality habitat, characterized as high quality denning habitat in the assessment area. Prior to the widespread tree mortality observed between 2014 and 2016, the SSNFCS estimated that 805,000 acres (3,260 km²) of denning habitat existed in the southern Sierra Nevada. Using the same model parameters with updated (2016) canopy cover data, we now estimate that 493,000 acres (2,000 km²) remain, a loss of 39%. The number of denning habitat patches has dropped from 254 to 172, and the average size of these patches has dropped from 3169 acres to 2868 acres. Essentially, this translates to a loss of many of the smaller patches and a shrinking of the larger ones (Figure 3). Further analysis will be necessary to refine our understanding of these trends, once updated and complete vegetation data are available.

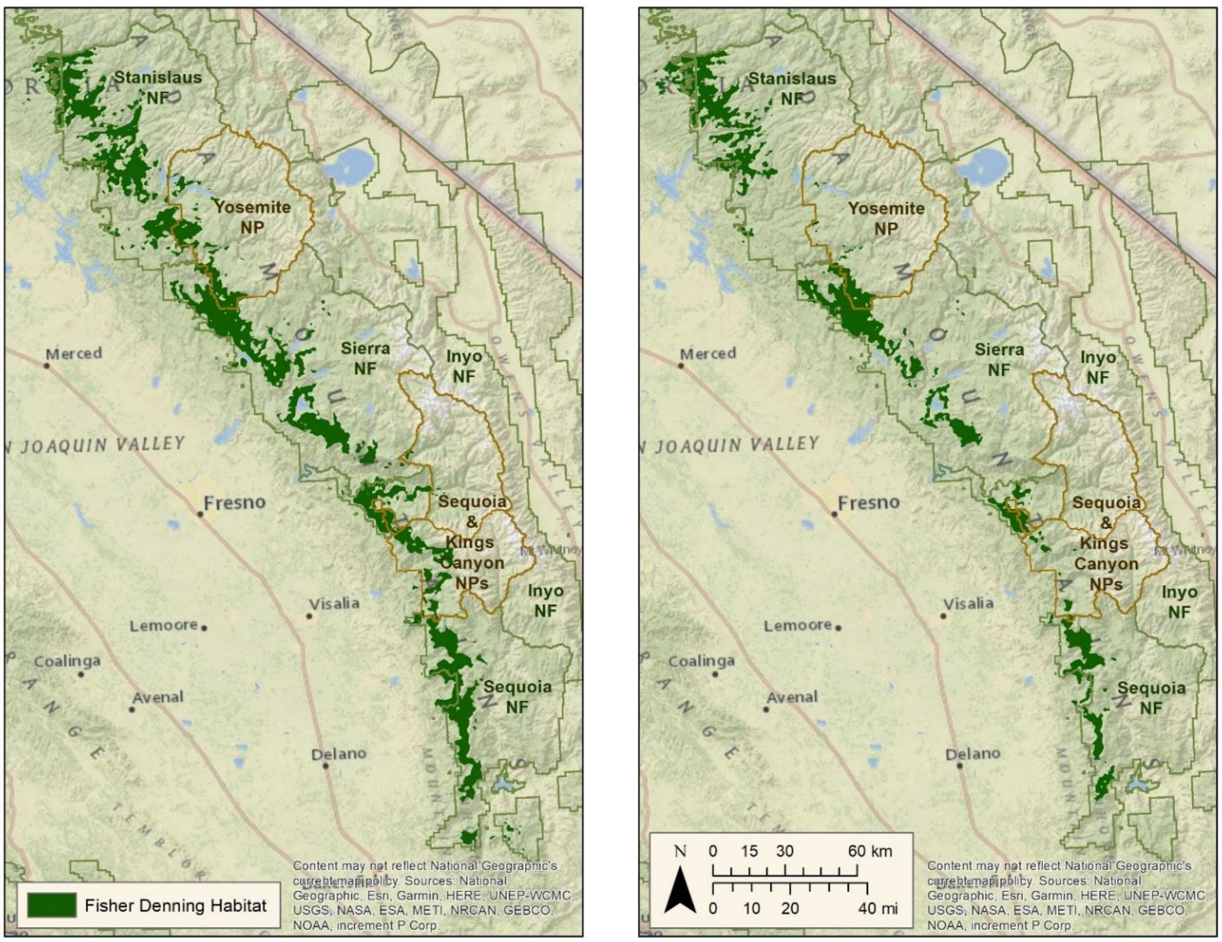

Figure 3. Pre- and post-drought distribution of fisher denning habitat across the Southern Sierra Nevada. Left panel (A) shows habitat based on 2012 vegetation data and pre-2014 fisher locations. Right panel (B) shows the same habitat model using updated canopy cover data.

3.1.2 Habitat configuration

In the 2016 SSFCS, the distribution of fisher habitat in the southern Sierra Nevada was described as "segmented into a series of core habitat areas separated primarily by major river canyons, across which fishers may occasionally disperse via linkage areas." The seven core areas averaged 839 km² (>200,000 acres), and they were separated by six key linkage areas identified by least-cost corridor analysis and averaging 6.6 km long (Figure 1A). The conceptual framework of the 2016 SSFCS was based on this overall habitat structure; maintaining a minimum number of viable female fisher home ranges within each core area, and protecting the integrity of linkages by encouraging landscape resilience. Based on expert opinion, a minimum of five contiguous female home ranges was determined to be the minimum number necessary to identify a core habitat area (Spencer et al. 2016). Each core area contained an average of approximately 400 km² of contiguous denning habitat, able to support approximately 10 to 30 female fishers each.

However, following the extreme habitat loss and fragmentation that occurred between 2014 and 2016, the landscape no longer reflects that pattern. Core areas have been fragmented and shrunk, and former linkage areas may now represent barriers to movement. While it is difficult to extrapolate without updated vegetation data, based on changes in canopy cover alone the average size of core habitat areas dropped from 839 to 626 km², and only five contiguous blocks of denning habitat remain large enough support five female fisher home ranges, with the average size dropping from about 400 km² to 278 km² (range: 100 to 480 km²).

It is also worth noting a dramatic increase in habitat lost to high severity fire in recent years, and that the rate of habitat loss has been nearly twice as high in linkage areas as in core areas (Figure 4). Figure 5 illustrates fire perimeters in the last decade compared to the distribution of fisher habitat in the southern Sierra Nevada.

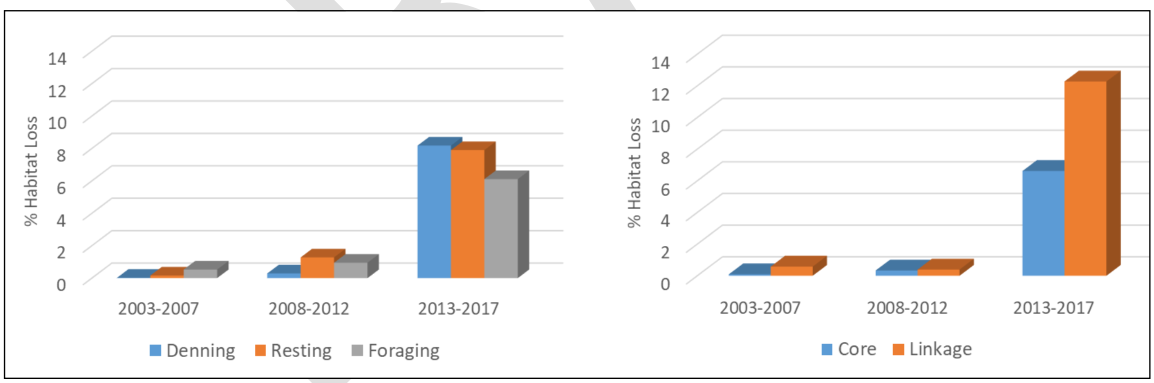

Figure 4. Proportion of habitat exposed to high severity fire within the SSN Fisher Conservation Area by habitat type (left) and by SSNFCS 2016 habitat designation (right). High severity is defined using the US Forest Service Region 5 Burn Severity data, and represents areas where the dominant vegetation has high to complete mortality (Composite Burn Index between 2.25 and 3.0)

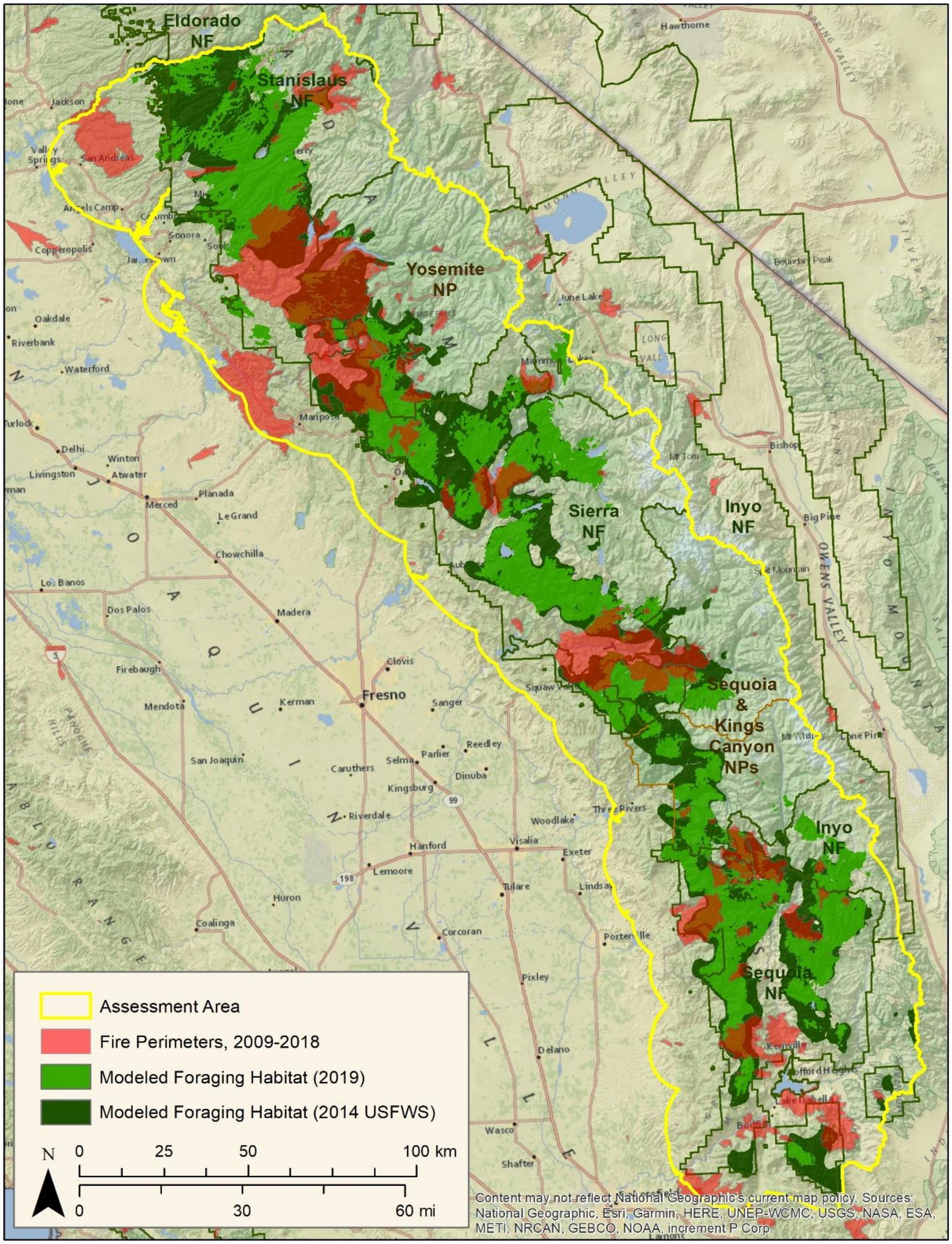

Figure 5. Map of 2014 and 2019 fisher foraging habitat models, overlaid with fire perimeters from 2009-2018.

3.1.3 Habitat connectivity

To provide a preliminary assessment of post-drought connectivity concerns, we ran a least-cost analysis using patches of modeled denning habitat (using the updated 2018 canopy cover values, as described in Section 3.1) greater than 24,000 acres as core areas and an inverse habitat suitability map to represent resistance to fisher movements. Based on Green (2017) and the 2016 SSNFCS, we estimated 24,000 acres as the approximate area necessary to support 5 adult female fisher. While female fishers sometimes use areas other than high quality denning habitat to support themselves and kits, these modeled denning habitat patches represent the best remaining blocks of habitat in the southern Sierra Nevada, and are the most likely source of emigrants. The habitat suitability map used as a surrogate for landscape resistance reflected an updated (2019) version of the fisher foraging model. Habitat values were inverted and multiplied by 1000 to create a resistance surface. The analysis was run using LinkageMapper 2.0 software (McRae and Kavanagh 2011) followed by application of the LinkagePriority tool.

Connectivity results indicated two major concerns for managers (Figure 6). First, the highly fragmented nature of denning habitat indicates that the permeability of remaining foraging habitat is critical for juvenile fisher dispersal. In areas such as northern Sequoia National Park and the border between western Yosemite National Park and southern Stanislaus National Forest, extensive north-south stretches of remaining foraging habitat help provide connectivity between blocks of high quality denning habitat. In these areas, efforts to reduce the likelihood of future large, high-severity forest while retaining critical habitat features and promoting the development of pockets of denning habitat may provide significant benefits to the regional fisher population. The use of topographically-aligned shaded fuelbreaks in these areas may help disrupt future fire behavior and protect habitat connectivity.

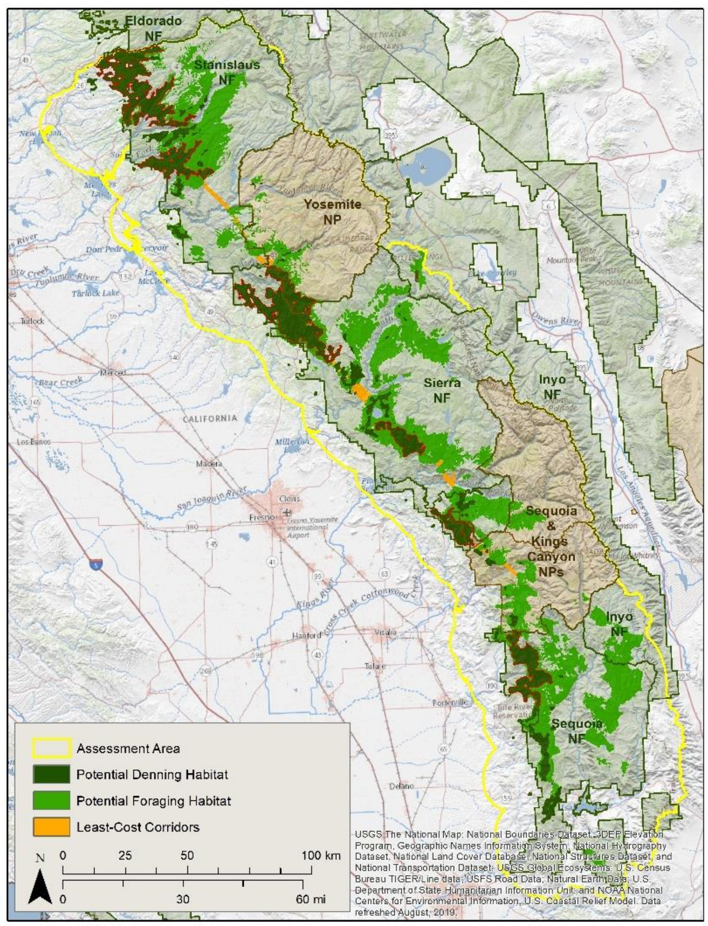

Figure 6. Current distribution of fisher denning and foraging habitat in the southern Sierra Nevada.

The second concern is four areas where cumulative disturbances to previous linkage areas have created significant gaps in suitable habitat and may prevent north-south movement by dispersing fishers. Three of the four are associated with recent fire footprints; the Rim, French/Aspen, and Rough fires. The fourth is located in the northern portion of Sequoia National Forest, in the Panther Creek area between the Marble and Middle

Forks of the Kaweah River. In this area, approximately 42,000 acres of denning habitat has been lost due to tree mortality and only small pockets of high quality habitat remain.

In these areas, efforts to restore habitat connectivity could provide significant population benefits. Within fire footprints, identifying and retaining unburned or lightly burned habitat patches can provide "stepping-stone" opportunities, where a dispersing fisher may find prey and resting opportunities. Other cover-sensitive forest carnivores, such as lynx, have been shown to use these types of islands extensively when exploring post-fire landscapes (citation?). The promotion of shrub development or hardwood re-sprouting along riparian corridors can also provide travel corridors in the absence of mature forest. Limiting salvage logging in these potential corridors, and allowing snags to fall, can help provide the complex ground-level structure preferred by fisher.

3.3 Comparison to historic conditions

Fishers in the southern Sierra Nevada evolved in a landscape that looked significantly different than what they have occupied in recent decades, both before and after the recent extensive tree mortality. Over the past century but before the recent mortality event, stand densities increased by 80 to 600 percent, canopy cover estimates increased by 33%, and average tree size dropped by 26-60% (Lydersen et al. 2013, Taylor et al. 2014, Safford and Stevens 2017, Stephens et al. 2018). In the pre-settlement Sierra Nevada, trees were more patchily distributed, with the landscape being dominated by larger trees found individually or in small clumps (Bonnickson and Stone 1981). Changes, driven largely by fire suppression and the subsequent growth of shade-tolerant conifers, have resulted in a landscape with larger, more well-defined patches at the landscape scale and reduced fine-scale heterogeneity at the stand or within-stand scale (North et al. 2012). As the recent large-scale drought mortality and fires demonstrate, this increase in coarse-scale patch structure is self-sustaining, with larger, more intense disturbances creating larger post-disturbances patches (Safford and Stevens 2017). Similarly, fine-scale heterogeneity, once-established, has the capacity to be self-sustaining, as interacting disturbances leave behind a fine-scale mosaic of structural conditions, gaps, and tree clumps (North et al. 2012, Larson and Churchill 2012, Safford and Stevens 2017). Active management is necessary to break the self-sustaining coarse-scale pattern and re-establish fine-scale heterogeneity.

While fishers may thrive in the dense forest conditions that follow a century of fire suppression, there is evidence suggesting that they are capable of persisting in a wider range of habitat conditions (Niblett et al. 2014, Zielinski et al. 2017). Historically, they likely utilized a patchier distribution of high-quality habitat (e.g. valley bottoms, north facing slopes, fire refugia) connected by a network of riparian areas or other suitable travel corridors. In this environment, they may have persisted at lower densities than currently found along the west slope of the Sierra Nevada, densities more similar to those currently found on the Kern Plateau (Zielinski et al. 2013). On the Kern Plateau, fishers use what is considered atypical habitat; a patchy mosaic of forest stand ages and sizes, intermixed with open areas and shrub communities, with a notable lack of modeled resting and denning habitat. This mosaic is partly the result of more frequent fires in recent decades, including both large, severe fires and mixed severity fires managed for resource values (SSNFCS 2016).

While we do not know how fishers behaved in more open, pre-settlement forests, we do know that they successfully traverse home ranges and navigate forest management activities and post-management landscapes, as long as the spatial scale of the management activities is small enough, relative to the home range, to avoid habitat fragmentation (Sweitzer et al. 2016, Niblett et al. 2017). Garner (2103) quantified the response of fishers to past management activities, and found that the mean size of treatments within occupied fisher home ranges was 40 ac (range: 1-1200 ac). Both Sweitzer et al. (2016) and Zielinski et al, (2013) found that fishers tolerated approximated 3% of a home range being impacted by management per year, or roughly 150 ac. Therefore there is evidence to suggest that management promoting forest heterogeneity, using NRV as a guide, is not necessarily detrimental to fisher habitat characteristics in the near-term, and may be beneficial to long-term habitat retention as long as critical elements are identified and protected.

Currently, a primary management focus in the Sierra Nevada is restoring more naturally heterogeneous conditions at multiple scales, along with restoring the disturbance regimes that can maintain that pattern (North et al. 2012). There is widespread recognition that the historic pattern was based on three structural features: tree clumps, widely spaced large trees, and gaps or openings (Larson and Churchill 2012). The historic number of trees per clump ranged from 2 to 76, clumps ranged in size from 0.003 ha to 0.4 ha, and the number of clumps per ha ranged from 10 to 27 (Stephens and Fry 2005, Lydersen et al. 2013, Fry et al. 2014). Historically, gaps constituted nearly 50% of the landscape and averaged 6.2 gaps/ha. However, following a century of fire suppression, gaps in the forest canopy have grown increasingly rare with an average of 0.2 gaps/ha (Lydersen et al. 2013).

It is important to recognize that the comparisons above relate to the landscape prior to the 2014-2016 tree mortality event that created the need for these revised recommendations, and contributed to widespread habitat loss. The scales and patterns of heterogeneity or homogeneity that will result from this event are still unknown, as conifer trees continue to die, canopy cover is lost, and species such as oaks and shrubs respond to the changed conditions. Of particular importance may be the preferential loss of the largest pines on the landscape. However, even in the face of this uncertainty, thoughtful use of NRV data can guide habitat restoration efforts and help identify functional and resilient habitat patterns. While NRV data describes a generally more open forest, they also suggest high variability, with dense stands on north facing slopes or in riparian areas, where canopy cover could reach 90% (Stephens and Elliott-Fisk 1998, Bouldin 1999, Stephens 2000, Safford and Stevens 2017). This high spatial variability in forest density offers an opportunity to maintain critical fisher habitat features, and habitat connectivity, while concurrently promoting more landscape-scale resiliency and heterogeneity.

3.4 Additional population-scale influences

The 2016 SSNFCS identified a suite of mortality factors impacting the Southern Sierra fisher population, as well as potential management interventions to help reduce fisher mortality and promote population increase. Desired conditions included: reduction in exposure to poisonous substances; vegetation conditions that do not promote interspecific carnivore interactions (intraguild predation); a population resilient to periodic disease outbreaks; rare instances of vehicle-fisher collisions; and limited instances of fishers dying due to interactions with human-built structures such as water tanks or vent pipes. Two of these conditions, exposure to poisonous substances and intraguild predation, warrant attention here, as conditions have changed. In addition, there is evidence that changed habitat conditions have resulted in increased physiological stress to fishers, which may have consequences for a variety of physiological and behavioral risks.

3.4.1 Rodenticide exposure

In the 2015 fisher assessment and 2016 conservation strategy, exposure to pesticides associated with illegal marijuana grow sites on public lands was recognized as a novel and growing threat to population health and persistence. At that time, 87% of necropsied fishers showed exposure to anticoagulant rodenticides and three mortalities had been directly attributed to these poisons. Since then, exposure rates have continued to increase; of 22 additional fisher carcasses tested between 2015 and 2017, 100% tested positive for rodenticide exposure and the total of known direct mortalities is now 17 (Thompson et al. 2017). The statewide mortality rate associated with rodenticide exposure has climbed from 5.6% to 18.7% since testing began in 2007 (USFWS 2019).

The most recent data available indicate that 15 to 40% of fisher home ranges in the Southern Sierra Nevada are at high risk of containing illegal marijuana grows (citation?). Throughout the Southern Sierra Nevada fisher conservation area, 18% of pre-drought modeled denning habitat qualified as high risk for trespass grow sites (Figure 6). According to the US Fish and Wildlife Service, over 50% of fisher habitat in northern California/southern Oregon, and approximately 22% of the fisher habitat in the southern Sierras, may overlap with trespass grow sites (USFWS 2019).

3.4.2 Predation

Recent and ongoing changes within the Southern Sierra Nevada landscape include the loss of dense forest, the creation of more open, oak and shrub dominated habitat, and the fragmentation of existing closed canopy forest. These changes suggest the area will see greater use by larger predators such as bobcat and cougar, and that the potential for predation on fishers may increase (Witmer and deCalesta 1986, Meinke 2004, Constible et al. 2006, Litvaitis et al. 2006, Dellinger et al. *in press*). Wengert (2013) found that areas of likely interaction between bobcats and fishers in Northwestern California included forested areas with higher proportions of open and shrub habitat, and that fisher mortalities due to bobcat predation generally occurred in proximity to the edges associated with these non-forested areas.

3.4.3 Role of habitat change in stress and mortality

Kordosky et al. (in review) found that cortisol levels in fisher hair samples, a strong indicator of physiological stress, were most consistently explained by the level of drought-related tree mortality in a fisher's home range than by any other variable. The authors also reported that for female fishers, cortisol levels were inversely related to annual survival rates, indicating that increased stress may increase susceptibility to a variety of mortality factors, such as predation or disease. Therefore, when considering the need for mitigating mortality factors, it is important that managers consider the potential cumulative effects of landscape change and mortality.

It is worth noting that other studies suggest that fishers are capable of tolerating certain levels of management activity, remaining within their home ranges and navigating around project areas (Garner 2013, Zielinski et al 2013, Sweitzer et al. 2016). Two possible mechanisms may help explain this apparent contradiction. First, most studies looking at whether fishers respond to habitat modification rely on presence data, i.e. if the animal remains in the area then it must be tolerating the change. This is a very coarse assessment that ignores physiological responses; the level of change necessary to make a territorial animal abandon its home range is unknown. Cortisol levels, on the other hand, are a more precise measure of an animal's physiological response to disturbance or change. Second, management-related change is generally limited to a specific spatial footprint while the drought-related tree mortality that occurred between 2014 and 2016 was widespread. It is possible that fishers can avoid small-scale management activities successfully, but are unable to avoid the changes associated with large-scale habitat change, including possible changes in prey availability, access to cover, or thermal conditions. Taken together, this evidence suggests that resiliency-based management designed to minimize negative impacts to fisher should distribute management actions across the landscape, strive to keep the spatial footprint of any given project small or dispersed, and retain sufficient unaltered habitat in the matrix to allow for movement between intact habitat patches.

4. Habitat Conservation and Enhancement

Habitat changes in recent years have made it clear that altered disturbance regimes in the Southern Sierra Nevada are a major threat to fisher habitat. Habitat changes from fire and drought-related tree mortality have disproportionately removed crucial habitat features for fishers, including large live trees and forest cover in linkage areas. Areas previously defined as core habitat areas have become highly fragmented with questionable connectivity to allow fisher dispersal amongst remaining habitat patches. In this type of landscape, research has shown that the effects of large scale disturbances is amplified, often resulting in longer recovery times and greater probability of local extirpation of focal species (Foppen et al. 1999, Opdam et al. 2004).

Opdam et al. (2004) emphasized three critical actions necessary to address this type of conservation challenge and stabilize degrading habitat in an emerging metapopulation framework:

1) *Stabilize key habitat*. This will require the identification, retention, and creation of key fisher habitat elements at multiple spatial scales. It will also require active management to increase habitat resilience and protect these elements from future disturbances.

2) *Restore landscape permeability*. Ensuring that fishers can move between remnant high quality habitat patches is necessary to maintain population viability. This requires understanding what types of habitat fishers are willing to traverse, and identifying management activities that can help restore corridor functionality where it has been lost.

3) *Promote landscape heterogeneity*. Heterogeneity at multiple scales has been shown to buffer the impact of ecological disturbances, and to reduce the risk of large-scale habitat loss. Promoting habitat heterogeneity in areas surrounding remnant high quality habitat will help ensure long-term functionality

4.1 Stabilize key habitat

Fishers select habitat at multiple scales, from specific den cavities for raising young to the greater landscape over which they forage, establish home ranges, and interact with other wildlife. Biologists should therefore consider habitat conservation measures across all scales, from the fine-scale retention of structures (e.g., snags, trees, logs) to conservation of key stand characteristics (e.g., canopy cover, basal

DRAFT

area) to promotion of beneficial landscape patterns (habitat continuity and connectivity).

4.1.1 Retaining fine-scale habitat elements

Microsite retention

Green et al. (2019) quantified the characteristics of den and rest over 9 years in the Southern Sierra Nevada. In alignment with previous work (Paragi et al. 21996, Purcell et al. 2009, Weir et al. 2012, Aubry et al. 2013, Aubry et al. 2018) the authors found that fishers used a variety of structures for resting but typically selected the largest structures available, and females almost exclusively used cavities in live or dead trees for denning. The majority of denning and resting occurred in live trees, although conifer snags made up roughly 1/5 of denning and resting structures.

Table 1. Characteristics of fisher denning (n=301) and resting (n=1040) structures in the Southern Sierra Nevada, taken from Green et al. 2019, Tables 2 & 3. Converted to English units.

Structure Type	**Denning**		**Resting**	
	%	**Mean DBH**	**%**	**Mean DBH**
Hardwood – live	51.3	30 in (± 7.3)	26.3	30.2 in (± 8.1)
Hardwood – snag	4.1	27.2 in (± 5.0)	2.6	29.3 in (± 8.6)
Conifer – live	22.5	44.6 in (± 9.6)	35.4	37.4 in (± 13.2)
Conifer – snag	21.3	41.3 in (± 11.7)	20.1	41.5 in (± 13.78)
Other[1]	0.7	na	15.7	na

[1] Other structures uses as maternal dens and resting sites include logs, underground burrows, slash piles, and rock piles.

Live tree retention

Fisher use of cavities in large trees and snags has been well documented, and the 2016 SSNFCS emphasized retention of these structural elements. However recent research has further highlighted the importance of live trees to denning female fishers. Two research efforts, one in northern California and one in the southern Sierra Nevada, have independently verified the hypothesis that cavities in live trees provide greater thermal insulation and buffering against external temperature fluctuations than those in snags (Green 2017), and that natal dens provide greater thermal protection than later-season dens or rest sites (Matthews et al. 2019). Therefore, female fisher selection for natal dens in cavities in large trees (hardwoods > 23" and conifers > 35"; Table 1) may be a critical consideration in protecting vulnerable kits during variable spring weather.

In the Southern Sierra Nevada, 55% of dens were found in California back oak, 24% in white fir, and 12% in incense cedar (Green et al. 2019). Resting structures were more variable, including black oak (30%), white fir (29%), ponderosa pine (19%), incense cedar (13%), and sugar pine (6%). Given the recent widespread loss of large conifers across the Sierra Nevada, conservation of surviving large trees and promotion of California black oaks should be a primary management concern.

Zielinski and Schlexer (2018) evaluated the effects of time and disturbance on rest site functionality, and determined that over 20 years, 50% of fisher rest sites were exposed to fire and only 15-25% were potentially usable by resting fishers. It is important for managers to promote a future crop of resting structures while also retaining existing potential resting structures... This may be achieved by creating small openings and removing accumulated fuel around suppressed oak trees, retaining some piled, unburnt debris containing larger diameter logs, felling some large snags and leaving them on the ground during salvage operations or hazard abatement, and retaining trees with some decay or damage during thinning operations.

Snag/Log retention

Compared to natal dens, maternal dens and rest sites are more often found in large snags, logs, and other ground structures such as mistletoe brooms, stick nests, slash piles, ground burrows, and rock piles (Green et al. 2019, Aubry et al. 2018). The use of snags and logs as rest sites appears to depend on size and the presence of moderate amounts of decay. Aubry et al. (2018) defined large snags/logs as >50cm (~20 in) DBH, and very large as >100 cm (~40 in) DBH. Creating or leaving these structures on site will increase habitat quality for both resident and dispersing fishers.

In order to provide additional future fisher resting opportunities in areas with currently limited habitat quality, managers might consider retaining 5-10 snags/acre greater than 20" DBH, with particular emphasis on retaining any conifer snags >35" DBH or ≥ 27" DBH for hardwood) (Fry et al. 2014), when doing so does not pose an immediate risk to human safety. Managers might also consider leaving some proportion of slash piles unburned to provide additional rest sites and prey habitat. These elements could help facilitate the development of functional habitat more rapidly than the ecological processes that create tree cavities.

Rest site reuse rates

Research has suggested that fishers reuse previous rest sites approximately 10-15% of the time. However these estimates are typically based on ground-based, VHF telemetry efforts limited to 1-2 locations per week. More recently, Moriarty et al. (unpublished report) documented reuse rates of 46-100%. These data suggest that suitable rest sites may be less available than previously thought, and retaining them during management may therefore be more important than previously understood.

4.1.2 Retaining mid-scale habitat patches

Recognizing suitable denning habitat and retaining it on the landscape is critical to the species' persistence in the southern Sierra Nevada. Green (2017) quantified the behavior of 45 adult, reproductively-active female fishers in the Southern Sierras during the denning season, looking at how many den structures they used, average distances moved by denning female fishers, and what spatial scales were appropriate for protecting denning activity. She identified two relevant spatial footprints; den cluster (60 acre) and den buffer (370 acre). At each spatial scale, different risks must be considered and a different balance between habitat conservation and resilience must be pursued.

Den clusters

Sixty acres represents the core spatial area used by a female fisher during the breeding season. It is an estimate of the area within which she will move kits between natal and maternal dens, and management activities within this area during the denning season are the most likely to cause harm

The suitability of any particular patch of denning habitat for use as a den cluster obviously depends on the availability of suitable microsites. While the presence of an adult female in March and April is the most reliable verification of habitat suitability, 1) the presence of an adult male between 15 March and 7 April or 2) the presence of suitable structural conditions greatly increase the probability of use.

Forest conditions in the vicinity of dens included dense overstory (>60%) and understory (>50%) cover, the presence of large (>24 in DBH) California black oak, greater basal area of black oaks, greater basal area of large (>35 in) snags, and higher stand density (Green 2017). Similar conditions were identified by Blomdahl et al. (2019), who used Lidar-based metrics to determine that cover above 2m, presence of tall trees (>32m), and a lower foliage height between 4 and 14m, indicating a multistory forest structure, were associated with denning habitat. The importance of large oaks, in particular, highlights the value of open stands in the early years of denning habitat development. Without light and resources, and likely frequent low severity fire, oaks are rapidly outcompeted by overtopping conifers, limiting the potential to grow future suitable denning habitat.

Within either known or potential den clusters, management activity during the denning season (March 1 – June 30) should be avoided. Outside the denning season, management activities that alter the structural characteristics of a den cluster, such widespread reduction in stand density or canopy cover, should also be avoided. Once a den cluster has been identified, it should be treated as occupied until it no longer retains the characteristics described by Green (2017).

Den Buffers

Three-hundred and seventy acres, surrounding a known or potential den cluster, represents the second tier of fisher denning habitat protection. Within this area, female fishers may be sensitive to disturbance during the denning season. At the same time, resiliency-based management may have the benefit of protecting the integrity of the den cluster within. Therefore management activities within this footprint should be carefully assessed with respect to the timing, intensity, and potential for cumulative effects. Whenever possible, management within this footprint should be avoided between March 1 and June 1. When unavoidable, potential negative impacts should be minimized and/or mitigated.

For example, commercial thinning during that temporal window would be highly disruptive while hand thinning of surface and ladder fuels may not be. Mechanical work can be deferred until after June 1, while prescribed fire often cannot. And a management activity in one area may cause a female fisher to relocate kits away from the disturbance, but if multiple management activities are ongoing around the den she may be forced to move kits further and leave them unattended longer, increasing the risk of mortality to both mother and kits.

4.2 Restore landscape permeability

Given the recent fragmentation of fisher habitat across the Southern Sierra Nevada region, maintaining habitat permeability at multiple scales has become a primary concern for fisher conservation. Elements involved in landscape permeability include maintaining the utility of existing habitat within home ranges, protecting existing habitat corridors, and restoring connectivity where it has been lost. The

DRAFT

multiple scales associated with maintaining landscape permeability and connectivity may best be thought of as within home range, between home range, and regional.

4.2.1 Maintaining existing habitat utility (within home range)

A fisher home range represents a mix of landscape elements, some more useful than others. While west slope Sierra Nevada fishers generally orient their home ranges to minimize openings and maximize the availability of dense, late-successional forest (Kordosky 2019), fisher on the Kern Plateau use much more open landscapes consisting of a mosaic of habitat types connected by riparian corridors and shrublands. While the Kern Plateau landscape may provide fewer of the key structural elements fisher use, possibly reflected by the low population density observed there (Zielinski et al. 2013), the landscape remains permeable to fishers.

Given the widespread mortality of pines and other conifers across the southern Sierra Nevada, the permeability of the landscape to fishers may be in question. While limited data is currently available on how fishers are behaving and moving in this new environment, researchers actively monitoring the animals describe their behavior as "reacting to the live trees, not the dead ones". Meaning the animals are being observed using remnant stands of live trees, and finding opportunities to move between them.

Therefore in existing suitable habitat, managers should strive to maintain existing pockets of live trees and protect or restore corridors between them. Riparian areas, which typically suffer less tree mortality than upland areas, are a primary source of habitat connectivity. In other areas, fishers may use younger stands or even shrub fields to move between mature, live stands.

4.2.2 Protecting existing corridors (between home range)

The current distribution of suitable habitat in the southern Sierra Nevada reflects a larger number of smaller and clumped habitat patches than were observed pre-2016. This requires fishers to traverse less suitable habitat in search of open territories or breeding opportunities. Identifying and protecting existing corridors, between habitat patches or clumps is a challenge because animals will often use suboptimal habitat for travel between more desirable habitat in a fragmented landscape (Sawyer et al. 2011, Scharf et al. 2018). LaPoint et al. (2013) documented that fishers' use of corridors differed from their use of home ranges, based on land cover classifications, and therefore the typical habitat characteristics associated with home ranges or high quality resting/denning sites do not necessarily apply to travel corridors between blocks of suitable habitat.

4.2.3 Creating additional corridors (regional)

Connectivity across linkage areas (i.e. between cores) is generally considered more tenuous and at risk from stochastic events (Opdam and Wascher 2004). This appears to be the case in the southern Sierra Nevada, as habitat in linkage areas has been lost at a greater rate over the past decade than habitat outside linkage areas (Figure 3). These losses have created potential barriers to fisher movement in four areas throughout the southern Sierra Nevada.

Both the Rim and Rough Fires converted large swaths of previously suitable habitat to inhospitable landscapes Together, these two fire footprints destroyed 670 km^2 of suitable habitat and greatly disrupted the connectivity of the southern Sierra Nevada fisher population by creating 15km and 13km gaps (respectively) in previously permeable habitat. The Aspen and French fires, while significantly smaller, were however inopportunely located on either side of the Kings River drainage where suitable fisher habitat narrowed to a small crossing below Mammoth Pool reservoir. Within these fire footprints, restoration actions that identify remnant habitat patches (e.g. lightly or unburned forest patches, fire refugia) and seek to connect them may provide large benefits to the regional population. In areas such as these, the identification of opportunities to provide short-term connectivity, in the form of shrub cover, re-sprouting oaks, or riparian hardwoods, particularly along riparian corridors or other more sheltered microclimates, should be considered in tandem with long-term habitat restoration. In these areas, limiting salvage logging operation and allowing snags to fall will help create complex, ground-level cover for dispersing fisher.

4.3 Promoting landscape heterogeneity

The three steps outlined by Opdam et al. (2004); stabilizing key habitat, restoring landscape permeability, and promoting heterogeneity, effectively outline a process to restore habitat functionality and increase the likelihood of population persistence in the face of fragmentation. Chambers et al. (2019) take this several steps further, and outline a process for "operationalizing ecological resilience concepts" when managing species and ecosystems at risk. Some of the relevant steps include:

- Understanding the importance of landscape context, including patterns of habitat distribution and potential thresholds in connectivity
- Understanding key pattern and process interactions, such as the influence of landscape pattern on disturbances, and associated variability or ongoing change

4.3.1 Promoting appropriate landscape patterns and context

Historically, fishers persisted in a landscape dominated by clumped trees, widely spaced large trees, well-distributed gaps and openings, and pockets of dense canopy and cover in suitable microclimates. Bonnickson and Stone (1981) described the landscape as a "mosaic of aggregations". Key to their persistence on this landscape may have been the connectivity offered by riparian areas and other linear habitat patches. While they are willing to cross more open areas, they typically go around larger ones whenever possible and when not, use intermediate islands of cover to move safely. Therefore, habitat quality in that landscape likely depended on the fine-scale nature of the mosaic; no single patch was too large to cross or avert.

Once existing or potential corridors, and potential denning habitat, have been delineated, restoration-based management in surrounding areas can help protect those areas. Variable density thinning projects that explicitly target between and within-stand heterogeneity (e.g. Larson and Churchill 2012, North and Sherlock 2012, Lydersen et al. 2013) will improve the chances of restoring some degree of landscape resilience and protecting remaining high-quality fisher habitat. Focusing thinning and other fuel management activities outside high quality denning habitat, and in locations that would not historically have supported high stand densities or created potential fire refugia, may help strike that balance between habitat conservation and promoting resilient landscapes.

With most species, there exists a threshold in connectivity beyond which populations cannot persist. This threshold is tightly bound to both the dispersal capacity of the species and the matrix the species must cross to reach higher-quality habitat or reproductive opportunities. In the pre-2014 Sierra Nevada

DRAFT

landscape, it was likely the male fishers' willingness to cross linkage areas that maintained the genetic viability of the regional population. However now, given the level of habitat fragmentation that has occurred, the ability of a dispersing female fisher to find a suitable territory is more in question. As a result, that threshold in connectivity may have lowered accordingly. Given the highly fragmented nature of southern Sierra Nevada fisher habitat, and the tenuous nature of many of the associated corridors, a detailed population viability analysis designed to identify critical core areas, corridors, and restoration opportunities, could help guide conservation efforts in the region.

4.3.2 Understanding pattern and process interactions

The interaction between the scale of landscape heterogeneity and both the size and severity of disturbances is a critical concern. Evidence indicates that historically, the Sierra Nevada region was dominated by fine-scale heterogeneity in vegetation, and this pattern was self-sustaining through the influence of this pattern on disturbances. The intensity of disturbance in any given area was influenced by the vegetation pattern, and the resulting, post-disturbance landscape therefore portrayed similar fine-scale heterogeneity, Disruptions of this cycle, though fire suppression and climate change, have moved the dynamic to a new framework where large, intense, and uniform disturbances create large, homogeneous patterns. Without intervention, this pattern will also be self-sustaining as large, homogenous areas respond uniformly to disturbances, e.g. a large, uniform patch of stem exclusion forest that burns will create a large, uniform patch of early seral forest.

This new pattern of large-scale disturbances and landscape homogeneity can best be described as a "boom/bust" cycle for fisher. While they may thrive in large patches of dense forests, the eventual disturbance is catastrophic in terms of habitat loss and results in additional population fragmentation. Ultimately, this pattern will not allow fisher to persist in the southern Sierra Nevada. Therefore management aimed at restoring the fine-scale pattern, done in concert with careful recognition of the fragile state in which the population currently persists, represents the best hope for the species in that region.

4.4 Recommended Conservation Measures:

Unless specifically stated, the recommendations below refer to suitable fisher habitat within the SSN Fisher Conservation Area (Figure 1) as defined in Section 3. Until updated habitat models are available this refers CWHR class 4M, 4D, 5M, 5D, and 6, within the relevant elevation range and habitat types.

4.4.1 Tree and Snag Retention Measures

- 4.4.1a - Retain most, if not all, large trees and snags when implementing treatments, especially those with structural deformities or decadence. Focus retention efforts on live conifers >30" DBH, live hardwoods >20" DBH, conifer snags > 35" DBH, and hardwood snags >27" DBH. Outside of high quality denning habitat, exceptions to this recommendation could include:
    - Removal of select shade-tolerant trees to promote existing shade-intolerant pine species in the same area of comparable size, such as ponderosa pine or sugar pine, or shade-intolerant broadleaved species, such as black oak or aspen.
    - Removal of select shade-intolerant trees to promote the establishment, growth, and development of stands with multiple size and age classes.

    - Thinning of trees in homogeneous plantations where large diameter trees are at risk due to competition.
    - Intentional creation of habitat variability and/or coarse woody debris, where cut trees are left on site.
- 4.4.1b – Outside high quality denning habitat, judiciously remove smaller (< 12” DBH) trees to promote recruitment and survival of the larger (>20” DBH) live trees and increase habitat heterogeneity. In particular, focus on providing growing space for California black oaks and canyon live oaks in areas where conifer cover has been reduced. Creating small (3-5m diameter) openings near mature oaks will also help facilitate natural regeneration. Reduce competition to surviving medium and large conifers to promote more resilient large trees.
- 4.4.1c – Within high quality denning habitat, retain understory trees in the immediate vicinity (within 10-12 m) of large trees and snags to provide cover for denning females.
- 4.4.1d – Except where it threatens public safety or the ability to meet fisher habitat objectives based on site conditions, preferentially retain ≥4 of the largest snags per acre (>20” DBH), particularly those surrounded by remaining live trees and in current denning habitat.
- 4.4.1e – Retain all known rest and den trees unless they are designated a safety hazard.
- 4.4.1f – During project implementation, educate marking crews on identifying potential fisher rest/den trees, and retain them.

4.4.2 Stand Structure Retention Measures

- 4.4.2a – In areas identified as known or potential den clusters, retain canopy cover >60% and retain multistory conditions where present.
- 4.4.2b – Outside den clusters and where ecologically appropriate, retain patches of overtopping and multi-storied canopy conditions, including some shade-tolerant understory trees (firs and cedars), especially in drainages, swales, and canyon bottoms and on north and east-facing slopes. Target retaining shade-tolerant overstory trees in key areas for connectivity where the overstory pine component has been largely removed by drought/insect mortality.
- 4.4.2c - When vegetation management is performed in potential reproductive habitat, identify and retain clumps of medium to large trees in cooler microclimates such as drainages or on north-facing slopes. Emphasize retention of clumps containing trees with some element of damage or deformity. The number of trees in a clump may vary widely (4 to 70), though in general the number of trees should vary inversely with the size of the dominant trees.
- 4.4.2d – Using variable density thinning techniques, create gaps adjacent to clumps to increase resources and resilience of clumps; gap size could range from 0.01 to 0.2 ha, with larger on drier sites and smaller on moister sites. Under a heterogeneous, variable density thinning approach
- 4.4.2e – Use uneven-age management to promote a range of tree size and age classes to recruit future larger trees.
- 4.4.2f – To the degree feasible, retain a patchy mosaic of shrubs and understory vegetation separated by more open areas to reduce fuels continuity, increase habitat heterogeneity, support fisher prey, and provide fishers with concealment cover—with a goal of 10-20% shrub cover at

the landscape scale (North et al. 2002, North et al. 2009, North and Sherlock 2012). This mosaic should be fine-scaled, with average patch sizes < 0.25 ha.

- 4.4.2g – Where possible, retain 3-5 tons of large (>20-in diameter) logs per acre (roughly 2-5 logs/acre). Log density should vary across the landscape, with some patches of high abundance (≥ 5 logs/ac) and others with lower densities (<1 log/ac). If large trees or snags must be felled, leave 3-5 tons per acre on the ground in the largest size classes where they do not pose a significant fuel or safety risk.
- 4.4.2h – Pile brush and retain some slash piles for fisher escape cover and prey habitat.
    - Preference should be given to larger sized piles in the vicinity of remnant high quality denning habitat
    - Preference should be given to burn piles with the following characteristics: at least 2 larger diameter logs, enough interstitial spaces that a fisher could hide in it, small enough to not be a significant fire hazard but large enough to be useful to a fisher (roughly 4m x 6m).

4.4.3 Habitat Retention Measures

- 4.4.3a – In areas defined as high quality denning habitat, limit restoration activities to hazard tree abatement, surface/ladder fuel treatment, and single-tree selection for the purpose of separating tree clumps. Use methods that do not fundamentally change stand structure, canopy cover, or CWHR category. Retain multistory conditions and understory heterogeneity (both vertical and horizontal) where ecologically appropriate.
- 4.4.3b – In areas defined as either high quality denning habitat or potential reproductive habitat, avoid fragmenting habitat through the creation of open fuelbreaks (< 40% overstory and < 10% understory), regeneration harvest gaps larger than 0.1 ha, or similar structure-reducing activities.
- 4.4.3c – When vegetation management is performed in suitable habitat, identify and retain clumps of medium to large trees in cooler microclimates such as drainages or on north-facing slopes. Emphasize retention of clumps containing trees with some element of damage or deformity. Define clumps based on overlapping crown and topographic features whenever possible.
- 4.4.3d – In suitable habitat, emphasize the use of gap-based variable density thinning to reduce fuel continuity and promote fine-scale heterogeneity (Lydersen et al. 2013, Fry et al. 2014, Collins et al. 2015).
    - Thinning prescriptions should emphasize the creation of a clump/gap stand structure, with clumps defined as clusters of trees with overlapping crowns.
    - The locations of clumps and gaps should be topographically-driven, with an emphasis on retaining larger, denser clumps in areas with suitable growing conditions
    - Clumps can be single or multi-age, and the number of trees should vary (~1 to 50). However the number of trees should vary inversely with the size of the dominant trees (more small trees vs. fewer large trees).

DRAFT

- The number of trees/clump should vary with roughly a third containing $\leq$ 4 trees, a third with 5-10 trees, and a third with $\geq$ 10.
- Gaps should range up to ~0.3 ha, should separate distinct tree clumps, and should cover 30-50% of a stand.
- Gap size should vary, with the majority being small (< $25m^2$; Lydersen et al. 2013), approximately a quarter being between $25m^2$ and $250m^2$, and few larger than $250m^2$.

4.4.4 Corridor/Connectivity Retention and Restoration Measures

- 4.4.4a – When working in post-disturbance landscapes, consider whether the proposed activity is located in an area that may serve as a corridor between existing habitat patches (e.g. riparian corridor, valley bottom, unburned island, etc.) In these areas, attempt to create or maintain 40-60% total canopy cover using a combination of overstory and understory vegetation.
- 4.4.4b – When planning reforestation efforts in currently unsuitable habitat, delineate areas for short and long term connectivity separately. In areas identified for short-term connectivity, allow shrubs and understory to recover alongside larger trees. In long-term corridors, promote planting and regeneration of drought-resistant conifers and oaks.
- 4.4.4c – When planning restoration efforts within post-fire landscapes, identify potential 'stepping-stone' habitat patches (e.g. fire refugia or unburned islands), and look for ways to promote fisher movement between them, such as shrub fields or downed wood.
- 4.4.4d – Avoid bisecting potential corridors with cleared linear features such as fuelbreaks or new roads. Where fuelbreaks are necessary, emphasize the use of shaded fuelbreaks and leave non-flammable cover whenever possible (e.g. berms or rocks)
- 4.4.4e – Avoid creating openings (<30% tree or shrub cover) that completely sever any identified corridor, while strategically breaking up vegetation continuity as necessary to achieve desired fuel condition. Based on site potential, retain and promote shrub cover clumps, downed logs and standing trees, either single or in small groups, within open areas (Freel 1991, Heinemeyer and Jones 1994).
- 4.4.4f – Where site conditions permit, maintain or increase tree canopy cover to >40% in delineated corridors, particularly in drainages, more mesic north-facing slopes, and riparian corridors.

4.4.5 Promoting Habitat Resiliency

- 4.4.5a – Outside high quality denning habitat, increase the resilience of large tree clumps within and adjacent to high quality denning habitat, by creating gaps directly adjacent to clumps. Gaps can range between approximately 0.001-0.3 ha each, with some larger gaps on drier sites. When creating gaps, focus on removing smaller (<20" trees) whenever possible.
- 4.4.5b –Inside high quality denning habitat, limit overstory removal to the creation of small gaps (< 0.1 ha) to help define tree clumps.
- 4.4.5c - To reduce stress on current and future large trees in areas outside high quality denning habitat, reduce tree density in remaining areas of medium and large live trees, while promoting multi-age/size characteristics

- 4.4.5d – Reduce surface and ladder fuels in a heterogeneous fashion to both limit spread of fire into continuous canopies while also providing clumps of concealment cover for fisher at appropriate spatial scales. The scale of these activities should be similar to those outlined in Section 4.4.3.

4.4.6 Increase Fisher Reproduction and Kit Survival

- 4.4.6a – Buffer any known den structure by 60 acres, and designate this as a potential den cluster as long as the surrounding conditions continue meet the criteria of high quality denning habitat.
- 4.4.6b – In areas meeting the criteria for high quality denning habitat, a biologist familiar with fisher ecology should work with marking crews to identify potential den clusters as leave areas.
- 4.4.6c – Within both known and potential den clusters, avoid intensive mechanical treatments or new road creation, and limit vegetation management to reducing surface and ladder fuels. In these areas, ensure that any management activity retains the essential fisher habitat characteristics such as structural diversity, large trees and microsites, and multi-level canopy.
- 4.4.6d – Protect known and potential den clusters from disturbance by implementing a limited operating period (LOP) from March 1 through May 1 for prescribed fire, and March 1 through June 30 for other disturbance-producing vegetation treatments. The LOP may be waived or modified for individual projects of limited scope and duration, when a biological evaluation documents that such projects are unlikely to result in breeding disturbance considering their intensity, duration, timing, and specific location, or where pre-project camera surveys have been conducted.
- 4.4.6e – Within a 360 acre den buffer (around and including a den cluster), consider the potential for cumulative disturbances during the denning season. Avoid mechanical activities that can be deferred to after June 30, and avoid multiple activities that extend over multiple weeks whenever possible.

5. Mitigating Management Actions

5.1 Fuelbreaks

There is very little direct evidence regarding the impact of linear clearing, such as fuelbreaks, on fisher movement, habitat use or intraguild interactions. However existing evidence suggests that cleared linear corridors promote use by larger carnivores, can shift community composition toward larger bodied carnivores and away from mid-sized carnivores, and promotes intraguild predation (Catterall 2019, McKenzie et al. 2012, Pattison and Catterall 2019). In the southern Sierra Nevada, Nichols (2017) found that both mountain lion movement and predation rates were associated with forest roads and skid trails. Given the ecological uncertainties regarding the impact of widespread use of fuelbreaks (Shinneman et al. 2019), and the documented increase in large predator activity (DeMars and Boutin 2018), use of fuelbreaks inside remaining fisher denning habitat should be avoided whenever possible. Placing fuelbreaks outside remnant patches of high quality denning habitat could help reduce additional habitat loss. Where placement of a fuelbreak within fisher habitat is unavoidable, effects may be mitigated through the use of shaded fuelbreaks or providing non-flammable crossing cover (e.g. berms, rock piles, or high fuel-hour structures such as large logs). When encountering a hard habitat edge, animals often

DRAFT

move linearly along the edge looking for a crossing opportunity. Providing crossing opportunities every 100-200 meters will help mitigate the impacts of habitat fragmentation and predation risk to fishers.

5.2 Hazard Tree Removal

Hazard trees pose a threat to human safety but can also provide a fisher resting or denning sites.

Hazard tree abatement along primary roads or in the vicinity of recreation areas or occupied structures is unlikely to significantly conflict with fisher habitat conservation. Fishers are less likely to den in these areas (Spencer et al. 2016), and deterring fishers from resting or denning near high traffic volume roads can help avoid vehicle-related mortality.

The most likely source of conflict between hazard tree removal and fisher habitat conservation is along unpaved forest roads, especially, within fisher denning habitat away from areas of concentrated human use, such as trailheads and campgrounds. Hazard tree removal projects should carefully assess whether trees pose a true hazard (e.g. proximity to human activity), and if so, what potential mitigation measures can be employed (e.g. leaving sections of the trunks standing or as down logs). Trees with potential hazard characteristics likely provide the most benefit to fishers, and avoiding removal by mitigating the potential hazard in some other way should be considered.

In prescribed fire operations, snags in the vicinity of firelines or other places of firefighter activity should be removed following approved guidelines. However snags within the interior of planned fire operations should be left whenever possible to provide post-fire structural diversity. For prescribed fires conducted within the LOP window (March 1 to May 1), the removal of snags should be avoided due to the possible presence of fisher kits.

5.3 Salvage Logging

Salvage logging is a controversial topic, with extensive debate over the need, utility, and relative risk. Regardless of that controversy, it is a management reality particularly on those forests currently undergoing large, uncharacteristically severe disturbances and in places where the thresholds associated with ecological type conversions are being approached. Rather than debate the utility of salvage logging, our intent is to present suggestions on how salvage logging may be conducted with minimal impacts to a fisher population of conservation concern.

It is important for managers to consider the possibility that post-fire or post-tree mortality landscapes are not necessarily devoid of fisher activity. Surveys, using cameras, track plates, hair snares, scat detection dogs or a combination of survey techniques, conducted after a fire but before any management activity, would be the most effective way to demonstrate that previously suitable habitat is no longer occupied by resident fishers. This may be particularly important in areas that were previously identified as denning habitat, or are adjacent to existing denning habitat, and burned at low severity.

In planning salvage efforts within large fire footprints and away from denning habitat, the consideration of habitat connectivity across these large, degraded landscapes is a critical concern. Patches of remaining live trees should be retained, and potential travel routes between these stands should be carefully considered. Along some of these potential travel routes, leaving standing snags, coarse woody debris, and allowing shrubs or re-sprouting vegetation to remain will facilitate fisher movement in the short-term. These short-term mitigation efforts should be focused in areas where understory species will develop rapidly or where irregular topography can help provide security. Other corridors should be

DRAFT

considered for long term connectivity-restoration. In these areas, the removal of snags and planting or regeneration of drought-resistant conifers or oaks will help facilitate habitat recovery.

Another focus in planning salvage activities should be the long-term creation of a fine-scale habitat mosaic, which will create a more resilient landscape and buffer the effects of subsequent disturbances. Leaving an irregular patchwork, with areas where a high density of snags are left as well as areas where they are removed, will help facilitate this effort. Therefore whenever possible, salvage removals should follow a similar clump/gap process, likely with greater emphasis on gaps, which is being recommended for thinning projects in fire-prone western forests (see Section for recommended patch/gap sizes) 4.4.3 .

5.4 Limited operating periods for non-emergency actions

Some management activities should be avoided or minimized in occupied denning habitat during the season when kits or their mothers are most sensitive to disturbance (March-June). The following recommendations are intended to reduce the potential for harm to fisher kits that may result from human activities, including temporary abandonment by the mother, forced relocation prior to appropriate development, or smoke accumulation in the natal den cavity. Moreover, mating occurs just after birthing, and disruption during the mating period could result in reduced reproduction the following year. Nevertheless, these interim recommendations recognize that the potential harm to one or a few individuals from management actions in denning habitat and season should be balanced against the potential benefits to fishers by increasing long-term habitat quality and resiliency.

In general, the period March 1 through May 1 is of heightened concern for management actions in or near denning habitat, especially long-duration, noisy activities, smoke producing activities, or those involving felling of trees. During this time, females typically do not move kits between dens and the kits are presumed to be more at risk of exposure and abandonment. The following dates are recommended for Limited Operating Periods (LOP) for potentially disruptive activities within denning habitat, *unless a project-specific analysis determines that the a denning female is not present or potential benefits to fishers outweigh the potential harm*.

Projects proposed in fisher denning habitat between March 1 and June 30 should be assessed by a qualified biologist, in collaboration with USFWS, to determine whether potential benefits to fishers are likely to outweigh the risks. If such a determination is made, activities may be exempt from the LOP restrictions if they are carefully designed and implemented to mitigate risks. This benefit-risk evaluation should recognize uncertainties on both sides, and consider the scale, duration, expected noise levels, and vegetation impacts of the actions.

5.5 Recommended Conservation Measures:

5.5.1 Fuelbreaks

- 5.5.1a – Where linear features are essential to hazard reduction or other management needs, create visual breaks in the continuity of openings with berms, rocks, or large logs. Where feasible, create a crossing opportunity for fishers every 100-200 m using nonflammable material.
- 5.5.1b – Where linear features are essential to hazard mitigation, avoid straight clearings and instead follow topography and/or natural features to create sinuous pathways that minimize predator sight lines.

- 5.5.1c – Where linear features are essential to hazard mitigation, avoid crossing riparian areas. Where it is necessary to cross riparian areas, follow riparian area guidance to leave sufficient cover to facilitate fisher movement across the fuelbreak.
- 5.5.1d – Where linear features are essential to hazard mitigation, prioritize the use of shaded fuelbreaks, maintaining >40% overstory canopy cover and 10% understory cover whenever possible. If not possible, document rationale.
- 5.5.1e – Avoid creating permanent linear or otherwise continuous areas of open habitat in denning habitat. Vegetation treatments within denning habitats should be fine-grained and discontinuous to avoid creating continuously open understories that facilitate access by fisher predators, and should utilize topography whenever possible to focus open areas on ridgetops, south facing slopes, or other areas that would historically support lower vegetation densities.
- 5.5.1f – In key connectivity areas or along key travel routes, avoid creating permanent fuel breaks whenever possible. Placement of fuel breaks adjacent to key habitat areas can both resist fire spread, provide firefighter access, and provide protection to high value habitat.

5.5.2 Prescribed fire management

- 5.5.2a – Design prescribed fires to create a mixed-severity mosaic, including some unburned patches (up to 25% of total area within the burn perimeter), to provide heterogeneity and refugia for fisher and their prey, especially in larger burn units, if environmental conditions allow.
- 5.5.2b – Focus prescribed burn activity in areas that would have historically supported shorter fire return intervals, such as south or west facing slopes, ridgetops or drier microclimates. In areas that historically would have supported denser vegetation and burned less often (e.g. cooler/wetter microclimates, riparian areas) but now carry high fuel loads, emphasize low intensity broadcast burning and repeated entries to reduce fire risk.
- 5.5.2c – Use methods described in Hood (2010) to reduce losses of large trees and potential denning structures during prescribed fires. Where feasible, this may include raking or targeted preparatory burning around high-value (e.g., large, structurally complex) trees and snags where surface fuel conditions increase the risk of loss to the fire.
- 5.5.2d – Known high quality habitat areas, key connectivity areas, and information on important habitat elements should be available to the Incident Management Team before fire season.
- 5.5.2e – Avoid prescribed fire in suitable denning habitat between 1 March and 1 May unless the effects of smoke accumulation can be mitigated and the loss of large structures can be avoided.

5.5.3 Hazard tree removal

- 5.5.3a – In denning habitat and along secondary or unpaved, low-traffic roads, consider hazard mitigation options other than complete removal for conifer snags > 35” DBH and hardwood snags >27” DBH.
    - If it can be done safely, cut the hazard tree as high as possible to leave a portion of the trunk (~10-20’) standing in order to provide potential microsites.
    - Leave 15’-20’ of the thickest part of the trunk on site as a large log, particularly if decay is evident.

5.5.4 Salvage logging

- 5.5.4a – Fire refugia (unburned or lightly burned areas within a fire perimeter) may be particularly important to fishers attempting to cross or recolonize burned landscapes. These areas should be delineated by qualified wildlife biologists and silviculturists and retained on the landscape.
- 5.5.4b – During salvage operation, anticipate potential habitat corridors between unburned refugia. In these areas, leave significant amounts of standing snags, and allow shrubs to recover. While large, standing snags typically represent a higher resource value for fisher, smaller snags that will fall and create complex ground cover may help facilitate movement across post-fire landscapes. While the width of a potential corridor will depend on site conditions, corridors >100m wide are more likely to provide movement opportunities.
- 5.5.4c – During salvage operation, anticipate potential habitat corridors between remaining high quality habitat patches. In these areas, promote the recovery of drought-resistant conifers and oaks.

5.5.5 Vegetation management in previous fisher habitat

- 5.5.5a – When working in areas of historic, but currently unsuitable, habitat, actively pursue fine-scale heterogeneity through the use of clump/gap-based treatments as described in Section 4.4.3. Avoid creating large, homogenous patches that may support uniform disturbances in the future.
- 5.5.5b – Identify areas capable of providing short-term habitat connectivity, and allow the growth of shrubs or deciduous cover to promote fisher movement.

DRAFT

5.5.6 Limited operating periods

- The following is a summary of LOPs for management activities within current fisher habitat. Exemptions from these restrictions must be justified by a project-specific biological evaluation documenting mitigation efforts to limit negative impacts to fisher habitat and avoid negative impacts to remaining fisher denning habitat.

LOP	Restricted activities
March 1 to June 30	Logging, thinning, or other tree-cutting activities within stands identified as den clusters or den buffers Application of Glyphosate with mild surfactant (e.g., R-11) if vegetation and ground that is sprayed will not be dry within 4 hours New road construction and development of infrastructure in high quality denning habitat
March 1 to June 1	Logging, thinning, or other tree-cutting activities within stands identified as high quality denning habitat but not designated as den clusters or buffers Post-fire salvage logging within 250 m of the high quality denning habitat. Mastication within stands typed as Sierran mixed conifer (SMC), conifer-hardwood (MHC), and ponderosa pine (PPN) CWHR 4D, 5M, 5D, or 6, in denning habitat.
March 1 to May 1	Prescribed fire in potential reproductive habitat (*unless designed to minimize potential harm to fishers, including the judicious use of topography and weather conditions to minimize smoke accumulation in denning habitat and the avoidance of large structure removal*) Prescribed fire within den clusters
March 15 to May 1	Burning slash or woody debris piles (>0.1 ac), piles adjacent to possible den structures, or situations where simultaneous lighting would create intense smoke Special use permit events for off-highway vehicles or over-snow vehicles, in areas not usually exposed to high levels of OHV/OSV traffic.

DRAFT

6. Managing Cumulative Effects

Fisher habitat in the southern Sierra Nevada region has been severely degraded, and to use current conditions as a baseline for cumulative effects analyses would be ecologically inappropriate. Vegetation management projects should therefore strive to not only limit negative effects to remaining habitat, they should strive to increase habitat availability and functionality whenever possible. Often this may be accomplished indirectly, such as through promotion of landscape resiliency or creating growing conditions that will support large tree development. However the regional fisher population must survive the short-term challenges in order to reap these long-term benefits. Therefore projects focusing on long-term habitat management objectives should, whenever possible, avoid short-term habitat loss and additional fragmentation in areas where site conditions are capable of supporting high quality habitat.

7. Additional Conservation Measures Carried Over From 2016 SSFCS

Reduce Pesticide Poisoning

- 7.1a – Continue and expand aggressive law enforcement to prevent and locate trespass marijuana grow sites; interrupt grow operations as early in the season as possible to prevent poisoning.
- 7.1b – Continue and expand remediation efforts at grow sites to remove toxicants and trash.
- 7.1c – Prioritize remediation efforts in high quality denning habitat to minimize impacts to reproduction
- 7.1d – Conduct research and monitoring to determine how long toxicants remain in the environment and affect wildlife, and assess and implement effective means of mitigating adverse effects.

Reduce Predation

- 7.2a – Close, remediate, and re-vegetate unneeded roads, off-highway vehicle trails, skid trails, or other linear openings that facilitate access by coyotes, mountain lions, and bobcats in fisher habitat.

Reduce Fisher Vehicle Strikes

- 7.3a – Improve efficacy of road-crossing structures by regularly maintaining damaged or blocked culverts and retrofitting existing culverts to improve wildlife use. Retrofitting can include repairing perched inlets/outlets, draining pools blocking entrances, removing debris blocking entrances, creating pathways directing animals to culverts, or installing shelves in culverts to provide passage above high water flow.
- 7.3b – Install new wildlife undercrossings in fisher habitat, especially in modeled denning habitat or other heavily used areas, similar to efforts on the Sierra National Forest and Yosemite National Park. Construct underpass structures designed for wildlife (Corlatti et al. 2009, Kintsch and Cramer 2011), and use fencing or other barriers to help funnel animals to crossing structures. Considerations include retrofitting culverts to increase size and provide an upper platform to facilitate crossing even during high water (Figure 6), as well as the use of a 2-culvert system; a lower one to provide water flow and an upper, "dry" one to facilitate crossing (see Cline 2014 for details).
- 7.3c – Reduce speed limits to 25 mph in identified roadkill areas. Use portable radar speed feedback signs to slow drivers during denning season (March 1–June 30). Work with Caltrans, California Highway Patrol, and National Park Service Law Enforcement to enforce speed limits along Highway 41/Wawona Road and other roads with documented roadkill.
- 7.3d – Research and apply vegetation management or other measures along roads to discourage aboveground crossings and funnel fishers to crossing structures, for example, by reducing

DRAFT

roadside vegetation to increase visibility in upland areas, but maintaining natural vegetation in drainages close to the road to funnel fishers to culverts or undercrossings.

- 7.3e – Encourage rapid removal of road-killed wildlife, especially deer, to locations far from roads to reduce risk of fishers foraging near roads. Coordinate with Caltrans to deposit road-killed animals that could be scavenged by fisher ≥0.25 mile from highway corridors.

Reduce Impacts of Human Development and Infrastructure

- 7.4a – Retrofit pipes, water tanks, and other such structures to avoid entrapment of wildlife.
- 7.4b – Identify and maintain or remove old tanks, pipes, irrigation canals, etc., potentially using citizen science volunteers. Folliard (1994) recommends that abandoned water tanks be covered, given drain holes, or modified by inserting branches, poles, or metal bars (which do not rot) so that wildlife can self-rescue from "accidental traps."
- 7.4c – Avoid construction activities in or near fisher denning habitat from March 1 to June 30. Maintenance of existing infrastructure within high quality fisher denning habitat will require Section 7 consultation during this time period.

DRAFT

8. Literature Cited

Aubry, K.B., C.M. Raley, and P/G/ Cunningham. 2018. Selection of rest structures and microsites by fishers in Oregon. Journal of Wildlife Management 82: 1273-1284.

Aubry, K.B., and C.M. Raley. 2006. Ecological characteristics of fishers (*Martes pennanti*) in the Southern Oregon Cascade Range. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Olympia, WA.

Blomdahl, E.M., C.M. Thompson, J.R. Kane, V.R. Kane, D. Churchill, L.M. Moskal, and J.A. Lutz. 2019. Forest structure predictive of fisher (*Pekania pennanti*) dens exists in recently burned forest in Yosemite, California, USA. Forest Ecology and Management 444: 174-186.

Bouldin, J. 1999. Twentieth-century changes in forests of the Sierra Nevada, California. Ph.D. dissertation. University of California, Davis. Davis, CA. 223 p.

Chambers J.C., C.R. Allen, and S.A. Cushman. 2019. Operationalizing ecological resilience concepts for managing species and ecosystems at risk. Frontiers in Ecology and Evolution 7:241. doi: 10.3389/fevo.2019.00241

Cline, L. 2014. Mitigating fisher road-kill in Yosemite National Park with wildlife crossing structures 2011-2014 final report. Unpublished internal report. Yosemite National Park. 57 pp.

Constible, J.M., M.J. Chamberlain, and B.D. Leopold. 20076. Pattern and space use of three mammalian carnivores in central Mississippi. American Midland Naturalist 155: 352-362.

Corlatti, L., K. Hacklander, and F. Frey-Roos. 2009. Ability of wildlife overpasses to provide connectivity and prevent genetic isolation. Conservation Biology 23: 548-556.

Dellinger, J.A., B. Cristescu, J. Ewanyk, D. Garcelon, Q. Martins, C. Thompson, T.W. Vickers, C.C. Wilmers, H.U. Wittmer, and S.G. Torres. Using mountain lion habitat selection in management. Journal of Wildlife Management *in press*.

DeMars, C.A. and S. Boutin. 2018. Nowhere to hide: Effects of linear features on predator-prey dynamics in a large mammal system. Journal of Animal Ecology 87: 274-284.

Donaldson, L., R.J. Wilson, and I.M.D. Maclean. 2017. Old concepts, new challenges: adapting landscape-level conservation to the twenty-first century. Biological Conservation 26: 527-552.

Ellington, E.H., S.W. Gess, E.L. Koen, J.E. Duchamp, M.J. Lovallo, M.R. Dzialak, and J.L. Larkin. 2017. Habitat patch use by fishers in the deciduous forest-dominated landscape of the central Appalachian Mountains, USA. Journal of Fish and Wildlife Management 8: 365-376.

Folliard, L. 1994. Discovery of an accidental trap for Pacific fishers. The Marten 2:7.

Foppen, R.P.B., C.J.F. Ter Braak, J. Verboom, and R. Reijnen. 1999. Dutch sedge warblers *Acrocephalus schoenobaenus* and West-African rainfall: empirical data and simulation modeling show low population resilience in fragmented marshlands. Ardea 87: 113-127.

Fraterrigo, J.M., S.M. Pearson, and M.G. Turner. 2009. Joint effects of habitat configuration and temporal stochasticity on population dynamics. Landscape Ecology 24: 863-877.

Freel, M. 1991. A literature review for management of the marten and fisher on national forests in California. Unpublished report, USDA Forest Service, Pacific Southwest Region. 22 p.

Green. R.E. 2017. Reproductive ecology of the fisher (*Pekania pennanti*) in the southern Sierra Nevada: an assessment of reproductive parameters and forest habitat used by denning females. PhD Dissertation, University of California, Davis, Davis, CA. 188 p.

Green, R.E., K.L. Purcell, C.M. Thompson, D.A. Kelt, and H.U. Wittmer. 2019. Microsites and structures used by fishers (*Pekania pennanti*) in the southern Sierra Nevada: A comparison of forest elements used for daily resting relative to reproduction. Forest Ecology and Management 440: 131-146.

Hanson, C.T. 2013. Habitat use of Pacific fishers in a heterogeneous post-fire and unburned forest landscape on the Kern Plateau, Sierra Nevada, California. Open Forest Science Journal 6: 24-30.

Hanson, C.T. 2015. Use of higher severity fire areas by female Pacific fishers on the Kern Plateau, Sierra Nevada, California, USA. Wildlife Society Bulletin 39: 497-502.

Happe, P.J., K.J. Jenkins, R.M. McCafferry, J.C. Lewis, K.L. Pilgrim, and M.K. Schwartz. 2019. Occupancy patterns in a reintroduced fisher population during reestablishment. Journal of Wildlife Management doi 10.1002/jwmg.21788

Heinmeyer, K.S., and J.L. Jones. 1994. Fisher biology and management in the western United States: a literature review and adaptive management strategy (version 1.2). Unpublished report prepared for USDA Forest Service Northern Region and the Interagency Forest Carnivore Working Group. 41 p.

Hood, S.M. 2010. Mitigating old tree mortality in long-unburned, fire-dependent forests: a synthesis. Gen Tech. Rep. RMRS-GTR-238. USDA Forest Service, Rocky Mountain Research Station. Missoula MT.

Kintsch, J. and P.C> Cramer. 2011. Permeability of existing structures for terrestrial wildlife: a passage assessment system. Washington Dept. of Transportation No. WA-RD 777.1.

Kordosky, J. 2019. Landscape of stress: Does drought prevail over anthropogenic activity in influencing cortisol levels and fitness in the Pacific fisher? MS thesis. Utah State University, Logan UT. 129 pp.

Kordosky, J.R., E.M. Gese, C.M. Thompson, P.A. Terletzky, L.A. Neuman-Lee, J.D. Schniderman, K.L. Purcell, and S.S. French. Landscape of stress: drought prevails over anthropogenic modifications in influencing cortisol levels and survival in the Pacific fisher. Biological Conservation *in review*.

LaPoint, S., P. Gallery, M. Wikelski, and R. Kays. 2013. Animal behavior, cost-based corridor models, and real corridors. Landscape Ecology 28: 1615-1630.

Larson, A.J. and D. Churchill. 2012. Tree spatial patterns in fire-frequent forests of western North America, including mechanisms of pattern formation and implications for designing fuel reduction and restoration treatments. Forest Ecology and Management 267: 74-92.

Litvaitis, J.A., J.P Tash, and C.L. Stevens. 2006. The rise and fall of bobcat populations in New Hampshire: Relevance of historical harvests to understanding current patterns of abundance and distribution. Biological Conservation 128: 517-58.

Lydersen, J., M. North, E. Knapp, and B. Collins. 2013. Quantifying spatial patterns of tree groups and gaps in mixed –conifer forests: reference conditions and long-term changes following fire suppression and logging. Forest Ecology and Management 304: 370-382.

DRAFT

Matthews, S.M., D.S. Green, J.M. Higley, K.M. Rennie, C.M. Kelsey, and R.E. Green. 2019. Reproductive den selection and its consequences for fisher neonates, a cavity-obligate mustelid. Journal of Mammalogy 100: 1305-1316.

McKenzie, H.W., EH. Merrill, R.J. Spiteri, and M.A. Lewis. 2012. How linear features alter predator movement and the functional response. Interface Focus 2: 205-216.

McRae, B.H., and D.M. Kavanagh. 2011. Linkage Mapper Connectivity Analysis Software. The Nature Conservancy, Seattle WA. Available at: http://www.circuitscape.org/linkagemapper.

Meinke, C.W. 2004. Mountain lion habitat use relative to human activities in and around Redwood National and State Parks of northwest California. M.S Thesis. Humboldt State University. Arcata, CA. 84 pp.

Naney, R. H., L. L Finley, E. C. Lofroth, P. J. Happe, A. L. Krause, C. M. Raley, R. L. Truex, L. J. Hale, J. M. Higley, A. D. Kosic, J. C. Lewis, S. A. Livingston, D. C. Macfarlane, A. M. Myers, and J. S. Yaeger. 2012. Conservation of Fishers (*Martes pennanti*) in South-Central British Columbia, Western Washington, Western Oregon, and California–Volume III: Threat Assessment. USDI Bureau of Land Management, Denver, Colorado, USA.

Niblett, M.R., S.S. Sweeney, R.L. Church, and K.H. Barber. 2014. Structure of fisher (*Pekania pennanti*) habitat in a managed forest in an interior northern California Coast Range. Forest Science 61: 481-493.

Niblett, M., R.L. Church, S.H. Sweeney, and K.H. Barber. 2017. Characterizing habitat elements and their distribution over several spatial scales: the case of the fisher. Forests 8, 186. doi:10.3390/f8060186

Nichols, B.C., 2017. Foraging ecology of mountains lions in the Sierra National Forest, California. MS Thesis. Utah State University. Logan, UT. 109 p.

North M.P., B. Oakley, J. Chen, H. Erickson, A. Gray, A. Izzo, D. Johnson, S. Ma, J. Marra, M. Meyer, K. Purcell, T. Rambo, D. Rizzo, B. Roath, and T. Schowalter, 2002. Vegetation and ecological characteristics of mixed-conifer and red fir forests at the Teakettle Experimental Forest. USDA Forest Service, Pacific Southwest Research Station. Albany, CA. Gen. Tech. Rep. PSW-GTR-186.

North, M., P. Stine, K. O'Hara, W. Zielinski, and S. Stephens. 2009. An ecosystem management strategy for Sierra mixed-conifer forests. Gen Tech Rep. PSW-GTR-220 with addendum. USDA Forest Service, Pacific Southwest Research Station. 52 p.

North, M.P., B.M. Collins, and S.L. Stephens. 2012. Using fire to increase the scale, benefits, and future maintenance of fuels treatments Journal of Forestry 110: 392-401.

North, M.P. and J. Sherlock. 2012. Marking and assessing forest heterogeneity, Pp. 95-105 *in* Managing Sierra Nevada forests. M.P. North editor. USDA Forest Service, Pacific Southwest Research Station. Albany, CA. Gen. Tech, Rep. PSW-GTR-237.

Opdam, P. and D. Wascher. 2004. Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels in research and conservation. Biological Conservation 117: 285-297.

Paragi, T.F., S,M, Arthur, and W.B. Krohn. 1996. Importance of tree cavities as natal dens for fishers. National Journal of American Forestry 13: 79-83.

Pattison, C.A. and C.P. Catterall. 2019. Effects of narrow linear clearings on movement and habitat use in a boreal forest mammal community during winter. PeerJ 7:e6504 DOI 10.7717/peerj.6504

Purcell, K.L., A.K. Mazzoni, S. Mori, and B.B. Boroski. 2009. Resting structures and resting habitat of fishers in the southern Sierra Nevada, California. Forest Ecology and Management. 258: 2696–2706.

Robinson, C.D., J.C. Crawford, L. Corcoran, E.M. Schauber, and C.K. Nielsen. 2016. Metapopulation viability of swamp rabbits in southern Illinois: potential impacts of habitat change. Journal of Mammalogy 97: 68-79.

Safford, H, D. and J.T. Stevens. 2017. Natural range of variation for yellow pine and mixed-conifer forests in the Sierra Nevada, southern Cascades, and Modoc and Inyo National Forests, California, USA. Gen. Tech. Rep. PSW-GTR-256. Albany, CA. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 229 p.

Sawyer, S.C., C.W. Epps, and J.S. Brashares. 2011. Placing linkages among fragmented habitats: do least-cost models reflect how animals use landscapes? Journal of Applied Ecology 48: 668-678.

Scharf, A.K., J.L. Belant, D.E. Beyer Jr, M. Wikelski, and K. Safi. 2018. Habitat suitability does not capture the essence of animal-defined corridors. Movement Ecology 6:18 https://doi.org/10.1186/s40462-018-0136-2

Shinneman, D.J., M.J. Germino, D.S. Pilliod, C.L. Aldridge, N.M. Vaillant, and P.S. Coates. 2019. The ecological uncertainty of wildfire fuel breaks: examples from the sagebrush steppe. Frontiers in Ecology and the Environment 17: 279-288.

Smith, K., A. Facka, and R. Powell. Using reintroduction to elucidate breeding system, breeding phenology and infanticide for a solitary carnivore. Canadian Journal of Zoology *in review*.

Spencer, W.D., S.C. Sawyer, H.L. Romsos, W.J. Zielinski, C.M. Thompson, and S.A. Britting. 2016. Southern Sierra Nevada fisher conservation strategy. Unpublished report produced by the Conservation Biology Institute. 136 pp.

Stephens, S.L. 2000. Mixed conifer and red fir forest structure and uses in 1899 from the central and northern Sierra Nevada, California. Madrono 47: 43-52.

Stephens, S.L. and D.L. Elliott-Fisk. 1998. *Sequioadendron giganteum*-mixed conifer forest structure in 1900-1901 from the southern Sierra Nevada, CA. Madrono 45: 221-230.

Stephens, S.L., J.T. Stevens, B.M. Collins, R.A. York, and J.M. Lydersen. 2018. Historical and modern landscape forest structure in fir (*Abies*)-dominated mixed conifer forests in the northern Sierra Nevada, USA. Fire Ecology 14. doi:10.1186/s42408-018-0008-6

Sweitzer, R.A., B.J. Furnas, R.H. Barrett, K.L. Purcell, and C.M. Thompson. 2016. Landscape fuel reduction, forest fire, and biophysical linkages to local habitat use and local persistence of fishers (*Pekania pennanti*) in Sierra Nevada mixed-conifer forests. Forest Ecology and Management. 261-208-225.

Taylor, A.H., A.M. Vandervlugt, R.S. Maxwell, R.M. Beaty, C. Airey, and C.N. Skinner. 2014. Changes in forest structure, fuels, and potential fire behavior since 1873 in the Lake Tahoe Basin, USA. Applied Vegetation Science 17: 17-31.

DRAFT

Thompson, C.M., M.W. Gabriel, and K.L. Purcell. 2017. An ever-changing ecological battlefield: Marijuana cultivation and toxicant use in western forests. Wildlife Professional 11: 42-46.

U.S. Fish and Wildlife Service. 2016. Final Species Report: Fisher (*Pekania pennanti*), West Coast Population. USFWS, March 2016.

U.S. Fish and Wildlife Service. 2019. Endangered and Threatened Wildlife and Plants; Threatened species status for west coast distinct population segment of fisher with section 4(d) rule. Federal Register 7 November 2019, https://federalregister,giov/d/2019-23737.

Verboom, J., P. Schippers, A. Cormont, M. Sterk, C.C. Vos, and P.F.M. Opdam. 2010. Population dynamics under increasing environmental variability: implication of climate change for ecological network design criteria. Landscape Ecology 25: 1289-1298.

Weir, R.D., M. Phinney and E.C. Lofroth. 2012. Big, sick, and rotting: why tree size, damage, and decay are important to fisher reproductive habitat. Forest Ecology and Management 265: 230-240.

Wengert, G.M. 2013. Ecology of intraguild predation on fishers (*Martes pennanti*) in California. PhD Dissertation. University of California, Davis. Davis, CA. 126 p.

Witmer, G.W. and D.S. DeCalestra. 1986. Resource use by unexploited sympatric bobcats and coyotes in Oregon. Canadian Journal of Zoology 64: 2333-238.

Ye, X., A.K. Skidmore and T. Wang. 2013. Within-patch habitat quality determines the resilience of specialist species in fragmented landscapes. Landscape Ecology 28: 135-147.

Ye X., Skidmore A.K., and T. Wang. 2014 Joint Effects of Habitat Heterogeneity and Species' Life-History Traits on Population Dynamics in Spatially Structured Landscapes. PLoS ONE 9(9): e107742. doi:10.1371/journal.pone.0107742.

Zielinski, W.J., J.M. Tucker, and K.M. Rennie. 2017. Niche overlap of competing carnivores across climatic gradients and the conservation implications of climate change at geographic range margins. Biological Conservation 209: 533-545.

Zielinski, W.J. and F.V. Schlexer. 2019. The effect of time and forest disturbances on the structural and functional characteristics of fisher (*Pekania pennanti*) resting structures. Northwest Science 93: 75-84.

DRAFT