Focal Resource: PACIFIC FISHER

Taxonomy and Related Information

Pacific fisher (*Pekania pennanti*, formerly *Martes pennanti)*[1]; southern Sierra population south of Merced River (small population: 100-400 adults); one introduced population north-western California; historic: two separate populations (separated over 1000 years).

General Overview of Process

EcoAdapt, in collaboration with the U.S. Forest Service and California Landscape Conservation Cooperative (CA LCC), convened a 2.5-day workshop entitled *A Vulnerability Assessment Workshop for Focal Resources of the Sierra Nevada* on March 5-7, 2013 in Sacramento, California. Over 30 participants representing federal and state agencies, non-governmental organizations, universities, and others participated in the workshop[2]. The following document represents the vulnerability assessment results for the **PACIFIC FISHER**, which is comprised of evaluations and comments from a participant breakout group during this workshop, peer-review comments following the workshop from at least one additional expert in the subject area, and relevant references from the literature. The aim of this synthesis is to expand understanding of resource vulnerability to changing climate conditions, and to provide a basis for developing appropriate adaptation responses. The resulting document is an initial evaluation of vulnerability based on existing information and expert input. Users are encouraged to refer to the Template for Assessing Climate Change Impacts and Management Options (TACCIMO, http://www.taccimo.sgcp.ncsu.edu/) website for the most current peer-reviewed literature on a particular resource. This synthesis is a living document that can be revised and expanded upon as new information becomes available.

Geographic Scope

The project centers on the Sierra Nevada region of California, from foothills to crests, encompassing ten national forests and two national parks. Three geographic sub-regions were identified: north, central, and south. The north sub-region includes Modoc, Lassen, and Plumas National Forests; the central sub-region includes Tahoe, Eldorado, and Stanislaus National Forests, the Lake Tahoe Basin Management Unit, and Yosemite National Park; and the south sub-region includes Humboldt-Toiyabe, Sierra, Sequoia, and Inyo National Forests, and Kings Canyon/Sequoia National Park.

Key Definitions

Vulnerability: Susceptibility of a resource to the adverse effects of climate change; a function of its sensitivity to climate and non-climate stressors, its exposure to those stressors, and its ability to cope with impacts with minimal disruption[3].

Sensitivity: A measure of whether and how a species or system is likely to be affected by a given change in climate or factors driven by climate.

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[1] Following Koepfli et al. 2008.

[2] For a list of participant agencies, organizations, and universities please refer to the final report *A Climate Change Vulnerability Assessment for Focal Resources of the Sierra Nevada* available online at: http://ecoadapt.org/programs/adaptation-consultations/calcc.

[3] Glick, P., B.A. Stein, and N.A. Edelson, editors. 2011. Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment. National Wildlife Federation, Washington, D.C.

Adaptive Capacity: The degree to which a species or system can change or respond to address climate impacts.

Exposure: The magnitude of the change in climate or climate driven factors that the species or system will likely experience.

Methodology

The vulnerability assessment comprises three vulnerability components (i.e., sensitivity, adaptive capacity, and exposure), averaged rankings for those components, and confidence scores for those rankings (see tables below). The sensitivity, adaptive capacity, and exposure components each include multiple finer resolution elements that were addressed individually. For example, sensitivity elements include: whether the species is a generalist or specialist; physiological sensitivity to temperature, precipitation, and other factors (e.g., pH, salinity); dependence on sensitive habitats; species' life history; sensitivity of species' ecological relationships (e.g., predator/prey, competition, forage); sensitivity to disturbance regimes (e.g., wind, drought, flooding); and sensitivity to non-climate stressors (e.g., grazing, recreation, infrastructure). Adaptive capacity elements include: dispersal ability and barriers to dispersal, phenotypic plasticity (e.g., can the species express different behaviors in response to environmental variation), species' potential to adapt evolutionarily to climate change, species' intraspecific/life history diversity (e.g., variations in age at maturity, reproductive or nursery habitat use, etc.), and species' value and management potential. To assess exposure, participants were asked to identify the climate and climate-driven changes most relevant to consider for the species and to evaluate exposure to those changes for each of the three Sierra Nevada geographic sub-regions. Climate change projections were provided to participants to facilitate this evaluation[4]. For more information on each of these elements of sensitivity, adaptive capacity, and exposure, including how and why they were selected, please refer to the final methodology report *A Climate Change Vulnerability Assessment for Focal Resources of the Sierra Nevada*[5].

During the workshop, participants assigned one of three rankings (High (>70%), Moderate, or Low (<30%)) to each finer resolution element and provided a corresponding confidence score (e.g., High, Moderate, or Low) to the ranking. These individual rankings and confidence scores were then averaged (mean) to generate rankings and confidence scores for each vulnerability component (i.e., sensitivity, adaptive capacity, exposure score) (see table below). Results presented in a range (e.g. from moderate to high) reflect variability assessed by participants. Additional information on ranking and overall scoring can be found in the final methodology report *A Climate Change Vulnerability Assessment for Focal Resources of the Sierra Nevada*[5].

Recommended Citation

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[4] Geos Institute. 2013. *Future Climate, Wildfire, Hydrology, and Vegetation Projections for the Sierra Nevada, California: A climate change synthesis report in support of the Vulnerability Assessment/Adaptation Strategy process.* Ashland, OR. http://ecoadapt.org/programs/adaptation-consultations/calcc.

[5] Kershner, J.M., editor. 2014. *A Climate Change Vulnerability Assessment for Focal Resources of the Sierra Nevada.* Version 1.0. EcoAdapt, Bainbridge Island, WA. http://ecoadapt.org/programs/adaptation-consultations/calcc.

This document is available online at EcoAdapt (http://ecoadapt.org/programs/adaptation-consultations/calcc).

Table of Contents

Overview of Vulnerability Component Evaluations

SENSITIVITY

Sensitivity Factor	Sensitivity Evaluation	Confidence
Generalist/Specialist	**1 Generalist**	**3 High**
Physiology	**2 Moderate**	**2 Moderate**
Habitat	**3 High**	**2 Moderate**
Life History	**3 High**	**3 High**
Ecological Relationships	**No answer provided by participants**	**1 Low**
Disturbance Regimes	**3 High5**	**3 High**
Non-Climatic Stressors – Current Impact	**3 High**	**3 High**
Non-Climatic Stressors – Influence Overall Sensitivity to Climate	**1.5 Low-Moderate**	**2 Moderate**
Other Sensitivities	**None**	**2 Moderate**

Overall Averaged Confidence (Sensitivity)[6]: Moderate-High

Overall Averaged Ranking (Sensitivity)[7]: Moderate–High

ADAPTIVE CAPACITY

Adaptive Capacity Factor	Adaptive Capacity Evaluation	Confidence
Dispersal Ability	**2 Moderate**	**3 High**
Barriers Affect Dispersal Ability	**1 Low**	**1 Low**
Plasticity	**3 High**	**No answer provided by participants**
Evolutionary Potential	**1 Low**	**3 High**
Intraspecific Diversity/Life History	**1 Low**	**1 Low**
Species Value	**3 High**	**3 High**
Specificity of Management Rules	**2 Moderate**	**2 Moderate**
Other Adaptive Capacities	**None**	**2 Moderate**

Overall Averaged Confidence (Adaptive Capacity)[6]: Moderate

Overall Averaged Ranking (Adaptive Capacity)[7]: Moderate

EXPOSURE

Relevant Exposure Factor	Confidence
Wildfire	**3 High**
Snowpack	**1 Low**
Shifts in vegetation structure	**3 High**

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[6] 'Overall averaged confidence' is the mean of the entries provided in the confidence column for sensitivity, adaptive capacity, and exposure, respectively.

[7] 'Overall averaged ranking' is the mean of the perceived rank entries provided in the respective evaluation column.

Exposure Region	Exposure Evaluation (2010-2080)	Confidence
Northern Sierra Nevada	**2 Moderate**	**No answer provided by participants**
Central Sierra Nevada	**Not applicable**	**No answer provided by participants**
Southern Sierra Nevada	**2 Moderate**	**No answer provided by participants**

Overall Averaged Confidence (Exposure)[6]: Moderate

Overall Averaged Ranking (Exposure)[7]: Moderate

Sensitivity

1. **Generalist/Specialist.**
   a. Where does species fall on spectrum of generalist to specialist: Generalist – overall; specialist in terms of resting/denning structures
      i. Participant confidence: High
   b. Factors that make the species more of a specialist: Other dependencies – denning/resting

Additional comments: The species has multiple prey and habitat elements. Important structures for denning/resting include decadent structures and old growth habitats.

Black oaks do seem important in the southern Sierra Nevada, but oaks may not be critical in other regions.

References: Although the Pacific fisher utilizes multiple prey (Zielinski et al. 1999) and multiple habitat elements, the Pacific fisher is considered a habitat specialist, with resting and denning structures considered to be the most important habitat elements required for maintenance of fisher populations (Lofroth et al. 2010 cited in Zhao et al. 2012; Weir et al. 2012). Fishers prefer habitats with dense canopy cover and decadent structures for denning and resting (Purcell et al. 2009), such as large trees with visible signs of decay (Weir et al. 2012). Black oaks appear to contribute to fisher habitat quality by providing good cavities for denning and resting, and by providing mast that support fisher prey in the southern Sierra Nevada (Purcell et al. 2012, Spencer and Rustigian-Romsos 2012), but may be less critical in other regions. Sensitivity of Pacific fisher prey species to climate change is largely unknown (Purcell et al. 2012).

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2. **Physiology.**
   a. Species physiologically sensitive to one or more factors including: Temperature, precipitation
   b. Sensitivity of species' physiology to one or more factors: Moderate
      i. Participant confidence: Moderate

Additional comments: Fisher responds to warmer temperature by moving to riparian areas, canyon bottoms, dense canopies, and north facing slopes to avoid extremes (especially high temperatures and/or high daily temperature amplitudes). Snow limits movement ability; in general, fishers do not do well with deep, persistent, fluffy snows. Fishers are more sensitive to climate stress in denning season. More information is needed on physiological constraints of fishers.

References: Fisher are sensitive to deep snow, which limits movement ability (Krohn et al. 1997).

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3. **Sensitive habitats.**
   a. Species dependent on sensitive habitats including: Other: Old growth/complex forest, riparian areas
   b. Species dependence on one or more sensitive habitat types: High
      i. Participant confidence: Moderate

Additional comments: Old growth and complex forests are sensitive to indirect climate change effects such as drought and altered fire regimes. Fishers use riparian areas as travel corridors.

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4. **Life history.**
   a. Species reproductive strategy: K-selection
      i. Participant confidence: High

   b. Species polycyclic, iteroparous, or semelparous: Iteroparous

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5. Ecological relationships.

   a. Sensitivity of species' ecological relationships to climate change including: Habitat
   b. Types of climate and climate-driven changes that affect these ecological relationships including: Temperature, precipitation
   c. Sensitivity of species to other effects of climate change on its ecology: No answer provided by participants
      i. Participant confidence: Low

Additional comments: Habitat components that are sensitive include old growth and complex components. Temperature and precipitation changes may result in drought and water deficit, potentially affecting important habitat components. Fisher may depend on other species, such as the pileated woodpecker, mistletoe, and witches broom to create habitat to rest in or on. The sensitivity of these other species to climate change is unknown. Prey species' sensitivities are also unknown and could be critical. While competition may be enhanced with American marten due to snowpack decreases at transitional elevations, fishers are actually likely to 'win' these competitive interactions.

References:

Vegetation structure and distribution: Fishers depend on the presence of water (Purcell et al. 2009), and habitat persistence is sensitive to water deficit and altered fire regimes (Zielinski et al. 2013). In the Sierra Nevada, conifer forests are predicted to be largely replaced by deciduous forests at low and middle elevations (Lenihan et al. 2008). Because California black oaks appear to enhance fisher habitat in the southern Sierra Nevada, predicted shifts of conifer-dominated forest types to mixed woodland and hardwood forest types may benefit fishers (Purcell et al. 2012). However, the expectation is for an overall decrease in the availability of fisher habitat as changes in fire regime are projected to result in loss of late seral habitat, and decreases in the density of large conifer and hardwood trees and canopy cover (Purcell et al. 2012). In the Sierra Nevada, the Sierra mixed conifer/white fir/Jeffrey pine vegetation type is projected to decrease (by 12-32%), while blue oak/foothill pine and ponderosa pine/Klamath mixed conifer are projected to increase by 2070 (PRBO Conservation Science 2011). An increase in both the severity and frequency of fire could lead to vegetation conversion and a corresponding decrease in old growth forest (Lenihan et al. 2008). These changes will likely increase the threat to species associated with closed-canopy forests (McKenzie et al. 2004), such as fishers. A drier future may also result in the mixed conifer forest inhabited by fishers being replaced by grasslands and shrublands (Lenihan et al. 2008), which are unsuitable for fishers.

Fishers are associated with areas of low or intermediate snowfall in which topographic breaks change snowfall amounts over small areas, since deep snow limits movement ability and mitigates competitive interaction between fisher and marten (Krohn et al. 1997). Future reductions in snowpack could alter competitive relationships between martens and fishers, providing fishers a competitive advantage (Krohn et al. 1997; Purcell et al. 2012). Fishers also uses cavities created by other species such as the pileated woodpecker, and clusters created by mistletoe and rust broom (Purcell et al. 2012), whose sensitivity to climate change is largely unknown. Sensitivity of prey species to climate change is also largely unknown (Purcell et al. 2012).

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6. Disturbance regimes.

   a. Disturbance regimes to which the species is sensitive include: Wildfire, drought, insects, wind, disease

   b. <u>Sensitivity of species to one or more disturbance regimes</u>: High
      i. Participant confidence: High

Additional comments: Uncharacteristically severe wildfire and drought may negatively impact fisher by reducing canopy cover and killing larger trees. Fisher may be positively impacted by increased wind and tree disease over smaller scales, which may provide structure for denning and resting sites. Increased insects over smaller scales may also be a benefit to fisher, as they cause more cavities and decadence in forest structure. However, larger scale effects in any of these disturbances (wind, disease, insects, wildfire) could remove habitat value over large areas.

References: Large-scale or uncharacteristically severe wildfire and drought may reduce canopy cover and kill larger trees, removing habitat value over large areas and potentially impacting prey dynamics. Periods of water shortage are associated with tree susceptibility to infections and insects, such as dwarf mistletoe (*Arceuthobium abietinum f. sp. magnificae*), root disease (*Heterobasidion annosum*), and bark beetles (North et al. 2002; Grulke et al. 2009; Grulke 2010), whose impacts can be both beneficial and detrimental to fisher, depending on the scale of the impact. Diseases such as mistletoe and rust broom in trees of declining health may be beneficial to Pacific fishers by creating perches and cavities (Purcell et al. 2012) used for denning and resting, whereas major mortality events resulting from pest complexes (e.g. root diseases/dwarf mistletoe/bark beetles) (North et al. 2002) may reduce habitat available to fisher.

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7. Interacting non-climatic stressors.

   a. <u>Other stressors that make the species more sensitive include</u>: Residential and commercial development, transportation and service corridors, altered interspecific interactions, poisons, other – fuel management
   b. <u>Current degree to which stressors affect the species</u>: High
      i. Participant confidence: High
   c. <u>Degree to which non-climate stressors make species more sensitive</u>: Low-Moderate
      i. Participant confidence: Moderate

Additional comments: Fishers are impacted by wildland-urban interface (WUI) fuel treatments related to residential development. Urban development is very minor in fisher range in California; exurban (e.g., cabins, summer homes) development increases risks due to increased likelihood of fire, increased need for forest thinning, increased exposure to pets, etc. Fishers are victim to road mortality and increased predation. Predation is the primary, ultimate cause of death for most fishers, with predation rates "unnaturally high" probably due to synergistic threats (e.g., rodenticides weaken fishers, making them more susceptible to predation) and the opening of forests by roads and management actions that increase access for predators (especially bobcats, coyotes, and pumas). Although it is poorly understood, altered availability of larger prey (e.g., porcupine, lagomorphs) in the southern Sierra Nevada may also increase fisher sensitivity to climate change. There is a lack of data on influence of recreation use, although it is likely a minor impact. Rodenticides, pesticides, and insecticides used at marijuana grow sites may reduce individual animals' ability to respond to other stressors, or cause direct mortality. These stressors make the fisher more sensitive to climate change to a lesser degree, but they keep the fisher population size small, and small populations are less able to expand and recover from any perturbation. Not implementing fuel treatments /vegetation management because of its short-term negative effect on fisher habitat ultimately increases species' sensitivity due to projected increases in fire (both frequency and severity) as a result of climate change. Therefore, fuel treatment stressors actually make the fisher less sensitive to the stress of increased fire (caused by climate change) in the long term. This highlights the trade-offs between short and long term sensitivities.

References: The Pacific fisher population is also stressed by numerous non-climate factors that increase mortality and may increase population sensitivity to climate change. Habitat alterations due to timber harvest (Zielinski et al. 2013); fire management (Scheller et al. 2011, Zielinski et al. 2013); exurban development (e.g., cabins, summer homes) and its influence on fuel treatments; exposure to domestic pet diseases (Spencer and Rustigian-Romsos 2012); road mortality (Spencer and Rustigian-Romsos 2012); reduced fitness or direct mortality associated with rodenticides and other pesticides used at marijuana grow-sites (Gabriel et al. 2012, Thompson et al. 2013); altered prey availability; and predation (Spencer and Rustigian-Romsos 2012). Pacific fishers in the southern Sierra Nevada lack the larger prey (e.g. porcupines, lagomorphs) that compose a large portion of fisher diet in other regions, but the effects of prey availability are poorly understood, and sensitivity of Pacific fisher prey species to climate change is largely unknown (Purcell et al. 2012). Prey consumed by fishers in the southern Sierra Nevada, including insects and plant material, small mammals, birds, and carrion (Zielinski et al. 1999; Zielinski and Duncan 2004), may expose them to direct and secondary toxicants (Thompson et al. 2013). Direct and secondary exposure to rodenticides and pesticides represent a significant risk to isolated California populations (Gabriel et al. 2012), and appear to cause both mortality and decreased fitness by increasing fisher susceptibility to hypothermia, parasites, pathogens and predation (Berny et al. 1997, Winters et al. 2010, and Lemus et al. 2011 cited in Thompson et al. 2013; Gabriel et al. 2012). Poisoning risk has the potential to shift a population from positive to negative growth rate (Thompson et al. 2013). Predation by bobcats (*Lynx rufus*) and cougars (*Puma concolor*) appears to be the leading cause of mortality, facilitated by road building and forest thinning, which likely provide access to fisher habitat by predators while reducing fisher cover and escape (Spencer and Rustigian-Romsos 2012).

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8. Other sensitivities.

a. <u>Other critical sensitivities not addressed</u>: None
    i. Participant confidence: Moderate
b. <u>Collective degree these factors increase species' sensitivity to climate change</u>: Not applicable

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9. Overall user ranking.

a. <u>Overall sensitivity of this species to climate change</u>: Moderate
    i. Participant confidence: Moderate

Additional comments: General sensitivity was low, except for extreme risk of fire, so perhaps overall, the fisher gets a "high", rather than the averaged rating of "moderate", indicated here.

Adaptive Capacity

1. Dispersal ability.

a. Maximum annual dispersal distance: 75-100 km (46-62 mi)
    i. Participant confidence: High
b. Ability of species to disperse: Moderate
    i. Participant confidence: High
c. General types of barriers to dispersal include: Road – highway, major river canyons, unforested areas
d. Degree barriers affect dispersal for the species: Low
    i. Participant confidence: Low
e. Possibility for individuals to seek out refugia: Available

Additional comments: Dispersal distance is given in CDFG (2010[8]). Roads may affect dispersal if road mortality is high enough. Fishers readily cross roads in the region; occasional roadkill, especially during denning season, are a problem and road-crossing structures are needed. Additional barriers or strong filters to dispersal movements appear to include steep ravines, major river canyons, and unforested areas. Snow could also present a barrier. Other interacting stressors impacting the population include predation, roadkill, rodenticides, etc., and this may be contributing to the population's lack of dispersal.

References: Fishers have failed to expand into historically occupied habitat (Thompson et al. 2013) for unknown reasons. Elevated mortality rates may be limiting the population's potential for expansion (Spencer et al. 2011) despite long dispersal capacity. Installation of movement corridor structures may aid expansion (Spencer and Rustigian-Romsos 2012) and reduce mortality from road strikes.

2. Plasticity.

a. Ability of species to modify physiology or behavior: High
    i. Participant confidence: No answer provided by participants
b. Description of species' ability to modify physiology or behavior: Fisher may move upslope, or into shade, riparian areas, or cavities to escape high temperatures. The fisher has long dispersal capabilities, and is able to move long distances in a short time. The fisher also has the ability to change prey focus seasonally / annually. It has no physiological change capacity.

References: Resting sites are used to regulate body temperatures (Powell and Zielinski 1994 cited in Zhao et al. 2012).

3. Evolutionary potential.

a. Ability of species to adapt evolutionarily: Low
    i. Participant confidence: High
b. Description of characteristics that allow species to adapt evolutionarily: The fisher's low genetic diversity (Tucker et al. 2012), lack of connectivity with other populations (Tucker et al. 2012), and small population size (Zielinski et al. 2013, CDFG 2010[9]) limit its evolutionary potential.

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[8] http://www.dfg.ca.gov/wildlife/nongame/publications/docs/FisherStatusReviewComplete.pdf

References: The fisher is a candidate species for listing under Federal, Oregon, and California Endangered Species Acts (Zhao et al. 2012; Thompson et al. 2013). In California, fishers occur in two isolated populations (Davis et al. 2007, Knaus et al. 2011 cited in Zhao et al. 2012); the southern Sierra Nevada population is completely isolated and has an estimated 100 to 400 individuals (Lamberson et al. 2000 cited in Zielinski et al. 2013, Spencer et al. 2011). A second larger fisher occupancy area extends from the northern Sierra Nevada into the Klamath-Cascades region of Oregon, and populations are considered at high risk of local extinction from stochastic events such as disease or wildfire (Spencer et al. 2011; Thompson et al. 2013).

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4. **Intraspecific diversity/life history.**
    a. Degree of diversity of species' life history strategies: Low
        i. Participant confidence: Low
    b. Description of diversity of life history strategies: None recorded

Additional comments: Participants know of no examples of life history diversity.

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5. **Management potential.**
    a. Value level people ascribe to this species: High
        i. Participant confidence: High
    b. Specificity of rules governing management of the species: Moderate
        i. Participant confidence: Moderate
    c. Description of use conflicts: Conflicts between vegetation management and fisher protection, economic harvest and fisher protection, and marijuana gardens and fisher protection (due to the rodenticide used and the secrecy involved in law enforcement activities).
    d. Potential for managing or alleviating climate impacts: Possibilities for managing or alleviating climate impacts include vegetation management and fuel treatment to reduce the risk of altered fire regimes and catastrophic fire and reintroduction and assisted migration. However, source population may not have enough individuals to reintroduce from the southern Sierra population, but possibly different population in Northern California. Perhaps more kits of mothers killed by cars could be relocated.

Additional comments: Potential ESA listing may have huge impacts on specificity and flexibility of "rules" governing management.

References: Forest management can affect the fisher both positively and negatively (Spencer and Rustigian-Romsos 2012). Tree removal may reduce fisher habitat, while fuel treatments that reduce the risk of catastrophic fire may indirectly benefit fisher (Scheller et al. 2011).

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6. **Other adaptive capacity factors.**
    a. Additional factors affecting adaptive capacity: None
        i. Participant confidence: No answer provided by participants
    b. Collective degree these factors affect the adaptive capacity of the species: Not applicable

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7. **Overall user ranking.**
    a. Overall adaptive capacity of the species: Low
        i. Participant confidence: Moderate

Additional comments: Adaptive capacity is influenced by their low population density, small population size, and low genetic diversity. The southern Sierra population is not growing for some reason, and may be impacted by an unidentified stressor. It is unknown why the fisher is not currently expanding into theoretically suitable habitat.

References: The Pacific fisher's capacity to accommodate climate changes is limited by its small population size, low reproductive rate, geographic and genetic isolation, and low genetic diversity (Purcell et al. 2009, Purcell et al. 2012, Spencer et al. 2011, Tucker et al. 2012, Zielinski et al. 2013).

Exposure

1. **Exposure factors**[9]**.**
   a. Factors likely to be most relevant or important to consider for the species: Snowpack, wildfire, shifts in vegetation structure
      i. Participant confidence: High (wildfire), High (vegetation), Low (snowpack)

2. **Exposure region.**
   a. Exposure by region: North – High; Central – N/A; South – High
      i. Participant confidence: No answer provided by participants

3. **Overall user ranking.**
   a. Overall exposure of the species to climate changes: Moderate
      i. Participant confidence: Low

Additional comments: Due to reliance on multi-structure and old growth and dense habitats, exposure risk is higher for catastrophic fire. Climate change effects models show major shifts in vegetation due in part to fire, but not entirely. Overall major reductions in fisher habitat are predicted over the next 50 years. Vegetation type, per se, is not as important as vegetation structure. Information on location of future refugia in relation to recreation and other uses would be helpful.

References:

Snow volume and timing: Overall, April 1st snowpack in the Sierra Nevada, calculated as snow water equivalent (SWE), has seen a reduction of 11% in the last 30 years (Flint et al. 2013), as a consequence of earlier snowmelt (Cayan et al. 2001; Stewart et al. 2005; Hamlet et al. 2007), increased frequency of melt events (Mote et al. 2005), and increased rain:snow ratio (Knowles et al. 2006). However, trends in snowpack in the Sierra Nevada have displayed a high degree of interannual variability and spatial heterogeneity (Mote et al. 2005; Safford et al. 2012). SWE in the southern Sierra Nevada has actually increased during the last half-century, due to increases in precipitation (Mote et al. 2005; Mote 2006; Moser et al. 2009; Flint et al. 2013).

Despite modest projected changes in overall precipitation, models of the Sierra Nevada region largely project decreasing snowpack (Miller et al. 2003; Dettinger et al. 2004b; Hayhoe et al. 2004; Knowles and Cayan 2004; Maurer 2007; Young et al. 2009) and earlier timing of runoff center of mass (Miller et al. 2003; Knowles and Cayan 2004; Maurer 2007; Maurer et al. 2007; Young et al. 2009), as a consequence of early snowmelt events and a greater percentage of precipitation falling as rain rather than snow (Dettinger et al. 2004a, 2004b; Young et al. 2009; Null et al. 2010).

Annual snowpack in the Sierra Nevada is projected to decrease between 64-87% by late century (2060-2079) (Thorne et al. 2012; Flint et al. 2013; Geos Institute 2013). Under scenarios of 2-6˚C warming, snowpack is projected to decline 10-25% at elevations above 3750 m (12303 ft), and 70-90% below 2000 m (6562 ft) (Young et al. 2009). Several models project greatest losses in snowmelt volume between 1750 m to 2750 m (5741 ft to 9022 ft) (Miller et al. 2003; Knowles and Cayan 2004; Maurer 2007; Young et al. 2009), because snowfall is comparatively light below that elevation, and above that elevation, snowpack is projected to be largely retained. The greatest declines in snowpack are anticipated for the northern Sierra Nevada (Safford et al. 2012), with the current patterns of snowpack retention in higher-

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[9] Participants were asked to identify exposure factors most relevant or important to the species but were not asked to evaluate the degree to which the factor affects the species.

elevation southern Sierra Nevada basins expected to continue through the end of the century (Maurer 2007).

Average fractions of total precipitation falling as rain in the Sierra Nevada can be expected to increase by approximately 10% under a scenario of 2.5˚C warming (Dettinger et al. 2004b). Snow provides an important contribution to spring and summer soil moisture in the western U.S. (Sheffield et al. 2004), and earlier snowmelt can lead to an earlier, longer dry season (Westerling et al. 2006). A shift from snowfall to rainfall is also expected to result in flashier runoff with higher flow magnitudes, and may result in less water stored within watersheds (Null et al. 2010).

Wildfire: Large, severe wildfires may pose a potential risk to the remaining fisher populations in the southern Sierra Nevada. Fisher habitat in the Sierra Nevada occurs at elevations where fire risk is greatest (Miller et al. 2009; Scheller et al. 2011). Models by Scheller et al. (2011) projected that the ability of fuel treatments to preserve fisher habitat will vary by elevation, with the best results at higher elevations (Scheller et al. 2011). Treatments under more severe fire regimes, and in proximity to high-quality habitat (>0.5 fisher occurrence probability) provided the greatest benefit to fishers. Under a heightened fire regime simulation, fuel treatments in marginal fisher habitat also benefited fishers as fires spread more readily between high and low quality habitat (Scheller et al. 2011).

Both the frequency and annual area burned by wildfires in the western U.S. have increased strongly over the last several decades (Westerling et al. 2006). Increasing temperatures and earlier snowmelt in the Sierra Nevada have been correlated with an increase in large (>1000 acre or >404 ha) extent fire since the 1980s (Westerling and Bryant 2006). Between 1972-2003, years with early arrival of spring conditions accounted for 56% of wildfires and 72% of area burned in the western U.S., as opposed to 11% of wildfires and 4% of area burned in years with a late spring (Westerling et al. 2006; Geos Institute 2013). Fire severity also rose from 17% to 34% high severity (i.e. stand replacing) from 1984-2007, especially in middle elevation conifer forests (Miller et al. 2009).

Fire activity within the Sierra Nevada is influenced by distinct climate patterns and diverse topography. Higher fire activity is weakly associated with El Niño (warm) conditions in parts of the southern Cascades (Taylor et al. 2008) and northern Sierra Nevada (Valliant and Stephens 2009 cited in Taylor and Scholl 2012), while in Yosemite National Park (YNP) large fires are associated with La Niña (cool) conditions, which are characteristically drier (Taylor and Scholl 2012). Some evidence suggests that fire frequency is higher on southern aspect than northern aspect slopes in mid- and upper-montane forests (Taylor 2000); however, in YNP mixed conifer forests, no spatial trend in fire frequency was found (Scholl and Taylor 2010). Burn condition heterogeneity may promote different forest understory responses in mixed conifer forests across a landscape, with lower intensity burns promoting tree regeneration, and higher intensity or more frequent burns creating shrub habitat (Lydersen and North 2012).

Reconstruction of pre-suppression fire regimes using fire scars indicates that years with widespread fires in dry pine and mixed conifer forests are strongly related to drought in YNP (Taylor and Scholl 2012), other sites in California (Taylor and Beaty 2005; Taylor et al. 2008), and the southwest U.S. (Swetnam and Betancourt 1998, Sakulich and Taylor 2007 cited in Taylor and Scholl 2012). Current year drought combined with antecedent wet years with increased production of fine fuels are associated with fire in the southwest U.S. (Swetnam and Betancourt 1990, McKenzie et al. 2004 cited in Strom and Fule 2007) as well as at some sites in the Sierra Nevada (Taylor and Beaty 2005), but not in YNP, suggesting that "heterogeneity of forest floor vegetation may influence the temporal structure of fire-climate relationships, even at local scales" (Taylor and Scholl 2012).

Large fire occurrence and total area burned in California are predicted to continue increasing over the next century, with total area burned increasing 7-41% by 2050, and 12-74% by 2085 (Westerling et al.

2011). Models by Westerling et al. (2011) project annual area burned in the northern, central and southern Sierra Nevada to increase by 67-117%, 59-169%, and 35-88%, respectively (Geos Institute 2013). Greatest increases in area burned in the Sierra Nevada are projected to occur at mid-elevation sites along the west side of the range (Westerling et al. 2011).

Changes in vegetation: Decreases in winter precipitation combined with increases in summer temperature may produce declines in conifer tree growth in mixed conifer forest of northern California (Yeh and Wensel 2000). Models suggest that the increase in fuel and temperature could increase both the severity and frequency of fire, potentially leading to vegetation conversion and a corresponding decrease in old growth forest (Lenihan et al. 2008).

More information on downscaled projected climate changes for the Sierra Nevada region is available in a separate report entitled *Future Climate, Wildfire, Hydrology, and Vegetation Projections for the Sierra Nevada, California: A climate change synthesis in support of the Vulnerability Assessment/Adaptation Strategy process* (Geos Institute 2013). Additional material on climate trends for the species may be found through the TACCIMO website (http://www.sgcp.ncsu.edu:8090/). Downscaled climate projections available through the Data Basin website (http://databasin.org/galleries/602b58f9bbd44dffb487a04a1c5c0f52).

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