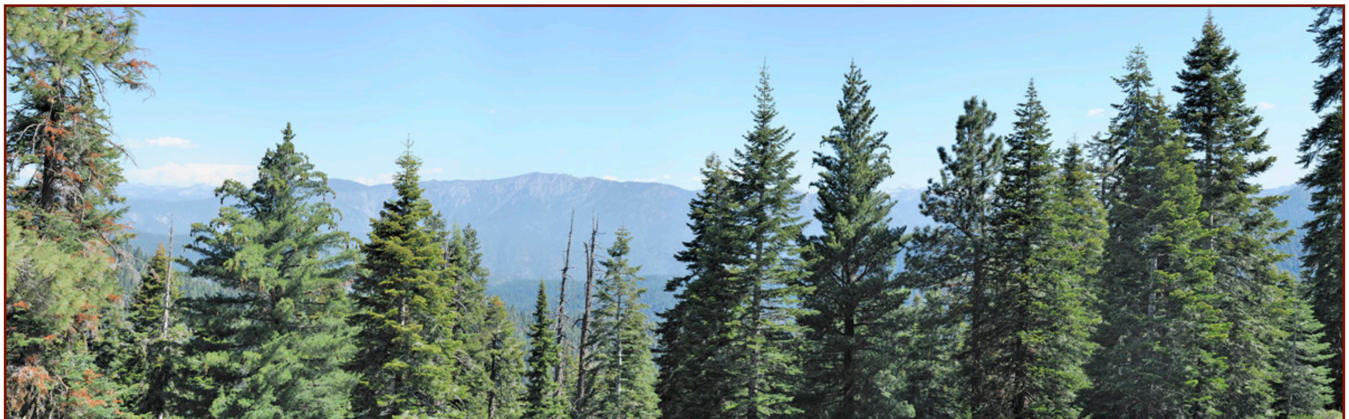

Mixed Conifer Forest, Pacific Fisher, and California Spotted Owl

A Southern Sierra Adaptation Workshop Information Brief

MIXED CONIFER FOREST

Distribution

Throughout federal and state lands, there are 3,344,960 acres of mixed conifer forest in the Sierra Nevada[1,2,3]. Mixed conifer forests are found between 1,200-2,400 meters (4,000-8,000 feet) elevation. Major tree species in the S. Sierran mixed conifer forests are black oak, ponderosa pine, incense cedar, sugar pine, giant sequoia, white fir, Jeffrey pine, and red fir (listed in a general elevation gradient from low to high). Relative abundances vary across the S. Sierra; for example, in the Tehachapi Range to the south the conifer forest lacks sequoia and is dominated by white fir with lesser amounts of incense cedar, Jeffrey, and ponderosa pine[4].

Current Status and Stressors

Forest cover throughout the region is relatively intact and has a high level of contiguity[1]. The composition and distribution of forest types has changed during the last century, however (for example, 64% decline and general upslope migration of ponderosa pine in the central Sierra Nevada)[5]. Background (non-catastrophic) tree mortality rates in southern Sierran forests have doubled in recent decades, most likely as a consequence of warming over the last century[6,7]. Furthermore, the density of large-diameter trees has declined with more marked reductions occurring in higher elevation forest types[8], which could lead to a 'snag famine' in the future if new recruitment into this size class does not occur.

Additionally, fire suppression has led to higher fuel loads, forest structural homogeneity, and shifts towards areas of dense small trees dominated by shade-tolerant incense cedar and white fir[4,9,10]. Key structural elements of late-successional forests – including large diameter trees, snags, and downed wood – are generally at low levels in Sierran forests. Only 14% of the studied state/federal mixed conifer forests had high or very high contribution to late-successional forest functions[1], with national parks generally earning better scores than national forests. In contrast, forests not subject to extensive fire exclusion are characterized by high structural complexity, including heterogeneity in tree spatial patterns resulting from fire[11,12].

A proxy often used to assess forest condition related to fire is the fire return interval departure (FRID). Based on the reconstructed fire regime prior to Euroamerican settlement, low FRIDs indicate that the last fire occurred within the historic FRI, and extreme FRIDs indicate that 5+ return intervals have passed[13]. More than 70% of the forested landscape in the Sierra Nevada has not been burned since 1910, and with an average historic FRI of 14 years, most lands are in severe FRID[14]. Less than 20% of the Sierra Nevada's forests are receiving fuels treatments required to restore historic forest conditions[15].

Sugar pine is also a point of concern. In Sequoia and Kings Canyon National Parks (SEKI), most areas of sugar pine have had 2+ FRIs pass with no fire[16]. Sugar pine is very sensitive to air pollution and the exotic pathogen white pine blister rust. Outside of the Sierra Nevada in Glacier National Park, blister rust has caused up to 90% mortality in other white pine species[17,18]. Within SEKI there was a 21% incidence rate in sugar pines surveyed[16,18]. For this and other stressors effecting mixed conifer forests, see Table 1.

PACIFIC FISHER

Historic Distribution

Fishers were widely distributed on the west coast until European settlement, when habitat loss and fragmentation, predator and pest control campaigns, and over-trapping drove their populations down[19,20,21,22,23]. Their current range in California is less than half of their historical range as described in 1937 (Figure 1)[24,25]. The complete closure of fisher hunting in California occurred in 1946. Recent genetic studies demonstrate that the S. Sierra Nevada population has been isolated from the northern California population for 1,000 years or more, but that Euroamerican settlement caused another but smaller genetic bottleneck to occur[26,27,28].

Current Status and Stressors

The Pacific fisher is a species of special concern in CA and is under consideration by the USFWS to be listed as endangered.

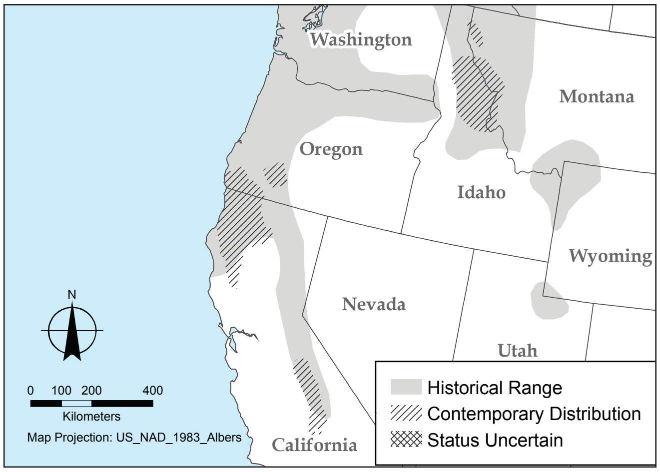

Figure 1: Historical (gray shading) and current (hash marks) distribution of fisher. (Adapted from Conservation of Fishers Volume 1 2010)

However, the S. Sierra population is considered "stable" based on occupancy trends between 2002 and 2009[29]. Current fisher habitat has been estimated using extensive surveys conducted during the 1990s-2000s[30,31,32,33,34,35,36,37] and regional habitat modeling[38,39]. S. Sierra fisher population is estimated to be between 100 to 600 individuals[39,40], however many researchers believe the population to be less than 300[41]. Based on detection surveys from 2002-2006, fishers are more common on the west slope of Sequoia National Forest (SQF) than on the Kern Plateau of Sierra National Forest (SNF)[42], with 23-28% of the sites on SQF having fishers.

Fishers occur in narrow elevation bands between 1,200-2,800 m (4,000-9,000 ft) elevation[34], in mid-elevation conifer forests. Fishers are associated with structural characteristics of late-successional forests, but can survive in mature forests and second growth if critical structural elements, such as dense canopies, large trees, and dead wood, are present[41,43,44,45,46,47,48,49,50,51]. Large deformed limbs[52], fungal infections and other decay that create cavities and susceptibility to parasites such as mistletoe (all of which are more common in older trees) support the creation of fisher resting and nesting habitat. Fire also is important for creating snags and cavities in trees for fisher use, generating damage to allow certain fungus to infect trees and create more cavities[25,53,54,55], creating coarse down wood, gap creation, and age structure variation.

Stressors that affect fisher include habitat fragmentation (especially roads), rodenticide poisoning, and management activities. Forest roads encourage fishers to use them as trails, making them more vulnerable to predation by bobcats, mountain lions, and other predators that use these roads to access previously inaccessible fisher habitat[41]. Road kill is also a large problem, especially for breeding females[41]. Illegal marijuana grow sites use pesticides and rodenticides, which can cause mortality or decreased fitness for fishers making them more likely to succumb to predation and other mortality causes[41]. This problem has become so severe that out of a sampling of fishers tested for rodentiicide compounds in the S. Sierra, 83% of them had been exposed[56]. See Table 1 for more details.

A study conducted on habitat suitability after different kinds of treatment in SEKI showed that in terms of fisher resting habitat, prescribed burned areas do not differ significantly from the control plots. In the Blodgett Forest Research Station, however, mechanical only and mechanical plus fire treatments significantly reduced resting habitat features[57]. Foraging habitat did not appear to be as affected by treatment. However, model simulations found that when considered over the scale of the S. Sierra over a 45 to 60 year timeframe, the positive effects of fuel treatments (i.e. decreasing fuel load and reducing fire severity) generally outweigh their negative effects (i.e. directly removing woody structures) on fisher habitat[58,59]. Severe wildfires have the potential to destroy large tracts of fisher habitat for a much longer time than fuels treatments and could isolate portions of the already small fisher population in the S. Sierra. The highest net benefits of fuel treatments to fisher were found at higher elevations (above 2,120 m; 6,950 ft)[58].

CALIFORNIA SPOTTED OWL

Distribution and Current Status

The California spotted owl is listed as a sensitive species by the Forest Service[60]. They are found in the southern Cascades, Sierra Nevada, mountains in the Southern California Province, and the central Coast Ranges[60]. All four subpopulations of California spotted owl were declining or remained steady from 1990-2005, with the population in SEKI showing the highest survival rates[61]. The Sierra population numbered over 1,865 owl sites from a 2006 survey[62,63], composing the majority

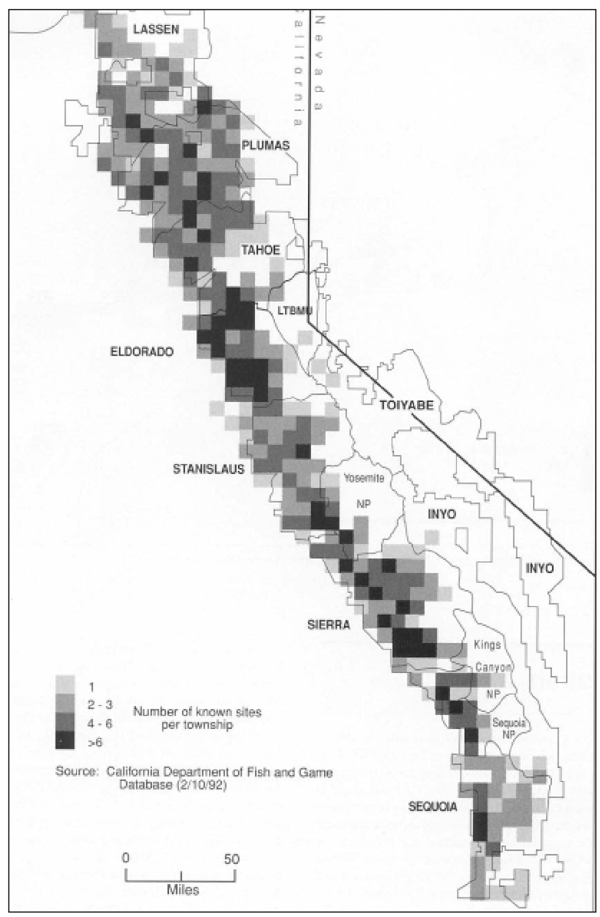

Figure 2: Distribution and relative abundances of California spotted owls in the Sierra Nevada. Adapted from Verner et al. 1992)

Table 1: Current stressors for the mixed conifer forest, Pacific fisher, and California spotted owl

Current Stressors	Mechanism	Potential Impact to Mixed Conifers	Potential Impact to Fisher	Potential Impact to CSO
Fire Exclusion	Homogeneous soils[127]; forest structure shift; closed forest conditions; fewer gaps; lower shrub & herbaceous plant abundance[128,129,130]	Halted regeneration; increased competition for water and nutrients; reduced tree health; increased likelihood of pathogen infection[86]	May temporarily increase suitability of fisher habitat, but long-term may cause more severe fires (see below); decreased cavity creation[23]	Decreased survival in homogeneous forests[104], increased survival in high canopy closure areas; decreased nesting sites[105]; thick stands impede foraging; decrease in key prey[60]
	More severe wildfires from buildup of fuels	Severe tree mortality, including large trees; creation of large forest gaps[86]	Dense canopy loss; changes in prey abundance/movement; habitat loss; decreased survival & reproduction; increased competition; large gap creation/ habitat fragmentation*[23]	Within burned areas, strong selection for low-severity patches[106]; decrease in certain prey[107]; decreased survival in early successional forests[108]
Fuels Management/ Timber Harvesting	Overstory reduction[23]	Decreased competition for water and nutrients; decreased risk of drought or insect induced mortality; accelerated growth of residual trees[23]	Exposure to weather extremes; more competition[93,94,95]; less mobility in thinned areas[96]	Require high canopy closure for nesting sites, but moderate cover for foraging[104]
	Understory reduction[23]		Loss in cover; reduction in prey habitat and abundance; reduction in seeds and berries[23]	Loss of habitat for prey species[104]
	Reduction of structural elements[23]	N/A	Increased travel time to resting/ den sites, thermal refugia & safe places to eat prey[97]	
Human Development	Major highways and forest roads[23]	Not assessed	Vehicle impact mortality[23]; habitat fragmentation; increased predation of fishers on roads[98,99]	Not assessed
	Poaching, rodenticide poisoning, drowning in water tanks[81], harassment by dogs, pet diseases[87], predator control, noise, smoke[23]	N/A	Mortality; decreased fitness; changes in behavior, prey availability, home range establishment, movement, reproduction, dispersal, predation, competition & disease[23]	
	Urbanization, agriculture, grazing, reservoir creation, resource extraction[23]	Spatial and temporal changes in water availability	Habitat loss; fragmentation; changes in prey availability, movement, survival, reproduction, recruitment, dispersal, predation & disease[23]	Grazing decreases shrub cover needed for prey in foothills[109]
	Recreational activities (tourism, hiking, camping, etc.)	Soil compaction, loss of soil around roots; reduced regeneration, increased mortality of mature trees via root pathogens	Possible habitat changes[23,98,99]	Possible habitat changes
		Invasive plant introductions may lead to reduced regeneration, change in fire regimes and nutrient cycling		
		Changes in nutrient cycle from waste		
Pathogens and Insects	Disease outbreaks	Structural failure from annosus root rot (white fir), amarillaria root disease, and carpenter ants; bark beetles; blister rust[88]	Rabies[101]; antibodies found in fisher blood for 16 pathogens[102,103]; Forest disease outbreaks may change habitat structure[23]	Possible habitat changes
Air Pollution	Increased ozone levels	Foliar injury/lowered photosynthetic efficiency in seedlings/saplings, especially of ponderosa pine, mid-elevation conifers	Possible habitat changes	Possible habitat changes
	Increased nitrogen (N) deposition	Reduced germination; advantage for species that can rapidly utilize extra N[89]; reduction in fine root biomass; lichen species shifts; increased nitrate in streams[90,91]		
Competition	Inter/intraspeicies competition for resources and space	Large mature trees compete for resources with dense growth of younger trees[92]	N/A	Barred owl moving in from north competes for territory and prey[110,111,112]

*Habitat fragmentation effects are many and include: population isolation and decreased genetic exchange[126]; changes in how prey move across the landscape - effects prey composition, abundance, availability[45,94,99]; additional travel time and energy needed to go around unsuitable areas and increased predation risk[94].

(72%) of known nesting sites occurring in California. Within the Sierra, much of the suitable habitat and known nesting sites occur on USFS lands, with the rest being distributed between the National Park Service, Bureau of Land Management, industrial timberlands, and private ownership.

Stressors

Like the fisher, these owls also are strongly associated with late-successional forests[104]. The owls tend to select remnant trees from the late-successional conifer forest (200-400 years old) for roosting and nesting sites. Territory occupancy has been associated with the amount of forest dominated by large trees (>61 cm dbh) with high canopy cover (>70%) around the nest area[64]. Foraging habitat is much more varied[104]. Loss of late-successional habitat is the most important stressor affecting these owls today. Additionally, encroachment of the competively dominant barred owl (native to eastern North America) has resulted in displacement of northern spotted owls over large areas of their range[65]. The barred owl has been detected in the S. Sierra (first reported in 2004)[63,66] and may be an increasing concern for California spotted owl in the Sierra Nevada.

Fire exclusion has affected the spotted owl in a similar way to the fisher – loss of large trees, higher risk of high-severity wildfires, more homogenous forests, and more (see Table 1)[63]. Unlike the fisher studies described above, no study has assessed fuels treatment effects on owl vigor. Modeling suggests that landscape-scale fuels treatments can minimize detrimental habitat changes[63,67,68] and reproductive effects[63,69] and that the long-term benefits of reducing wildfire severity outweigh short-term treatment effects on spotted owls[63,70]. Furthermore, many studies indicate that low to moderate severity fires do not affect spotted owls[63,71,72,73].

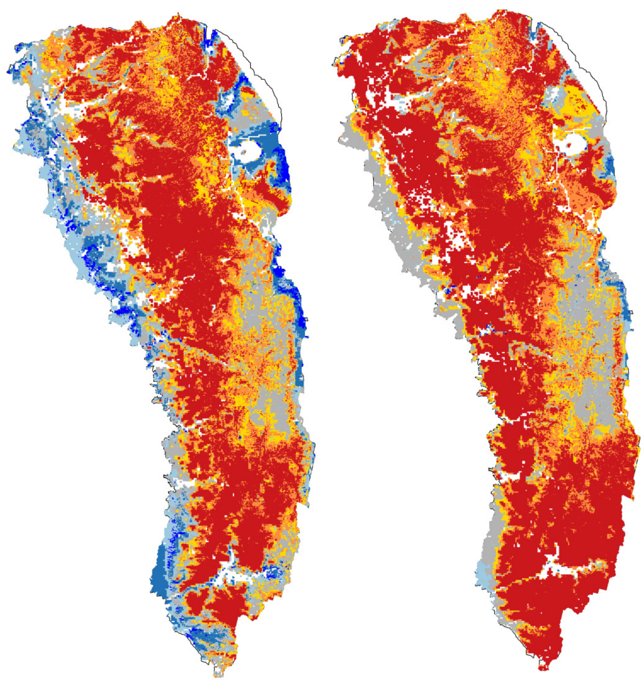

Figure 3: Projected future (2070-2099) fire probabilities in the PACE for the GFDL "much warmer-drier" (left) and PCM "moderately warmer –same precip" (right) climate scenarios. Blue colors represent decreased fire probabilities, grey is no change, and orange/red are increased probabilities. Figure adapted from Max Moritz, UC Berkeley.

POSSIBLE FUTURE CHANGES AND ADAPTIVE CAPACITY

Although predicting future climates is extremely complex, the climate models driven by the three main Intergovernmental Panel on Climate Change (IPCC) emission scenarios agree that temperature in the S. Sierra Nevada will warm, with predictions between +2.6-3.9°C by 2100[74]. Less certain is the change in precipitation – of the 18 general circulation models that include California, about half predict decreases and half predict increases for the Sierra region[74]. Even with little change in precipitation, effective drought will increase as snow melts earlier and evaporative demand increases, and could cause changes in wildfire regimes, snowmelt patterns, and more (Table 2).

Synergistic effects of climate change with other stressors, such as fire exclusion and air pollution, are likely to cause scenarios of increased drought stress, more frequent, larger, and more severe wildfires (Figure 3), more insect and pathogen outbreaks, and increased invasions by non-native species including at higher elevations than observed today[75]. The observed increase in tree mortality rates[6] likely will accelerate. Eventually, major shifts in species composition are expected, including new assemblages without modern analogs, with general upslope movement limited by dispersal and soil conditions. These compositional changes may be gradual or potentially more rapid following disturbances such as high severity fires; insect outbreaks; or mass wasting events. Conifer forests are predicted to decrease by up to a half of current extent by 2099 under three climate models. In these projections mixed conifer is replaced by a mixed evergreen forest dominated by ponderosa pine and black oak[76] (Figure 4). Another way of projecting potential change is shown in Figure 5, which shows oak woodlands areas predicted to be at "high risk soonest" and "most resilient longest" (potential climate refugia) under two future scenarios.

Fisher and California spotted owl may be affected directly by changes in temperature, precipitation, and snowpack or indirectly by affects to their habitat, competitors, and prey. One potentially beneficial outcome for fishers is a reduction in snowpack, as deep snow restricts travel for fishers[63,77], but this could increase competition with marten[78]. Predicted shifts in the composition and locations of the mixed conifer forest raises the question of whether enough overlap of required temperature, snowpack, and habitat conditions will exist in the future for Pacific fisher and California spotted owl. Life history patterns also will affect a species ability to react to a changing environment – owls have large spatial requirements, low population densities, are habitat specialists, and sporadically reproduce when environmental conditions are favorable[63], and fisher have slow maturation and low reproductive rates[79,80,81,82,83,84,85]. Overall, a decrease in the structural elements required for fishers and owls is expected[63], with the largest impacts occurring in the S. Sierra[78].

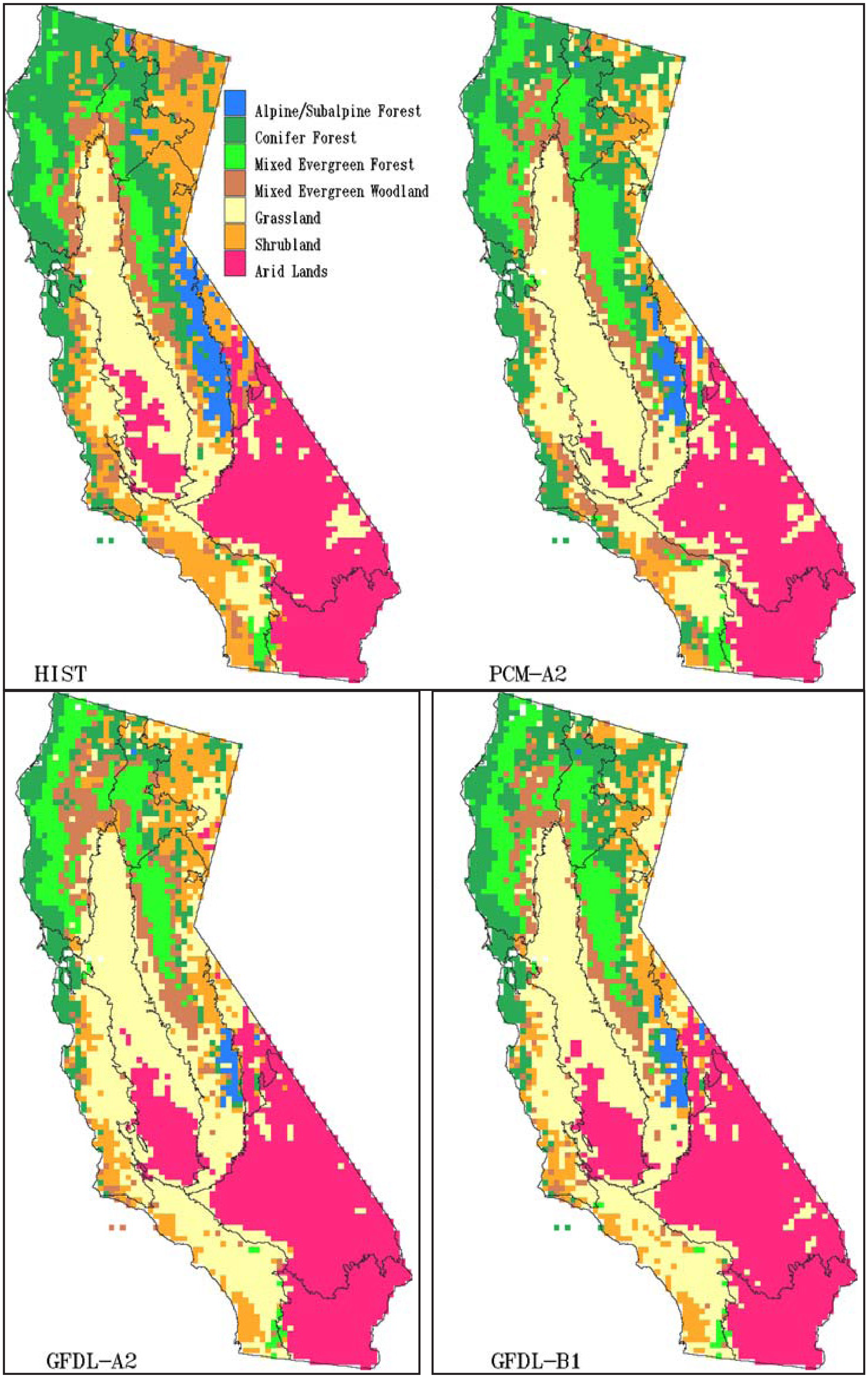

Figure 4: Vegetation class distribution for historical period (1961-1990), PCMI-A2 future (no change in precipitation and an intermediate temperature increase of less than 3 degrees), GFDL-A2 (moderately dry with intermediate temperature increases), and GFDL-B1 (hottest and driest of the scenarios) for 2070-2099. Note the encroachment of the light green mixed evergreen forest over the dark green mixed conifer forest in all scenarios. Adapted from Lenihan et al. 2008[76].

Table 2: Potential climate change impacts and vulnerability characteristics for the mixed conifer forest, Pacific fisher, and California spotted owl

Climate Scenario	Potential Results	Potential Impact to Mixed Conifers	Potential Impact to Fisher	Potential Impact to Owl
"Much Warmer/ Much Drier" Scenario	Earlier snow melt[113,114]; decreased snow pack[115,119]; changes in hydrology; increased summer soil evaporation[116]	More intense/longer summer drought; trees weakened and more susceptible to insect attack, disease, air pollution, etc.[4]	Detrimental change in conifer forest structure; other trees beneficial to fisher, like hardwoods, may expand[76,120]	Detrimental change in forest structure[120]; decreased prey abundance; decreased adult survival & reproduction; weather during incubation affects reproductive output[123]
	Expanding ranges of pathogens	Increased mortality[4]	Detrimental change in forest structure[120]	Detrimental change in forest structure[120]
	Increased fires at all elevations except lowest foothills[117,118]; increase area burned[76]	Increased large tree mortality - homogenized forest structure with loss of LSOG[4]	Reduced connectivity and extent of LSOG will pose migration issues; decrease in habitat	Decrease in habitat
	Range shifts	Conifers may move higher and northward	Loss of required overlap in habitat & climate	Unknown
	Shift in plant species composition	New assemblages without modern analogs	Unknown	
"Moderately Warmer/ Same Precip" Scenario	Increased fire probability at almost all elevations[118]	Increased large tree mortality - homogenized forest structure with loss of LSOG	Reduced connectivity and extent of LSOG will pose migration issues; decrease in habitat	Decrease in habitat

Vulnerability	Explanation	Potential Impact to Mixed Conifers	Potential Impact to Fisher	Potential Impact to Owl
Moisture Requirements	Moisture requirements vary by species (and potentially by genotype)	Regeneration failure and mortality of weakened adult trees	Decreased habitat	Decreased habitat
Low Genetic Diversity	More susceptible to disease, mutation, stochastic event; less adaptive capacity	N/A	SSN population already has lower genetic diversity than other populations[121,122]	N/A
Spatial Isolation	Isolated populations could lead to further decreases in genetic diversity	N/A	Isolated populations in California	Isolated local populations, low density areas, and gaps/bottlenecks in distribution
Reproductive Methods & Ability to Disperse	Slow maturation/low reproductive success can cause population decline; suitable environment may move and reproduction and dispersal is required to shift range	Ponderosa Pine: mature at 7-350yr, heavy crops every 8yr, low dispersal; Incense Cedar: med seed crops every 4yr, far wind-dispersal, 30% germination; Jeffrey Pine: mature at 8yr, large crop every 5yr, dispersal=tree height, animal dissemination, low germination; Sugar Pine: low seed production, low dispersal, animal dissemination, high germination; White Fir: mature at 40-300yr, heavy crop every 6yr, limited wind dispersal <2X tree height; Red Fir: mature at 35yr, heavy crop every 3yr, wind dispersal <2.5X tree height	Maturation at 2 yrs[79,80]; ~25% of females reproduce and wean at least 1 kit annually[81,82,83,84,85]; most individuals die <8 yrs; 50 km (30 mi) dispersal[41]; unable to cross transecting landscape features such as steep river canyons	Maturation at 2 years, but often do not nest for 1+ yrs after this[109,124,125]; owls may not nest every year[109]; Juveniles disperse < 13km (8 mi) from nesting sites[60]; adults can fly to find new habitat
Synergistic Effects	Already weakened flora and fauna may become more vulnerable to new stressors and new combinations of stressors brought on by climate change			

*Habitat fragmentation effects are many and include: population isolation and decreased genetic exchange[126]; changes in how prey move across the landscape - effects prey composition, abundance, availability[45,94,99]; additional travel time and energy needed to go around unsuitable areas and increased predation risk[94].

Authorship Note

This information brief was created by Katy Cummings (NPS) and Koren Nydick (NPS), with review and contributions from John Battles (UC-Berekely), Marc Meyer (USFS), Tom Munton (USFS), Mark Schwartz (UC-Davis), and Wayne Spencer (Conservation Biology Institute). Additional thanks to Erika Williams (NPS for graphic design assistance.

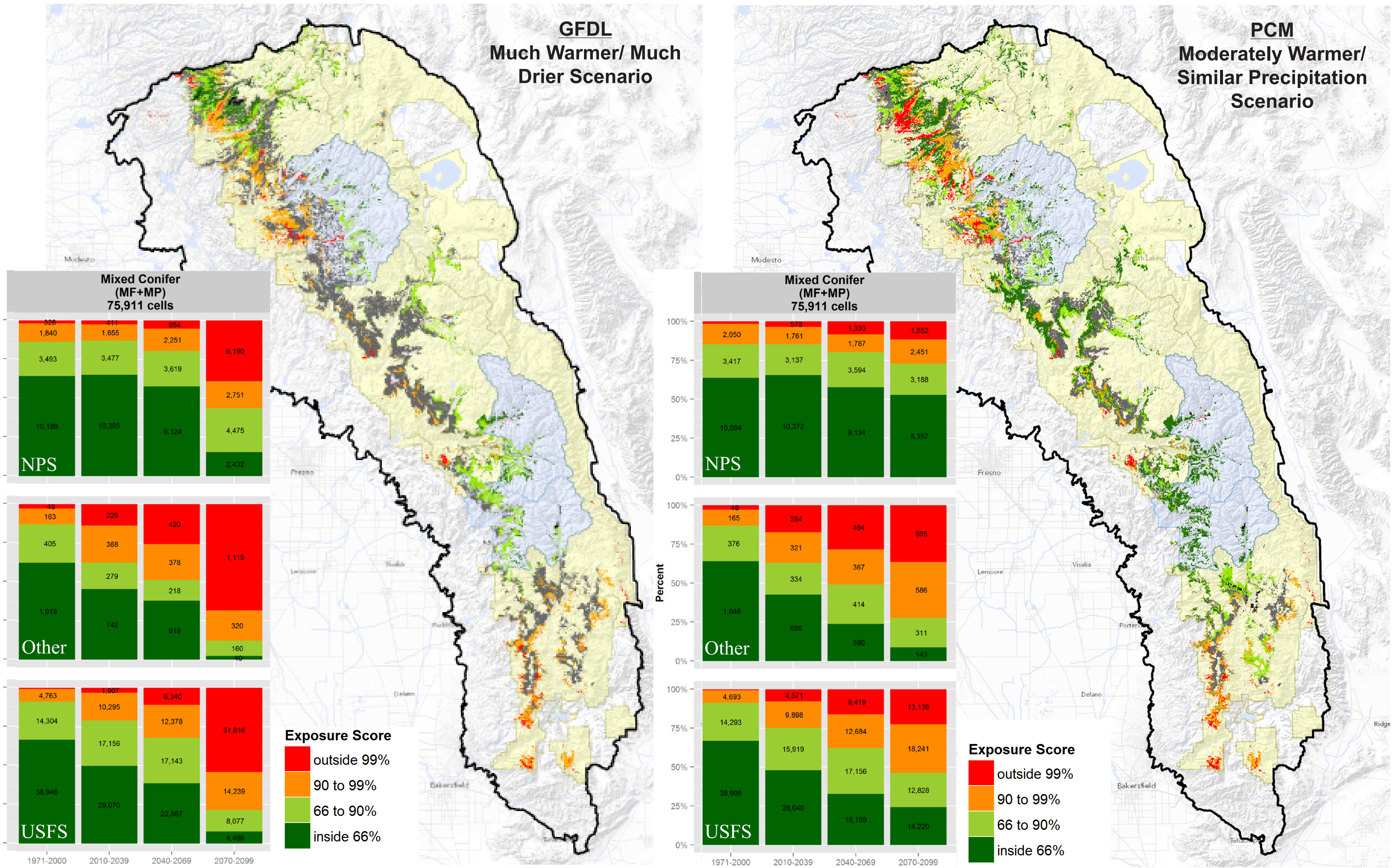

Figure 5. Two scenarios of future climate exposure for mixed conifer forests in the southern Sierra Nevada study area. Maps show grove area predicted to be at risk soonest (high exposure in 2010-2039) in red and orange; resilient longest (low exposure in 2070-2099) in dark and light green; and at risk later (high exposure by 2070-2099) in gray. Blue borders = NPS; yellow shading = USFS. Bar graphs show percent of study area falling within different climate exposure score categories over time (1971-2000; 2010-2039; 2040-2069; 2070-2099) for NPS, other, and USFS lands. Exposure score percentiles are based on projected future climate conditions compared to the baseline (1971-2000) climate envelope for mixed conifer forests, which include mixed conifer-fir and mixed conifer-pines CalVeg types. These results use the IPCC A2 emissions scenario. Adapted from Schwartz et al. In Prep.

POTENTIAL MANAGEMENT STRATEGIES (WORK IN PROGRESS)

- Manage for persistence (resist change or build resilience):
  - Restore/maintain structural complexity of forests
  - Restore a natural fire regime to avoid high severity fires
  - Minimize mechanical disturbances in late-successional forests; if mechanical disturbances are necessary, limit them to areas outside high-quality late-successional forests (includes shaded fuel breaks, removal of small/ medium sized trees, and other fuel reduction activities)
  - Encourage harvesting practices that retain structural features and large-diameter trees
  - Install artificial snags as nesting and resting habitat
  - Prioritize protection of late successional forests in known fisher and California spotted owl habitat
  - Close and remediate old roads
  - Protect known and modeled potential fisher denning habitat from significant modification
  - Protect known owl nest stands from significant modification
  - Manage forests for high quality, large area, contiguous blocks of late seral/old growth forests
  - Identify problem road crossing areas for fishers (and other wildlife) and add road-crossing structures where needed.
  - Locate and remediate marijuana grow sites by removing all chemicals.
  - Capture and translocate/kill barred owls that ingress into spotted owl territory

- Manage for change (facilitate transformation):
  - Create seeds banks for use in assisted migration efforts for vulnerable tree and herbaceous species
  - Anticipate and plan for large disturbance events -do compliance ahead of time and have a planting plan that includes experimentation
  - Reduce barriers to species movement; protect contiguous migration corridors
  - Capture-release programs/assisted migration for fisher and California spotted owl

- Delay deciding (monitor and research):
  - Monitor fisher and California spotted owl populations, reproductive success, and mortality
  - Monitor large tree mortality rate, distribution, and causes of death
  - Monitor shifts in range for conifer forest
  - Monitor spread of white pine blister rust
  - Conduct studies to assess before-and-after-control-impact of fuels treatments, prescribed burning, and wildfire for fisher and California spotted owl
  - Model how California spotted owl populations may respond to future climate scenarios
  - Monitor spread of barred owl

References

[1] Franklin, J.F. and J. Fites-Kaufman. 1996. Assessment of late successional sorests of the Sierra Nevada in Sierra Nevada Ecosystems Project: Final report to congress, vol. II, Assessments and scientific basis for management options. Davis: University of California, Centers for Water and Wildland Resources, 1996.

[2] Scholl, A. E., and A. H. Taylor. 2010. Fire regimes, forest change, and self-organization in an old growth mixed-conifer forest, Yosemite National Park, USA. Ecological Applications 20:362–380.

[3] Collins, B.M., R.G. Everett, and S.L. Stephens. 2011. Impacts of fire exclusion and recent managed fire on forest structure in old growth Sierra Nevada mixed-conifer forests. Ecosphere 2:51

[4] Southern Sierra Partnership. 2010. Framework for Cooperative Conservation and Climate Adaptation for the southern Sierra Nevada and Tehachapi Mountains, CA, USA.

[5] Thorne, J.H., B.J. Morgan, J.A. Kennedy. 2008. Vegetation change over sixty years in the central Sierra Nevada, California, USA. Madroño, 55(3):223-237.

[6] van Mantgem, P. J., and N. L. Stephenson. 2007. Apparent climatically-induced increase of tree mortality rates in a temperate forest. Ecology Letters 10:909-916.

[7] van Mantgem, P.J., N.L. Stephenson, J.C. Byrne, et al. 2009. Widespread increase of tree mortality rates in the western United States. Science. 323(5913):521-524

[8] Lutz, J.A., J.W. van Wagtendonk, and J.F. Franklin. 2009. Twentieth-century decline of large-diameter trees in Yosemite National Park, California, USA. Forest Ecology and Management 257: 2296-2307.

[9] Sierra Nevada Ecosystem Project. 1996. Final Report to Congress. University of California-Davis, Centers for Water and Wildland Resources.

[10] Miller, J. D., H. D. Safford, M. A. Crimmins, and A. E. Thode. 2009. Quantitative evidence for increasing forest fire severity in the Sierra Nevada and southern Cascade Mountains, California and Nevada, USA. Ecosystems 12:16–32.

[11] North, M., P. Stine, K. O'Hara, W. Zielinski, and S. Stephens. 2009. An Ecosystem Management Strategy for Sierran Mixed-Conifer Forests. USDA Forest Service PSW-General Technical Report-220.

[12] Larson, A.J. and Churchill, D. 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.

[13] Caprio, A.C. and P. Lineback. 2002. Pre-twentieth century fire history of Sequoia and Kings Canyon National Park: A review and evaluation of our knowledge. Fire in California Ecosystems: Integrating Ecology, Prevention, and Management. AFE Misc. Publ. No. 1

[14] Schmidt, D. Appendix H: Fire Return Interval Departure – Mean Departure in Southern Sierra Partnership. 2010. Framework for Cooperative Conservation and Climate Adaptation for the southern Sierra Nevada and Tehachapi Mountains, California, USA.

[15] North, M., B.M. Collins, and S. Stephens. 2012. Using fire to increase the scale, benefits, and future maintenance of fuels treatments. Journal of Forestry 110(7):392-401.

[16] Eschtruth, A.K., J.J. Battles, D. Saah. 2012. Five Needle Pine. Appendix 11, in: National Park Service. 2012. Natural Resource Condition Assessment for Sequoia and Kings Canyon National Parks. Natural Resource Report NPS/SEKI/NRR-2012/XXX. Eds. Panek, J.A. and C.A. Sydoriak. National Park Service, Fort Collins, CO.

[17] Kendall, K. 1994. A whitebark pine editorial, a case for monitoring whitebark pine stands. In Nutcracker Notes, USDA Forest Service Intermountain Research Station Newsletter, Missoula, MT, Number 4, November 10, 1994, p. 2.

[18] Duriscoe, D.M. and C.S. Duriscoe. 2002. Survey and Monitoring of White Pine Blister Rust in Sequioia and Kings Canyon National Parks: final Report on 1995-1999 Survey and Monitoring Plot Network. Science and Natural Resources Management Divison – Sequoia and Kings Canyon National Parks. Three Rivers, CA, USA.

[19] Douglas, C. W., and M. A. Strickland. 1987. Fisher. Pages 511–529 in M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources and the Ontario Trappers Association, Toronto, Ontario, Canada

[20] Powell, R. A. 1993. The fisher: life history, ecology and behavior. Second edition. University of Minnesota Press, Minneapolis, MN, USA.

[21] Powell, R. A., and W. J. Zielinski. 1994. Fisher. Pages 38–73 in L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, and W. J. Zielinski, eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. USDA Forest Service, Rocky Mountain Forest and Range Experimental Station, General Technical Report-254, Fort Collins, CO, USA.

[22] USDI Fish and Wildlife Service. 2004. 12-month finding for a petition to list the west coast distinct population segment of the fisher (Martes pennanti). Federal Register 69(68):18770–18792.

[23] Naney, R.H., L.L Finley, E.C. Lofroth, et al. 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, CO, USA.

[24] Grinnell, J., J.S.Dixon, and J.M.Linsdale.1937.Furbearing mammals of California, Vol I.University of California Press, Berkeley, CA, USA.

[25] Lofroth, E.C., C.M. Raley, J.M. Higley, et al. 2010. Conservation of Fishers (Martes pennanti) in South-Central British Columbia, Western Washington, Western Oregon, and California–Vol. I: Conservation Assessment. USDI Bureau of Land Management, Denver, CO, USA.

[26] Tucker J.M., M.K. Schwartz, R.L. Truex, K.L. Pilgrim, and F.W. Allendorf. 2012. Historical and Contemporary DNA Indicate Fisher Decline and Isolation Occurred Prior to the European Settlement of California. PLoS ONE 7(12): e52803. doi:10.1371/journal.pone.0052803

[27] Knaus B.J., R. Cronn, K. Pilgrim, and M.K. Schwartz. 2011. Mitochondrial genome sequences illuminate maternal lineages of conservation concern in a rare carnivore. BMC Ecol 11: 10 p.

[28] Aubry, K., S. Wisely, C. Raley, and S. Buskirk. 2004. Zoogeography, spacing patterns, and dispersal in fishers: insights gained from combining field and genetic data. Pages 201-220 in D.J. Harrison, A.K. Fuller, and G. Proulx, eds. Martens and fishers (Martes) in human-altered environments: an international perspective. Springer Academic+Business Media, New York, NY.

[29] Zielinski et al. (2013) Estimating Trend in Occupancy for the Southern Sierra Fisher Martes pennanti Population. Journal of Fish and Wildlife Management. 4(1).

[30] Laymon, S.A., L.Overtree, G.Collings, and P.L.Williams.1991.Final report on the distribution of marten, fisher, and other carnivores in the Starvation, Tyler, Deer, and Capinero Creek and White River drainages of the Sequoia National Forest: summer 1991.Kern River Research Center report to The Nature Conservancy and USDA Forest Service, Sequoia National Forest, California Hot Springs, California, USA.

[31] Zielinski, W.J., R.L.Truex, C.V.Ogan, and K.Busse.1997.Detection surveys for fishers and American martens in California, 1989–1994: summary and interpretations.Pages 372–392 in G.Proulx, H.N.Bryant, and P.M.Woodard, editors. Martes: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmonton, Alberta, Canada.

[32] Zielinski, W.J., R.L.Truex, F.V.Schlexer, L.A.Campbell, and C.R.Carroll.2005.Historical and contemporary distributions of carnivores in forests of the Sierra Nevada, California, USA. Journal of Biogeography 32(8):1385–1407

[33] Boroski, B.B., R.T.Golightly, A.K.Mazzoni, and K.A.Sager.2002.Fisher research and the Kings River sustainable forest ecosystems project: current results and future efforts. Pages 143–154 in USDA Forest Service, Pacific Southwest Research Station General Technical Report PSW-GTR-183, Albany, CA, USA.

[34] USDA Forest Service. 2006.Sierra Nevada Forest Plan accomplishment monitoring report for 2005–Sierra Nevada Forest Plan implementation: fisher and marten status and trend monitoring.<http://www.fs.fed.us/r5/snfpa/am/monitoringreport2005/fishermarten.html>.

[35] Green, R.E.2007.Distribution and habitat associations of forest carnivores and an evaluation of the California Wildlife Habitat Relationships model for the American marten in Sequoia and Kings Canyon National Parks. Thesis. Humboldt State University, Arcata, California, USA.

[36] Jordan, M.J.2007.Fisher ecology in the Sierra National Forest, California. Dissertation, University of California, Berkeley, USA.

[37] USDA Forest Service.2009.Forest carnivore surveys in the Pacific states home page. <http://maps.fs.fed.us/carnivore/Modules/application/home.html>.

[38] Davis, F.W., C.Seo, and W.J.Zielinski.2007.Regional variation in home-range-scale habitat models for fisher (Martes pennanti) in California. Ecological Applications 17(8):2195–2213.

[39] Spencer, W.D., H.L.Rustigian, R.M.Scheller, A.Syphard, J.Strittholt, and B.Ward.2008.Baseline evaluation of fisher habitat and population status, and effects of fires and fuels management on fishers in the southern Sierra Nevada. Unpublished report prepared for USDA Forest Service, Pacific Southwest Region.Conservation Biology Institute, Corvallis, OR, USA.

[40] Lamberson, R.H., R.L.Truex, W.J.Zielinski, and D.C.Macfarlane.2000.Preliminary analysis of fisher population viability in the southern Sierra Nevada. Humboldt State University, Arcata, CA, USA.

[41] Wayne Spencer, Conservation Biology Institute. Personal communication.

[42] USDA Forest Service.2008.Sierra Nevada Forest Plan accomplishment monitoring report for 2006–Sierra Nevada Forest Plan implementation: fisher and marten status and trend monitoring.<http://www.fs.fed.us/r5/snfpa/monitoringreport2006/fishermarten/>.

[43] Thomas, J.W., M.G. Raphael, R.G. Anthony [et al.] 1993. Viability assessments and management considerations for species associated with late-successional and old-growth forests of the Pacific Northwest. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 523 p.

[44] Ruggiero, L.F., K.B. Aubry, S.W. Buskirk, L.J. Lyon, and W.J. Zielinski (Eds.) 1994. The Scientific Basis for Conserving Forest Carnivores: American marten, fisher, lynx, and wolverine in the western United States. United States Department of Agriculture. Forest Service General Technical Report RM-254. Fort Collins, CO, USA.

[45] Buskirk, S.W., and R.A. Powell. 1994. Habitat ecology of fishers and American martens. Pages 283–296 in S. W. Buskirk, A. S. Harestad, M. G. Raphael, and R.A. Powell, eds. Martens, sables and fishers: biology and conservation. Cornell University Press, Ithaca, NY, USA.

[46] Zielinski, W.J., R.L.Truex, G.A.Schmidt, F.V.Schlexer, K.N.Schmidt, and R.H.Barrett.2004a.Resting habitat selection by fishers in California.Journal of Wildlife Management 68(3):475-492.

[47] Purcell, K.L., A.K. Mazzoni, S.R. 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. Spies, T.A.1998.Forest structure: a key to the ecosystem. Northwest Science 72(Special Issue No.2):34–39.

[48] Lofroth, E.C., C.M. Raley, J.M. Higley, et al. 2010. Conservation of Fishers (Martes pennanti) in South-Central British Columbia, Western Washington, Western Oregon, and California–Vol I: Conservation Assessment. USDI Bureau of Land Management, Denver, CO, USA.

[49] Raley, C. M., E. C. Lofroth, R. L. Truex, J. S. Yaeger, and J. M. Higley. 2012. Habitat ecology of fishers in western North America: a new synthesis. Pages 231-254 in Aubry, K.B., W.J. Zielinski, M.G. Raphael, G. Proulx, and S.W. Buskirk, editors. Biology and conservation of martens, sables, and fishers: a new synthesis. Cornell University Press, Ithaca, NY, USA.

[50] Zielinski, W.J. 2013. The Forest Carnivores: Fisher and Marten In: Science Synthesis to support land and resource management plan revision in the Sierra Nevada and Southern Cascades. USFS. Pacific Southwest Research Station. USA (unpublished).

[51] Marc Meyers, United States Forest Service. Personal communication.

[52] Franklin, J.F., and T.A.Spies.1991.The structure of natural young, mature, and old-growth Douglas-fir forests in Oregon and Washington. Pages 91-110 in L.F.Ruggiero, K.B.Aubry, A.B.Carey, and M.H.Huff, editors. Wildlife and vegetation of unmanaged Douglas-fir forests. USDA Forest Service, Pacific Northwest Research Station General Technical Report PNW-GTR-285, Portland, OR, USA.

[53] Wagener, W.W., and R.W.Davidson.1954.Heart rots in living trees.Botanical Review 20(2):61–134.

[54] Manion, P.D.1991.Tree disease concepts. Second edition. Prentice Hall Career and Technology, New Jersey, USA.

[55] Bull, E.L., C.G.Parks, and T.R.Torgersen.1997.Trees and logs important to wildlife in the interior Columbia River basin.USDA Forest Service, Pacific Northwest Research Station General Technical Report PNW-GTR-391, Portland, Oregon, USA.

[56] Gabriel, M.W., L.W. woods, R. Poppenga, et al.2012. Anticoagulant rodenticides on our public and community lands: Spatial distribution of exposure and poisoning of a rare forest carnivore. PLoS ONE 7(7): e40163. doi:10.1371/journal.pone.0040163

[57] Truex, R.L., and W.J.Zielinski.2005.Short-term effects of fire and fire surrogate treatments on fisher habitat in the Sierra Nevada: Final report, Joint Fire Science Program Project JFSP 01C-3-3-02.USDA Forest Service, Sequoia National Forest, Porterville, California, and USDA Forest Service, Pacific Southwest Research Station, Arcata, CA, USA.

[58] Scheller, R.M., W.D. Spencer, H. Rustigian-Romsos, et al. 2011. Using stochastic simulation to evaluate competing risks of wildfires and fuels management on an isolated forest carnivore. Landscape Ecology. 26:1491-1504.

[59] Thompson, C.M., W.J. Zielinski, and K.L. Purcel. 2011. Evaluating management risks using landscape trajectory analysis: a case study of California fisher. The Journal of Wildlife Management 75(5):1164–1176.

[60] USDA Forest Service. 1995. Draft Environmental Impact Statement: Managing California Spotted owl habitat in the Sierra Nevada National Forests of California – An Ecosystem Approach. Sacramento, CA, USA

[61] Blakesley, J.A.; Seamans, M.E.; Conner, M.M.; Franklin, A.B.; White, G.C.; Gutiérrez, R.J.; Hines, J.E.; Nichols, J.D.; Munton, T.E.; Shaw, D.W.H.; Keane, J.J.; Steger, G.N.; McDonald, T.L. 2010. Population dynamics of spotted owls in the Sierra Nevada, California. Wildlife Monographs. 174: 1–36.

[62] U.S. Fish and Wildlife Service. 2006. 50 CFR Part 17 Endangered and threatened wildlife and plants; 12-month finding for a petition to list the California spotted owl (Strix occidentalis occidentalis) as threatened or endangered. Federal Register 71:29886-29908.

[63] Keane, J. 2013. California Spotted Owl: Scientific Considerations for Forest Planning. Chapter 7.2 in Science Synthesis to Support Land and Resource Management Plan Revision in the Sierra Nevada and Southern Cascades. DRAFT: 1/9/2013. Pacific Southwest Research Station, USDA Forest Service, Albany, CA.

[64] Blakesley, J.A.; Noon, B.R.; Anderson, D.R. 2005. Site occupancy, apparent survival, and reproduction of California spotted owls in relation to forest stand characteristics. Journal of Wildlife Management. 69: 1554–1654.

[65] Dugger, K. M., R. G. Anthony, and L. S. Andrews. 2011. Transient dynamics of invasive competition: Barred owls, spotted owls, habitat, and the demons of competition present. Ecological Applications 21:2459-2468.

[66] Steger, G., L. Werner, and T. Munton. 2006. First documented record of the barred owl in the southern Sierra Nevada. Western Birds 37:106-109.

[67] Ager, A. A., M. A. Finney, B. K. Kerns, and H. Maffei. 2007. Modeling wildfire risk to northern spotted owl (Strix occidentalis caurina) habitat in Central Oregon, USA. Forest Ecology and Management 246:45-56.

[68] Lehmkuhl, J. F., M. Kennedy, E. D. Ford, et al. 2007. Seeing the forest for the fuel: Integrating ecological values and fuels management. Forest Ecology and Management 246:73-80.

[69] Lee, D. C. and L. L. Irwin. 2005. Assessing risks to spotted owls from forest thinning in fire-adapted forests of the western United States. Forest Ecology and Management 211:191-209

[70] Roloff, G. J., S. P. Mealey, and J. D. Bailey. 2012. Comparative hazard assessment for protected species in a fire-prone landscape. Forest Ecology and Management 277:1-10.

[71] Jenness, J. S., P. Beier, and J. L. Ganey. 2004. Associations between forest fire and Mexican spotted owls. Forest Science 50:765-772.

[72] Lee, D. E., M. L. Bond, and R. B. Siegel. 2012. Dynamics of breeding-season site occupancy of the California spotted owl in burned forests. Condor 114:792-802.

[73] Roberts, S. L., J. W. van Wagtendonk, A. K. Miles, and D. A. Kelt. 2011. Effects of fire on spotted owl site occupancy in a late-succesional forest. Biological Conservation 144:610-619.

[74] Gonzalez, P. 2012. Climate change trends and vulnerability to biome shifts in the Southern Sierra Nevada. Draft Report for Climate Change Response Program, August 29 2012. National Park Service: Washington, D.C.

[75] McKenzie D.; Peterson, D.L.; Littell, J.S. 2009. Global warming and stress complexes in forests of western North America. In: Bytnerowicz,A.; Arbaugh, M.; Riebau, A.; Anderson, C., eds. Wildland fires and air pollution. Amsterdam, The Netherlands: Elsevier Science: 319–337.

[76] Lenihan, J.M., D. Bachelet, R.P. Neilson, R. Drapek. 2008. Response of vegetation distribution, ecosystem productivity, and fire to climate change scenarios for California. Climatic Change 87 (Suppl 1):S215-S230.

[77] Krohn, W.B., W.J. Zielinski, and R.B. Boone. 1997. Relations among fishers, snow, and martens in California: results from small-scale spatial comparisons. Pages 211-232 in G. Proulx, H. Bryant, and P. Woodard, editors. Martes: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmonton, Canada.

[78] Lawler, J.J., H.D. Safford, and E.H. Girvetz. 2012. Martens and fishers in a changing climate. Pages 371-397 in Aubry, K.B., W.J. Zielinski, M.G. Raphael, G. Proulx, and S.W. Buskirk, editors. Biology and conservation of martens, sables, and fishers: a new synthesis. Cornell University Press, Ithaca, New York.

[79] Hodgson, R.G.1937.Fisher farming.Fur Trade Journal of Canada.Toronto, Ontario, Canada.

[80] Hall, E.R.1942.Gestation period in the fisher with recommendations for the animal's protection in California.California Fish and Game 28(3):143–147.

[81] Truex, R.L., W.J.Zielinski, R.T.Golightly, R.H.Barrett, and S.M.Wisely.1998.A meta-analysis of regional variation in fisher morphology, demography, and habitat ecology in California. Draft report submitted to California Department of Fish and Game, Wildlife Management Division, Nongame Bird and Mammal Section, Sacramento, California, USA.

[82] Aubry, K.B., and C.M. Raley.2006.Ecological characteristics of fishers (Martes pennanti) in the Southern Oregon Cascade Range.USDA Forest Service, Pacific Northwest Research Station, Olympia, Washington, USA.

[83] Higley, J.M., and S. Matthews.2006.Demographic rates and denning ecology of female Pacific fishers (Martes pennanti) in northwestern California: preliminary report October 2004–July 2006.Hoopa Valley Tribe and Wildlife Conservation Society, Hoopa, California, USA.

[84] Matthews, S. 2007.Hoopa Valley Pacific Fisher Ecology and Conservation Project: August 2007 update.The Wildlife Conservation Society and Hoopa Tribal Forestry, Hoopa, California, USA.

[85] Matthews, S.2008.Hoopa Valley Pacific Fisher Ecology and Conservation Project: June 2008 update.The Wildlife Conservation Society and Hoopa Tribal Forestry, Hoopa, California, USA.

[86] Southern Sierra Partnership. 2010. Appendix A: Souther Sierra Conservation Action Plan (CAP) in Southern Sierra Partnership. Framework for Cooperative Conservation and Climate Adaptation for the southern Sierra Nevada and Tehachapi Mountains, California, USA.

[87] Riley, S. P. D., J. Foley, and B. Chomel. 2004. Exposure to feline and canine pathogens in bobcats and gray foxes in urban and rural zones of a national park in California. Journal of Wildlife Diseases 40:11–22.

[88] USDA Forest Service.2006a.Forest insect and disease conditions in the United States 2005.Washington, D.C., USA.

[89] Chapin, F. S., III. 1980. The mineral nutrition of wild plants. Annu. Rev. Ecol. Syst. 11:233-260.

[90] Fenn, M.E., J.S. Baron, E.B. Allen, et al.2003. Ecological Effects of Nitrogen Deposition in the Western U. S. BioScience.53(4):404-420

[91] Temple, P.J., A. Bytnerowicz, M. E. Fenn, and Mark A. Poth. 2005. Air Pollution Impacts in the Mixed Conifer Forests of Southern California. USDA Forest Service Gen. Tech. Rep. PSWGTR-195.

[92] Southern Sierra Partnership. 2010. Appendix F: Hypotheses of Change. Framework for Cooperative Conservation and Climate Adaptation for the southern Sierra Nevada and Tehachapi Mountains, CA, USA.

[93] Weir, R.D., and A.S.Harestad.2003.Scale-dependent habitat selectivity by fishers in south-central British Columbia.Journal of Wildlife Management 67(1):73–82.

[94] Weir, R.D., and F.B.Corbould.2008.Ecology of fishers in sub-boreal forests of north-central British Columbia. Final report PWFWCP Report No.315.Peace/Williston Fish & Wildlife Compensation Program, Prince George, British Columbia, Canada.

[95] Weir, R.D., F.B.Corbould, and A.S.Harestad.2004.Effect of ambient temperature on the selection of rest structures by fishers. Pages 187–197 in D.J.Harrison, A.K.Fuller, and G.Proulx, editors.Martens and fishers (Martes) in human-altered environments: an international perspective.Springer Science+Business Media, New York, NY, USA.

[96] Powell, R.A., and W.J.Zielinski.1983.Competition and coexistence in mustelid communities.Acta Zool.Fennica 174:223–227.

[97] Green, G. A., L. A. Campbell, and D. C. Macfarlane. 2008. A conservation assessment for fishers (Martes pennanti) in the Sierra Nevada of California. USDA Forest Service, Pacific Southwest Region, Vallejo, CA, USA.

[98] Woods, J.G., and R.H. Munro. 1996. Roads, rails and the environment: wildlife at the intersection in Canada's western mountains. Pages 39–45 in G. Evink, D. Ziegler, P. Garrett, and J. Berry, editors. Highways and movement of wildlife: improving habitat connections and wildlife passageways across highway corridors. US Department of Transportation, Federal Highways Administration, Orlando, FL, USA.

[99] Hayes, G.E., and J.C. Lewis. 2006. Washington State recovery plan for the fisher. WA Dept of Fish and Wildlife, Olympia, WA, USA.

[100] Powell, R.A. 1993. The fisher: life history, ecology and behavior. 2nd edition. University of Minnesota Press, Minneapolis, MN, USA.

[101] Krebs, J.W., S.M.Williams, J.S.Smith, C.E.Rupprecht, and J.E.Childs.2003.Rabies among infrequently reported mammalian carnivores in the United States, 1960–2000.Journal of Wildlife Diseases 39:253–261.

[102] Philippa, J.D., F.A.Leighton, P.Y.Daoust, O.Nielsen, M.Pagliarulo, H.Schwantje, T.Shury, R.Van Herwijnen, B.E.Martina, T.Kuiken, M.W.Van de Bildt, and A.D.Osterhaus.2004.Antibodies to selected pathogens in free-ranging terrestrial carnivores and marine mammals in Canada.Veterinary Record 155:135–140.

[103] Brown, R.N., M.W.Gabriel, G.M.Wengert, S.Matthews, J.M.Higley, and J.E.Foley.2008.Pathogens associated with fishers. Pages 2–48 in Pathogens associated with fishers (Martes pennanti) and sympatric mesocarnivores in California.Final Report submitted to the USDI Fish and Wildlife Service, Yreka, California, USA.

[104] Roberts, S. and M. North. Chapter 5: California Spotted Owls in Managing Sierra Nevada Forests. General Technical Report PSW-GTR-237.

[105] Agee, J.K.; Bahro, B.; Finney, M.A.; Omi, P.N.; Sapsis, D.B.; Skinner, C.N.; van Wagtendonk, J.W.; Weatherspoon, C.P. 2000. The use of fuel breaks in landscape fire management. Forest Ecology and Management. 127: 55–66.

[106] Bond, M.L.; D.E. Lee, R.B. Siegel, and J.P. Ward. 2009. Habitat use and selection by California spotted owls in a postfire landscape. Journal of Wildlife Management. 73: 1116–1124.

[107] Roberts, S.L.; van Wagtendonk, J.W.; Miles, A.K.; Kelt, D.A. 2011. Effects of fire on spotted owl site occupancy in a late-successional forest. Biological Conservation. 144: 610–619.

[108] Dugger, K.M.; Wagner, F.; Anthony, R.G.; Olson, G.S. 2005. The relationship between habitat characteristics and demographic performance of northern spotted owls in southern Oregon. Condor. 107: 863–878.

[109] Verner, J.; Gutiérrez, R.J.; Gould, G.I., Jr. 1992. The California spotted owl: general biology and ecological relations. In: Verner, J.; McKelvey, K.S.; Noon, B.R.; Gutiérrez, R.J.; Gould, G.I., Jr.; Beck, T.W., tech. coords. The California spotted owl: a technical assessment of its current status. Gen. Tech. Rep. PSWGTR-133. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 55–77.

[110] Hamer, T.E.; Forsman, E.D.; Glenn, E.M.; Elizabeth, M. 2007. Home range attributes and habitat selection of barred owls and spotted owls in an area of sympatry. The Condor. 109: 750–768.

[111] Keane, J. 2007. Personal communication. Research wildlife biologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station,1731 Research Park Dr., Davis, CA 95618.

[112] Verner, J., K.S. McKelvey, B.R. Noon, R.J. Gutiérrez, G.I. Gould Jr., and T.W. Beck. 1992. The Assessment of the Current Status of the California Spotted owl, with Recommendations for Management. In: Verner, J.; McKelvey, K.S.; Noon, B.R.; Gutiérrez, R.J.; Gould, G.I., Jr.; Beck, T.W., tech. coords. The California spotted owl: a technical assessment of its current status. Gen. Tech. Rep. PSWGTR- 133. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 3–26Krohn, W.B., S.M. Arthur, T.F. Paragi. 1994. Mortality and vulnerability of a heavily trapped fisher population. In: Buskirk, S.W., . Harestad, M. Raphael, comps. Eds. Martens, sables and fishers: biology and conservation. Ithaca, NY: Cornell University Press: 137-145.

[113] Null, S.E., J.H. Viers, and J.F. Mount. 2010. Hydrologic response and watershed sensitivity to climate warming in California's Sierra Nevada. PLoS One 5: e9932.

[114] Young, C.A., M.I. Escobar-Arias, M. Fernandes, B. Joyce, M. Kiparsky, J.F. Mount, V.K. Mehta, D. Purkey, J.H. Viers, and D. Yates. 2009. Modeling the hydrology of climate change in California's Sierra Nevada for subwatershed scale adaptation. Journal of the American Water Resources Association 45: 1409-1423.

[115] Cayan, D., E. Maurer, M. Dettinger, M. Tyree, and K. Hayhoe. 2008. Climate change scenarios for the California region. Climatic Change 87(S1): 21–42.

[116] Lutz, J.A., J.W. van Wagtendonk, and J.F. Franklin. 2009. Twentieth-century decline of large-diameter trees in Yosemite National Park, California, USA. Forest Ecology and Management 257: 2296-2307.

[117] Westerling, A.L. and B. P. Bryant. 2008. Climate change and wildfire in California. Climatic Change 87: 231-249.

[118] Moritz, M. 2012. Moritz Lab, University of California at Berkeley. Personal communication.

[119] Gonzalez, P., R.P. Neilson, J.M. Lenihan, and R.J. Drapek. 2010. Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. Global Ecology and Biogeography 19: 755-768.

[120] Safford, H. D. 2007. Potential impacts of climate change to fisher habitat in California: a preliminary assessment. USDA FS, Vallejo, CA, USA.

[121] Shaffer, M. 1981. Minimum population sizes for species conservation. BioScience 31:131–134.

[122] Shaffer, M. 1987. Minimum viable populations: Coping with uncertainty. Pages 60–86 in M. E. Soulé, editor. Viable populations for conservation. Cambridge University Press, New York, NY, USA.

[123] Glenn, E.M.; Anthony, R.G.; Forsman, E.D. 2010. Population trends in northern spotted owls: associations with climate in the Pacific Northwest. Biological Conservation. 143: 2543–2552.

[124] Barrows, C.W. 1985. Fledging success relative to fluctuations in diet for spotted owls in California. In: Gutierrez, R.J.; Carey, Andrew B., eds. Ecology and management of the spotted owl in the Pacific northwest. Gen.. Tech. Rep. PNW-185. Portland, OR: Pacific Northwest Forest and Range Experiement Station, Forest Service, U.S. Department of Agriculture; 50-54.

[125] Miller, G.S., S.K. Nelson, and W.C. Wright. 1985. Two-year old female spotted owl breeds successfully. Western Birds 16:93-94.

[126] Norse, E.A., K.L. Rosenbaum, D.S. Wilcox, et al.1986. Conserving biological diversity in our national forests. The Wilderness Society, Washington, D. C., USA.

[127] Gebauer, S.B. 1992. Changes in soil properties along a post-fire chronosequence in a sequoia-mixed conifer forest in Sequoia National Park, California. M.S. Thesis, Duke University, Durham, NC.

[128] Bonnicksen, T.M. and E.C. Stone. 1978. An analysis of vegetation management to restore the structure and function of presettlement giant sequoia-mixed-conifer forest mosaics. National Park Service.

[129] Bonnicksen, T.M. and E.C. Stone. 1982. Reconstruction of a presettlement giant sequoia-mixed conifer forest community using the aggregation approach. Ecology 63(4): 1134-1148.

[130] Stephenson, N.L. 1987. Use of tree aggregations in forest ecology and management. Environmental Management 11:1-5.