Focal Resource: WOODRATS

Taxonomy and Related Information

Big-eared woodrat (*Neotoma macrotis)*; Dusky-footed woodrat (*Neotoma fuscipes*) (following Matoqc 2002); Arboreal and semi-arboreal: Southern Sierra Nevada.

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[1]. The following document represents the vulnerability assessment results for **BIG-EARED & DUSKY-FOOTED WOODRATS**, 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[2].

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] 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.

[2] 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: direct sensitivity of the system to temperature and precipitation, sensitivity of component species within the system, ecosystem sensitivity to disturbance regimes (e.g., wind, drought, flooding), sensitivity to other climate and climate-driven changes (e.g., snowpack, altered hydrology, wildfire), and sensitivity to non-climate stressors (e.g., grazing, recreation, infrastructure). Adaptive capacity elements include: ecosystem extent, integrity, and fragmentation; ecosystem ability to resist or recover from stressors; landscape permeability; ecosystem diversity (e.g., physical, topographical, component species, functional groups); and ecosystem value and management potential. To assess exposure, participants were asked to identify the climate and climate-driven changes most relevant to consider for the ecosystem 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[3]. 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*[4].

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*[4].

Recommended Citation

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[3] 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.

[4] 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.

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Overview of Vulnerability Component Evaluations

SENSITIVITY

Sensitivity Factor	Sensitivity Evaluation	Confidence
Generalist/Specialist	**2 Between generalist & specialist**	**2 Moderate**
Physiology	**3 High**	**3 High**
Habitat	**3 High**	**3 High**
Life History	**3 K-selection**	**2 Moderate**
Ecological Relationships	**No answer provided by participants**	**No answer provided by participants**
Disturbance Regimes	**3 High**	**3 High**
Non-Climatic Stressors – Current Impact	**1 Low**	**1 Low**
Non-Climatic Stressors – Influence Overall Sensitivity to Climate	**2 Moderate**	**1 Low**
Other Sensitivities	**No answer provided by participants**	**No answer provided by participants**

Overall Averaged Confidence (Sensitivity)[5]: Moderate

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

ADAPTIVE CAPACITY

Adaptive Capacity Factor	Adaptive Capacity Evaluation	Confidence
Dispersal Ability	**No answer provided by participants**	**No answer provided by participants**
Barriers Affect Dispersal Ability	**No answer provided by participants**	**No answer provided by participants**
Plasticity	**No answer provided by participants**	**No answer provided by participants**
Evolutionary Potential	**No answer provided by participants**	**No answer provided by participants**
Intraspecific Diversity/Life History	**2 Moderate**	**2 Moderate**
Species Value	**1 Low**	**3 High**
Specificity of Management Rules	**1 Low**	**3 High**
Other Adaptive Capacities	**No answer provided by participants**	**No answer provided by participants**

Overall Averaged Confidence (Adaptive Capacity)[5]: Moderate-High

Overall Averaged Ranking (Adaptive Capacity)[6]: Low-Moderate

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

[6] Overall averaged sensitivity, adaptive capacity, and exposure are the mean of the ranks provided for the sensitivity, adaptive capacity, and exposure evaluation entries above, respectively.

EXPOSURE

Relevant Exposure Factor	**Confidence**
Temperature	**No answer provided by participants**
Dominant vegetation type	**No answer provided by participants**
Wildfire (biomass consumed)	**No answer provided by participants**
Low flows	**No answer provided by participants**
High flows	**No answer provided by participants**

Participants were unable to assess Exposure by region in the time allotted. Consequently, no averaged ranking or confidence score for exposure are provided.

Sensitivity

1. **Generalist/Specialist.**
    a. Where does species fall on spectrum of generalist to specialist: In between
        i. Participant confidence: Moderate
    b. Factors that make the species more of a specialist: Predator/prey relationship, foraging dependency, seed dispersal dependency

Additional comments: Requires relatively dense chaparral, streamside thicket, and mixed coniferous forest with well-developed undergrowth (Murray and Barnes 1969); understory canopy closure is more important than overstory. Woodrats can use fragmented landscapes but not with plots smaller than 1 acre (0.4 ha). Woodrat diet consists of sticks, seeds, and leaves of a variety of plants.

Dusky-footed and big-eared woodrats can reach high densities in communities without trees (e.g., see Vogl 1967).

References: *Neotoma* have a diet consisting of seeds, stems, and leaves of a variety of plants, and they occupy relatively dense chaparral, broad-leaf woodland, riparian thickets, or mixed-conifer forest (Carraway and Verts 1991; Innes et al. 2007). East of the Cascade divide *N. fuscipes* consistently utilize juniper trees for lodging and food (Murray and Barnes 1969), and in mixed-conifer forests, *N. fuscipes* displays strong associations with California black oak (Innes et al. 2007). The most important habitat features appear to be high shrub density and diversity regardless of habitat type. Densities of both *Neotoma* species are highest where shrub cover is high (Vestal 1938, Linsdale and Tevis 1956, Vogl 1967, and Biswell 1989 cited in Lee and Tietje 2005) and understories are well developed, and lowest in open areas (Murray and Barnes 1969; Carraway and Verts 1991; Haynie et al. 2007; Innes et al. 2007).

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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: High
        i. Participant confidence: High

Additional comments: Upper thermal limit is 35˚C and optimum temperature 20˚C. Woodrats require water – a minimum 10% of body mass.

References: In the absence of a persisting blanket of snow, occasional severe weather such as a freeze in the wake of heavy rainfall, may cause large mortality events in *N. fuscipes* (Murray and Barnes 1969).

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3. **Sensitive habitats.**
    a. Species dependent on sensitive habitats including: Seasonal streams, seeps/springs
    b. Species dependence on one or more sensitive habitat types: High
        i. Participant confidence: High

Additional comments: Dense vegetative cover and drinking water are required (Carraway and Verts 1991).

References: Drinking water is required by big-eared woodrats (Lee 1963 cited in Carraway and Verts 1991) and probably dusky-footed woodrats, and as aridity increases big-eared (Spevak 1983 cited in Carraway and Verts 1991) and dusky-footed (Gillespie et al. 2008) population densities decrease significantly.

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4. **Life history.**

a. Species reproductive strategy: K-selection
    i. Participant confidence: Moderate

b. Species polycyclic, iteroparous, or semelparous: Iteroparous

Additional comments: Breeding season is from February to September, and woodrats have 2-6 offspring per year.

References: The preceding winter's low temperature has also been correlated with fecundity in *N. macrotis* (Lee and Tietje 2005).

5. Ecological relationships.

a. Sensitivity of species' ecological relationships to climate change including: Predator/prey relationship, forage, habitat, hydrology

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: No answer provided by participants

Additional comments: Woodrats are susceptible to other species taking over their nests (e.g., king snakes), and nests support other animals (salamanders, arthropods), with woodrats thereby functioning as a keystone species (Carraway and Verts 1991).

References: Precipitation is thought to be important for small mammal population dynamics through its effect on food resources (Meserve et al. 2001 cited in Lawson 2011), although woodrats in southern coastal California did not show a response to extreme precipitation associated with El Niño-Southern Oscillation (ENSO) (Braswell 2007 cited in Lawson 2011).

6. Disturbance regimes.

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

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

Additional comments: Woodrats are susceptible to plague and grazing.

References: The species probably has a low sensitivity to fire overall, being common in communities that experienced frequent fire historically. However, changes in fire regimes due to climate change, human ignitions, invasive species, or a combination of factors could negatively affect the species. For example, very frequent fires in chaparral (<10 years; Keeley 1995) are likely to be detrimental to *Neotoma* because of the potential conversion of chaparral communities to nonnative annual grasslands (Bolger et al. 1997).

Low- to moderate-severity fire in oak woodland may reduce habitat suitability for *N. fuscipes* in the short term by reducing understory cover, destroying houses, removing woody debris used to build houses (Lee and Tietje 2005), and causing direct mortality. Carraway and Verts (1991) cited Tevis (1956) to support their statement that *N. fuscipes* prefers areas "undisturbed by fire", but Tevis states that *N. fuscipes* is most common in early-seral Douglas-fir forests and least common in mid- and late-successional Douglas-fir forests. In mixed conifer forests, they are common in early succession (30-40 years post-logging; Innes et al. 2007). In chaparral, *Neotomas* are likely to be at their lowest densities soon after fire when food and cover is sparse but they probably are common in both early and late succession habitats. *N. fuscipes* and *N. macrotis* occur in many communities that are fire-adapted and experienced relatively frequent fire historically. California chaparral has a stand-replacement fire regime and a mean fire interval of 50 years. California mixed conifer forests (south slopes) experienced mostly low-severity fires about every 10 years[7].

Conversely, long fire periods in mixed conifer forests may also result in understory habitat less suitable to *N. fuscipes* due to reduced understory shrub density and diversity, and less favorable conditions for California black oaks (Innes et al. 2007).

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7. **Interacting non-climatic stressors.**
    a. Other stressors that make the species more sensitive include: Residential and commercial development, agriculture, biological resource use, pollution and poisons
    b. Current degree to which stressors affect the species: Low
        i. Participant confidence: Low
    c. Degree to which non-climate stressors make species more sensitive: Moderate
        i. Participant confidence: Low

Additional comments: Non-climate stressors include grazing (categorized under agriculture), poop collection (categorized under biological resource use), rodenticide used in marijuana farms (categorized under pollution and poisons), and development (an issue due to the woodrats' low dispersal extent).

References: Loss and fragmentation of habitat, and introduction of invasive plant species pose non-climate threats to *Neotoma* populations, particularly in sage-scrub and chaparral systems (Bolger et al. 1997; Haynie et al. 2007). Both grazing and historic use of non-native annuals for post-fire rehabilitation in chaparral can introduce non-native invasive grasses, which contribute to greater fire frequency (Keeley 1995).

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8. **Other sensitivities.**
    a. Other critical sensitivities not addressed: No answer provided by participants
        i. Participant confidence: No answer provided by participants
    b. Collective degree these factors increase species' sensitivity to climate change: No answer provided by participants

Additional comments: Woodrats are susceptible to plague, but the participants are unsure of the importance of diseases and parasites. The relationship between episodes of plague and increased temperature is unknown.

Murray and Barnes (1969) and Caraway and Verts (1991) also proposed that disease (e.g., bubonic plague) may affect *N. fuscipes* distribution.

References identified by participants: Holt et al. 2009 examined plague in California and the potential response to climate change.

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9. **Overall user ranking.**
    a. Overall sensitivity of this species to climate change: Low-Moderate
        i. Participant confidence: Low-Moderate

Additional comments: Overall sensitivity ranked low to moderate based on fire threat.

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[7] http://www.fs.fed.us/database/feis/fire_regime_table/PNVG_fire_regime_table.html#California

Adaptive Capacity

1. **Dispersal ability.**
    - a. Maximum annual dispersal distance: 1-2 km (0.6-1.2 mi)
        - i. Participant confidence: High
    - b. Ability of species to disperse: No answer provided by participants
        - i. Participant confidence: No answer provided by participants
    - c. General types of barriers to dispersal include: Road – highway, rivers, waterfalls
    - d. Degree barriers affect dispersal for the species: No answer provided by participants
        - i. Participant confidence: No answer provided by participants
    - e. Possibility for individuals to seek out refugia: No answer provided by participants

References identified by participants: NatureServe (http://www.natureserve.org/explorer/)

References: Although home-range sizes for adult dusky-footed woodrat range widely (0.2-5.9 ha) (0.5-14.6 ac) (Innes et al. 2009) and previous studies indicate good dispersal ability (Smith 1965 cited in Lawson 2011), females are largely philopatric and do not disperse from natal areas (Innes et al. 2012). Although female big-eared woodrats do not appear to display high levels of philopatry (Matocq and Lacey 2004 cited in Lawson 2011; Haynie et al. 2007), essentially no elevational shift was recorded for this species during 100 years of climate warming in the Yosemite National Park (Moritz et al. 2008). Dispersal of both species may be limited by the presence of roads, water bodies, and open spaces (Carraway and Verts 1991; Bolger 1997).

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2. **Plasticity.**
    - a. Ability of species to modify physiology or behavior: No answer provided by participants
        - i. Participant confidence: No answer provided by participants
    - b. Description of species' ability to modify physiology or behavior: Unknown

References: The capacity of *Neotoma* to adapt to climate changes may be high, based on prehistoric midden data for congeners (Smith and Betancourt 2003 cited in Lawson 2011).

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3. **Evolutionary potential.**
    - a. Ability of species to adapt evolutionarily: No answer provided by participants
        - i. Participant confidence: No answer provided by participants
    - b. Description of characteristics that allow species to adapt evolutionarily: Unknown

References: *Neotoma* displays moderate to high genetic diversity in California (Haynie et al. 2007).

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4. **Intraspecific diversity/life history.**
    - a. Degree of diversity of species' life history strategies: Moderate
        - i. Participant confidence: Moderate
    - b. Description of diversity of life history strategies: Woodrats are fairly plastic in terms of food sources and shelter species.

References: *Neotoma* have a diet consisting of seeds, stems, and leaves of a variety of plants, and they occupy relatively dense chaparral, broad-leaf woodland, riparian thickets, or mixed conifer forest (Verts and Carraway 1991; Innes et al. 2007).

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5. **Management potential.**
    - a. Value level people ascribe to this species: Low
        - i. Participant confidence: High

   b. Specificity of rules governing management of the species: Low
      i. Participant confidence: High
   c. Description of use conflicts: No answer provided by participants
   d. Potential for managing or alleviating climate impacts: No answer provided by participants

References: Management techniques that promote growth and retention of large California black oaks in mixed conifer systems may benefit *N. fuscipes* (Innes et al. 2007).

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6. **Other adaptive capacity factors.**
   a. Additional factors affecting adaptive capacity: No answer provided by participants
      i. Participant confidence: No answer provided by participants
   b. Collective degree these factors affect the adaptive capacity of the species: No answer provided by participants

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

Exposure

1. **Exposure factors[8].**
    a. Factors likely to be most relevant or important to consider for the species: Temperature, dominant vegetation type, wildfire, low flows, high flows
        i. Participant confidence: No answer provided by participants

2. **Exposure region.**
    a. Exposure by region: No answer provided by participants
        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: Moderate

References:

Vegetation changes: Projections conflict on the distribution of suitable future habitats for woodrats. While some projections predict an increase in the distribution of chaparral, oak, and pine in northern California by 2070 (PRBO Conservation Science 2011), others predict the loss of virtually all suitable habitat for *N. macrotis*, with negligible amounts of emergent suitable habitat (Lawson 2011).

Temperature: Over the next century, temperatures in California are expected to rise (Hayhoe et al. 2004: Cayan et al. 2008), with the lower range of warming projected between 1.7-3.0°C, 3.1-4.3°C in the medium range, and 4.4-5.8°C in the high range (Cayan et al. 2008). Temperatures along the western slope of the Sierra Nevada are forecast to increase between 0.5-1°C by 2049, and 2-3°C by 2099 (Das et al. 2011). On average, summer temperatures are expected to rise more than winter temperatures throughout the Sierra Nevada region (Hayhoe et al. 2004; Cayan et al. 2008; Geos Institute 2013). Temperature projections using global coupled ocean-atmospheric models (GDFL[9] and PCM[10]) predict summer temperatures to increase 1.6-2.4˚C by mid- century (2049), with the least increases expected in the northern bioregion, and greatest increases expected in the southern bioregion (Geos Institute 2013). By late century (2079), summer temperatures are forecast to increase 2.5-4.0˚C, with changes of least magnitude occurring in the central bioregion (Geos Institute 2013). Winter temperatures are forecast to increase 2.2-2.9˚C by late century (2079), with changes of least magnitude occurring in the central bioregion (Geos Institute 2013). Associated with rising temperatures will be an increase in potential evaporation (Seager et al. 2007).

High and Low Flows: 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). Increased rain:snow ratio and advanced timing of snowmelt initiation are expected to advance the runoff center of mass by 1-7 weeks by 2100 (Maurer 2007), although advances will likely be non-uniformly distributed in the Sierra Nevada (Young et al. 2009). 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

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[8] 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.

[9] Delworth, T. L., Broccoli, A. J., Rosati, A. et al. (2006) GFDL's CM2 Global Coupled Climate Models. Part I: Formulation and Simulation Characteristics. Journal of Climate, 19:643-674.

[10] Washington, W. M., Weatherly J. W., Meehl G. A. et al. (2000) Parallel climate model (PCM) control and transient simulations. Climate Dynamics 16:755-744.

expected to result in flashier runoff with higher flow magnitudes, and may result in less water stored within watersheds, decreasing meal annual flow (Null et al. 2010). Mean annual flow is projected to decrease most substantially in the northern bioregion (Null et al. 2010).

Wildfire: 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).

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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