Southern California Pinyon-Juniper Woodland Habitats
Climate Change Vulnerability Assessment Synthesis

An Important Note About this Document: *This document represents an initial evaluation of vulnerability for pinyon-juniper woodland habitats based on expert input and existing information. Specifically, the information presented below comprises habitat expert vulnerability assessment survey results and comments, peer-review comments and revisions, and relevant references from the literature. The aim of this document is to expand understanding of habitat vulnerability to changing climate conditions, and to provide a foundation for developing appropriate adaptation responses.*

Executive Summary

In southern California, pinyon-juniper woodland habitats are typically found in mid- to high-elevation areas of the Mojave Desert, and in the San Jacinto and Santa Rosa Mountains (between 1,070 and 2,440 m; Laudenslayer and Boggs 1988). They are typically located on slopes above desert or Joshua Tree forests (Laudenslayer and Boggs 1988), where the climate is characterized by low precipitation, hot summers, and intense sunlight (Larson 1980). Pinyon-juniper woodlands are characterized by an open overstory, and tree height is usually less than 15 m; the understory ranges from very dense to open and shrubs may reach heights up to 1.5 m (Laudenslayer and Boggs 1988).

The relative vulnerability of pinyon-juniper woodland habitats in southern California was evaluated to be moderate-high[1] by habitat experts due to moderate-high sensitivity to climate and non-climate stressors, high exposure to climate changes, and moderate adaptive capacity.

Sensitivity and Exposure	Climate sensitivities: Precipitation, drought Disturbance regimes: Wildfire, insects Non-climate sensitivities: Pollution, fire suppression practices

Pinyon-juniper woodland habitats are sensitive to drought, primarily due to low seedling recruitment and growth rates that may prevent habitat regeneration; dry conditions have been linked to tree mortality and range contraction. Moisture-stressed trees are more vulnerable to insects and disease, and anthropogenic stressors such as pollution can exacerbate the impacts of climate stressors. Human activity may contribute to increased fire ignitions, and more frequent and/or severe wildfires may not allow stand regeneration, resulting in the loss of large areas of habitat.

Adaptive Capacity	Habitat extent, integrity, and continuity: Moderate-high geographic extent, moderate integrity (altered but not degraded), moderate-high continuity Resistance and recovery: Low-moderate resistance, low recovery potential Habitat diversity: Moderate-high overall diversity Management potential: Moderate-high societal value, low-moderate management

[1] Confidence: High

potential

Pinyon-juniper woodland habitats are still relatively extensive in southern California. However, they are extremely slow to recover from disturbance, and habitat migration in response to climate change is limited by the slow growth of component species, as well as geographic and anthropogenic barriers. Pinyon pines (e.g., *Pinus monophylla*, *P. quadrifolia)* are less resilient to the effects of climate change and disturbances than juniper species (*Juniperus spp.*), which have longer-lived seeds, asynchronous seed production, and can establish in open areas without nurse plants. Pinyon-juniper woodlands are appreciated for their recreational and cultural value, as well as for the ecosystem services they provide.

Sensitivity

The overall sensitivity of pinyon-juniper woodland habitats to climate and non-climate stressors was evaluated to be moderate-high by habitat experts.[2]

Sensitivity to climate and climate-driven changes

Habitat experts evaluated pinyon-juniper woodland habitats to have moderate-high sensitivity to climate and climate-driven changes,[3] including precipitation and drought.[4]

<u>Temperature and precipitation</u>

Typically, annual precipitation in southern California pinyon-juniper woodlands varies between 17.5 cm and 50 cm and low winter temperatures range from -13°C to 1°C (Laudenslayer and Boggs 1988). Historical data on this habitat type demonstrate that climate plays an important role in its distribution (Barger et al. 2009; Cole et al. 2013; Gori and Bate 2007). Pinyon-juniper woodlands have responded to warming temperatures by moving northward in latitude and upward in elevation (Gori and Bate 2007; Cole et al. 2013), although migration rates are slow (20-60 m per year; Cole et al. 2013). Periods of low precipitation have contributed to mortality and habitat contraction in some areas (Breshears et al. 2005; Romme et al. 2009), and the relatively low rate of pinyon-juniper expansion since 1950 is likely due to increasingly arid conditions (Miller et al. 2008; Slaton and Stone 2013). Juniper woodland dieback at lower elevations has been linked to climate changes (e.g., higher temperatures, drought) in Saudi Arabia, a region with an average annual precipitation similar to California (55.9 cm; Fisher 1997).

Conversely, periods of lower temperature and increased precipitation have been associated with pinyon-juniper expansion (Slaton and Stone 2013) and increased growth (Barger et al. 2009; Macalady and Bugmann 2014). For example, a notable example of rapid pinyon-juniper expansion occurred during a period of increased precipitation in the late 1800s and early 1900s (Slaton and Stone 2013). Increased pinyon growth rates during cool and wet climatic periods

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[2] Confidence: High
[3] Confidence: High
[4] Factors presented are those ranked highest by habitat experts. A full list of evaluated factors can be found in the appendices of the report *Climate Change Vulnerability Assessment for Focal Habitats of Southern California.*

may increase their ability to survive subsequent drought periods, but response to favorable conditions may be moderated by stand density (Macalady and Bugmann 2014).

The climate sensitivity of pinyon-juniper habitats is driven, in large part, by successful recruitment on a time scale that allows the community to sustain itself. Seedling survival is directly tied to rainfall (especially summer rain), soil moisture, and temperatures that are moderate enough to not wilt and kill the small seedlings (C. Barrows, pers. comm., 2015). Pinyon regeneration and growth is highly synchronous, and is primarily tied to years with cool and wet conditions; growth has a very strong positive correlation with winter and spring precipitation, and a negative correlation with June temperatures (Barger et al. 2009).

Current stands of singleleaf pinyon (*Pinus monophylla*) appear to be at their range limits for minimum annual precipitation and maximum mean summer temperatures in Joshua Tree National Park (Hoines et al. in press), and are restricted to only high-elevation desert mountains (Wells and Berger 1967; Thorne 1986). The persistence of nurse plants may play a critical role in facilitating pinyon establishment by moderating harsh conditions (e.g., providing shade, ameliorating high surface temperatures; Sthultz et al. 2007). Established junipers often act as nurse plants for pinyon establishment (Chambers et al. 1999; Mueller et al. 2005).

<u>Drought</u>
Pinyon-juniper woodlands are very sensitive to periods of extreme drought (Breshears et al. 2005; Romme et al. 2009), particularly when moisture deficits are combined with high temperatures (Breshears et al. 2005). Periods of extreme drought can cause direct mortality through moisture stress or indirect mortality by facilitating outbreaks of insects or pathogens (Breshears et al. 2005; Romme et al. 2009; Macalady and Bugmann 2014). These outbreaks are especially common in high-density stands, as well as those occupying suboptimal microsites, such as dry slope aspects or areas with poor soil (Greenwood and Weisberg 2008). Increased stand density is considered a sign of ecosystem degradation for pinyon-juniper woodlands (West 1999), and may undermine the ability of established tress to survive and recover after drought (Macalady and Bugmann 2014).

Drought conditions can also predispose certain trees to future drought mortality by altering growth rates for decades afterward (Macalady and Bugmann 2014). For example, if trees respond to drought periods by shedding leaf or root mass or losing xylem conductance, their post-drought recovery may be compromised, as well as their ability to survive future drought episodes (Macalady and Bugmann 2014).

Sensitivity to disturbance regimes
Habitat experts evaluated pinyon-juniper woodland habitats to have moderate-high sensitivity to disturbance regimes,[5] including wildfire and insects.[6] Habitat experts also identified disease as an additional factor that may impact pinyon-juniper woodland habitats.

[5] Confidence: High

Wildfire

Both pinyon and juniper species have thin bark and low canopies, making this habitat type relatively intolerant of fire (Huffman et al. 2008; Romme et al. 2009). Historically, fire intervals in pinyon-juniper woodlands have been very long, and are often measured in centuries (Romme et al. 2009). However, variation in fire frequency does occur due to the heterogeneous nature of this habitat type (Huffman et al. 2008), and fire behavior is influenced by numerous factors including understory, stand density, and local weather conditions (Huffman et al. 2008; Romme et al. 2009). Stands with high densities and/or a significant shrub understory are more likely to experience severe fires and high tree mortality (Romme et al. 2009), and, under these conditions, stand-replacing crown fires may kill almost all pinyon and juniper trees regardless of age (Huffman et al. 2008; Romme et al. 2009).

High severity fires may be more frequent now than they were historically, possibly due to changes in temperature, precipitation, stand density, and/or increasing abundance of fire-promoting grasses (Romme et al. 2009). Fire severity is one of the most important factors determining the mortality rate for pinyon and juniper species (Romme et al. 2009), but the timing of fire may also determine stand recovery (Chambers et al. 1999). For example, fires in June, July, and August could cause significant seedbank reductions by burning seed-bearing trees before dispersal, and fires occurring soon after seedling establishment could limit seedling survival and successful recruitment (Chambers et al. 1999). Overall, shifts in the wildfire regime toward more severe and/or more frequent fire have the potential to damage large areas of pinyon-juniper habitat, which could require centuries for full re-establishment (C. Barrows, pers. comm. 2015).

Insects

Because wildfire was historically infrequent, climatic fluctuations, insects, and disease were important drivers of stand dynamics in pinyon-juniper woodland habitats (Romme et al. 2009). Bark beetle infestations have been associated with warming temperatures (Chambers 2008), and can cause seed loss (Chambers et al. 1999) and extensive tree mortality (Breshears et al. 2005; Romme et al. 2009; Macalady and Bugmann 2014). The risk of insect outbreaks is heightened during drought periods (Breshears et al. 2005; Romme et al. 2009; Macalady and Bugmann 2014), and exposure to additional stressors (e.g., air pollution) appears to lower resistance to beetle attacks (Eatough Jones et al. 2004).

Disease

Singleleaf pinyons are the primary species affected by black stain root disease (*Leptographium wageneri*), a fungus that affects water movement within trees (Minnich 2007). Parasitic dwarf mistletoes (*Arceuthobium spp.*) also affect pinyon species, and they can drastically reduce resources available to the tree because they use both water and photosynthate produced by the host (Minnich 2007).

[6] Factors presented are those ranked highest by habitat experts. A full list of evaluated factors can be found at the end of this document.

Sensitivity and current exposure to non-climate stressors

Habitat experts evaluated pinyon-juniper woodland habitats to have moderate-high sensitivity to non-climate stressors,[7] with an overall moderate-high exposure to these stressors within the study region.[8] Key non-climate stressors identified by habitat experts for pinyon-juniper woodland habitats include pollution and fire suppression practices.[9] Livestock grazing, recreation, and transportation corridors were also identified as factors that may cause additional impacts to pinyon-juniper woodland habitats.

Pollution

Even at relatively low levels, nitrogen deposition accelerates the growth of non-native grasses, which act as fine fuel and increase the risk of wildfire in pinyon-juniper woodlands (Fenn et al. 2010). Pollution also stresses vegetation, making pinyon and juniper trees more susceptible to mortality due to other causes, such as beetle outbreaks or drought (Eatough Jones et al. 2004).

Fire suppression practices

Fire suppression can accelerate trends toward denser pinyon-juniper stands (Mueller et al. 2005), increasing drought vulnerability and susceptibility to insect invasion (Vulnerability Assessment Reviewers, pers. comm., 2015). While fire suppression can facilitate fuel build-up (Vulnerability Assessment Reviewers, pers. comm., 2015), pinyon-juniper stands usually have an open canopy and understory, making significant fuel build-up unlikely (C. Barrows, pers. comm., 2015). However, in areas where pinyon and/or juniper stands are found within a dense shrub cover of montane chaparral, the risk of severe fire is high and fuel management may help prevent loss of the stand (C. Barrows, pers. comm., 2015). Overall, fire suppression in pinyon-juniper woodlands is unlikely to be a threat, and may in fact prevent a stand-replacing fire from which recovery could take centuries (C. Barrows, pers. comm., 2015).

Livestock grazing

Pinyon-juniper woodlands have been used for livestock grazing since the late 1800s (Bolsinger 1989). Heavy grazing by livestock has reduced herbaceous and grass understory in pinyon-juniper woodlands and adjacent systems (Bolsinger 1989; West 1999). Reduced understory vegetation could have both positive and negative impacts; for instance, increased erosion (West 1999) could cause the loss of soil moisture and nutrients required for vegetation establishment or, conversely, the loss of understory vegetation may release soil moisture and nutrients for use by trees (Bolsinger 1989; West 1999). Grazing may also increase shrub density, which could, in turn, increase nurse plants available for tree seedlings (Miller and Wigand 1994). Finally, the removal of fine fuels could reduce the incidence of wildfire (Miller and Wigand 1994). Few studies have examined the relationship between grazing patterns and the expansion of pinyon-juniper woodlands over the last century; however, Barger et al. (2009) found that pinyon recruitment and growth appears to be tied more closely to climate

[7] Confidence: High

[8] Confidence: High

[9] Factors presented are those ranked highest by habitat experts. Habitat experts were not in full agreement on these factors, but all were individually scored a 4 or above. A full list of evaluated factors can be found at the end of this document.

conditions than to historical grazing practices, and that there was no significant difference in the density or basal area of pinyon trees between grazed and ungrazed sites.

Recreation and transportation corridors

Pinyon-juniper woodlands are valued for their aesthetic and recreational opportunities, which include activities such as hiking, bird watching, and hunting (Slaton and Stone 2013). However, overuse can degrade habitat, and transportation corridors can fragment stands and create heat islands that may impact adjacent vegetation (C. Barrows, pers. comm., 2015). Both recreational areas and transportation corridors are associated with human-caused fire ignitions (Stephens and Ruth 2005).

Future Climate Exposure

Habitat experts evaluated pinyon-juniper woodland habitats to have high exposure to future climate and climate-driven changes,[10] and key climate variables to consider include: increased air temperature, changes in precipitation, increased drought, increased wildfire, and decreased soil moisture (**Error! Reference source not found.**).[11] For a detailed overview of how these factors are projected to change in the future, please see the Southern California Climate Overview (http://ecoadapt.org/programs/adaptation-consultations/socal). Optimal microsites, higher elevations, and northern areas will likely act as refugia for this habitat type (Cole et al. 2008; Friggens et al. 2012; Rehfeldt et al. 2006; Slaton and Stone 2013).

Temperature and precipitation

Warming temperatures will likely contribute to increased pinyon pine mortality and pinyon-juniper habitat contraction, particularly when combined with decreased soil moisture, more variable precipitation, and drought stress (Rehfeldt et al. 2006; Cole et al. 2008, 2013). Increasingly harsh conditions may also increase pinyon dependency on nurse plants, although climate changes may shift competitive interactions with these nurse plants as pinyons age (Sthultz et al. 2007). Under future climate conditions, which are expected to be increasingly warm and dry, pinyon regeneration rates could be very low, leading to an overall decline in the species (Barger et al. 2009).

Drought

Increasing drought frequency, as well as changes in drought intensity and duration, may make pinyon pines more vulnerable to extirpation during future drought events by reducing the length of recovery time between drought periods (Macalady and Bugmann 2013). Increasing drought pressure may also limit pinyon recruitment to areas with associated nurse species (Sthultz et al. 2007).

[10] Confidence: High

[11] Factors presented are those ranked highest by habitat experts. A full list of evaluated factors can be found at the end of this document.

Species distribution

Studies using downscaled bioclimatic models project that pinyon-juniper distribution in California will decline and become more fragmented in the future (Lenihan et al. 2008; Finch 2012). Pinyon-juniper woodlands are projected to move upward in elevation and northward in latitude (Rehfeldt et al. 2006; Cole et al. 2008; Friggens et al. 2012; Slaton and Stone 2013), as they have in the past due to drought stress and temperature increases (Cole et al. 2013). However, migration rates are slow (20-60 m per year; Cole et al. 2013), and competition may increase at upper elevations, including competition with species that act as nurse plants at lower elevations (Sthultz et al. 2007). Overall, future projections indicate a decrease in California pinyon-juniper habitats (Lenihan et al. 2008; Barger et al. 2009), and woodland area could convert to grasslands, primarily due to increased fire frequencies (Lenihan et al. 2008).

Table 1. Anticipated pinyon-juniper woodland habitat response to climate and climate-driven changes.

Climate and climate-driven changes	**Anticipated pinyon-juniper response**
Temperature and precipitation *+2.5 to +9°C by 2100; variable annual precipitation volume and timing*	• Reduced growth, tree mortality, and range contraction, especially on harsh sites • Shift towards increasingly dense, young-age stands • Possible range shifts to the north and upward in elevation
Drought *Decreased soil moisture, especially in the summer; longer, more severe droughts with drought years twice as likely to occur*	• Tree mortality, large-scale dieback, and/or range contraction • Lowered reproductive and establishment success • Reduced growth for up to several decades • Possible shift in composition towards juniper-dominated stands, as pinyons are less likely to re-establish and are very slow-growing • Increased vulnerability to insects, pests, disease, and future drought events
Wildfire *Increased fire size, frequency, and severity*	• Increased mortality from more frequent or more severe fires • Loss of seeds and/or seedlings from summer fires, reducing regeneration rates • Possible shift towards shrub and grass dominated habitats • Very long recovery times could lead to long-term loss in pinyon-juniper woodlands

Adaptive Capacity

The overall adaptive capacity of pinyon-juniper woodland habitats was evaluated to be moderate by habitat experts.[12]

[12] Confidence: High

Habitat extent, integrity, continuity and landscape permeability

Habitat experts evaluated pinyon-juniper woodland habitats to have moderate-high geographic extent (i.e., habitat occurs across state[s]),[13] moderate integrity (i.e., habitat is altered but not degraded),[14] and feature moderate-high continuity (i.e., habitat is fairly continuous with some breaks).[15] Woodlands dominated by different combinations of juniper and pinyon pines occur in almost every western state and represent some of the most extensive vegetation types in western North America (Romme et al. 2009). Bolsinger (1989) estimated the extent of California's pinyon-juniper woodlands at 3.9 million acres, the majority of which occurred on national forest and publically owned lands. Pinyon-juniper woodlands expanded across the western United States beginning in the mid to late 1800s, but began to decline after 1950; however, patterns of expansion and contraction are variable and may be influenced by many factors (Miller et al. 2008; Romme et al. 2009). In areas where pinyon-juniper woodlands are currently expanding (e.g., Great Basin, Oregon, Idaho; Miller and Wigand 1994; Weisberg et al. 2007; Bradley and Fleishman 2008), patch sizes and habitat continuity have increased. In many areas, newly recruited trees are infilling existing woodlands, and this may increase landscape permeability by wildlife (Slaton and Stone 2013). Both pinyons and junipers rely primarily on seed dispersal by animals, such as the Clark's nutcracker (*Nucifraga columbiana*), corvids (e.g., crows, ravens), small mammals, and rodents, and seeds can be dispersed over fairly long distances (Chambers et al. 1999).

Habitat experts identified geologic features as the primary barrier to habitat continuity and dispersal for this ecosystem type.[16] For instance, the San Gorgonio pass forms an extensive barrier to the movement of moderate to higher elevation species (C. Barrows, pers. comm., 2015).

Resistance and recovery

Habitat experts evaluated pinyon-juniper woodland habitats to have low-moderate resistance to climate stressors and maladaptive human responses,[17] and low recovery potential.[18] Overall, pinyon-juniper woodlands are very slow to recover from disturbance, given their slow growth rate and limited seedling recruitment. Factors such as competition and stand density likely influence recovery after drought periods (Macalady and Bugmann 2014), as does the presence of nurse plants for seedling establishment (Sthultz et al. 2007). Injury from drought increases the possibility of future drought-related mortality, and reduced growth may persist for decades, leaving trees less resistant to stress and future climatic fluctuations (Macalady and Bugmann 2014).

[13] Confidence: High
[14] Confidence: High
[15] Confidence: High
[16] Barriers presented are those ranked most critical by habitat experts (not all habitat experts agreed on these landscape barriers). A full list of evaluated barriers can be found at the end of this document.
[17] Confidence: High
[18] Confidence: High

Pinyon pines may be less resilient to climate change than juniper species (Vulnerability Assessment Reviewers, pers. comm., 2015), due in part to their short-lived seeds and dependence on nurse plants for establishment in new areas, particularly in harsh environments (Sthultz et al. 2007). In contrast, junipers have longer-lived seeds and can establish in open areas without nurse plants (Chambers et al. 1999). Juniper seed production is also highly variable amongst individuals and within populations, while pinyon seed production varies synchronously within populations in response to local conditions (Chambers et al. 1999). In addition, slow-growing, long-lived pinyons may not have sufficiently high migration rates to keep pace with climate change (Cole et al. 2013), although some range shifts may be possible (Cole et al. 2008). Shifts in species composition within pinyon-juniper woodlands will likely persist long term (Mueller et al. 2005), and researchers hypothesize that pinyon populations would take millennia to equilibrate to projected range changes, even in the absence of further climate change (Cole et al. 2013).

Habitat diversity

Habitat experts evaluated pinyon-juniper woodland habitats to have moderate-high physical and topographical diversity,[19] moderate-high component species diversity,[20] and moderate functional group diversity.[21]

Pinyon-juniper woodland species composition varies widely by location and climate. In southern California the dominant tree species can include western juniper (*Juniperus occidentalis*), Utah juniper (*J. osteosperma*), California juniper (*J. californica*), singleleaf pinyon (*Pinus monophylla*), Parry pinyon (*P. quadrifolia*), Jeffrey pine (*P. jeffreyi*), ponderosa pine (*P. ponderosa*), Oregon white oak (*Quercus garryana*), and interior live oak (*Q. wislizeni*; Meeuwig and Bassett 1983; Bolsinger 1989). Although understory associates of pinyon-juniper woodlands vary considerably, composition usually consists of one or more of the following: big sagebrush (*Artemesia tridentata*), blackbrush (*Coleogyne ramosissima*), common snakeweed (*Gutierrezia sarothrae*), narrowleaf golden bush (*Haplopappus linearifolius*), Parry's nolina (*Nolina parryi*), curl-leaf mountain mahogany (*Cercocarpus ledifolius*), antelope bitterbrush (*Purshia tridentata*), Parry's rabbitbrush (*Ericameria parryi*), chamise (*Adenostoma fasciculatum*), and redshank (*A. sparsifolium*; Laudenslayer and Boggs 1988).

Pinyon-juniper woodlands provide important habitat for many southern California wildlife species, the most characteristic of which are the pinyon mouse (*Peromyscus truei*), bushy-tailed woodrat (*Neotoma cinerea*), pinyon jay (*Gymnorhinus cyanocephalus*), juniper titmouse (*Baeolophus ridgwayi*), and bushtit (*Psaltriparus minimus*; Laudenslayer and Boggs 1988). Additional threatened or endangered species associated with this habitat include the Joshua tree (*Yucca brevifolia*), southern sagebrush lizards (*Sceloporus graciosus vandenburgianus*), coast horned lizards (*Phrynosoma coronatum*), and gray vireos (*Vireo vicinior*; C. Barrows, pers. comm., 2015).

[19] Confidence: High
[20] Confidence: High
[21] Confidence: Moderate

Management potential

Habitat experts evaluated pinyon-juniper woodland habitats to be of moderate-high societal value.[22] Pinyon-juniper woodland habitats are valued for wildlife habitat, timber, aesthetics, livestock grazing, and cultural importance (Vulnerability Assessment Reviewers, pers. comm., 2015). They provide many important ecosystem services, including biodiversity, grazing, carbon sequestration, and timber (Vulnerability Assessment Reviewers, pers. comm., 2015).

Habitat experts identified that there is low-moderate potential for managing or alleviating climate impacts for pinyon-juniper woodland habitats.[23] Managing stand density may bolster drought resilience, although more research on the effects of conspecific and heterospecific competition is needed (Macalady and Bugmann 2014). Habitat experts also identified management of fire regimes and grazing as important opportunities for alleviating climate impacts (Vulnerability Assessment Reviewers, pers. comm., 2015). Fuel modification has been recommended in pinyon-juniper woodlands surrounded by dense montane chaparral and understory shrubs to prevent stand-replacing fire from which it may take centuries to recover (USDA Forest Service 2005).

Recommended Citation

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[22] Confidence: Moderate

[23] Confidence: High

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Pinyon-Juniper Woodland Habitats – Overview of Vulnerability Component Evaluations

Overall Vulnerability Ranking:[1] **4 Moderate-High** **Overall Confidence:**[2] **3 High**

SENSITIVITY

Sensitivity Factor[3]	Sensitivity Evaluation[4]	Confidence[4]
Sensitivities to Climate & Climate-Driven Factors • *Precipitation* • *Extreme events: drought* • *Air temperature* • Soil moisture[5] • Extreme events: high temperature[5] • Extreme events: low temperature[5]	**Overall: 4 Moderate-High** • 5 High • 5 High • 2 Low-Moderate • 5 High • 3 Moderate • 2 Low-Moderate	**Overall: 3 High** • 3 High • 3 High • 2 Moderate • 3 High • 2 Moderate • 2 Moderate
Disturbance Regimes • *Wildfire* • *Insects* • Disease[5]	**Overall: 4 Moderate-High** • 5 High • 5 High • 3 Moderate	**Overall: 3 High** • 3 High • 3 High • 2 Moderate
Non-Climate Stressors – Degree Stressor Affects Sensitivity • Pollution & poisons[5] • Fire suppression practices[5] • Livestock grazing[5] • Transportation corridors[5]	**Overall: 4 Moderate-High** • 5 High • 4 Moderate-High • 3 Moderate • 3 Moderate	**Overall: 3 High** • 3 High • 2 Moderate • 2 Moderate • 3 High
Non-Climate Stressors – Current Exposure to Stressor • Pollution & poisons[5] • Fire suppression practices[5] • Livestock grazing[5] • Transportation corridors[5]	**Overall: 4 Moderate-High** • 5 High • 4 Moderate-High • 4 Moderate-High • 3 Moderate	**Overall: 3 High** • 3 High • 2 Moderate • 2 Moderate • 3 High
Other Sensitivities: None identified	N/A	N/A

Overall Averaged Ranking (Sensitivity):[6] **4 Moderate-High**

Overall Averaged Confidence (Sensitivity):[7] **3 High**

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[1] Overall vulnerability is calculated according to the following formula: Vulnerability = Sensitivity * (0.5*Exposure) - Adaptive Capacity.
[2] Overall confidence is an average of the overall averaged confidences for sensitivity, exposure, and adaptive capacity.
[3] Factors with expert consensus are *italicized*; all other factors indicate the percentage of experts who identified that factor as important to consider for the habitat.
[4] Scores presented reflect an average of all scores given by habitat experts for a given factor.
[5] Identified by 50% of habitat experts.
[6] Overall averaged ranking is an average of the sensitivity, adaptive capacity, or exposure evaluation columns above.

EXPOSURE

Exposure Factor[3]	Exposure Evaluation[4]	Confidence[4]
Future Climate Exposure Factors • *Increased air temperature* • *Changes in precipitation* • *Extreme events: increased drought* • *Increased wildfire* • *Decreased soil moisture* • Extreme events: high temperatures[5] • Extreme events: low temperatures[5]	**Overall: 5 High** • 5 High • 5 High • 5 High • 5 High • 5 High • 5 High • 2 Low-Moderate	**Overall: 3 High** • 3 High • 3 High • 3 High • 3 High • 3 High • 3 High • 2 Moderate

Overall Averaged Ranking (Exposure):[6] 5 High

Overall Averaged Confidence (Exposure):[7] 3 High

ADAPTIVE CAPACITY

Adaptive Capacity Factor	Adaptive Capacity Evaluation[4]	Confidence[4]
Habitat Extent, Integrity & Continuity • Geographic Extent • Structural & Functional Integrity • Habitat Continuity	**Overall: 4 Moderate-High** • 4 Moderate-High (Occurs across state) • 3 Moderate (Altered but not degraded) • 4 Moderate-High (Fairly continuous with some breaks)	**Overall: 3 High** • 3 High • 3 High • 3 High
Landscape Permeability[3] Key barriers: • Geologic features[5] • Grazing[5]	**Overall: 2 Low-Moderate** Impact on landscape permeability: • High • Moderate	**Overall: 3 High** • 3 High • 2 Moderate
Habitat Resistance & Recovery • Resistance • Recovery	**Overall: 1 Low** • 2 Low-Moderate • 1 Low	**Overall: 3 High** • 3 High • 3 High
Habitat Diversity • Physical/Topographical Diversity • Component Species Diversity • Functional Group Diversity	**Overall: 4 Moderate-High** • 4 Moderate-High • 4 Moderate-High • 3 Moderate	**Overall: 3 High** • 3 High • 3 High • 2 Moderate
Management Potential • Habitat Value • Likelihood of Managing or Alleviating Climate Impacts	**Overall: 3 Moderate** • 4 Moderate-High • 2 Low-Moderate	**Overall: 2 Moderate** • 2 Moderate • 3 High

[7] Overall averaged confidence is an average of the confidence column for sensitivity, adaptive capacity, or exposure.

Adaptive Capacity Factor	Adaptive Capacity Evaluation[4]	Confidence[4]
Other Adaptive Capacities: None identified	N/A	N/A

Overall Averaged Ranking (Adaptive Capacity):[6] 3 Moderate

Overall Averaged Confidence (Adaptive Capacity):[7] 3 High
