Southern California Subalpine Habitats

Climate Change Vulnerability Assessment Synthesis

An Important Note About this Document: *This document represents an initial evaluation of vulnerability for subalpine 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.*


USFS/Photo by Joseph Torok

Executive Summary

Subalpine forests typically occur at elevations above 2,590 m, and only cover about 8,250 acres in southern California, where they are found in the San Jacinto, San Bernardino, and San Gabriel mountains, as well as in isolated patches on the summits of Mount Pinos and Mount Abel (Stephenson and Calcarone 1999). Subalpine habitats are characterized by short growing seasons, cool temperatures, high wind, and extended periods of winter snowpack (Fites-Kaufman et al. 2007). Subalpine forests are strongly dominated by lodgepole pine (*Pinus contorta*) and limber pine (*P. flexilis*), and the forest understory is often sparse (Fites-Kaufman et al. 2007).

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

Sensitivity and Exposure	Climate sensitivities: Air temperature, snowpack depth, timing of snowmelt and runoff, drought, precipitation Disturbance regimes: Wildfire, insects, disease Non-climate sensitivities: Recreation

Subalpine forests are sensitive to increasing temperatures, and older trees are especially sensitive. In young trees, warming can improve growth, contributing to a shift toward dense stands that are more vulnerable to stand-replacing fire. Moisture is the primary limiting factor in these systems, and drought stress can prevent germination and severely limit growth. In subalpine habitats, climate and non-climate stressors such as drought, air pollution, and beetle outbreaks interact with one another and increase the likelihood of further stress or tree mortality.

Adaptive Capacity	Habitat extent, integrity, and continuity: Low-moderate geographic extent, moderate-high integrity (i.e., minor/moderate alterations), low continuity Resistance and recovery: Low resistance, low-moderate recovery potential

[1] Confidence: Moderate

Habitat diversity: Low-moderate overall diversity
Management potential: High societal value, low-moderate management potential

Subalpine habitats are isolated in southern California, though they remain relatively intact due to their low accessibility. Species are somewhat resilient to the individual impacts of climate change, but climate and non-climate stressors often interact to increase the likelihood of future injury and/or mortality. Because of harsh conditions, subalpine species grow slowly and recovery from disturbance can take 100 years. Subalpine forests harbor many specialized species and/or species that depend on one another for survival (e.g., limber pine and Clark's nutcracker [*Nucifraga columbiana*]). Potential management options may focus on preventing stand-replacing wildfire, establishing nursery and seed stock, and reducing extreme disturbances.

Sensitivity

The overall sensitivity of subalpine habitats to climate and non-climate stressors was evaluated to be low-moderate by habitat experts.[2]

Sensitivity to climate and climate-driven changes
Habitat experts evaluated subalpine habitats to have moderate-high sensitivity to climate and climate-driven changes,[3] including: air temperature, snowpack depth, timing of snowmelt and runoff, drought, and precipitation.[4] Soil moisture, high lentic/lotic temperatures, and extreme high temperature events were also indicated as potential stressors for this habitat.[5]

Air temperature
Longer growing seasons have begun a demographic shift in subalpine conifers over the last 75 years, in which sparse, old-age stands have gradually transitioned to denser young-age stands (Office of Environmental Health Hazard Assessment [OEHHA] 2013). In the central Sierra Nevada, Dolanc et al. (2013) found that the stem density of subalpine forests had increased by 30% since 1934, and that while species composition stayed the same, age classes did not shift evenly: the number of small trees had increased by 63%, while large trees had decreased by 20%. Based on these results, it seems likely that warming temperatures and steady to increasing precipitation is beneficial to the growth of small trees, but may increase mortality in large trees (Dolanc et al. 2013). Some studies have also found that warmer temperatures are related to decreased mortality in lodgepole pine (Bouldin 1999 in Hauptfeld et al. 2014). Maximum growth rates occur when winter precipitation is high and summers are warm (Fites-Kaufman et al. 2007).

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[2] Confidence: Moderate
[3] Confidence: Moderate
[4] Factors presented are those ranked highest by habitat experts. A full list of evaluated factors can be found at the end of this document.
[5] Not all habitat experts agreed on these factors.

Snowpack depth and timing of snowmelt and runoff

Slow-growing conifer and dwarf-shrub ecosystems rely on snowfall and snowmelt as one of their primary means of moisture (Benson 1988), and the timing of snowmelt is tied to the beginning of yearly growth in conifers (Chmura et al. 2011). In years with adequate winter precipitation, snowpack remains in subalpine habitats until June and dry periods are limited (Minnich 2007). However, increasing temperatures and a greater percentage of annual precipitation falling as rain would reduce snowpack and contribute to earlier snowmelt and peak stream flows, decreasing the amount of soil moisture available to subalpine forests during the growing season (Knowles et al. 2006).

Precipitation and drought

Water is a growth-limiting factor for many subalpine species (Fites-Kaufman et al. 2007). Pines found in subalpine ecosystems may have deep, spreading root systems, which could help them access water from cracks in the granite bedrock (Fites-Kaufman et al. 2007). Limber pine is more tolerant of water stress than other species, showing the least sensitivity to drought in relatively open stands (Millar et al. 2004). Dolanc et al. (2013) found that, overall, growth in subalpine conifers was impacted most significantly by the previous year's growing conditions, as photosynthate can continue to be produced after annual growth has ceased and is then available for early growth in the following year. In lodgepole pine, growth rates were higher when snow was deep in the previous spring and conditions were dry late in the previous summer (Dolanc et al. 2013). When species are under stress from low moisture conditions, they may also be more susceptible to insects and other stressors (McKenzie et al. 2009).

Sensitivity to disturbance regimes

Habitat experts evaluated subalpine habitats to have moderate sensitivity to disturbance regimes[6] including: wildfire, insects, and disease.[7] Within the literature, wind and avalanches are described as additional disturbance regimes in subalpine habitats (Fites-Kaufman et al. 2007; Meyer 2013).

Wildfire

Historically, wildfire occurred infrequently in subalpine ecosystems, and fire return intervals of greater than 200 years are common (Fites-Kaufman et al. 2007; Meyer 2013). When fires do occur they are typically small (<10 ha) low- to moderate-intensity fires with occasional torching (Meyer 2013, Sheppard and Lassoie 1998). Sheppard and Lassoie (1998) found that, in many cases, fires in lodgepole-limber pine forests in the San Jacinto mountains were single-tree burns, and that most fires started after a lightning strike. Tree species in subalpine habitats tend to have thin bark, and damage to the cambium is often fatal even if a tree is only partially burned; because of this, most wildfire events are stand-replacing (Minnich 2007). However, limber pine has slightly thicker bark and is more fire-tolerant than lodgepole pine (Minnich 2007), and subalpine forests with a relatively open canopy and/or at a higher elevation are

[6] Confidence: High

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

likely less vulnerable to wildfire (M. Meyer, pers. comm., 2015). Denser stands may be more likely to burn because of greater fuel availability (OEHHA 2013, Steel et al. 2015). Because tree species in subalpine forests are slow-growing and extremely long-lived, wildfire events require long regeneration periods of about 100 years (Minnich 2007). Canopy gaps due to wildfire can encourage seedling recruitment of lodgepole pine and limber pine, both of which are shade-intolerant (Minnich 2007).

Subalpine forests in southern California have not been impacted heavily by fire suppression, as average fire return intervals are longer than fire suppression practices have been taking place (Minnich 2007). Currently, fire frequency in subalpine systems is still within the historic range of variability based on pre-settlement conditions (Steel et al. 2015).

Insects

Bark beetle outbreaks in subalpine ecosystems are historically infrequent and usually confined to small clumps of trees (Meyer 2013). However, warming temperatures and increasing water stress may make subalpine ecosystems more vulnerable to insect outbreaks (OEHHA 2013). Forests that are homogeneous are more likely to experience a broad-scale mortality event related to insect pests (Bentz et al. 2010).

Disease

Subalpine ecosystems are vulnerable to pathogens such as white-pine blister rust, caused by *Cronartium ribicola*, which affects limber pine (Maloney 2011). Root diseases that can affect both limber pine and lodgepole pine are annosus root rot (*Heterobasidion annosum*), black-stain root disease (*Leptographium wageneri*), and armillaria root disease (*Armillaria* spp.) (Minnich 2007). Parasitic dwarf mistletoes (*Arceuthobium* spp.) are also relatively common in subalpine systems, and reduce resources available to the tree by using water and photosynthate produced by the host (Minnich 2007).

Wind and avalanches

Wind plays a role in disturbance at forest edges and in thin stands, placing additional stress on trees already living near the edge of their physiological tolerance (Fites-Kaufman et al. 2007). Trees battered by high winds can form krummholz near the treeline, becoming stunted and twisted with few or no branches on the windward side (OEHHA 2013). In areas that are often swept bare by wind, exposed areas may become desiccated and soil may erode (Fites-Kaufman et al. 2007). On steep slopes, avalanches can occur many times in the same location, leading to paths that are chronically devoid of trees (Fites-Kaufman et al. 2007); however, Rixen et al. (2007) found that avalanches may play a role in maintaining species diversity in subalpine systems.

Sensitivity and current exposure to non-climate stressors

Habitat experts evaluated subalpine habitats to have low sensitivity to non-climate stressors,[8]

[8] Confidence: Low

with a low exposure to these stressors within the study region.[9] The key non-climate stressor identified by habitat experts for subalpine habitats was recreation,[10] and the scientific literature suggests that pollution and invasive species also act as stressors (Fites-Kaufman et al. 2007; Minnich 2007; Stephenson and Calcarone 1999). Due to the relatively low economic importance and inaccessibility of subalpine ecosystems, logging, development, agriculture, and livestock grazing have had a relatively negligible impact on the system (Meyer 2013).

Recreation

Recreational activities (e.g., hiking, camping, skiing) can cause localized damage to sensitive soils and vegetation (Stephenson and Calcarone 1999); recreation areas and associated transportation corridors can also be a source of fire ignitions (Syphard and Keeley 2015). Within southern California, development in subalpine habitats is primarily limited to ski areas, and widespread disturbance is currently unlikely due to limited accessibility (Hauptfeld et al. 2014). Loss of snowpack and earlier snowmelt would have implications for winter recreation activities (e.g., ski season would become shorter; CCCC 2006).

Pollution

Nitrogen deposition from pollution sources located upwind of subalpine forests can have localized effects, contributing to densification in these locations (OEHHA 2013). Ozone can also impact subalpine species, causing injuries that affect photosynthesis and growth; however, surveys suggest that lodgepole pine trees are relatively tolerant of ozone (Minnich 2007). Air pollution can also interact with other stressors (e.g., bark beetle attacks, disease outbreaks, and drought stress), contributing to increased tree mortality (Eatough Jones et al. 2004, Minnich 2007).

Invasive species

Currently, invasive species are not common in subalpine habitats, and their effect on the ecosystem has not been well studied (Fites-Kaufman et al. 2007). However, increases in invasive annual grasses (e.g., cheatgrass [*Bromus* spp.]) are thought to be an important factor in fire regimes throughout lower-elevation forests, including mixed conifer and pinyon-juniper, due to the increased availability of fine fuels (Stephenson and Calcarone 1999). Expansion of cheatgrass into subalpine habitats would likely increase fire frequency, preventing successful regeneration of slow-growing tree species (M. Meyer, pers. comm., 2015).

Future Climate Exposure

Habitat experts evaluated subalpine habitats to have moderate-high exposure to future climate and climate-driven changes,[11] and key climate variables to consider include: increased air temperature, decreased snowpack, increased drought, changes in precipitation, increased

[9] Confidence: Moderate

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

[11] Confidence: Moderate

wildfire, earlier snowmelt and runoff, and decreased soil moisture (Table 1).[12] 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).

Potential refugia may occur in moist microsites or at the highest elevations, where climatic water deficit would be lower (M. Meyer, pers. comm., 2015).

Table 1. Anticipated subalpine ecosystem response to climate and climate-driven changes.

Climate and climate-driven changes	**Anticipated subalpine habitat response**
Increasing temperatures *+2.5 to +9°C by 2100*	• Transition toward denser young-age forest stands • Longer growing seasons and potential productivity increases for some species at high elevations
Reduced snowpack and earlier timing of snowmelt/runoff *Up to 50% reduction in snowfall and 70% reduction in snowpack by 2100 (greatest loss in low elevations); snowmelt and peak runoff occurring 1-3 weeks earlier*	• Longer growing seasons limited by photoperiod requirements rather than snowmelt • Reduced soil moisture and longer summer dry periods
Changes in precipitation, soil moisture, and drought *Variable annual precipitation volume and timing; decreased soil moisture; longer, more severe droughts with drought years twice as likely to occur*	• Increased tree mortality, especially at dry sites • Limited growth and germination • Increased susceptibility to wildfire and insect outbreaks
Wildfire *Increased fire size, frequency, and severity*	• Increased tree mortality • Increased recruitment of shade-intolerant species
Insects *Increased severity of outbreaks, possibility of new pests*	• Increased broad-scale mortality events, especially in homogeneous forests • Increased mortality in trees already stressed by other factors (e.g., drought, air pollution)
Disease *Potential decrease in outbreaks, possibility of new diseases*	• Injury and possible mortality from root diseases and parasitic dwarf mistletoe • Warmer temperatures and drier conditions may limit disease outbreaks

Throughout the state of California, warming temperatures have led to an increased proportion of precipitation falling as rain rather than snow, with snowmelt occurring earlier in the season (Stewart et al. 2005, Knowles et al. 2006). While it is difficult to predict the direction and degree of possible change in precipitation amounts, timing, and variability, changes in precipitation combined with warming temperatures are expected to lead to drier conditions overall (Sawyer et al. 2014). Warm temperatures may offer some benefit to species such as lodgepole pine and limber pine over the short term (10-20 years), but temperatures will likely continue to increase

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

beyond the point of benefit to growth and seedling recruitment. By mid- to late-century, increasing temperatures may cause a decline or failure in regeneration of these species, especially in harsh, dry sites (M. Meyer, pers. comm. 2015).

Although fire frequency and species composition have not changed relative to the historical range of variability in California subalpine ecosystems (Steel et al. 2015), future projections indicate that fires will increase in frequency and size, concurrent with warming temperatures (Fites-Kaufman et al. 2007; Meyer 2013). If non-native grasses invade subalpine habitats, changes to wildfire regimes would likely be impacted more significantly (M. Meyer, pers. comm., 2015). It is possible that localized areas of invasive grass could become widespread over several decades, although this has not yet been reported in the literature (M. Meyer, pers. comm., 2015).

A reduction in cold-induced mortality of beetles, as well as shifts in developmental timing, could contribute to more severe insect outbreaks, although these factors may not necessarily coincide (Bentz et al. 2010). Disease outbreaks, however, may be limited in the future by warmer temperatures, decreased humidity, and drier conditions (Sturrock et al. 2011). It is difficult to predict how interacting stressors such as drought, fire, insects, and disease may affect subalpine habitats (Hauptfeld et al. 2014), and whether new invasive plants, insects, or pathogens may arrive over the course of the next century (M. Meyer, pers. comm., 2015). Climate models have projected an overall decline of 75-90% for alpine/subalpine forest in California by the end of the 21st century (Hayhoe et al. 2004; Meyer 2013), and species near the southern edge of their range (e.g., lodgepole pine) are more vulnerable to climate impacts (Meyer 2013). Lower-elevation conifers and shrublands may gradually move upslope to replace subalpine species (Lenihan et al. 2003).

Adaptive Capacity

The overall adaptive capacity of subalpine habitats was evaluated to be low-moderate by habitat experts.[13]

Habitat extent, integrity, continuity and landscape permeability
Habitat experts evaluated subalpine habitats to have low-moderate geographic extent (i.e., habitat is quite limited in the study area),[14] moderate-high integrity (i.e., habitat has minor/moderate alterations),[15] and feature low continuity (i.e., habitat is isolated and/or quite fragmented).[16] Although subalpine ecosystems are contiguous throughout much of the Sierra Nevada, in southern California these ecosystems are discontinuous and isolated (Vulnerability Assessment Reviewers, pers. comm., 2015).

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[13] Confidence: Moderate
[14] Confidence: Moderate
[15] Confidence: Low
[16] Confidence: High

Habitat experts identified geologic features as barriers to subalpine habitat continuity and dispersal.[17] The lack of connectivity between mountaintops limits the ability of this habitat type to migrate northwards in the face of warming temperatures (Hauptfeld et al. 2014). The ability of subalpine species to track climatic changes across the landscape are further limited by very slow growth rates and long lives (Fites-Kaufman et al. 2007). However, some species can disperse their seeds over long distances, either by wind (e.g., lodgepole pine) or through specialized interspecies relationships, such as limber pine seed dispersal by the Clark's nutcracker (Meyer 2013, Minnich 2007). Compared to slow-growing trees, subalpine shrubs may be better able to shift upwards in elevation under changing climate conditions (M. Meyer, pers. comm., 2015).

Resistance and recovery
Habitat experts evaluated subalpine habitats to have low resistance to climate stressors and maladaptive human responses,[18] and low-moderate recovery potential.[19]

Species that require less moisture and fewer soil nutrients, such as limber pine, may be more resistant to the impacts of climate change; similarly, less dense stands may be both more resistant to stressors such as drought, fire, and insect outbreaks, and more likely to recover following these events. Limber pine and lodgepole pine are shade-intolerant, and can colonize recently burned areas where breaks in the canopy allow increased seedling recruitment (Meyer 2013, Minnich 2007). However, interactions among multiple climate and non-climate stressors greatly decrease both resistance and recovery (M. Meyer, pers. comm., 2015). Subalpine trees grow slowly and must endure harsh conditions (Benson 1988, Minnich 2007), and full recovery from disturbances can take up to 100 years (Minnich 2007).

Habitat diversity
Habitat experts evaluated subalpine habitats to have moderate physical and topographical diversity,[20] low-moderate component species diversity,[21] and low-moderate functional group diversity.[22]

Subalpine habitats are dominated by only two tree species: lodgepole pine and limber pine. The understory is characterized by species such as creambush oceanspray (*Holodiscus discolor*), mountain heather (*Phyllodoce breweri*), and montane chaparral including *Ceanothus cordulatus*, *Arctostaphylos patula*, *Chrysolepis sempervirens*, and *Cercocarpus ledifolius* (Minnich 2007, Benson 1988).

[17] Barriers presented are those ranked most critical by habitat experts. A full list of evaluated barriers can be found at the end of this document.
[18] Confidence: Low
[19] Confidence: Low
[20] Confidence: Moderate
[21] Confidence: Moderate
[22] Confidence: Moderate

Subalpine ecosystems serve as important habitat for many sensitive species of wildlife including two subspecies of lodgepole chipmunk (*Tamias speciosus callipeplus* and *T.s. speciosus*; Stephenson and Calcarone 1999), and a subspecies of the golden-mantled ground squirrel found only in the San Bernardino Mountains (*Spermophilus lateralis*; Bartels and Thompson 1993).

Clark's nutcracker plays a vital role as a seed disperser in subalpine forests, and limber pine depends upon the bird for regeneration (Fites-Kaufman et al. 2007). Clark's nutcracker reaches the southern limits of its range in southern California (Fites-Kaufman et al. 2007), and is expected to lose ~70% of its range by 2080 as climate conditions change (National Audubon Society 2013). Projected range maps indicate the probable loss of Clark's nutcracker from the region (National Audubon Society 2013), and this loss is likely to impact limber pine regeneration by limiting seed dispersal (M. Meyers, pers. comm., 2015). In the Sierra Nevada, bird species associated with subalpine habitats were ranked as more vulnerable to climate change than those associated with other habitat types (Siegel et al. 2014).

Management potential

Habitat experts evaluated subalpine habitats to be of high societal value.[23] Subalpine habitats are valued for their aesthetics, recreational opportunities, and water storage (Vulnerability Assessment Reviewers, pers. comm., 2015). Subalpine habitats provide a variety of ecosystem services, including: biodiversity, water supply/quality/sediment transport, recreation, air quality, and flood and erosion protection (Vulnerability Assessment Reviewers, pers. comm., 2015).

Habitat experts identified a low-moderate potential for managing or alleviating climate impacts for subalpine habitats,[24] and noted that the options for management of subalpine habitats are quite limited. However, restoration projects are currently underway for subalpine conifers in the Sierra Nevada (Keane et al. 2012), and it is possible that these techniques could be adapted for use in southern California (M. Meyer, pers. comm., 2015). Additional management actions could focus on establishing seed banks and nursery stock for limber pine, maintaining natural fire return intervals, and preventing stand-replacing fire (Vulnerability Assessment Reviewers, pers. comm., 2015). Additionally, addressing non-climate stressors within subalpine habitats would reduce additional stress and mortality; these actions could include monitoring for invasive species, bark beetle attacks, and white pine blister rust (M. Meyer, pers. comm., 2015), limiting the expansion of recreation and public use, and enhancing habitat connectivity to help species access potential refugia and/or migrate to more suitable conditions (Hauptfeld et al. 2014).

Recommended Citation

[23] Confidence: Moderate

[24] Confidence: Low

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

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Subalpine Habitats – Overview of Vulnerability Component Evaluations

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

SENSITIVITY

Sensitivity Factor[3]	Sensitivity Evaluation[4]	Confidence[4]
Sensitivities to Climate & Climate-Driven Factors • *Air temperature* • *Snowpack depth* • *Timing of snowmelt & runoff* • *Extreme events: drought* • *Precipitation* • Soil moisture[5] • High lentic/lotic temperature[5] • Extreme events: high temperature[5] • Other (air pollution)[5]	**Overall: 4 Moderate-High** • 5 High • 5 High • 4 Moderate-High • 4 Moderate-High • 4 Moderate-High • 3 Moderate • 3 Moderate • 3 Moderate • 1 Low	**Overall: 2 Moderate** • 3 High • 3 High • 2 Moderate • 2 Moderate • 2 Moderate • 2 Moderate • 1 Low • 1 Low • 2 Moderate
Disturbance Regimes • *Insects* • *Wildfire* • *Disease* • Wind[5]	**Overall: 3 Moderate** • 4 Moderate-High • 4 Moderate-High • 4 Moderate-High • 1 Low	**Overall: 3 High** • 3 High • 2 Moderate • 2 Moderate • 3 High
Non-Climate Stressors – Degree Stressor Affects Sensitivity • *Recreation* • Invasive & other problematic species[5]	**Overall: 1 Low** • 1 Low • 2 Low-Moderate	**Overall: 1 Low** • 1 Low • 1 Low
Non-Climate Stressors – Current Exposure to Stressor • *Recreation* • Invasive & other problematic species[5]	**Overall: 1 Low** • 1 Low • 1 Low	**Overall: 2 Moderate** • 1 Low • 2 Moderate
Other Sensitivities: None identified	N/A	N/A

Overall Averaged Ranking (Sensitivity):[6] 2 Low-Moderate

Overall Averaged Confidence (Sensitivity):[7] 2 Moderate

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

EXPOSURE

Exposure Factor[3]	Exposure Evaluation[4]	Confidence[4]
Future Climate Exposure Factors	**Overall: 4 Moderate-High**	**Overall: 2 Moderate**
• *Increased air temperature*	• 5 High	• 3 High
• *Decreased snowpack*	• 5 High	• 3 High
• *Extreme events: increased drought*	• 4 Moderate-High	• 2 Moderate
• *Changes in precipitation*	• 4 Moderate-High	• 2 Moderate
• *Increased wildfire*	• 4 Moderate-High	• 2 Moderate
• *Earlier snowmelt & runoff*	• 4 Moderate-High	• 3 High
• *Decreased soil moisture*	• 4 Moderate-High	• 3 High
• Increased lentic/lotic temperatures[5]	• 3 Moderate	• 1 Low
• Extreme events: high temperatures[5]	• 3 Moderate	• 1 Low

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

Overall Averaged Confidence (Exposure):[7] 2 Moderate

ADAPTIVE CAPACITY

Adaptive Capacity Factor	Adaptive Capacity Evaluation[4]	Confidence[4]
Habitat Extent, Integrity & Continuity	**Overall: 2 Low-Moderate**	**Overall: 2 Moderate**
• Geographic Extent	• 2 Low-Moderate (Habitat is quite limited in the study area)	• 2 Moderate
• Structural & Functional Integrity	• 4 Moderate-High (Minor/moderate alterations)	• 1 Low
• Habitat Continuity	• 1 Low (Isolated and/or quite fragmented)	• 3 High
Landscape Permeability[3] Key barriers: • *Geologic features*	**Overall: 1 Low** Impact on landscape permeability: • High	**Overall: 3 High** • 3 High
Habitat Resistance & Recovery	**Overall: 2 Low-Moderate**	**Overall: 1 Low**
• Resistance	• 1 Low	• 1 Low
• Recovery	• 2 Low-Moderate	• 1 Low
Habitat Diversity	**Overall: 2 Low-Moderate**	**Overall: 2 Moderate**
• Physical/Topographical Diversity	• 3 Moderate	• 2 Moderate
• Component Species Diversity	• 2 Low-Moderate	• 2 Moderate
• Functional Group Diversity	• 2 Low-Moderate	• 2 Moderate
Management Potential	**Overall: 3 Moderate**	**Overall: 1 Low**
• Habitat Value	• 5 High	• 2 Moderate
• Likelihood of Managing or Alleviating Climate Impacts	• 2 Low-Moderate	• 1 Low
Other Adaptive Capacities: None identified	N/A	N/A

Overall Averaged Ranking (Adaptive Capacity):[6] 2 Low-Moderate

Overall Averaged Confidence (Adaptive Capacity):[7] **2 Moderate**