Santa Cruz Mountains Climate Change Vulnerability Assessment and Adaptation Strategies Synthesis Report

2021

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Cover photo: A flowering meadow in Russian Ridge Open Space Preserve. Photo by Steve Jurvetson via Flickr (CC BY 2.0).

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Introduction

The Santa Cruz Mountains ecoregion features iconic habitats and species, such as coastal redwood forests, that are at risk from a number of stresses. Climate change impacts, coupled with non-climate stressors such as population growth and development and invasive species, have important implications for the natural resources and ecosystem services upon which millions of people rely. The goal of the Santa Cruz Mountains Climate Adaptation Project was to improve understanding of and capacity to reduce climate-related vulnerabilities of regionally-important habitats and species. This project convened staff from the Midpeninsula Regional Open Space District and members of the Santa Cruz Mountains Stewardship Network to identify regionally-important habitats and species, discuss their vulnerability to climate change, and explore potential adaptation options to reduce vulnerabilities and/or increase resilience of resources to climate change. Project objectives included:

1. Generate vulnerability assessment and adaptation planning products for habitats and species of interest;
2. In partnership with Pepperwood Preserve, create customized data products on recent and projected future climate changes and their potential impacts on the region;
3. Provide a framework and space for participating stakeholders to grapple with climate change impacts and how to manage resources effectively given these impacts; and
4. Help identify practical applications and next steps for stakeholders to incorporate information into their management plans and programs and on-the-ground projects.

This report synthesizes the results of the major project components – observed and projected climate changes, vulnerability assessment, and adaptation planning. The **Project Methods and Workshops** section provides an overview of the climate adaptation planning process and the methodology used for the vulnerability assessment and adaptation planning workshops. The **Overview of Climate Trends and Projections** section presents the observed and projected climate change information for the region, which was generated using the Basin Characterization Model.[1] The **Vulnerability Assessment and Adaptation Planning Results** section summarizes overall trends and findings for habitats and species. More detailed information is available in the habitat and species vulnerability assessment summaries (Appendix A), adaptation tables (Appendix B), and vulnerability-adaptation briefs (Appendix C) at the end of this report.

Project Methods and Workshops

Climate Adaptation Planning Overview

Climate change presents considerable challenges for natural resources and human communities. Within the Santa Cruz Mountains region, current and projected climate changes include increased wildfire risk, increased frequency and length of drought, reduced soil moisture, and increased heat wave frequency and intensity. Current non-climate stressors such as population growth and development, invasive species, and fire suppression/exclusion, coupled with climate

[1] https://ca.water.usgs.gov/projects/reg_hydro/basin-characterization-model.html

change, will lead to shifts in habitat distribution, range contractions, and/or extirpation of species. Natural resource managers are now faced with the challenge of developing and implementing strategies that offer a path forward for these habitats and species given changing climate conditions. Strategies undertaken to address the causes and effects of global climate change are classified as either *mitigation* or *adaptation*. *Mitigation* strategies aim to reduce the rate and extent of change by reducing greenhouse gas emissions or enhancing carbon uptake and sequestration. *Adaptation* strategies help people prepare for, respond to, and/or recover from the unavoidable effects of climate change. The adaptation planning process (Figure 1) reflects the intentional integration of climate change into resource management and conservation, and is meant to be iterative.

Figure 1. Climate adaptation planning process. Modified from Glick et al. 2011.

This project used a collaborative, expert opinion-based approach involving resource managers and other stakeholders from the Midpeninsula Regional Open Space District and Santa Cruz Mountains Stewardship Network. Eliciting expert opinion is an effective approach in situations where there is greater uncertainty about future climate projections and impacts, but stakeholders are able to contribute detailed knowledge and expertise about the ecology, management, and threats to regional resources of concern.

This project involved a series of four collaborative workshops, which are described in more detail below:

1. Project Scoping
2. Vulnerability Assessment

3. Adaptation Planning for the Midpeninsula Regional Open Space District
4. Adaptation Planning for the Santa Cruz Mountains Stewardship Network

Workshop 1: Project Scoping

The first workshop, held in June 2019, included resource managers, conservation planners, and others from the Midpeninsula Regional Open Space District and Santa Cruz Mountains Stewardship Network. The purpose of the workshop was to define the project boundary (Figure 2), identify the climate variables of interest, select the timeframe for the climate analysis, and select a suite of regionally important habitats and species. A draft list of 22 habitats and species/species groups was generated, which was ultimately narrowed down to a final list of ten habitats and nine species/species groups:

HABITATS

1. Chaparral
2. Coastal dunes, wet meadows, and prairies
3. Coastal redwood forests
4. Coastal scrub
5. Freshwater marshes, wetlands, and ponds
6. Mixed evergreen/montane hardwood forests
7. Mixed grasslands
8. Oak woodlands
9. Rivers, streams, and floodplains
10. Seeps and springs

SPECIES

1. American badger and western burrowing owl
2. Bats
3. Butterflies
4. California red-legged frog and San Francisco garter snake
5. Coyote brush
6. Marbled murrelet
7. Salamanders
8. Salmonids
9. Wide-ranging mammals

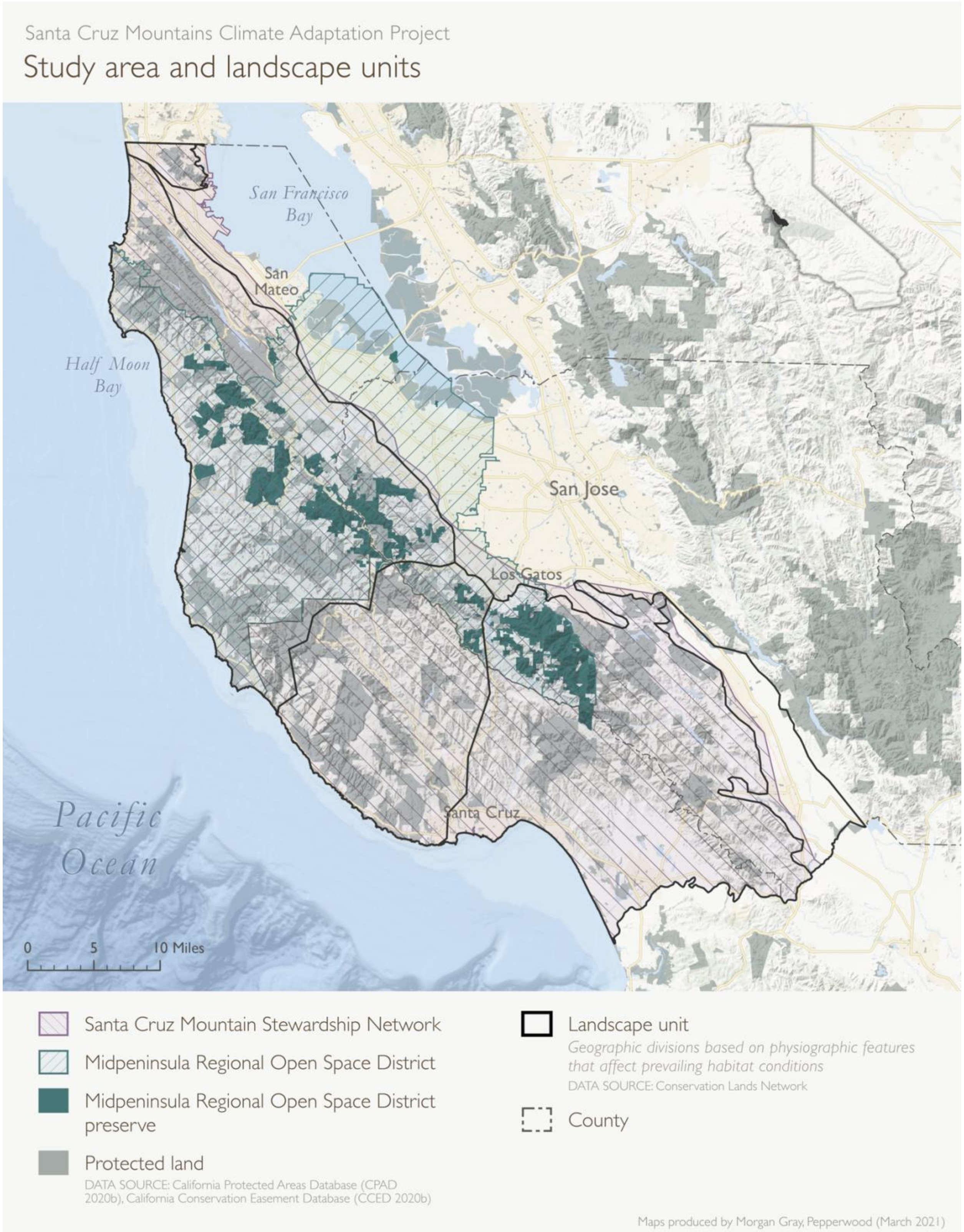


Figure 2. Study region geography and analysis units for the Santa Cruz Mountains Climate Adaptation Project.

Workshop 2: Vulnerability Assessment

The second workshop, held in October 2019, included resource managers, conservation planners, and others from the Midpeninsula Regional Open Space District and Santa Cruz Mountains Stewardship Network. The purpose of the workshop was to assess vulnerability of the selected habitats and species/species groups to climate change. Participants self-selected habitat and species breakout groups and evaluated each resource's vulnerability.

Vulnerability is defined as a function of the sensitivity of a particular resource to climate changes, its exposure to those changes, and its capacity to adapt to those changes (IPCC 2014; Figure 3). **Exposure** is a measure of how much of a change in climate or climate-driven factors a resource is likely to experience (Glick et al. 2011). **Sensitivity** is a measure of whether and how a resource is likely to be affected by a given change in climate or factors driven by climate (Glick et al. 2011). **Adaptive capacity** refers to the ability of a resource to accommodate or cope with climate change impacts with minimal disruption (Glick et al. 2011).

Vulnerability Assessment Model

The vulnerability assessment model applied in this process was developed by EcoAdapt[2] (EcoAdapt 2014a, 2014b; Kershner 2014; Hutto et al. 2015), and includes evaluations of relative vulnerability by local stakeholders who have detailed knowledge about and/or expertise in the ecology, management, and threats to regional habitats and species. Workshop participants evaluated vulnerability of each resource by discussing and ranking aspects of sensitivity, exposure, and adaptive capacity.

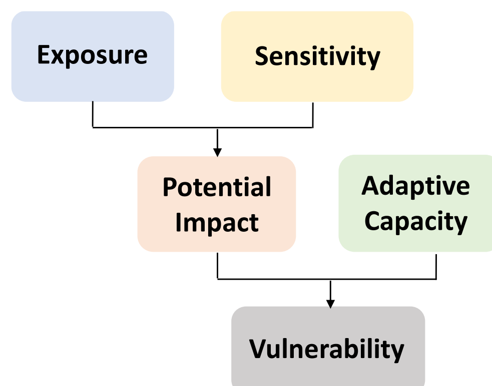


Figure 3. Components of vulnerability (IPCC 2014).

Participants were first asked to describe the habitat or species/species group, and then were asked to assign one of three rankings (High, Moderate, or Low) for sensitivity and adaptive capacity. EcoAdapt assigned rankings to climate exposure based on downscaled climate projections for the region. Rankings for each component were then converted into scores (High-3, Moderate-2, or Low-1) and the scores averaged (mean) to generate an overall score. For example, scores for each element of habitat sensitivity were averaged to generate an overall habitat sensitivity score. Scores for exposure were weighted less than scores for sensitivity and adaptive capacity because of greater uncertainty about the magnitude and rate of future change. Sensitivity, adaptive capacity, and exposure scores were combined into an overall vulnerability score calculated as:

Vulnerability = [(Climate Exposure*0.5) x Sensitivity] - Adaptive Capacity

[2] Sensitivity and adaptive capacity elements were informed by Glick et al. 2011, Manomet Center for Conservation Sciences 2012, and Lawler 2010.

Elements for each component of vulnerability were also assigned one of three confidence rankings (High, Moderate, or Low). Confidence rankings were converted into scores (High-3, Moderate-2, or Low-1) and the scores averaged (mean) to generate an overall confidence score. These approximate confidence levels were based on the Manomet Center for Conservation Sciences (2012) 3-category scale, which collapsed the 5-category scale developed by Moss and Schneider (2000) for the IPCC Third Assessment Report. The vulnerability assessment model applied here assesses the confidence associated with individual element rankings, and uses these rankings to estimate the overall level of confidence for each component of vulnerability as well as overall vulnerability.

Rankings and scores presented should be considered measures of relative vulnerability and confidence such that comparisons between habitat and species vulnerability should only be made within the context of this project.

Vulnerability Assessment Model Elements

Sensitivity & Exposure

- **Climate and Climate-Driven Factors:** e.g., air temperature, precipitation, freshwater temperature, sea level rise, soil moisture, altered streamflow
- **Disturbance Regimes:** e.g., wildfire, flooding, storms and related impacts, insect and disease outbreaks
- **Future Climate Exposure:** e.g., consideration of projected future climate changes (e.g., temperature and precipitation) as well as climate-driven changes (e.g., altered fire regimes, altered flow regimes, shifts in vegetation types). Participants were asked to identify any areas of potential refugia.
- **Non-Climate Stressors:** e.g., residential or commercial development, agriculture, transportation corridors (e.g., roads, railroads, trails), fire exclusion/suppression, invasive and other problematic species, pollution and poisons, etc. For non-climate stressors, participants were asked to evaluate sensitivity and the degree to which the resource is currently exposed to that stressor.
- **Dependencies (species only):** e.g., generalists that utilize multiple habitats and/or prey or forage species vs. specialists that have very narrow habitat requirements or utilize a single prey/forage species

Adaptive Capacity

- **Extent, Integrity, and Continuity (habitats only):** e.g., widespread distribution vs. occurrence in small areas; high structural and functional integrity vs. degraded habitats; highly continuous vs. isolated/fragmented
- **Extent, Integrity, and Connectivity (species only):** e.g., widespread distribution vs. occurrence in single populations and/or small areas; robust population health vs. degraded/declining; high connectivity among populations vs. isolated/fragmented
- **Landscape Permeability (habitats only):** e.g., permeable landscapes with few to no barriers to dispersal and/or movement vs. landscapes with multiple barriers that affect continuity/dispersal

- **Dispersal Ability (species only):** e.g., high ability to disperse with few to no barriers to dispersal and/or movement vs. poor dispersal ability with multiple barriers that affect movement and/or dispersal
- **Habitat Diversity (habitats only):** e.g., diversity of physical and topographical characteristics as well as component native species and functional groups in the habitat
- **Intraspecific/Life History Diversity (species only):** variety of life history strategies; genetic diversity; phenotypic and behavioral plasticity
- **Resistance and Recovery:** *resistance* refers to the stasis of a habitat in the face of change, *recovery* refers to the ability to "bounce back" more quickly from stressors once they do occur
- **Management Potential:** e.g., ability of resource managers to alter the adaptive capacity and resilience of a habitat; includes consideration of public value and societal support for management actions as well as management capacity and ability to alleviate impacts

Vulnerability Assessment Summaries

Vulnerability and confidence rankings and scores for a given component were supplemented with information from the scientific literature. The final vulnerability assessment summary for a given resource includes stakeholder-assigned rankings, confidence evaluations, and narratives summarizing expert opinions and information from the scientific literature. The draft vulnerability assessment summaries were reviewed by workshop participants to help address discrepancies and uncertainties. Links to the final summaries are available at the end of this report.

Workshops 3 & 4: Adaptation Planning

The third and fourth workshops, held in November and December 2020, included resource managers, conservation planners, and others from the Midpeninsula Regional Open Space District and Santa Cruz Mountains Stewardship Network. The purpose of the workshops was to develop adaptation strategies in response to habitat and species/species group vulnerabilities.

While the overall purpose of the workshops was similar, each workshop approached adaptation planning in a slightly different way:

1. *Midpeninsula Regional Open Space District Climate Change Adaptation Planning Workshop* (November 19-20, 2020). The Midpeninsula Regional Open Space District chose to focus on developing adaptation strategies and actions, including looking at existing or planned projects as well as possible future projects, and identifying specific implementation steps for priority strategies.
2. *Santa Cruz Mountains Stewardship Network Climate Change Adaptation Planning Workshop* (December 1-2, 2020). The Santa Cruz Mountains Stewardship Network wanted the workshop format to mirror TBC3's Climate Ready Vegetation Management in the Bay Area: A Pilot Workshop for Land Managers. Thus, this workshop used a scenario planning approach to identify current management actions that could help reduce vulnerabilities, potential future management actions to consider, and current actions that will become maladaptive under future scenarios.

Workshops are described in more detail below.

Adaptation refers to adjustments in natural or human systems in response to changing climate conditions. Adaptation strategies can build on existing management, conservation, and restoration of natural resources. Climate adaptation approaches typically fall into one or more of the following categories:

- **Resistance**. These strategies aim to maintain current conditions by limiting change. Examples include preventing the spread of invasive species or removing barriers to terrestrial or aquatic habitat connectivity.
- **Resilience**. These strategies accommodate some change but enable a return to prior desired conditions. Examples include promoting native genotypes and restoring hydrologic function.
- **Acceptance (or No Action)**. These strategies reflect a deliberate decision to accept change and/or take no action in response to climate impacts. Examples include allowing newly arriving species to persist or allowing transition from one habitat type to another in response to changing climate conditions.
- **Response (or Direct/Transition)**. These strategies intentionally facilitate or direct change and enable resources to adaptively respond to changing and new conditions. Examples include introducing species that were not historically present but may be better adapted to future climate conditions or proactively creating new places for habitat to migrate.
- **Knowledge**. These strategies are aimed at gathering more information about climate changes, impacts, and/or the effectiveness of management actions in addressing the challenges of climate change. Examples include identifying and monitoring rare species that are the most vulnerable to climate change or monitoring the long-term effectiveness of rare species management and restoration.
- **Collaboration**. These strategies focus on coordinating management efforts and/or capacity across organizational, departmental, or jurisdictional boundaries. Examples include improving data sharing within and between agencies and organizations or identifying and developing cooperative management and land acquisition opportunities to proactively address habitat shifts due to climate change.

Midpeninsula Regional Open Space District Climate Change Adaptation Planning Workshop
This adaptation workshop was held on November 19-20, 2020, and included a presentation sharing vegetation distribution modeling for the region, an overview of habitat and species vulnerability assessment results, and adaptation planning in breakout groups. For the breakout groups, participants identified four topic areas of interest to explore: (1) grasslands, (2) coastal redwood forests, (3) oak woodlands, and (4) connectivity. Participants self-selected breakout groups. Each breakout group activity consisted of a brainstorming session to identify potential adaptation strategies and selecting 1-3 adaptation strategies to develop implementation plans. Implementation plans considered:

1. the overarching adaptation strategy;
2. one to three specific actions to implement under that strategy; and

3. an evaluation of each action according to: implementation feasibility, effectiveness, timeline, where/how to implement, co-benefits and conflicts, and existing or needed management mechanisms.

Implementation feasibility: how feasible is the action to implement (e.g., given financial cost, staff capacity, etc.)?

Effectiveness: Is the action likely to reduce vulnerability and help you achieve your desired goal?

Timeline: When should the action be implemented (e.g., <5 years; 5-10 years; >10 years)?

Where/how to implement: Identify the management, site, or ecological conditions where the action could most appropriately be applied.

Co-benefits and conflicts: What co-benefits or conflicts may there be with other resources, activities, or values?

Existing or needed management mechanisms: Does the mandate to enact the strategy exist or would policy need to change? Are there legal or social barriers to implementing the strategy?

Santa Cruz Mountains Stewardship Network Climate Change Adaptation Planning Workshop
This adaptation workshop was held on December 1-2, 2020, and included a presentation sharing vegetation distribution modeling for the region, an overview of habitat and species vulnerability assessment results, and adaptation planning in breakout groups. For the breakout groups, participants identified four topic areas of interest to explore: (1) instream habitat/riparian restoration, (2) coastal redwood forests, (3) coastal grasslands, and (4) fire-catalyzed vegetation type conversion. Participants self-selected breakout groups. Breakout groups were asked to explore adaptation planning for two future scenarios (e.g., warmer and wetter conditions, hotter and drier conditions). For each scenario, participants were asked to identify:

- potential impacts on the topic area,
- current activities/actions to keep implementing and how they could be modified to better address impacts and vulnerabilities, and
- new activities or actions to consider implementing.

Participants were also asked to identify any current activities or actions that will likely become maladaptive under either scenario.

Adaptation Planning Summaries
These workshops generated a range of possible adaptation strategies that are currently being implemented as well as those that could be implemented both now and in the future. Strategies are summarized in this report as well as in resource briefs, which include both vulnerability and adaptation information. The adaptation strategies in the briefs were

supplemented with strategies from the literature as well as other workshops. The briefs were reviewed by workshop participants to help address discrepancies and uncertainties.

Overview of Climate Trends and Projections

The following climate change summary provided the foundation for the climate exposure component of the vulnerability assessment.

Projections for average annual air temperature, precipitation, climatic water deficit, and wildfire risk were generated using the Basin Characterization model (Flint et al. 2013, Flint & Flint 2014). Each variable was evaluated by comparing recent conditions (average between 1981 and 2010) with future conditions (mid-century time period of 2040–2060) using three different models selected because they span a range of temperature and precipitation possibilities (see Figure X): a warm/wet future (CNRM-CM5 model under a high-emissions or business-as-usual scenario), a cool/dry future (GFDL model under a low-emissions or sustainable development scenario), and a hot/dry future (MIROC ESM5 model under a high-emissions scenario).

Air Temperature and Extreme Heat

By mid-century, annual mean temperatures within the Santa Cruz Mountains study area are projected to rise by 2.7°F to 5.6°F compared to recent temperatures (1981–2010; Figure 4). However, there are pronounced seasonal differences in the degree of future change, with much greater warming projected in summer (+3.1°F to +7.4°F; Figure 5) compared to winter (2.7°F to 4.1°F; Figure 6).

Extreme heat is also expected to increase significantly, with more frequent and more severe heat waves (Gershunov & Guirguis 2012). In the Santa Cruz Mountains region, the maximum temperature on the hottest day of the year is likely to increase by 3.6–7.4°F by mid-century and up to 9.0°F by the end of the century (Pierce et al. 2018).

Precipitation

Precipitation in California is highly variable on seasonal, annual, decadal, and multidecadal scales, which contributes to a wide range of projections that disagree on both the direction and magnitude of change. By mid-century, projections for average annual precipitation within the Santa Cruz Mountains study area range from decreases of 8.8 inches up to increases of 6.0 inches (average 3% decrease across the study area; Figure 7).

Regardless of whether annual precipitation increases or decreases, it is highly likely that a larger proportion will occur during a shorter and more intense wet season, while the dry season becomes even longer and drier. It is also highly likely that precipitation totals will be even more variable from year to year (Swain et al. 2018).

Extreme Precipitation and Storms

The intensity and duration of storm events (including atmospheric rivers) are projected to increase over the coming century, resulting in greater maximum precipitation rates and volume (Dettinger 2011, Shields & Kiehl 2016, Prein et al. 2017; Pierce et al. 2018). The projected increases in extreme precipitation events are also expected to cause more frequent and more severe winter flooding (Dettinger 2011, Grantham et al. 2018; Swain et al. 2018; AghaKouchak et al. 2018), with one study suggesting that floods currently with a likelihood of occurring once every 200 years will become 50-year floods by the end of the century (Swain et al. 2018).

Soil Moisture and Climatic Water Deficit

Soil moisture is closely tied to *climatic water deficit (CWD)*, a metric that reflects moisture stress by taking into account the effects of both evapotranspiration and rainfall on the ecosystem water balance. Increases in CWD represent a net loss of water from the ecosystem through reduced water inputs (e.g., less precipitation) and/or increased water loss (e.g., more evapotranspiration, often as a result of warmer temperatures).

By mid-century, annual CWD is projected to increase by 27.7–110.6 mm (1.1–4.4 in), which represents an average 8% increase across the study area (Figure 8). Because increases in evapotranspiration occur as temperatures rise, increased climatic water deficit and decreased soil moisture are expected regardless of the direction of change in precipitation (Thorne et al. 2015, Pierce et al. 2018).

Drought

Although precipitation is the main driver of drought variability (Williams et al. 2015), warmer temperatures are expected to drive increased future drought risk even if precipitation increases (Cook et al. 2015; Diffenbaugh et al. 2015; Pierce et al. 2018). Drought years are projected to be twice as likely to occur in any given year (Cook et al. 2015). Severe droughts are also projected to become much more frequent, with those that now occur once every 20 years projected to happen once every 10 years by the end of the century, and once-in-a-century droughts projected to occur once every 20 years by 2100 (Pierce et al. 2018). Significant increases in extreme drought conditions are already being observed in California; for instance, the 2012–2016 drought had the lowest precipitation, highest temperatures, and most extreme drought indicators on record (Griffin & Anchukaitis 2014; Diffenbaugh et al. 2015).

Wildfire

Wildfire risk (i.e., the probability that at least one wildfire will occur within a 30-year time period) is projected to increase by an average of 16% across the study area (Figure 9). However, changes in wildfire risk are not spatially consistent in the region; little to no changes in wildfire risk are expected in the Santa Clara Valley while the most significant increases occur at higher elevations within the Santa Cruz Mountains. The most extreme changes in wildfire risk are correlated with areas that receive more rainfall. This is consistent with other studies demonstrating greater fire activity in wet years due to increased growth of fine fuels (e.g., annual grasses), which promote fire spread as they dry out in subsequent low-precipitation years (Williams et al. 2019). However, many other factors contribute to the wildfire probabilities projected by this model, including land use (e.g., urbanization), the presence of invasive species, and ignition frequency.

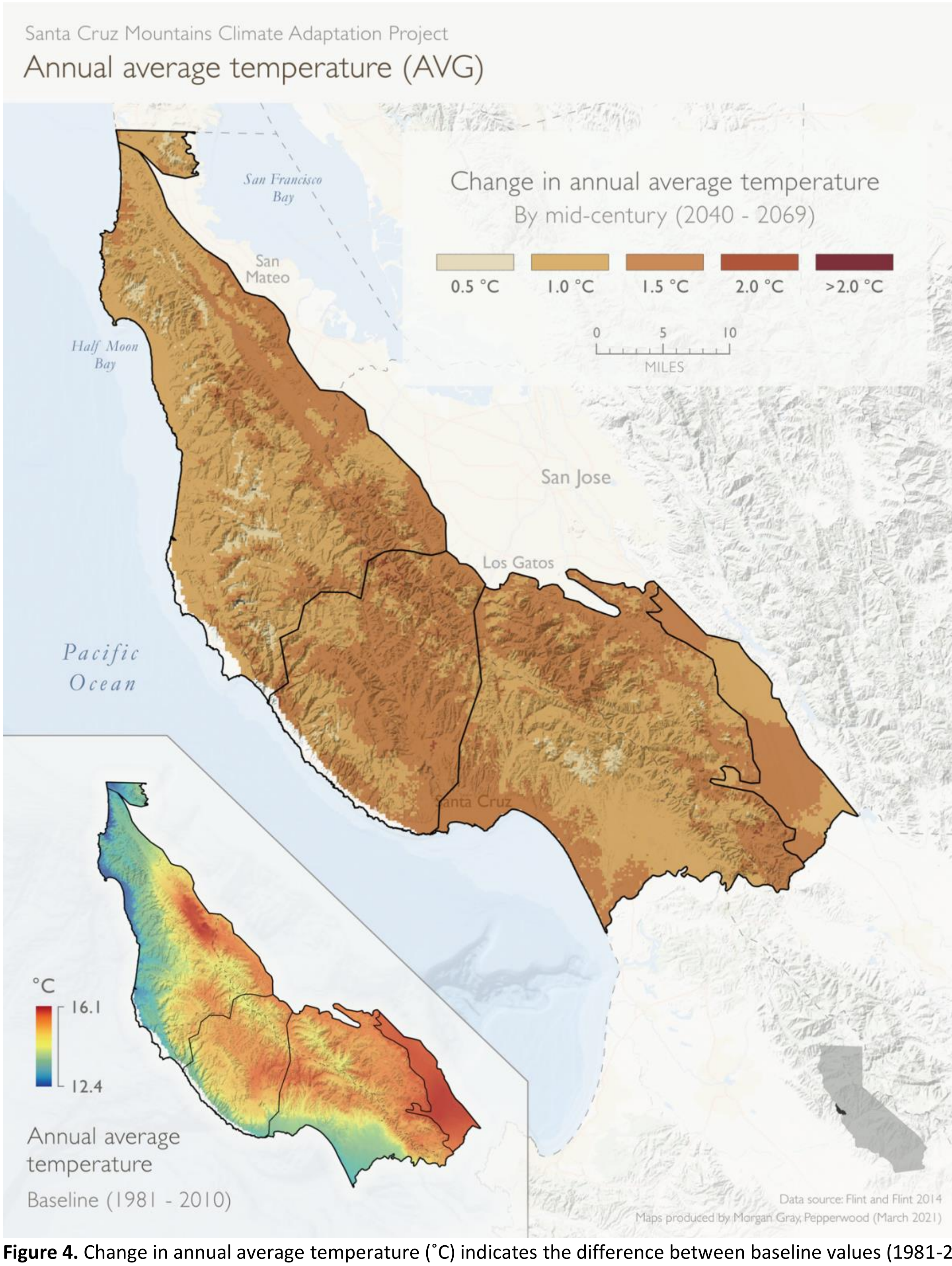


Figure 4. Change in annual average temperature (˚C) indicates the difference between baseline values (1981-2010; baseline shown in lower left map inset) and mid-century (2040-2069) projections for the average of three global climate models: CNRM-CM5 (warm/wet future scenario), GFDL-B1 (cool/dry future scenario), and MIROC-ESM5 (hot/dry future scenario). Relative to baseline values, annual average temperature is projected to be between +1.5 to +3.1˚C hotter by mid-century, representing an average increase of +15% across the study region.

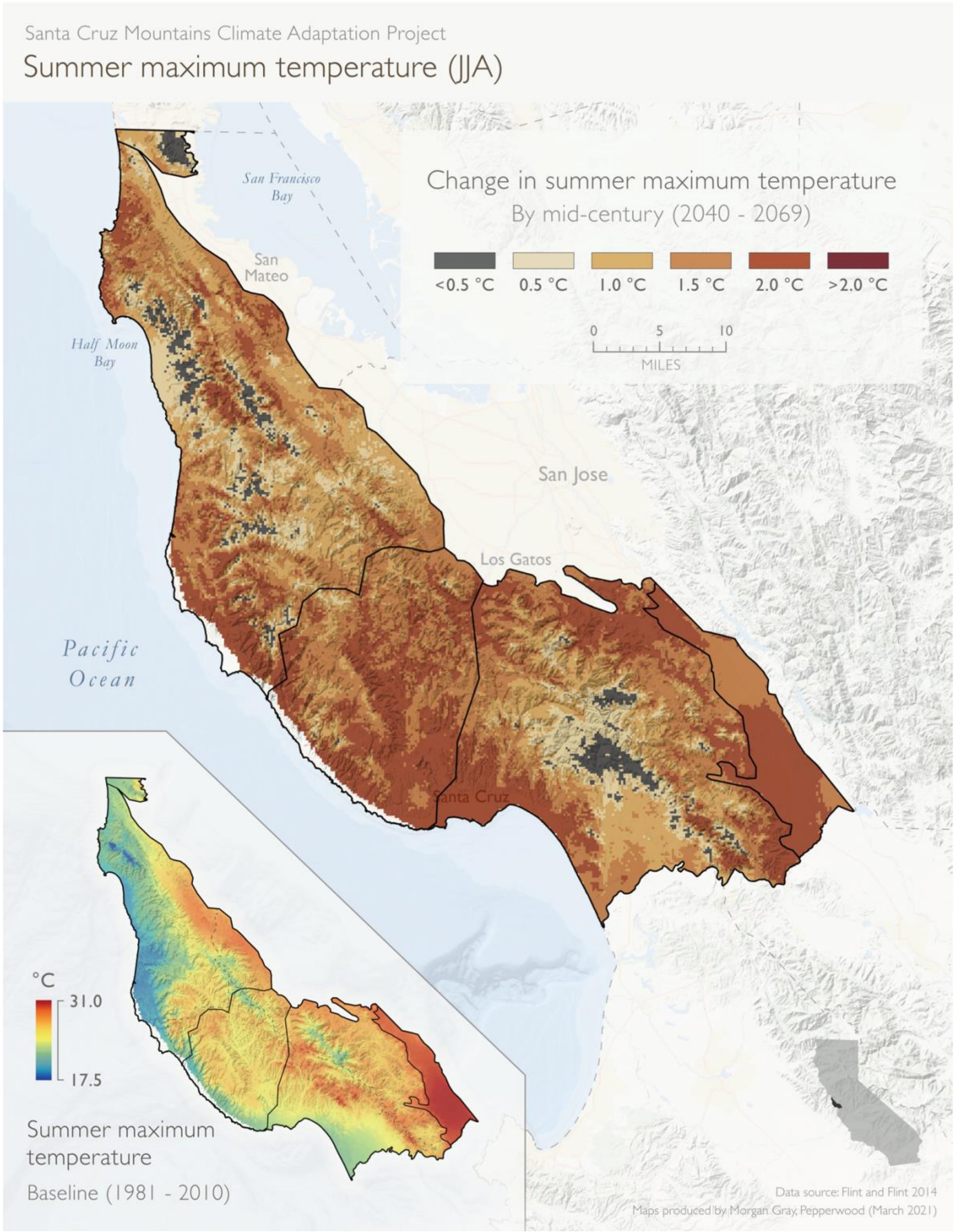


Figure 5. Change in summer maximum temperature (˚C) indicates the difference between baseline values (1981-2010; baseline shown in lower left map inset) and mid-century (2040-2069) projections for the average of three global climate models: CNRM-CM5 (warm/wet future scenario), GFDL-B1 (cool/dry future scenario), and MIROC-ESM5 (hot/dry future scenario). Relative to baseline values, summer maximum temperature is projected to be between +1.7 to +4.1˚C hotter by mid-century, representing an average increase of +10% across the study region.

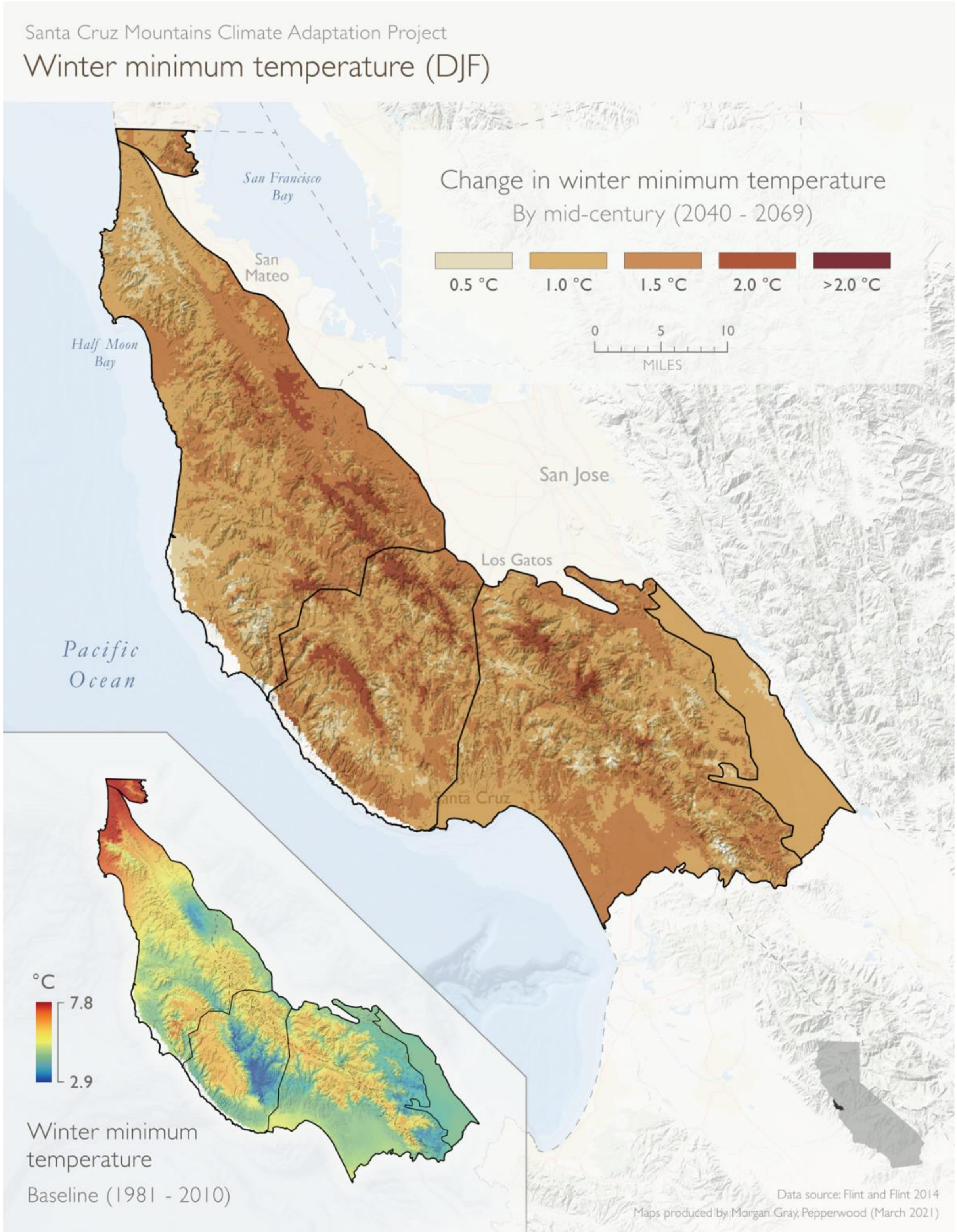


Figure 6. Change in winter minimum temperature (˚C) indicates the difference between baseline values (1981-2010; baseline shown in lower left map inset) and mid-century (2040-2069) projections for the average of three global climate models: CNRM-CM5 (warm/wet future scenario), GFDL-B1 (cool/dry future scenario), and MIROC-ESM5 (hot/dry future scenario). Relative to baseline values, winter minimum temperature is projected to be between +1.5 to +2.3˚C hotter by mid-century, representing an average increase of +36% across the study region.

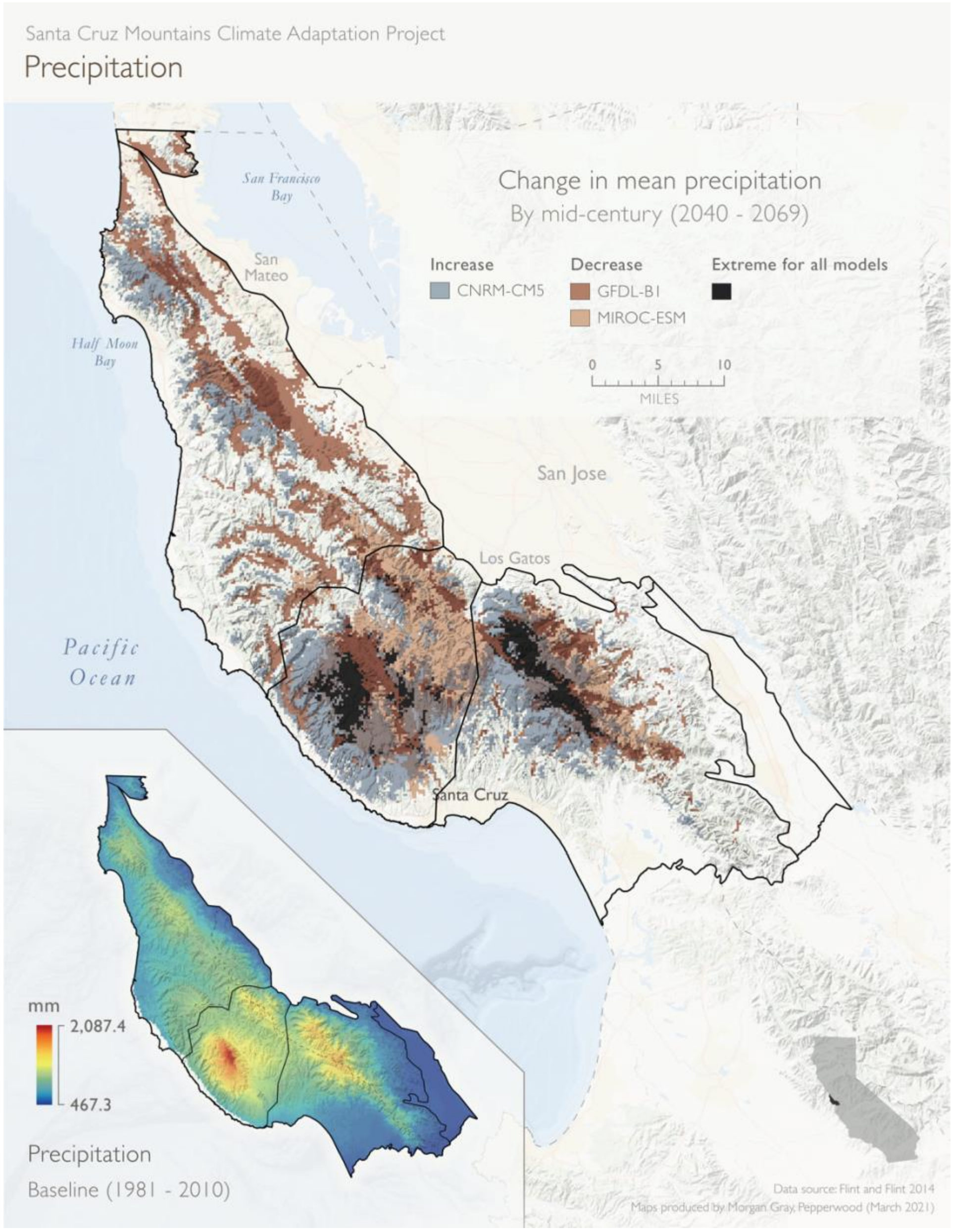


Figure 7. Direction of change in mean precipitation indicates the difference between baseline values (1981-2010; baseline shown in lower left map inset) and mid-century (2040-2069) projections for the average of three global climate models: CNRM-CM5 (warm/wet future scenario), GFDL-B1 (cool/dry future scenario), and MIROC-ESM5 (hot/dry future scenario). The three climate models predicted diverging trends in precipitation amount by mid-century. Relative to baseline values, GFDL-B1 and MIROC-ESM5 predicted a decrease while CNRM-CM5 predicted an increase in precipitation. Despite the difference in projected direction of change among the models (i.e., increasing or decreasing), there was agreement about the locations where the greatest change was expected to occur. Colored areas on the map represent locations within the study region where precipitation is projected to change the most (either increase or decrease, depending on the model) between baseline and mid-century timeframes. For the models that projected a decrease in precipitation (GFDL-B1: -33 mm to -289mm; MIROC-ESM5: -285 mm to -634 mm), the map shows the locations where the projected values are in the 20% quintile, as these are the lowest values. CNRM-CM5 projected an increase in precipitation (+194 mm to +474 mm), and the map shows locations where the projected values are in the 80% quintile, as these are the highest values. The locations with the greatest percent change for all three models (i.e., the overlap) are indicated by the black shading.

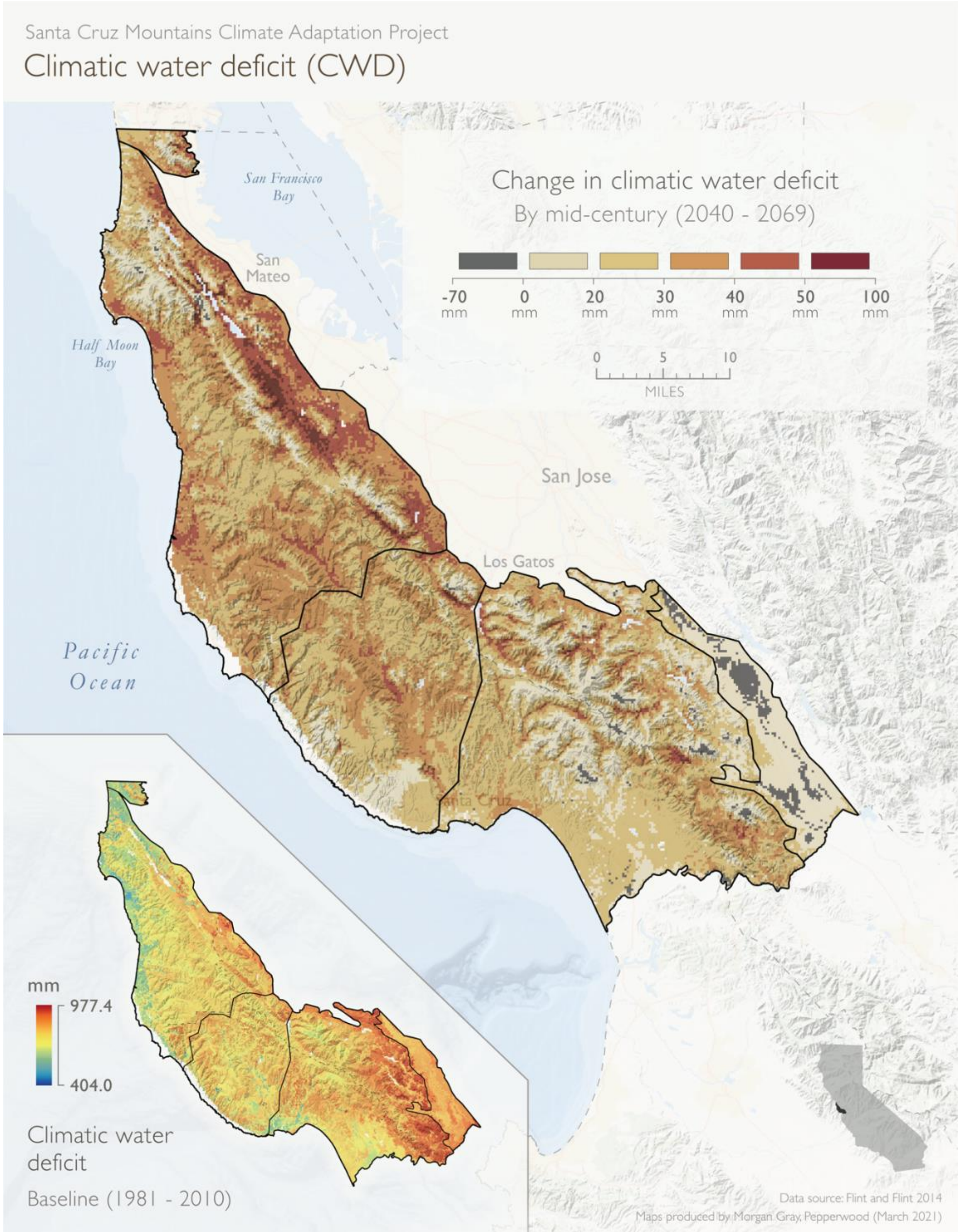


Figure 8. Climatic water deficit (CWD) is an estimate of drought stress on soils and plants, and can be thought of as a surrogate for water demand (i.e., greater deficit values indicate greater drought stress). Within this map, change in CWD (mm) indicates the difference between baseline values (1981-2010; baseline shown in lower left map inset) and mid-century (2040-2069) projections for the average of three global climate models: CNRM-CM5 (warm/wet future scenario), GFDL-B1 (cool/dry future scenario), and MIROC-ESM5 (hot/dry future scenario). Relative to baseline values, CWD is projected to be between +27.7 to +110.6 mm drier by mid-century, representing an average increase of +8% across the study region.

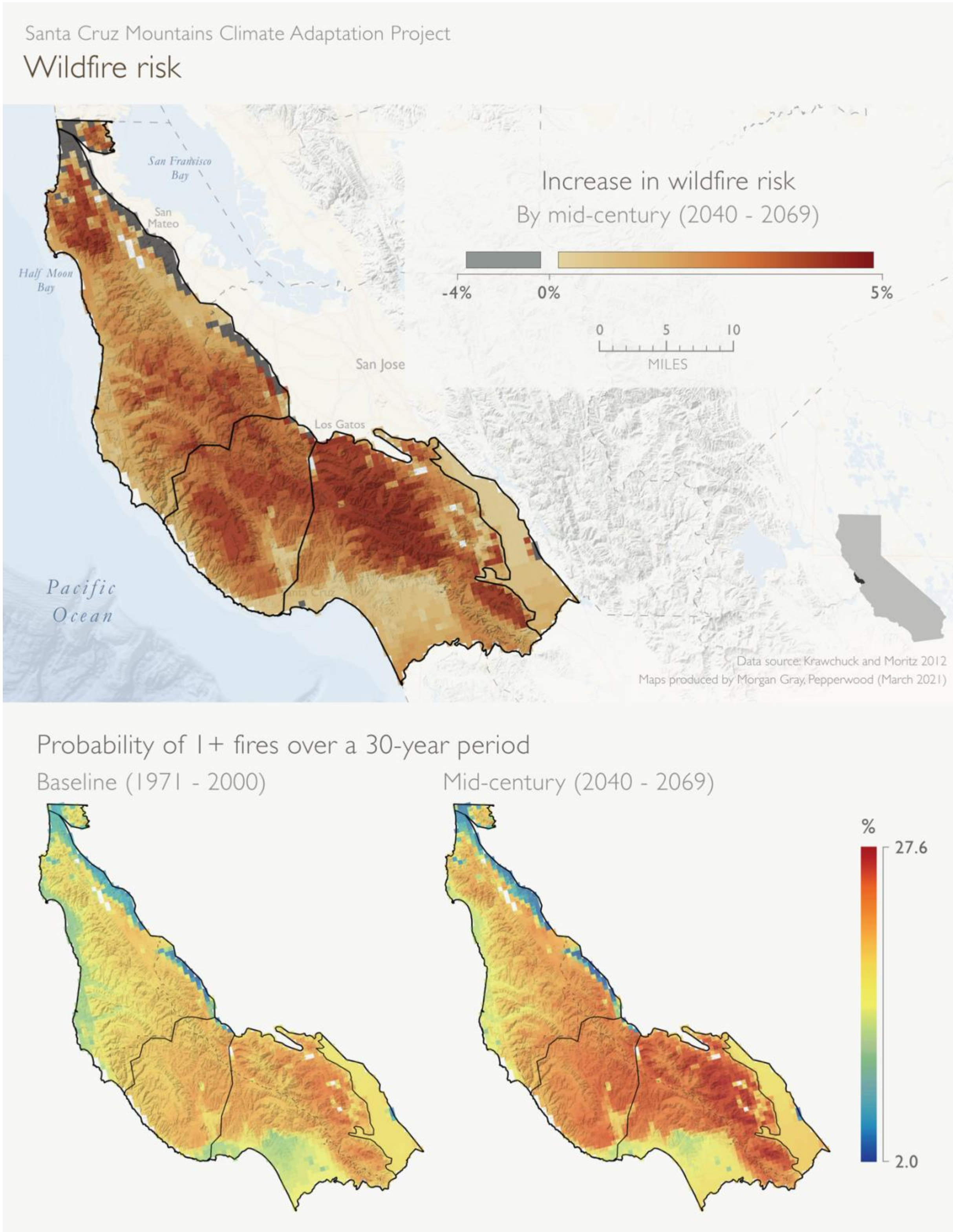


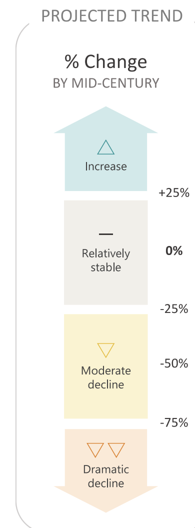
Figure 9. Increase in wildfire risk indicates the difference between baseline values (1971-2000; baseline shown in lower left map) and mid-century (2040-2069) projections for the GFDL-B1 model (cool/dry future scenario). Relative to baseline values, fires are projected to be between +0.5% to +3.1˚C more likely by mid-century, representing an average increase in wildfire risk of +16% across the study region.

Vegetation Changes

Several vegetation associations in the Santa Cruz Mountains study area are projected to increase across all potential future conditions (warm/wet to hot/dry scenarios), including valley oak forest/woodland, coast live oak forest/woodland, and chamise chaparral. Dramatic declines are expected to occur for tanoak forest, black oak forest/woodland, and canyon live oak forest, while more moderate declines are expected for a number of other groups including redwood forest, California bay forest, mixed grasslands, blue oak forest/woodland, mixed chaparral, mixed montane chaparral, and coastal scrub. All other vegetation associations show a more mixed response depending on the future scenario. For instance, both Douglas fir forest and Oregon oak woodlands are projected to increase under warm/wet scenarios and decrease under the hottest/driest scenario. Conversely, blue oak and interior live oak forests and woodlands are expected to decline under wetter scenarios and increase in hot/dry conditions, likely due to their ability to outcompete less drought-tolerant species.

Projected trends in modeled vegetation associations are shown by landscape unit in Figure 10, below.

Vegetation Type	San Francisco	Santa Clara Valley	Santa Cruz Mtns. North	Santa Cruz	Sierra Azul
Chamise chaparral	△	△	△	△	△
Valley oak forest / woodland	△	△	△	△	△
Interior live oak forest / woodland	—	△	△	—	△
Blue oak forest / woodland	△	△	△	—	△
Douglas fir forest	△	—	△	—	—
Coast live oak forest / woodland	▽	▽	△	△	▽
Blue oak-foothill pine woodland	△	—	▽	▽	—
Montane hardwoods	▽	△	▽	—	▽
Redwood forest	—	—	▽	▽	▽
California bay forest	▽▽	△	▽	▽	▽
Grassland	▽	▽	▽	▽	▽
Mixed chaparral	▽	△	▽	▽	▽
Mixed montane chaparral	—	▽	▽	▽	▽
Oregon oak woodland	—	▽	▽▽	—	▽
Tanoak forest	▽	—	—	▽▽	▽▽
Coastal scrub	▽	▽▽	▽	▽	▽
Black oak forest / woodland	▽▽	▽▽	▽▽	▽▽	▽▽
Canyon live oak forest	▽▽	▽▽	▽▽	▽▽	▽▽
All Vegetation Types	▽	▽	▽	▽	▽



Pepperwood Preserve

Figure 10. Average projected trend by mid-century for 18 vegetation associations modeled for this project. Trends represent an average of four possible climate futures (warm/wet, hot/wet, warm/dry, hot/dry), and are presented separately for each of the five landscape units that comprise the Santa Cruz Mountains study area. Within the table, one teal triangle pointing up represents increases in that vegetation association, grey horizontal lines represent relatively stable vegetation, one yellow triangle pointing down represents a moderate decline, and two orange triangles pointing down represents a dramatic decline.

Vulnerability Assessment and Adaptation Planning Results: Overall Trends

Vulnerability Assessment Summary

The vulnerabilities for all habitats and species/species groups in the Santa Cruz Mountains ecoregion are summarized in Figures 11–12. These figures are plotted by potential impact (average of sensitivity and exposure) and adaptive capacity. Thus, habitats or species appearing towards the upper-left corner were evaluated as less vulnerable (e.g., those with low potential impact and high adaptive capacity) than those appearing towards the lower-right side of the figure (e.g., those with high potential impact and low adaptive capacity).

The results and trends presented are comparable only within the habitats and species/species groups considered here, and are not standardized in any way to other climate change vulnerability assessments. The information supporting these results is available in the individual vulnerability assessment summaries,[3] and should be referred to before using the overall results and trends in decision-making.

Habitats

Habitats were roughly split between ratings of moderate and high vulnerability (Table 1; Figure 11). Overall, coastal dunes were ranked as the most vulnerable, with high sensitivity and exposure to both climate and non-climate stressors and low adaptive capacity. Sea level rise, changes in precipitation amount and timing, and increased storm events were selected as significant climate and climate-driven stressors for coastal dunes. Significant non-climate stressors identified included invasive species, roads and trails, recreation, and residential and commercial development. The low adaptive capacity ranking was driven by low geographic extent, integrity, and continuity as well as a low ability to resist and/or recover from the impacts of stressors.

Table 1. Overall vulnerabilities for habitats.

Habitat	Overall Vulnerability
Coastal Dunes	High
Freshwater Marshes, Wetlands, Ponds	High
Oak Woodlands	High
Rivers, Streams, Floodplains	High
Seeps & Springs	High

Habitat	Overall Vulnerability
Chaparral Shrublands	Moderate
Coastal Redwood Forests	Moderate
Coastal Scrub	Moderate
Mixed Evergreen/ Montane Hardwood Forests	Moderate
Mixed Grasslands	Moderate
Wet Meadows & Prairies	Moderate

[3] Available at http://ecoadapt.org/programs/awareness-to-action/santa-cruz-mountains

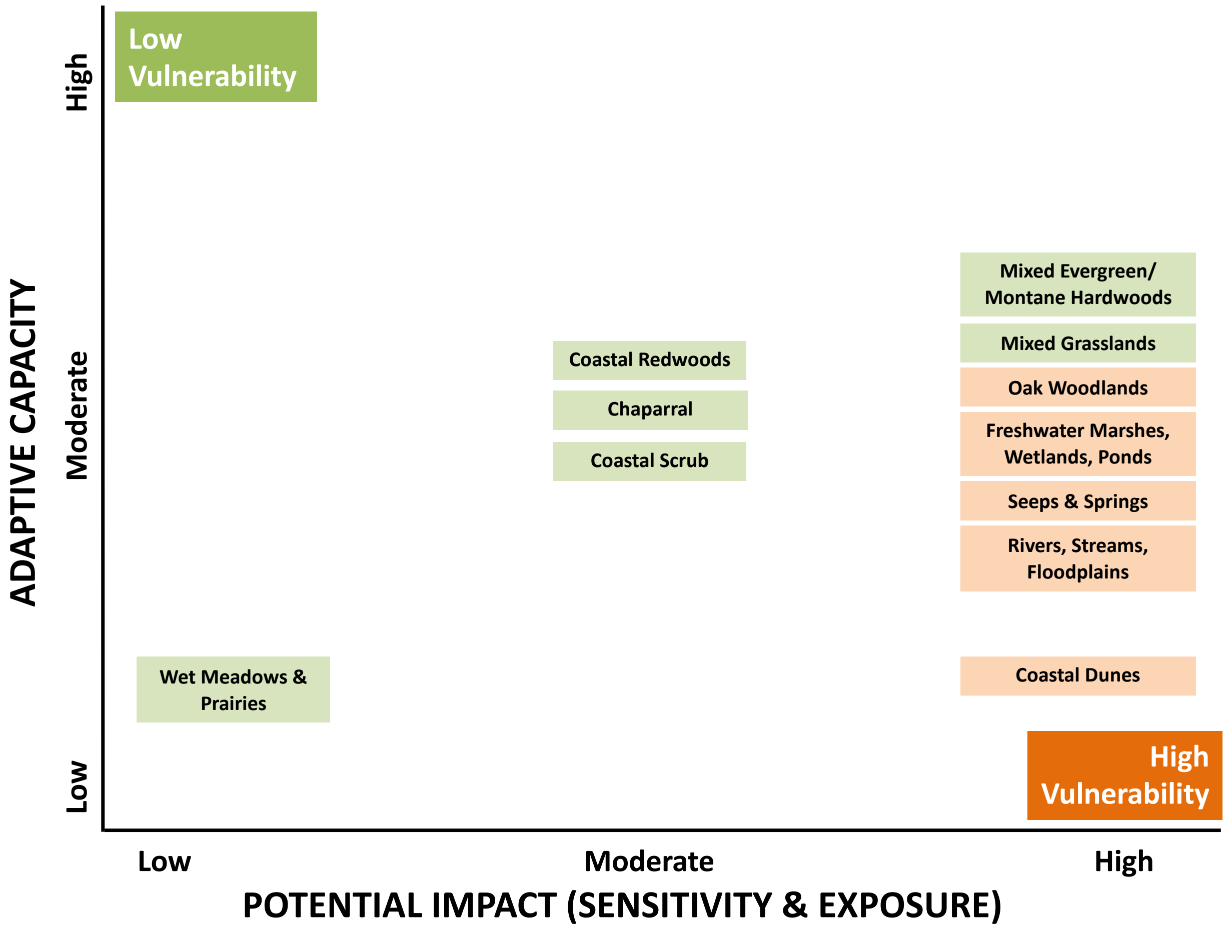


Figure 11. Overall vulnerabilities of 11 habitats based on sensitivity, exposure, and adaptive capacity rankings. Overall vulnerability increases with increasing sensitivity and exposure (i.e., potential impact) and decreasing adaptive capacity. Habitats listed towards the upper-left of the figure were assessed as less vulnerable than those listed towards the lower-right. Color code: Moderate vulnerability (light green), High vulnerability (light orange).

Although oak woodlands; seeps and springs; rivers, streams, and floodplains; and freshwater marshes, wetlands, and ponds were all evaluated as having overall high vulnerability, they may be somewhat less vulnerable compared with coastal dunes since they received a moderate adaptive capacity ranking. Changes in the amount and timing of precipitation, increased drought, and increased wildfire risk were all identified as significant climate and climate-driven stressors for these habitats. Oak woodlands were evaluated as being moderately impacted by current non-climate stressors such as residential and commercial development, roads and highways, conventional livestock grazing, fire exclusion/suppression, and invasive species. Seeps and springs, rivers and streams, and freshwater marshes and wetlands were all evaluated as being highly impacted by current non-climate stressors including residential and commercial development, dams and water diversions, and conventional livestock grazing. Each of these habitats varied in their individual adaptive capacity rankings, with no habitat receiving moderate rankings across the board. For example, oak woodlands were evaluated as having low habitat diversity but high management potential. Conversely, seeps and springs were evaluated as having low extent and integrity and low management potential, but high habitat diversity. It will be important for managers to pay attention to the varying rankings of individual adaptive capacity elements as they identify adaptation strategies for each habitat. For example, adaptation strategies aimed at improving public education and outreach about the value and importance of seeps and springs may be critical to gaining support for on-the-ground restoration activities. Similarly, freshwater marshes, wetlands, and ponds were evaluated as having low structural and functional integrity, highlighting the need for adaptation strategies aimed at improving habitat condition.

Coastal wet meadows and prairies received an overall moderate vulnerability ranking, with low sensitivity but moderate exposure to climate and climate-driven stressors, moderate sensitivity and exposure to current non-climate stressors, and low adaptive capacity. Current non-climate stressors, including residential and commercial development, invasive species, conventional livestock grazing, and agriculture appear to play more of a role in driving vulnerability of these habitats compared with climate stressors. These habitats also received a low structural/functional integrity ranking, further emphasizing the need for managers to focus on ways to reduce the impacts of current stressors.

Species/Species Groups

The majority of the species/species groups assessed were ranked as having overall high vulnerability (Table 2; Figure 12). Perhaps most significant is that all species/species groups, aside from coyote brush (generally considered a "problematic" species), were evaluated as having high sensitivity and exposure to climate and non-climate stressors. Adaptive capacity rankings differed the most among species, driving differences in overall vulnerability. For example, wide-ranging mammals, which includes mountain lions, coyote, bobcat, gray fox, and mule deer, received a high adaptive capacity ranking, which dropped their overall vulnerability to moderate even though sensitivity and exposure was ranked as high. Coyote brush was the only focal resource to receive a low vulnerability ranking, with few climate and non-climate sensitivities and high adaptive capacity.

Table 2. Overall vulnerabilities of species/species groups.

Species/Species Group	Overall Vulnerability
Badger	High
Bats	High
Burrowing Owl	High
Marbled Murrelet	High
Salmonids	High
San Francisco Garter Snake & California Red-Legged Frog	High

Species/Species Group	Overall Vulnerability
Butterflies	Moderate
Coyote Brush	Moderate
Wide-Ranging Mammals	Moderate

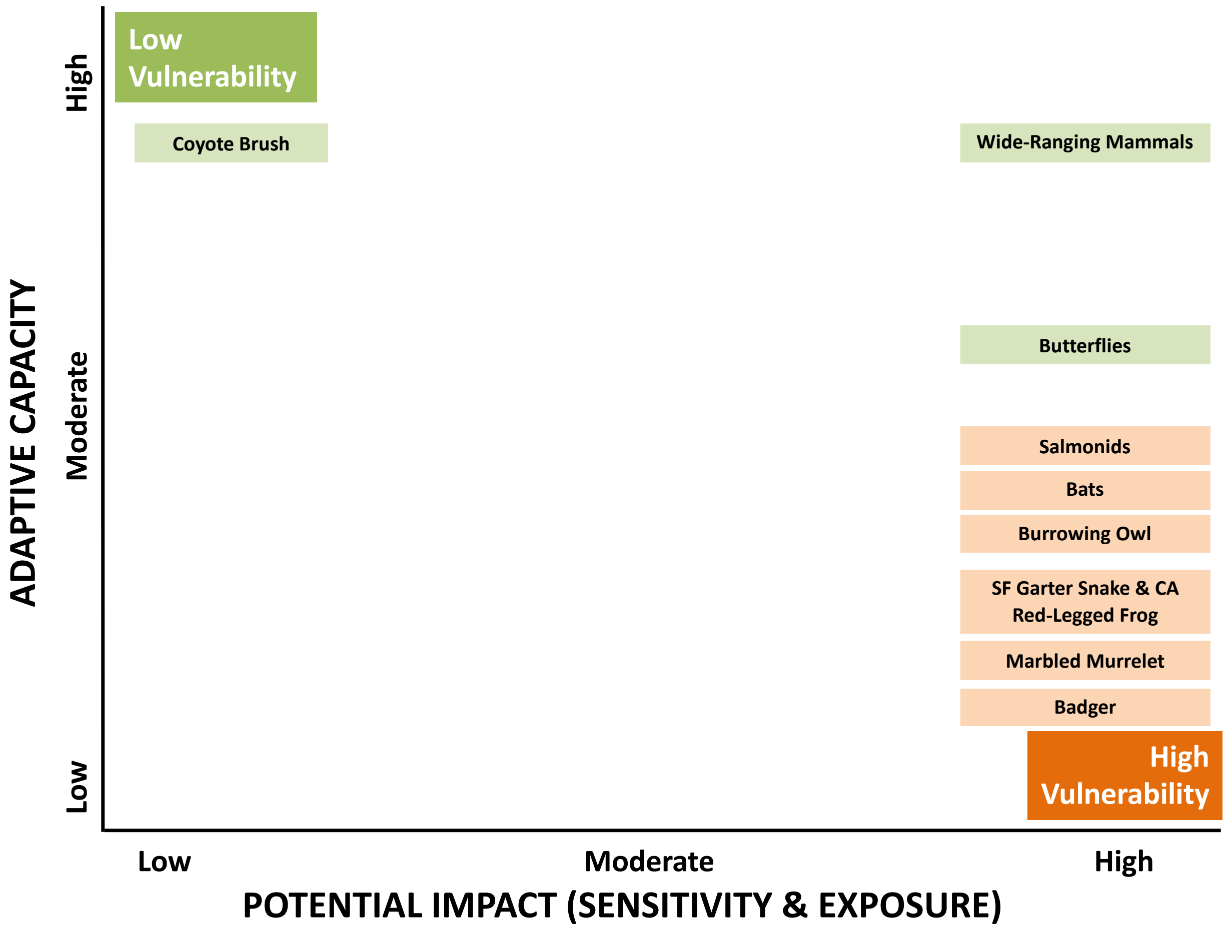


Figure 12. Overall vulnerabilities of nine species/species groups based on sensitivity, exposure, and adaptive capacity rankings. Overall vulnerability increases with increasing sensitivity and exposure (i.e., potential impact) and decreasing adaptive capacity. Species/species groups listed towards the upper-left of the figure were assessed as less vulnerable than those listed towards the lower-right. Color code: Moderate vulnerability (light green), High vulnerability (light orange).

While six species/species groups received overall high vulnerability rankings, Figure 12 demonstrates the importance of plotting potential impact and adaptive capacity. For example, badger, marbled murrelet, San Francisco garter snake, and California red-legged frog received high sensitivity and exposure and low adaptive capacity rankings, while were bats, burrowing owl, and salmonids received high sensitivity and exposure and moderate adaptive capacity rankings. Because bats, burrowing owl, and salmonids were evaluated as having moderate adaptive capacity, managers could focus on actions that reduce sensitivity and exposure, as those factors appear to be driving their overall high vulnerability ranking.

Adaptation Summary

Workshop participants were asked to identify adaptation strategies and actions that reduce vulnerabilities and/or increase resilience of the resources they manage. An *adaptation strategy* is a broad or general statement of how to reduce vulnerabilities or increase resilience, while an *adaptation action* is a specific activity that takes into account site and ecological conditions to facilitate progress towards achieving an adaptation strategy. Participants were encouraged to identify current activities to continue as well as new actions to consider implementing in light of climate vulnerablities (Table 3).

Several themes emerged from across habitats, such as:

- Restoring and protecting habitat structure and function;
- Removing invasive species and implementing early detection rapid response to catch invasions early;
- Identifying and protecting potential climate refugia and corridors;
- Implementing prescribed burns and improving efforts to coordinate and streamline permitting and burn timing;
- Increasing research and monitoring on climate impacts on habitats and species as well as management action effectiveness; and
- Increasing public education and outreach to improve awareness about the importance of habitats and the management actions necessary to maintain ecosystem services.

Table 3. Adaptation strategies and actions grouped by habitat type.

AQUATIC HABITATS (RIVERS, STREAMS, FLOODPLAINS, PONDS, WETLANDS)
Adaptation Strategies and Actions *Current activities to continue* • Improve water storage • Improve water conservation and efficiency • Prioritize infrastructure upgrades and retrofits in highly erosive areas • Restore natural sediment transport processes (e.g., by removing instream structures) • Modify water rights (e.g., apply for new appropriated rights for winter water; add beneficial use to water rights for instream flows) • Restore streams and floodplains (e.g., install large woody debris to stabilize banks and trap sediment; widen channel; floodplain benching) • Improve stream habitat by building up the streambed and water table and creating pools • Improve access to habitats by removing barriers to aquatic organism passage • Consider transporting fish to other aquatic habitats/areas if current locations dry up or flows are too low • Implement thinning and other vegetation management in riparian habitats • Increase monitoring and research on bats *New activities to consider* • Educate landowners about climate changes (e.g., increased storms and extreme precipitation events) and the impacts to streams as well as activities that secure water availability and reliability for landowners while also providing fish habitat • Create regional watershed maps of landownership, development, land use, and water use to better understand impacts of upstream actions on downstream areas • Improve/enhance fish passage during dry years • Increase storage potential for water users so they are less reliant on instream flows during dry years • Explore opportunities for flow augmentation

- Identify opportunities and/or ideas for how to keep water in the system (e.g., how to improve groundwater recharge)
- Remove water-hogging vegetation (e.g., eucalyptus)
- Identify cool, north-facing shaded areas to improve condition of riparian redwood forests
- Identify opportunities for diversifying water supply
- Encourage the creation of irrigation districts to improve strategic management of where water is coming from
- Use climatic water deficit analysis to identify what agricultural crops may or may not be best depending on water availability
- Utilize climate change modeling when designing pond inlet and outlet features, and design for increased pond capacity during flood events to reduce the risk of pond failure
- Improve understanding of where aquatic features (e.g., ponds, wetlands) are on the landscape
- Create a ranking of ponds and wetlands (e.g., prioritized based on species of special concern, drought risk, "old growth" ponds, etc.)
- Identify which ponds and wetlands are most at risk during periods of drought/low precipitation
- Improve soil health on rangelands to retain water

OAK WOODLANDS

Adaptation Strategies and Actions

Current activities to continue

- Remove invasive species, especially those that create ladder fuels and/or are likely to carry fire, and release allelopathic chemicals that retard regeneration
- Remove encroaching Douglas-fir
- Work with private landowners and neighbors to implement activities that support oaks
- Fence oak seedlings to limit browsing and allow survival to adulthood
- Identify individual trees that are healthy and thriving and collect and plant seeds
- Plant shrubs that can serve as nurse plants for oak seedlings
- Leave and/or place nursery logs
- Monitor for impacts from sudden oak death
- Work with experts to test the efficacy of sudden oak death mitigation measures

New activities to consider

- Identify microclimate refugia and prioritize for protection
- Use prescribed fire to address fuel loads, moisture stress, and insects and disease in oak woodlands
- Research acorn storage and germination and find ways to improve viability of stored seeds
- Determine where to plant better-adapted genotypes
- Investigate how to collect seed during "boom events" to have for future stock (e.g., when dry conditions decrease acorn production)
- Capitalize on opportunities presented by recent fires that helped reset fire regimes (e.g., restore frequent fire on the landscape through Indigenous burning and increased use of prescribed fire)

COASTAL REDWOOD FORESTS

Adaptation Strategies and Actions

Current activities to continue

- Thin understory to release larger trees, promote growth, improve forest health, and increase fog capture
- Increase use of prescribed fire and thinning

- Expand land protection efforts (e.g., fees, easements), and consider targeting relatively more degraded areas
- Restore topographical conditions (e.g., decommission old logging areas) to improve watershed health
- Coordinate work with utilities to repair, replace, or remove dangerous infrastructure located in redwood forests
- Collaborate with utilities on how to create fire breaks to minimize damage to forest integrity
- Work with private landowners to protect redwoods and improve stewardship and sustainable practices
- Work with logging industry to promote better stewardship and expand model of forestry management to larger enterprises
- Increase invasive species management efforts, including post-fire early detection rapid response
- Monitor the impact of increased carbon dioxide (e.g., increased tree growth)
- Implement carbon-smart forestry
- Implement old growth restoration strategies in second growth forests
- Increase public education and outreach on the importance of prescribed burns and sustainable timber management
- Improve connectivity among existing redwood forests to facilitate species migration
- Increase water retention and infiltration on land and in streams
- Reduce the number of and/or shrink existing roads and trails
- Increase monitoring of management action effectiveness and impacts over time

New activities to consider

- Create shaded fuel breaks and reduce understory fuels
- Consider increased planting of species like Douglas-fir that can provide similar habitat
- Consider thinning large enough areas to let light in to allow for succession
- Target protection and restoration efforts in drainages that have moisture from riparian areas and are near waterways that host salmonids
- Introduce naturally occurring understory species that retain more soil moisture (e.g., huckleberry or forbs)
- Encourage policy changes at county level and within agencies (e.g., California Coastal Commission) to require more sustainable practices
- Test out genomic mapping of redwoods to find drought tolerant individuals for cloning
- Conduct annual cone crop surveys and targeted seed collection for seed banking and outplanting
- Identify and monitor potential refugia
- Consider irrigating high value areas
- Explore possible changes to land use planning in the wildland-urban interface, including reducing homes and special considerations/requirements for rebuilding
- Explore opportunities to open post-fire areas to the public and increase public education and outreach in those areas to improve awareness and stewardship
- Monitor for and target removal of California bay trees infected with sudden oak death
- Experiment with removing tanoaks and Douglas-fir at different intensities, with the goal of restoring a balance and diversity of tree species
- Increase targeted land acquisition, focusing on potential refugia, corridors, and currently unprotected old growth forests
- Increase collaboration with state parks, including expanding research, treatments, and public education
- Plant more drought-tolerant and/or fire-resistant species and genomes (e.g., genetically engineer more drought-tolerant and fire-resistant species)

COASTAL AND MIXED GRASSLANDS

Adaptation Strategies and Actions

Current activities to continue

- Implement low-intensity prescribed burning, including finding ways to increase the pace and scale and/or frequency
- Implement targeted herbivory (e.g., goats and conservation grazing practices) for fuels management
- Decommission roads in areas not used for management activities
- Implement conservation grazing for managing coyote brush encroachment
- Increase water availability for conservation grazing (e.g., drilling wells, developing springs) to allow expansion of grazing into areas with no water
- Increase early detection rapid response to catch invasions more quickly (e.g., by increasing engagement with volunteers and research institutions that can contribute to invasive removal efforts)
- Increase rare species management (e.g., burrowing owls)
- Restore native plants (e.g., seeding, use prescribed fire for germination), including planting tarweed (a native, fire-resistant plant)
- Manage stormwater and gully erosion
- Maintain existing grassland habitats
- Improve connectivity between higher-quality habitat patches; consider targeting areas that are highly degraded/invaded that can serve as corridors
- Test out different management strategies over the long-term and rotate through to increase native species diversity (e.g., rotational grazing, intermittent mowing, no action, etc.)
- Inventory currently degraded wet meadow sites and actively plant to increase species diversity
- Identify opportunities to integrate monitoring of groundwater fluctuations over time
- Increase monitoring of grassland bird species to determine if species abundance, diversity, and composition are changing
- Identify and map wet meadows and wetter areas within grassland habitats as well as areas more impacted by conventional grazing and other stressors
- Increase monitoring of sites with perennial grass stands (e.g., high abundance of top three species)
- Improve regional collaboration and coordination with regard to data sharing and monitoring

New activities to consider

- Re-route roads and trails, consider decommissioning grassland trails that are more vulnerable to erosion, and limit introduction of new trails
- Apply compost to build topsoil
- Remove barriers to connectivity
- Increase education and outreach to enhance appreciation of grasslands and public support for management activities such as prescribed fire, coyote brush removal, conservation grazing, and habitat protection
- Improve efforts to coordinate and streamline burn permits and timing
- Manage recreation impacts on grasslands, including trail planning to reduce impacts
- Increase monitoring efforts to study impacts of recreation on grasslands
- Increase public education and outreach and evaluate/revise policies around wildlife conflicts in developed areas
- Capitalize on opportunities presented by recent fires, such as bringing back Indigenous burning and restoring fire on the landscape
- Develop post-disturbance event monitoring plan

- Increase seed banking efforts, looking at the right composition of species based on projected changes
- Model different future hydrologic scenarios and impacts on ponds and identify corresponding management actions
- Test out intermittent disturbance regimes in grasslands to maintain desired species and maximize heterogeneity in the system
- Identify and monitor places of high and moderate quality habitat and prioritize for invasive species management
- Evaluate current and potential new invasive species vulnerability/resilience to different climate scenarios to inform Integrated Pest Management (IPM)

Concluding Thoughts

The climate change vulnerability assessment and adaptation planning process and results from the Santa Cruz Mountains Climate Adaptation Project improves understanding of how habitats and species in the region are vulnerable to changing climate conditions and assists natural resource managers, conservation planners, and others in identifying, prioritizing, and implementing adaptation strategies designed to minimize vulnerabilities and/or increase resilience of natural resources. This information can be integrated into management and conservation plans, programs, and projects. As practitioners work toward this integration, it is important to monitor and evaluate climate impacts as well as the implemented adaptation strategies to determine if the strategies are having their intended effect and identify when or where changes might be needed. Monitoring and evaluation plans can be fairly simple – identify a desired outcome for each strategy, a corresponding parameter to track progress and the method to do so, a trigger or threshold that signals diversion from the desired outcome, and possible alternative adaptation strategies to pursue if that threshold is crossed.

Finally, keep in mind that climate adaptation is an iterative process and new research and modeling on projected climate changes and impacts is regularly released. Thus, it is important that managers and planners revisit and/or revise vulnerability assessments and adaptation strategies on a regular basis (e.g., every 5-10 years).

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Appendix A. Vulnerability Assessment Summaries

Habitats

1. Chaparral shrublands
2. Coastal dunes, wet meadows, and prairies
3. Coastal redwood forests
4. Coastal scrub
5. Freshwater marshes, wetlands, and ponds
6. Mixed evergreen/montane hardwood forests
7. Mixed grasslands
8. Oak woodlands
9. Rivers, streams, and floodplains
10. Seeps and springs

Species

1. American badger and western burrowing owl
2. Bats
3. Butterflies
4. California red-legged frog and San Francisco garter snake
5. Coyote brush
6. Marbled murrelet
7. Salamanders
8. Salmonids
9. Wide-ranging mammals

Appendix B. Adaptation Planning Tables

Habitat Connectivity

Possible adaptation strategies and actions identified included:

- Restore historical and/or novel ecosystems that have been completely lost and/or fragmented (e.g., floodplains)
- Limit introduction of new trails and hikers to important habitats (e.g., corridors, denning and rearing, Conservation Management Units)
- Prevent development in vulnerable areas that may cut off critical corridors
- Remove invasive species
- Create large wildlife corridor(s) across Highway 17 for larger animals and supplement with micro-corridors
- Decommission power lines that are no longer needed and transition to solar, where possible
- Remove interior-located structures that are harder to maintain (i.e., maintain developed structures in more developed areas)
- Reduce impact of cattle (e.g., create more forage opportunity for wildlife, improve access to natural and artificial water sources)
- Implement assisted migration of species to create suitable habitat as the climate changes[§]
- Create buffer zones/stepping stones (e.g., large patches that provide multiple benefits for wildlife) in corridors between sensitive habitats[§]
- Improve knowledge about existing native and invasive species and their migration ability and patterns to facilitate native species connectivity[§]
- Improve understanding of where aquatic features (e.g., ponds, wetlands) are on new land acquisitions[§]
- Identify which ponds are most at risk during periods of drought/low precipitation as well as from flood events[§]
- Create a ranking of ponds and wetlands (e.g., prioritized based on species of special concern, drought risk, "old growth" ponds, etc.) in order to capture a wider variation of pond types/health/utility in the portfolio[§]

Following a general brainstorming session to identify possible adaptation strategies and actions, workshop participants identified two overarching strategies for which to develop more detailed implementation plans:

1. Maintain/improve spatial distribution of terrestrial and aquatic corridors
2. Reduce non-climate stressors that may exacerbate issues for habitat connectivity in the region

[§] Indicates a possible new or emerging strategy

Adaptation strategy #1: Maintain/improve spatial distribution of terrestrial and aquatic corridors			
	Action (1)	**Action (2)**	**Action (3)**
Adaptation actions	Create buffer zones/stepping stones (e.g., large patches that provide multiple benefits for wildlife) in corridors between sensitive habitats	Reduce impact of cattle (e.g., rotation to create more forage opportunity for wildlife, improve access to natural and artificial water sources)	Implement assisted migration of species to create suitable habitat as the climate changes
Implementation feasibility	Moderate (inside preserve boundaries easier than outside)		Low to Moderate
Effectiveness	Moderate to High		Low to Moderate
Timeline	Near (< 5 years): Aquatic Mid (5 – 10 years): Terrestrial		Long (> 10 years)
Where/how to implement	Integrate into plans early on to boost effectiveness Look at climate vulnerability maps and compare with species' maps to prioritize areas across the landscape Prioritize buffer zones in ungrazed areas Determine acceptable sites of change		Prioritize reintroduction of species locally to improve genetic banks Implement land acquisition and assisted migration as a future step with more certainty in climate projections/impacts
Co-benefits & challenges	*Challenges*: Cattle access to water; how to limit risk of invasions	*Challenges*: Grazing agreements	*Challenges*: Politically difficult
Existing or needed management mechanisms	Need to improve monitoring to track effectiveness	No answer	No answer

Adaptation strategy #2: Reduce non-climate stressors that may exacerbate issues for habitat connectivity in the region			
	Action (1)	**Action (2)**	**Action (3)**
Adaptation actions	Limit introduction of new trails and hikers to important habitats (e.g., corridors, denning and rearing, Conservation Management Units)	Prevent development (e.g., trails, parking lots) in vulnerable areas *intra-preserve* that may cut off critical corridors	Improve education and communication on public trails (e.g., maintaining distance from habitat, importance for wildlife)
Implementation feasibility	High	High	High
Effectiveness	Moderate	High	Low to Moderate
Timeline	Near (< 5 years) to Mid (5 – 10 years)	As preserve plans are developed	Near (< 5 years)
Where/how to implement	In Midpeninsula Regional Open Space District Action Plan, add action to identify regional wildlife corridors		Create brochures, signage on site, and interpretive panels, and post on social media Lead talks and docent hikes Identify new talking points and find ways to integrate climate change by targeting people's interests (e.g., habitat, wildfire smoke, recreation, etc.)
Co-benefits & challenges	*Challenge*: Species keep getting listed	*Challenge*: ADA rules (access to trails may conflict with wildlife movement/corridors)	*Challenges*: Requires succinct messaging, attention, and behavior change of individuals/collective public; public perception of loss of access for recreation
Existing or needed management mechanisms		Planning processes	

Coastal and Mixed Grasslands

Possible adaptation strategies and actions for coastal and mixed grasslands and associated species identified included:

- **Increase monitoring of grassland bird species to determine if species abundance, diversity, and composition are changing**[**]
- Maintain existing grassland habitats
- Increase monitoring and research on bats
- Improve connectivity between higher-quality habitat patches; consider targeting areas that are highly degraded/invaded that can serve as corridors
- Test out different management strategies over the long-term and rotate through to increase native species diversity (e.g., rotational grazing, intermittent mowing, no action, etc.)
- Inventory currently degraded wet meadow sites and actively plant to increase species diversity
- Identify opportunities to integrate monitoring of groundwater fluctuations over time
- Increase monitoring of sites with perennial grass stands (e.g., high abundance of top three species)
- Improve regional collaboration and coordination with regard to data sharing and monitoring
- **Identify and map wet meadows and wetter areas within grassland habitats as well as areas more impacted by conventional grazing and other stressors**
- Model different future hydrologic scenarios and impacts on ponds and identify corresponding management actions[††]
- Increase seed banking efforts, looking at the right composition of species based on projected changes[††]
- Evaluate current and potential new invasive species vulnerability/resilience to different climate scenarios to inform Integrated Pest Management (IPM)[††]
- Identify and monitor places of high and moderate quality habitat and prioritize for invasive species management[††]
- Test out intermittent disturbance regimes in grasslands to maintain desired species and maximize heterogeneity in the system[††]
- Develop post-disturbance event monitoring plan[††]

Following a general brainstorming session to identify possible adaptation strategies and actions, workshop participants selected two strategies (in **bold** above) to develop out more detailed implementation plans.

[**] Could potentially link with annual grazing monitoring and/or work with Point Blue to develop a more coordinated bird monitoring framework for the region

[††] Indicates a possible new or emerging strategy

Adaptation strategy #1: Increase monitoring of grassland bird species to determine if species abundance, diversity, and composition are changing			
	Action (1)	**Action (2)**	**Action (3)**
Adaptation actions	Install artificial structures (e.g., bird boxes) and take advantage of existing natural structures (e.g., snags)	Examine species declines regionally vs. site-specific, what habitat changes have occurred, and what other species they are competing against and how they are performing	Develop corresponding management responses that address factors driving declines
Where/how to implement		Consult Audubon report on climate change and bird species Consult/coordinate with neighboring agencies that are also monitoring changes, and consider convening an annual meeting of monitoring partners	Identify existing conservation management plans as well as current management approaches to see how they can be integrated into responses

Adaptation strategy #2: Identify and map wet meadows and wetter areas within grassland habitats as well as areas more impacted by conventional grazing and other stressors			
	Action (1)	**Action (2)**	**Action (3)**
Adaptation actions	Use maps to identify which areas to focus on first and corresponding actions to implement, and link these areas across the landscape/watershed	Reintroduce beaver	Implement long-term hydrologic monitoring gauges

Oak Woodlands

Possible adaptation strategies and actions identified included:

- Remove invasive species, especially those that create ladder fuels and/or are likely to carry fire, and release allelopathic chemicals that retard regeneration
- Remove encroaching Douglas-fir, particularly around coast live oak, black oak, and interior live oak
- Work with private landowners and neighbors to implement activities that support oaks
- Fence oak seedlings to limit browsing and allow survival to adulthood
- Identify individual trees that are healthy and thriving and collect and plant seeds
- Plant shrubs that can serve as nurse plants for oak seedlings
- Leave and/or place nursery logs
- Identify microclimate refugia and prioritize for protection[‡‡]
- Use prescribed fire to address fuel loads, moisture stress, and insects and disease in oak woodlands[‡‡]
- Research acorn storage and germination and find ways to improve viability of stored seeds[‡‡]
- Determine where to plant better-adapted genotypes[‡‡]
- Investigate how to collect seed during "boom events" to have for future stock (e.g., when dry conditions decrease acorn production)[‡‡]

Following a general brainstorming session to identify possible adaptation strategies and actions, workshop participants identified two overarching strategies for which to develop more detailed implementation plans:

1. Increase oak recruitment
2. Reduce the impacts of wildfire, insects, and disease on oaks

[‡‡] Indicates a possible new or emerging strategy

Adaptation strategy #1:

Increase oak recruitment

	Action (1)	Additional actions
Adaptation actions	Investigate how to collect seed during “boom events” to have for future stock (e.g., when dry conditions decrease acorn production) Research acorn storage and germination and find ways to improve viability of stored seeds	• Fence oak seedlings to limit browsing and allow survival to adulthood • Identify individual trees that are healthy and thriving and collect and plant seeds • Plant shrubs that can serve as nurse plants for oak seedlings • Determine where to plant better-adapted genotypes • Leave and/or place nursery logs
Implementation feasibility	Moderate	
Effectiveness	Moderate to High (very effective for post-fire seeding)	
Timeline	Mid (5 – 10 years)	
Where/how to implement	Identify locations with large numbers of oaks to make collection easier Monitor weather events Create maps of historic and projected black oak range to determine where seeds should be planted Identify where oaks are now and locate parent stock and document corresponding climate conditions Identify any target individuals that have already demonstrated resilience to fire and/or disease and collect seeds (include broader geographic area than just Santa Cruz Mountains)	
Co-benefits & challenges	*Co-benefits*: Insect and bird diversity; lending research to scientific community and aiding future restoration projects; allow more strategic selection of plants for site restoration; knowledge/experience would help support work with other species and climate change *Challenges*: Grasslands in decline; potential financial losses due to Sudden Oak Death; may be no feasible way to store acorns for an extended period of	

	time; current lack of capacity (funding, staff time) for research; issues with genetic integrity and possible negative consequences of bringing in newer genetic material from outside geographic area	
Existing or needed management mechanisms	Need partners to examine seed genetics (UC Berkeley) Existing resource management policies that support this action Need Board to back this as a priority for funding and staff time Need acorn collecting field crew (have existing contract with nursery that does acorn collection; utilize volunteers)	

Adaptation strategy #2: Reduce the impacts of wildfire, insects, and disease on oaks	
	Action (1)
Adaptation actions	Use prescribed fire to address fuel loads, moisture stress, and insects and disease in oak woodlands
Implementation feasibility	Moderate to High
Effectiveness	Moderate to High (unsure of effectiveness for addressing Sudden Oak Death)
Timeline	Near (<5 years)
Where/how to implement	Currently developing burn unit plans (Russian Ridge grasslands will be first, followed by oak woodlands, redwoods, and chaparral) Work with Native American partners to support cultural burning Research appropriate fire regimes (frequency, intensity) for each species Coordinate with Air Quality Control Board and CAL FIRE (lead) Technical training for staff that will undertake burns
Co-benefits & challenges	*Co-benefits*: Supports tribal management practices; training experience for suppression activities; recognition as regional authority/leader; fire-dependent ecosystems; fuels management; limits encroachment and restores natural disturbance regimes

	Challenges: WUI (perceived vs. actual risk); public opinion (i.e., people who believe prescribed fire is not a valid management tool); air quality; limited burn locations due to fire protection districts; weather limits burn window and access/topography can limit ability to implement
Existing or needed management mechanisms	Need training for staff (e.g., Prescribed Fire Training Exchanges – TREX) Permitting, CEQA, reliance on CAL FIRE (ability to burn) Need a union MOA (e.g., negotiations to change job descriptions) Public relations campaign

Redwood Forests

Possible adaptation strategies and actions identified included:

- Thin understory to release larger trees, promote growth, improve forest health, and increase fog capture (by big trees)
- Increase use of prescribed fire (avoid riparian areas) and thinning
- Expand land protection efforts (e.g., fees, easements), and consider targeting relatively more degraded areas
- Restore topographical conditions (e.g., decommission old logging areas) to improve watershed health
- Continue to and/or increase pace and scale of work with utilities to repair, replace, or remove dangerous infrastructure located in redwood forests
- Collaborate with utilities on how to create fire breaks to minimize damage to forest integrity
- Work with private landowners with protect redwoods and improve stewardship and sustainable practices
- Work with logging industry to promote better stewardship (e.g., Big Creek, Red Tree) and expand model of forestry management to larger enterprises
- Coordinate with utilities to repair, replace, or remove dangerous infrastructure located in redwood forests
- **Create shaded fuel breaks and reduce understory fuels (e.g., ladder fuels and debris)** [§§]
- **Introduce naturally occurring understory species that retain more soil moisture (e.g., huckleberry or forbs)**[§§]
- Encourage policy changes at county level and within agencies (e.g., California Coastal Commission) to require more sustainable practices[§§]
- Target protection and restoration efforts in drainages that have moisture from riparian areas and are near waterways that host salmonids[§§]
- Increase planting of species like Douglas-fir that can provide similar habitat[§§]
- Consider thinning large enough areas to let light in to allow for succession[§§]

Following a general brainstorming session to identify possible adaptation strategies and actions, workshop participants selected two strategies (in **bold** above) to develop out more detailed implementation plans.

[§§] Indicates a possible new or emerging strategy

Adaptation strategy #1: Create shaded fuels breaks and reduce understory fuels to reduce the spread of wildfire in coastal redwood forests			
	Action (1)	**Action (2)**	**Action (3)**
Adaptation actions	Identify and map vulnerable and key areas to locate shaded fuel breaks	Develop criteria (e.g., easiest to implement, largest impact, easiest to maintain over time) and prioritize areas to determine where to implement shaded fuel breaks first	In priority areas, conduct thinning and follow up prescribed fire; maintain over time
Implementation feasibility	High	High	High/Moderate (dependent on political will, costs)
Effectiveness	High	Moderate	Moderate
Timeline	Near (< 5 years)	Near (< 5 years)	Mid (5 – 10 years)
Where/how to implement	Focus first on existing roads, trails, preserve boundaries, and interfaces with existing communities (i.e., WUI)	Focus first on existing roads, trails, preserve boundaries, and interfaces with existing communities (i.e., WUI)	Remove ladder fuels and trees with smaller diameter; follow up with prescribed fire and maintain over time Work with internal crews, local fire agencies (State Parks and CAL FIRE), and Conservation Corps for staffing
Co-benefits & challenges	*Co-benefit*: Relationship-building with other agencies and partners	*Challenges*: Potential conflicting priorities between staff/board; environmental impact report (programmatic CEQA question)	*Challenges*: Field Employee Association (union) negotiation
Existing or needed management mechanisms	Need funding Need to coordinate/collaborate with other park or regulatory agencies, private property owners, CAL FIRE and local fire departments, and	Need to reference Midpeninsula Regional Open Space District management policies Conduct public outreach to seek input and identify barriers	Coordinate under the Wildfire Fuels Reduction Program (WFRP) Cooperate and work with other agencies as this is a good training experience for associated staff

	general public (e.g., to obtain data, get buy in)		

Adaptation strategy #2: Introduce naturally occurring understory species that retain more soil moisture; (e.g., huckleberry or forbs) in coastal redwood forests			
	Action (1)	**Action (2)**	**Action (3)**
Adaptation actions	Research and identify candidate native species that could help retain more soil moisture in redwood communities	Identify and prioritize areas that are most vulnerable to moisture loss and could be feasible for planting	Identify seed sources, propagate, and plant in test plots Implement soil moisture probes and track soil moisture over time, and compare high/low fog years
Implementation feasibility	High	High	Moderate
Effectiveness	High	Unknown	Unknown
Timeline	Near (< 5 years)	Near (< 5 years)	Mid (5 – 10 years)
Where/how to implement	Review literature, hire consultant or designate staff lead Consider planning as a research project	Target areas that are modeled to receive less fog in coming century	Target areas that are modeled to receive less fog in coming century
Co-benefits & challenges	*Co-benefits*: Information-sharing with other partners and agencies, including sharing results of research	*Co-benefit*: Moisture maintained in vegetation (helps reduce fire risk)	*Co-benefits*: Research partnerships
Existing or needed management mechanisms		Reference resource management and BMPs	

Appendix C. Vulnerability and Adaptation Briefs

Resources

1. Bats
2. Chaparral
3. Coastal Dunes, Wet Meadows, and Prairies
4. Coastal Redwood Forests
5. Coastal Scrub
6. Freshwater Marshes, Wetlands, and Ponds
7. Mixed Evergreen/Montane Hardwood Forests
8. Mixed Grasslands
9. Oak Woodlands
10. Rivers, Streams, and Floodplains
11. Seeps and Springs
12. Wide-ranging Mammals