Vulnerability Assessment, Mapping, & Adaptation Strategies
FOR NORTHERN CALIFORNIA
Project Findings

- Vulnerability Assessments
- Regional Climate Impacts
- Climatic Water Deficit Maps
- Adaptation Strategies & Actions (*linked to vulnerability*)
Purpose of a vulnerability assessment:

- Exposure
- Sensitivity
- Adaptive Capacity

Identify *which* resources are most vulnerable and *why*

Vulnerability

\[ V = E \times S - AC \]
Vulnerability Assessment

EXPOSURE is a measure of how much change in climate that a resource is likely to experience.

Factors considered:
• Direction and magnitude of change in climate stressors and disturbance regimes
• Degree of uncertainty associated with projected changes
Vulnerability Assessment

**SENSITIVITY** is a measure of whether and how a resource is likely to be affected by a given change in climate factors.

Factors affecting sensitivity:
- Climate drivers
- Disturbance regimes
- Non-climate stressors

Photo by USFS/Mike McMillan (Public Domain)
ADAPTIVE CAPACITY is a measure of a resource’s ability to accommodate or cope with climate change impacts with minimal disruption.

Factors affecting adaptive capacity:
- Extent & integrity
- Connectivity
- Resistance & recovery
- Diversity
- Public, societal, and cultural value
- Management potential
Climate Change Vulnerability: Late-Successional-Dependent Species

**Exposure**
- **Moderate Exposure**
  - Low Confidence
- **Moderate Exposure**
  - Air temperature
  - Heat waves
  - Precipitation amount/timing
  - Drought
  - Snowpack
  - Timing of snowmelt/runoff
  - Storms
  - Wildfire

**Sensitivity**
- **Moderate-High Sensitivity**
  - High Confidence
  - Decreased survival and recruitment
  - Altered prey availability and interspecific competition for food/habitat resources
  - Changes in habitat structure and availability of critical habitat features
  - Reduced habitat extent and connectivity
  - Shifts in species distribution
  - *Non-climate stressors*: Fire exclusion, timber harvest, roads, poisons

**Adaptive Capacity**
- **Low-Moderate Adaptive Capacity**
  - High Confidence
  - Behavioral plasticity
  - Some regulatory and legislative support for species management
  - Declining regional populations
  - Small, isolated populations vulnerable to extirpation or genetic bottlenecks
  - Recovery limited by low reproductive potential & reliance on late-seral stand conditions
Vulnerability Results: Habitats

- Coastal redwood forest
- Mixed conifer/ponderosa forest
- Freshwater marshes
- Mixed grasslands
- Chaparral shrublands
- Seeps & springs
- Lakes
- Black oak & tanoak woodlands
- Wet meadows/fens
- Ponds
- Coastal conifer/hardwood forest
- Oak savannas & open woodlands
- Subalpine forest
- Alpine grassland/shrubland
- Rivers, streams, & floodplains
- Caves, karst, & lava tubes
- Mixed evergreen forest
- Rock outcrops/cliffs/talus slopes
- Coastal bluffs/scrub
- True fir forest
- Coastal dune systems
- Coastal bluffs/scrub
- Subalpine forest
- Lakes

Legend:
- Low Vulnerability
- High Vulnerability
Vulnerability Results: *Species*

Adaptive Capacity

Low Vulnerability

- Low Vulnerability
- Migratory shorebirds
- Native ungulates
- Frogs
- Riparian-nesting birds
- Anadromous fish
- Sugar pine
- Native pollinators
- Western pond turtle
- Marbled murrelet
- Knobcone pine, rare cypress, & Pacific yew
- Native mussels
- Late-successional-dependent species
- Port-Orford-cedar
- Salamanders
- Native mussels

High Vulnerability
Climate Stressors
• Precip/soil moisture
• Drought

Disturbance Regimes
• Wildfire
• Disease

Non-Climate Stressors
• Fire suppression
• Timber harvest
• Pollutions & poisons
• Dams & water diversions
• Roads, highways, & trails

Adaptive Capacity Factors
▲ High physical and topographical diversity
▲ Large areas of undeveloped/roadless land increase connectivity
▼ Many habitats & populations degraded
▼ Past management activities
▼ Low to mod management capacity & ability
Vulnerability Assessment Products

- Expert assessment
- Downscaled climate projections
- Review of scientific literature
- Peer review and evaluation of results

Product: Vulnerability assessment syntheses for 33 focal resources
Regional Climate Impacts

Table 1. Summary of trend direction and projected future changes for climate and climate-driven factors, extreme events, and major natural disturbance regimes within the Northern California Climate Adaptation Project study area.

<table>
<thead>
<tr>
<th>Climate and climate-driven factors</th>
<th>Projected Future Changes</th>
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</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td>+ 2.2–6.1°C (4.0–11.0°F) increase in annual mean 2080s</td>
</tr>
<tr>
<td>Winter temperature</td>
<td>- 0.4–6.0°C (-9–10.4°F) decrease in August through 2080s</td>
</tr>
<tr>
<td>Precipitation</td>
<td>+25% to &gt;100% change in mean annual precipitation</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>- 0.4–5.0% decrease in land vegetation evapotranspiration</td>
</tr>
<tr>
<td>Land surface temperature</td>
<td>+ 40–63°F increase in April 1st average winter region</td>
</tr>
<tr>
<td>Snowpack</td>
<td>- 5–16 lost days towards earlier timing of snowmelt</td>
</tr>
<tr>
<td>Streamflow</td>
<td>Change in streamflow and flows over the year due to increased temperature and precipitation</td>
</tr>
<tr>
<td>Coastal fog</td>
<td>Weak decline in frequency of days with less than 15°F</td>
</tr>
<tr>
<td>Sea level rise</td>
<td>0.03–0.24 m (1–1.8 in) rise in sea level over the past century</td>
</tr>
<tr>
<td>Extreme events and natural disturbance regimes</td>
<td></td>
</tr>
<tr>
<td>Heat waves</td>
<td>Significant increase in heat wave frequency and period</td>
</tr>
<tr>
<td>Storms and flooding</td>
<td>Increased storm intensity and duration, increased frequencies of extreme precipitation events</td>
</tr>
<tr>
<td>Drought</td>
<td>Drought years likely to occur, with signs of prolonged and/or severe drought</td>
</tr>
<tr>
<td>Wildlife</td>
<td>77% increase in mean annual area burned due to decreasing fire diversity</td>
</tr>
</tbody>
</table>

Trends and Projections for Climate and Climate-Driven Factors

Air Temperature
Annual, minimum, and maximum temperatures have increased relative to past century (Elovich et al. 2007; Condero et al. 2011; Fieser et al. 2014). With accelerated rates of warming since the 1970s (Condero et al. 2011). Minimum temperatures (representing nighttime lows) have warmed faster than mean and maximum temperatures in most regions, including northern California (Elovich et al. 2007; Condero et al. 2011; Fieser et al. 2014). However, mean annual temperatures have increased less in northern California [1.6°C (3.0°F)] compared to the state-wide average [1.0°C (1.8°F)] (Greathouse 2018; Fieser et al. 2014), and maximum temperatures in the region have exhibited slight decreases (Rapaccio et al. 2014). Within the study area, increases in annual and minimum temperatures over the past century have been greatest in the Great Valley escarpment; decreases in maximum temperatures are also greatest in this escarpment (Rapaccio et al. 2014).

By the end of the century (2090–2099), annual mean temperatures within the Northern California study area are projected to rise by 2.2–6.1°C (4.0–11.0°F) compared to historical temperatures (1931–1960), Figure 1 and Figure 2, with slighter greater warming in summer. Maximum temperatures [2.0–8.8°C (3.6–19.2°F)] compared to winter minimums [1.9–5.6°C (3.5–13.3°F)] (Fieser et al. 2013; Flint & Fieser 2016; Table 2). Because winters warm more slowly over land, interior zones are generally projected to experience greater temperature increases than coastal areas ventilated by ocean breezes (Fieser et al. 2014). Other factors associated with landscape-scale temperature variability include elevation and urbanization (Schulze et al. 2007).
Some areas of the landscape may be more vulnerable to significant ecosystem changes.
Climatic Water Deficit Maps

- **Areas with low interannual variability, where CWD is projected to increase significantly**
  - Prioritize species adapted to consistently hot/dry sites
  - May be vulnerable to vegetation change where CWD exceeds historical range of variability

- **Areas with high interannual variability, where CWD is projected to increase significantly**
  - Existing species may be adapted to climate extremes
  - May be less likely to experience dramatic shifts in vegetation

- **Areas with low interannual variability, where increases in CWD may be relatively low**
  - Stable conditions may provide refugia from climate extremes
  - May be vulnerable to vegetation change where CWD exceeds historical range of variability

- **Areas with high interannual variability, where increases in CWD may be relatively low**
  - Existing species may be adapted to climate extremes
  - Much less likely to experience dramatic shifts in vegetation

Data Sources: Basin Characterization Model (Flint & Flint 2014); Conservation Biology Institute Map produced by EcoAdapt, Sept. 2021
Climate change adaptation refers to adjustments in natural or human systems in response to changing climate conditions.

ADAPTATION STRATEGIES:

- Reduce climate impacts
  *(sensitivity & exposure)*

- Increase climate resilience
  *(adaptive capacity)*

Reduce climate change vulnerability
<table>
<thead>
<tr>
<th>Adaptation Approaches</th>
<th>Resistance/Resilience</th>
<th>Acceptance</th>
<th>Direct/Response</th>
<th>Knowledge</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Focused on managing for persistence of existing ecosystems</td>
<td>Focused on accommodating change in response to novel conditions</td>
<td>Focused on actively facilitating change/transformation in response to novel conditions</td>
<td>Focused on gathering information about climate impacts and/or management effectiveness</td>
<td>Focused on coordinating management efforts and/or capacity across organizations</td>
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<td><strong>Example</strong>: Use exclusion fencing in upland areas to prevent herbivory of oak seedlings</td>
<td><strong>Example</strong>: Identify areas where post-fire type conversion should be allowed to occur without management intervention</td>
<td><strong>Example</strong>: Experiment with seeds from climate analog zones for restoration projects</td>
<td><strong>Example</strong>: Expand research on hardwood silviculture techniques, esp. for drought- and heat-tolerant species</td>
<td><strong>Example</strong>: Develop and/or strengthen new and existing collaborative networks in order to leverage resources</td>
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</tr>
</tbody>
</table>
Adaptation Products

**Product: Vulnerability-adaptation summaries linking suite of adaptation strategies & actions to identified vulnerabilities**

- Summary of key habitat and species vulnerabilities
- Table linking suite of adaptation strategies & actions to identified vulnerabilities
# Adaptation Strategies & Actions

## GOAL 1. REDUCE THE IMPACT OF NON-CLIMATE STRESSORS

| 1.1 Prevent the introduction and establishment of invasive species and remove existing populations |
| 1.2 Manage herbivory to promote regeneration of desired species |
| 1.3 Retain biological legacies |
| 1.4 Reduce direct mortality of native ungulates |

## GOAL 2. REDUCE THE RISK AND IMPACTS OF SEVERE DISTURBANCES/EXTREME EVENTS

| 2.1 Utilize fuelbreaks to slow the spread of high-intensity fire |
| 2.2 Enhance the ability of forests to resist and/or recover from introduced pests and pathogens |

## GOAL 3. SUSTAIN FUNDAMENTAL ECOLOGICAL FUNCTIONS AND PROCESSES

| 3.1 Restore the role of fire as an ecological process on the landscape |
| 3.2 Reduce impacts to soils and nutrient cycling |
| 3.3 Restore coastal conifer hardwood forests |

## GOAL 4. ENHANCE HABITAT QUALITY AND AVAILABILITY FOR NATIVE UNGULATES

| 4.1 Increase forage quality and availability for native ungulates |

## GOAL 8. MAINTAIN AND PROTECT REFUGIA

| 8.1 Prioritize and maintain sites that may be more resistant to changes in climate (e.g., cooler, wetter sites), harbor high biodiversity, and/or provide habitat for rare species |

### Example adaptation actions:

- Identify forest areas of least/slower change to support the protection and management of potential climate change refugia (R/K)
- Protect mature and late-successional forests (R)
- Expand reserve boundaries to include mid-seral and complex early-seral forests that have high structural diversity and the potential to develop old-growth characteristics over time (R)

### Vulnerabilities addressed:

- Land-use conversion and human land uses that result in habitat loss and fragmentation
- Air temperature, precipitation, soil moisture, drought, wildfire (*loss of cool, moist refugia in mature and late-successional forests*)
- Habitat diversity (*loss of structural complexity and range of successional stages*)