Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Valley Oak

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

Vulnerability Component	Score
Sensitivity	Moderate
Exposure	Low-moderate
Adaptive Capacity	Moderate-high
Vulnerability	**Low-moderate**

Overall vulnerability of the valley oak was scored as low-moderate. The scores is the result of moderate sensitivity, low-moderate future exposure, and moderate-high adaptive capacity scores.

Key climate factors for valley oak include precipitation amount and altered streamflow regimes. Both of these factors influence water availability, thereby influencing valley oak distribution and recruitment.

Key non-climate factors for valley oaks include agricultural and rangeland practices and groundwater overdraft. Agricultural development has destroyed and fragmented valley oak populations, while groundwater overdraft can lower water tables and increase valley oak exposure to drought stress.

Key disturbance mechanisms for valley oak include wildfire, flooding, and grazing. Oaks are fairly resilient to fire, but grazing has variable impacts on recruitment. Flooding impacts succession and valley oak establishment in riparian areas. Valley oaks display mostly k-selected characteristics; they take several decades to reach reproductive maturity, and feature variable acorn production and seedling/sapling recruitment. Valley oaks are largely habitat generalists, although they do depend on relatively stable water availability.

Valley oaks have a wide distribution, and their historical extent is unknown[1]. Remaining present day populations are mainly riparian, although roughly 95% of riparian valley oak forests are thought to have been lost[1], and are highly fragmented due to agricultural and urban conversion, which may undermine genetic exchange. Low-moderate dispersal capacity and several landscape barriers – including agriculture/rangeland practices, urban development, and dams/levees/water diversions – undermine migration of valley oak in the face of climate change. This species exhibits high interspecific species diversity; high spatial genetic diversity indicates that valley oak may retain some capacity to adapt to different climatic gradients. Mature oaks are more resilient than young oak life stages.

Management potential for valley oaks was scored as moderate-high. Management options for valley oak may include preserving drought refugia (e.g., areas with groundwater tables, surface water and riparian areas, topographically complex landscapes) and restoring marginal, unused, or flood-prone agricultural areas.

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Introduction

Description of Priority Natural Resource

Valley oak (*Quercus lobata*) is endemic to California, and is commonly found in areas with high water tables, including in oak woodland forests and valley oak riparian woodlands (Howard 1992). This species can be found from the coast through the Central Valley and into the Sierra Nevada foothills (McLaughlin & Zavaleta 2013b).

As part of the Central Valley Landscape Conservation Project, workshop participants identified the valley oak as a Priority Natural Resource for the Central Valley Landscape Conservation Project in a process that involved two steps: 1) gathering information about the species' management importance as indicated by its priority in existing conservation plans and lists, and 2) a workshop with stakeholders to identify the final list of Priority Natural Resources, which includes habitats, species groups, and species.

The rationale for choosing the valley oak as a Priority Natural Resource included the following: the species has high management importance, the species' conservation needs are not entirely represented within a single priority habitat or species group, and because it is an iconic and keystone species for the region. Please see Appendix A: "Priority Natural Resource Selection Methodology" for more information.

Vulnerability Assessment Methodology

During a two-day workshop in October of 2015, 30 experts representing 16 Central Valley resource management organizations assessed the vulnerability of priority natural resources to changes in climate and non-climate factors, and identified the likely resulting pressures, stresses, and benefits (see Appendix B: "Glossary" for terms used in this report). The expert opinions provided by these participants are referenced throughout this document with an endnote indicating its source[1]. To the extent possible, scientific literature was sought out to support expert opinion garnered at the workshop. Literature searches were conducted for factors and resulting pressures that were rated as high or moderate-high, and all pressures, stresses, and benefits identified in the workshop are included in this report. For more information about the vulnerability assessment methodology, please see Appendix C: "Vulnerability Assessment Methods and Application." Projections of climate and non-climate change for the region were researched and are summarized in Appendix D: "Overview of Projected Future Changes in the California Central Valley".

Vulnerability Assessment Details

Climate Factors

Workshop participants scored the resource's sensitivity to climate factors and this score was used to calculate overall sensitivity. Future exposure to climate factors was scored and the overall exposure score used to calculate climate change vulnerability.

Climate Factor	Sensitivity	Future Exposure
Altered stream flow	Moderate-high	Low-moderate
Extreme events: drought	Moderate	-
Increased flooding	-	Low-moderate
Precipitation (amount)	Moderate-high	Moderate
Precipitation (timing)	Low-moderate	Low-moderate
Snowpack amount	Moderate	Low-moderate
Timing of snowmelt/runoff	Moderate	Low-moderate
Overall Scores	**Moderate**	**Low-moderate**

Precipitation (amount)

Sensitivity: *Moderate-high (high confidence)*
Future exposure: *Moderate (moderate confidence)*
Potential refugia: *Moister settings—north-facing slopes, functional floodplains, areas with high water tables.*

Higher precipitation may favor valley oak recruitment, although it likely interacts with other factors to influence recruitment at the site-scale (reviewed in Tyler et al. 2006; McLaughlin & Zavaleta 2013a, 2013b). Precipitation exerts a larger influence on valley oak recruitment in more xeric sites, and low precipitation causes recruitment to cluster around available surface water (McLaughlin & Zavaleta 2013a). Comparatively, higher precipitation facilitates recruitment farther from surface water sources, but also facilitates herbaceous growth, which can enhance competition for oak seedlings and saplings (McLaughlin & Zavaleta 2013a).

Streamflow

Sensitivity: *Moderate-high (high confidence)*
Future exposure: *Low-moderate (moderate confidence)*

Potential refugia: *Moister settings—north-facing slopes, functional floodplains, areas with high water tables.*

Valley oaks are common components of late successional riparian plant communities in the Central Valley (Trowbridge et al. 2005; California Department of Fish and Game 2016), and valley oak distribution, particularly young oaks, appears to be tied with water availability, including surface water and groundwater (McLaughlin & Zavaleta 2012, 2013a; California Department of Fish and Game 2016). Altered flow regimes – including lower low flows, higher peak flows, and altered flow timing – could impact valley oak distribution, establishment, and recruitment (Trowbridge et al. 2005) by altering water availability and disturbance regimes.

Drought

Workshop participants did not further discuss this factor beyond assigning a sensitivity score.

Sensitivity: *Moderate (high confidence)*

Snowpack amount

Sensitivity: *Moderate (moderate confidence)*
Future exposure: *Low-moderate (moderate confidence)*
Potential refugia: *Moister settings—north-facing slopes, functional floodplains, areas with high water tables.*

Snowpack amount influences the shape of the hydrograph and water availability (Yarnell et al. 2010), and therefore, oak recruitment (Trowbridge et al. 2005).

Timing of snowmelt & runoff

Sensitivity: *Moderate (moderate confidence)*
Future exposure: *Low-moderate (moderate confidence)*
Potential refugia: *Moister settings—north-facing slopes, functional floodplains, areas with high water tables.*

Snowmelt volume and timing affect flooding regimes (Yarnell et al. 2010), and therefore, riparian valley oaks (Trowbridge et al. 2005).

Precipitation (timing)

Sensitivity: *Low-moderate (moderate confidence)*
Future exposure: *Low-moderate (moderate confidence)*
Potential refugia: *Moister settings—north-facing slopes, functional floodplains, areas with high water tables.*

Precipitation timing influences the shape of the hydrograph and water availability (Meyers et al. 2010), and therefore, oak recruitment (Trowbridge et al. 2005).

Climatic changes that may benefit the species

- Timing and duration of flooding

Various regional modeling efforts indicate likely shifts in valley oak habitat suitability in response to climate change. Regional climatic modeling by Kueppers et al. (2005) predicts that range-wide, suitable habitat for valley oak is likely to contract by 46% by the end of the century and shift to more northerly and high elevation locations due to warmer and drier conditions. Serra-Diaz et al. (2014) found similar trends, and project that valley oak is likely to experience climate exposure at a rate of 0.29 km per year by mid-century. Regional bioclimatic modeling by Sork et al. (2010) shows that within broader regional patterns of habitat suitability shifts, different spatial groupings of valley oak likely have different exposure to climate-mediated shifts in habitat suitability. For example, in the northern portion of California, valley oak is likely to expand into foothill areas that completely or partially overlap current species extent. Comparatively, in the central Sierra Nevada foothills, current and projected suitable habitat do not overlap, and suitable habitat will likely shift upslope by 1-20 km by the end of the century (Sork et al. 2010). Bioclimate species distribution modeling by McLaughlin & Zavaleta (2012) additionally indicates that young tree sensitivity may further limit habitat climate suitability and dispersal patterns; they project that under a warmer and drier future, valley oak saplings will cluster around available water bodies (i.e., drought refugia) rather than exhibit uniform northerly and upward dispersal. In addition to sites with available surface and groundwater, topographical refugia (e.g., north-facing slopes, riparian drainages) were identified as important local drought refugia for blue oaks in areas of the study region expected to experience habitat contraction, and will likely be important refugia for valley oaks as well (McLaughlin et al. 2014).

Non-Climate Factors

Workshop participants scored the resource's sensitivity and current exposure to non-climate factors, and these scores were then used to assess their impact on climate change sensitivity.

Non-Climate Factor	Sensitivity	Current Exposure
Agriculture & rangeland practices	High	High
Dams, levees, & water diversions	Moderate	Moderate-high
Groundwater overdraft	Moderate-high	Moderate-high
Invasive & other problematic species	Low-moderate	Moderate-high
Urban/suburban development	Low-moderate	Moderate-high
Overall Scores	**Moderate**	**Moderate-high**

Agricultural & rangeland practices

> ***Sensitivity:*** *High (confidence not assessed)*
> ***Current exposure:*** *High (confidence not assessed)*
> ***Pattern of exposure:*** *Localized; floodplains.*

It is believed that almost 98% of historical valley oak woodland habitat has been lost in the San Joaquin Valley due to agricultural and rangeland development (Kelly et al. 2005), and similar patterns are evident across the Central Valley study area (Bolsinger 1988). Valley oak loss has cascading impacts on biodiversity and wildlife (Howard 1992; Kelly et al. 2005). Continued agricultural conversion of valley oak woodlands is possible (Grivet et al. 2008), particularly since valley oaks prefer level, fertile soils ideal for agricultural use (Sork et al. 2002).

Groundwater overdraft

> ***Sensitivity:*** *Moderate-high (moderate confidence)*
> ***Current exposure:*** *Moderate-high (high confidence)*
> ***Pattern of exposure:*** *Localized; where groundwater being over-drafted, also impacted by perched aquifers and groundwater connection to streams.*

Valley oaks occur in areas with high water tables and often utilize groundwater (Griffin 1973), so low groundwater levels can reduce valley oak survival if depth to groundwater exceeds valley oak taproot length (Brown & Davis 1991; Howard & Merrifield 2010). Groundwater pumping has increased in the state over the past century; annual state-wide overdraft is roughly 1.4 million acre-feet in an average year, with a large percentage of overdraft occurring in the Central Valley (Howard & Merrifield 2010 and citaitons therein). Groundwater basins and areas with high water tables likely provide landscape microrefugia from drought stress (McLaughlin & Zavaleta 2012) since surface water effects on valley oak are typically greater than groundwater effects[1]. However, reduced groundwater availability as a result of climate change and human groundwater withdrawals may exacerbate habitat loss and undermine *in situ* valley oak persistence in a warmer, drier climate (Howard & Merrifield 2010; McLaughlin & Zavaleta 2012).

Dams, levees, & water diversions

> ***Sensitivity:*** *Moderate (moderate confidence)*
> ***Current exposure:*** *Moderate-high (high confidence)*
> ***Pattern of exposure:*** *Localized; surface water diversions occurring in the Delta.*

Dams, levees, and water diversions impact groundwater and flooding regimes, which may affect oak recruitment. Water diversions degrade riparian habitat quality. Levees decrease habitat area by reducing amount of habitat that is seasonally flooded[1].

Urban/suburban development

Workshop participants did not further discuss this factor beyond assigning scores.

> ***Sensitivity:*** *Low-moderate (moderate confidence)*
> ***Current exposure:*** *Moderate-high (high confidence)*
> ***Pattern of exposure:*** *Localized.*

Invasive & other problematic species

> ***Sensitivity:*** *Low-moderate (moderate confidence)*
> ***Current exposure:*** *Moderate-high (high confidence)*
> ***Pattern of exposure:*** *Consistent; particularly in non-native annual grassland.*

Oak regeneration in non-native annual grasslands can be difficult because oak saplings must compete for water with introduced annuals (Jimerson & Carothers 2002; Tyler et al. 2006), potentially leading to recruitment failures (Gordon & Rice 1993).

Disturbance Regimes

Workshop participants scored the resource's sensitivity to disturbance regimes, and these scores were used to calculate climate change sensitivity.

> ***Overall sensitivity to disturbance regimes:*** *Moderate (moderate confidence)*

Flooding

> ***Future exposure:*** *Low-moderate (moderate confidence)*
> ***Potential refugia:*** *Functional floodplains.*

Flooding resets riparian succession, providing new habitat for eventual valley oak establishment via succession. However, altered flooding regimes (e.g., prolonged late season flooding) can scour and remove established valley oaks in riparian areas (Trowbridge et al. 2005). Historically, riparian valley oaks experienced flooding roughly every 5 years (Howard 1992).

Wildfire

Mature valley oaks are fairly resilient to fire. Oak seedlings and saplings occasionally experience complete mortality during fire, but more frequently experience topkill followed by resprouting. In general, smaller trees, higher fuel loads, and hotter fires undermine valley oak resilience to fire (Howard 1992; Holmes et al. 2008).

Grazing

Grazing has variable impacts on valley oaks (reviewed in Tyler et al. 2006). For example, cattle grazing can limit recruitment by browsing or trampling seedlings and saplings, but may also enhance recruitment by controlling non-native annual grasses, which compete with seedlings for soil moisture and provide cover for native herbivorous rodents that prey on acorns and seedlings (Bernhardt & Swiecki 1997). Cattle grazing in xeric areas where valley oaks are restricted around available surface water could be detrimental due to overutilization (McLaughlin & Zavaleta 2013a). Blue oaks have been found to be seasonally sensitive to grazing, with winter/spring grazing helping mitigate invasive annual grass impacts and summer grazing resulting in higher oak browsing damage (Hall et al. 1992); valley oaks likely exhibit similar sensitivity to grazing timing (Tyler et al. 2006).

Native ungulate browsing, rodent herbivory and burrowing, and wild turkey herbivory can also have significant impacts on valley oak recruitment (Gardner 2004; Tyler et al. 2006; Davis et al.

2011), particularly on wetter sites (McLaughlin & Zavaleta 2013a). For example, deer heavily browse seedlings (Davis et al. 2011), and wild turkeys (*Meleagris gallopavo*) utilize acorns in the fall and winter (Gardner 2004), which may have localized impacts on oak recruitment. Wild turkeys have become well established in oak woodlands since first being introduced in the 1870s (Gardner 2004).

Life history and reproductive strategy

Workshop participants scored the resource's life history and reproductive strategy, and these scores were used calculate climate change sensitivity.

> ***Species reproductive strategy, representing generation length and number of offspring****: Displays mainly k-selected characteristics (high confidence)*
> ***Average length of time to reproductive maturity:*** *5-10 years*

Valley oaks are wind-pollinated masting species (Barringer et al. 2013), and although not well studied, age of first reproduction is likely several decades, with peak reproductive periods occurring even later (Tyler et al. 2006 and citations therein). Similar to other oak species, acorn production is highly variable year-to-year (reviewed in Tyler et al. 2006). Acorn production causes a tradeoff with tree growth, a common characteristic in long-lived species (Barringer et al. 2013) such as the valley oak, which can live for 300 years or more (Sork et al. 2002). Valley oak seedling and sapling recruitment are controlled by different factors, including top-down (e.g., small mammal predation) and bottom-up effects (e.g., low soil moisture; McLaughlin & Zavaleta 2013a). Although there is a perceived lack of regional oak recruitment (Tyler et al. 2006; Davis et al. 2011), recent analyses indicate higher valley oak recruitment in California than previously thought (McLaughlin & Zavaleta 2013b). Competition with annuals, acorn predation, soil parameters, and depth to groundwater have all been implicated in discussions regarding sporadic and declining valley oak recruitment (Tyler et al. 2006; Howard & Merrifield 2010; Davis et al. 2011).

Dependency on habitat and/or other species

Workshop participants scored the resource's dependency on habitat and/or other species, and these scores were used calculate climate change sensitivity.

> ***Overall degree of specialization****: Low-moderate (high confidence)*
> ***Dependency on one or more sensitive habitat types:*** *Low-moderate (high confidence)*
> > ***Description of habitat:*** *Riparian/floodplain.*

Valley oaks occur in both upland and floodplain riparian areas; groundwater and surface water availability influence valley oak distribution and survival (Howard 1992; California Department of Fish and Game 2016).

Adaptive Capacity

Workshop participants scored the resource's adaptive capacity and the overall score was used to calculate climate change vulnerability.

Adaptive Capacity Component	Score
Extent, Status, and Dispersal Ability	Moderate
Landscape Permeability	Moderate-high
Intraspecific Species Diversity	Moderate-high
Resistance	Moderate-high
Overall Score	**Moderate-high**

Extent, status, and dispersal ability

Overall degree of extent, integrity, connectivity, and dispersal ability: *Moderate (high confidence)*
Geographic extent: *Occurs beyond small area but still quite limited (high confidence)*
Health and functional integrity: *Increasingly healthy (high confidence)*
Population connectivity: *Patchy, with some connectivity (high confidence)*
Dispersal ability: *Moderate (high confidence)*
Maximum annual dispersal distance of species: *1-5 km (moderate confidence)*

Valley oaks can be found from the coast through the Central Valley to the Sierra Nevada foothills, and a majority of valley oak distribution occurs on private rangelands (McLaughlin & Zavaleta 2013b). A majority of riparian and upland valley oak stands have been lost to development and agricultural conversion, and valley oaks now occur in scattered patches (Howard 1992). Habitat fragmentation is believed to reduce pollination opportunities and acorn dispersal, limiting genetic exchange (Sork et al. 2002) and migration opportunities in response to climate change (Sork et al. 2010). Small pollen and acorn dispersal distances (100 m) make it unlikely that this species will keep pace with rapid climate change, although long-distance dispersal events may occasionally occur (Sork et al. 2010).

Landscape permeability

Overall landscape permeability: *Moderate-high (moderate confidence)*
Impact of various factors on landscape permeability:
- ***Agricultural & rangeland practices:*** *Low-moderate (moderate confidence)*
- ***Urban/suburban development:*** *Low-moderate (moderate confidence)*
- ***Dams, levees, & water diversions:*** *Low-moderate (moderate confidence)*

Valley oaks may have limited ability to migrate in response to climate change (Kueppers et al. 2005), particularly due to small dispersal distances (Sork et al. 2010) and impacts of habitat fragmentation on genetic exchange and dispersal (Sork et al. 2002).

Resistance

> ***Resistance to stresses/maladaptive human responses:*** *Moderate-high (moderate confidence)*

Mature oaks are more tolerant of and adaptable to climatic fluctuations and disturbance than young oaks (Holmes et al. 2008; McLaughlin & Zavaleta 2012; McLaughlin et al. 2014). Preserving old stands may be a good strategy to implement now, as there are more old trees now than there will be in the future[1].

Species diversity

> ***Overall species diversity:*** *High (moderate confidence)*
> ***Diversity of life history strategies:*** *Moderate-high (moderate confidence)*
> ***Genetic diversity:*** *Moderate-high (moderate confidence)*
> ***Phenotypic plasticity:*** *High (high confidence)*

Valley oaks exhibit considerable genetic diversity across their spatial distribution (Grivet et al. 2008; Sork et al. 2010). Valley oaks also exhibit some genetic adaptation to different climate gradients, indicating some adaptive potential in response to climate change (Sork et al. 2010). Genetic exchange occurs via acorn and pollen transport, but habitat fragmentation limits gene flow via pollen exchange and acorn dispersal, and reproductive isolation could reduce fitness and impede recruitment (Sork et al. 2002, 2010).

Management potential

Workshop participants scored the resource's management potential.

Management Potential Component	Score
Species value	Moderate-high
Societal support	Moderate
Agriculture & rangeland practices	Moderate-high
Extreme events	Low-moderate
Converting retired land	Moderate-high
Managing climate change impacts	Moderate-high
Overall Score	**Moderate-high**

Value to people

Value to people: *Moderate-high (moderate confidence)*

Support for conservation

Degree of societal support for management and conservation: *Moderate (moderate confidence)*

Degree to which agriculture and/or rangelands can benefit/support/increase resilience: *Moderate-high (moderate confidence)*

Degree to which extreme events (e.g., flooding, drought) influence societal support for taking action: *Low-moderate (moderate confidence)*

Likelihood of converting land to support species

Likelihood of (or support for) converting retired agriculture land to maintain or enhance species: *Moderate-high (moderate confidence)*

Likelihood of managing or alleviating climate change impacts: *Moderate-high (high confidence)*

Maintaining groundwater levels and protecting riparian areas are likely important for valley oak persistence, particularly on the driest sites and in a warmer, drier future (McLaughlin & Zavaleta 2012, 2013a; McLaughlin et al. 2014). In addition, protecting areas with topographical diversity could help preserve additional drought refugia areas for valley oak and other *Quercus* species (McLaughlin et al. 2014). Valley oak habitat restoration on agricultural lands and rangelands is also a possibility; there are documented cases of oak riparian restoration occurring on frequently or severely flooded agricultural lands (e.g., Consumes River Preserve; Trowbridge et al. 2005). Massive oak woodland restoration is needed to create refugia areas for other species[1]. In addition, there have been regional efforts by state agencies and non-profit groups to protect remnant oak habitats in order to mitigate agricultural and development pressure and protect genetic and evolutionary hotspots in order to foster oak woodland habitat persistence and adaptive potential in the face of climate change (e.g., see Grivet et al. 2008).

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