Sierra Nevada Individual Species Vulnerability Assessment Briefing: Blue Oak

Quercus douglasii

Background and Key Terminology

This document summarizes the primary factors that influence the vulnerability of a focal resource to climate change over the next century. In this context, vulnerability is a function of the sensitivity of the resource to climate change, its anticipated exposure to those changes, and its capacity to adapt to changes. Specifically, sensitivity is defined as a measure of whether and how a resource is likely to be affected by a given change in climate, or factors driven by climate; exposure is defined as the degree of change in climate or climate-driven factors a resource is likely to experience; and adaptive capacity is defined as the ability of a resource to accommodate or cope with climate change impacts with minimal disruption (Glick et al. 2011). The purpose of this assessment is to inform forest planning by government, non-profit, and private sector partners in the Sierra Nevada region as they work to integrate climate change into their planning documents.

Executive Summary

The overall vulnerability of blue oak species is ranked as moderate, due to their moderate sensitivity to climate and non-climate stressors, moderate adaptive capacity, and low to moderate exposure.

The blue oak species is sensitive to climate-driven changes such as:

- decreased precipitation,
- decreased soil moisture (i.e. climatic water deficit), and
- increased fire intensity and frequency.

Soil moisture deficits are predicted to increase over the next century due to climate change, which may decrease seedling and sapling survival. Fire frequency and area burned are also predicted to increase over the next century, and may also impact blue oak persistence by reducing recruitment and survival, principally of seedlings and saplings, over the long term. However, in the short term, increased fire frequency and severity could reduce conifer densities, leaving blue oaks relatively more abundant.

Blue oaks are also sensitive to several non-climate stressors including:

- exotic species,
- predation pressure,
- habitat conversion, and
- disease outbreak.

These non-climate stressors can amplify the effects of climate-driven changes. For example, invasive grasses compete with oak seedlings for water, a resource that will likely be reduced in the future. The capacity of blue oak to adapt to changes in climate, however, will likely be facilitated by its wide distribution, extensive dispersal capacity, and the ability of mature trees to tolerate a wide range of environmental conditions, in part by modifying their physiology in response to unfavorable environmental conditions (e.g. drought).

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Sensitivity & Exposure

Sensitivity to climate and climate-driven changes

Blue oaks are sensitive to climate and climate-driven changes, including decreased precipitation, decreased soil moisture, and altered fire regimes. However, sensitivity to these climate-driven changes depends on life stage. For example, sensitivity of mature trees is limited by their apparent tolerance for a broad range of temperatures, precipitation, soil moisture, soil types and depth. While periodic droughts appear to have little impact on mature trees (McCreary 1991), sustained and repeated droughts could adversely affect these trees and make them more vulnerable to other stressors (e.g., insects and disease). Earlier life stages are more sensitive to fluctuations in water availability. Wet years can produce nearly double the seedling emergence of dry years (Borchert et al. 1989 cited in Tyler et al. 2006), and all published studies on the regeneration of blue oak woodlands reviewed by Tyler et al. (2006) found saplings to be more common on mesic sites. Acorn crop size in blue oaks is also influenced by rainfall and temperature (Koenig et al. 1999 cited in Waddell and Barrett 2005).

Blue oak may be sensitive to altered wildfire regimes, although relatively few studies have clearly established the effects of fire on blue oak persistence (Allen-Diaz and Bartolome 1992; Swiecki and Bernhardt 1999). Some studies have linked fire with positive recruitment of blue oak woodlands (e.g., McClaran and Bartolome 1989, Bartolome 1991 cited in Tyler et al. 2006), while other studies have found no positive effect of fire treatments on recruitment, survival, and/or growth of blue oak seedlings (Bartolome and McClaran 1988, Bartolome 1991, and Allen-Diaz and Bartolome 1992 cited in Tyler et al. 2006; Swiecki and Bernhardt 2002). Fire frequency and severity however, does appear to play a role in sapling recruitment and survival. Frequent fire is negatively associated with blue oak sapling recruitment in California (Swiecki et al. 1997b cited in Tyler et al. 2006). Similarly, moderate intensity fire resulting in partial or complete topkill was found to confer no survival or regrowth benefits to blue oak saplings, but instead to prolong the period that saplings were susceptible to subsequent fire and other damaging agents (Spero 2002). Although in the short-term fire could reduce conifer densities leaving blue oaks relatively more abundant, in the long-term, increased frequency and severity of fire may decrease blue oak perpetuation.

Future climate exposure

Climate and climate-driven factors most relevant to consider for blue oaks include changes in precipitation, soil moisture (i.e. climatic water deficit), and wildfire.

Precipitation and snow volume: Precipitation has increased slightly (~2%) in the Sierra Nevada over the past 30 years compared with a mid-twentieth century baseline (1951-1980) (Flint et al. 2013). Projections for future precipitation in the Sierra Nevada vary among models; in general, annual precipitation is projected to exhibit only modest changes by the end of the century (Hayhoe et al. 2004; Dettinger 2005; Maurer 2007; Cayan et al. 2008), with decreases in summer and fall (Geos Institute 2013). Frequency of extreme precipitation, however, is expected to increase in the Sierra Nevada between 18-55% by the end of the century (Das et al. 2011). Despite modest projected changes in overall precipitation, models of the Sierra Nevada region largely project decreasing snowpack and earlier timing of runoff (Miller et al. 2003; Dettinger et al. 2004b; Hayhoe et al. 2004; Knowles and Cayan 2004; Maurer 2007; Maurer et al. 2007; Young et al. 2009), as a consequence of early snowmelt events and a greater percentage of precipitation falling as rain rather than snow (Dettinger et al. 2004a, 2004 b; Young et al. 2009; Null et al. 2010). Snow provides an important contribution to spring and summer soil moisture in the western U.S. (Sheffield et al. 2004), and earlier snowmelt can lead to an earlier, longer dry season (Westerling et al. 2006).

Climatic water deficit: Climatic water deficit, which combines the effects of temperature and rainfall to estimate site-specific soil moisture, is a function of actual evapotranspiration and potential evapotranspiration. Increases in potential evapotranspiration will likely be the dominant influence in future hydrologic cycles in the Sierra Nevada, decreasing runoff even under forecasts of increased precipitation, and driving increased climatic water deficits (Thorne et al. 2012). In the Sierra Nevada, climatic water deficit has increased slightly (~4%) in the past 30 years compared with the 1951-1980 baseline (Flint et al. 2013). Future downscaled water deficit modeling using the Basin Characterization Model predicts increased water deficits (i.e., decreased soil moisture) by up to 44%, with the greatest increases in the northern Sierra Nevada (Thorne et al. 2012; Flint et al. 2013; Geos Institute 2013).

Wildfire: Both the frequency and annual area burned by wildfires in the western U.S. have increased strongly over the last several decades (Westerling et al. 2006). Fire severity in the Sierra Nevada also rose from 17% to 34% high-severity (i.e. stand replacing) fire, especially in middle elevation conifer forests (Miller et al. 2009). In the Sierra Nevada, increases in large fire extent have been correlated with increasing temperatures and earlier snowmelt (Westerling and Bryant 2006), as well as current year drought combined with antecedent wet years (Taylor and Beaty 2005). Occurrence of large fire and total area burned in California are predicted to continue increasing over the next century, with total area burned increasing by up to 74% by 2085 (Westerling et al. 2011). The area burned by wildfire in the Sierra Nevada is projected to increase between 35-169% by the end of the century, varying by bioregion, with the greatest increases projected at mid-elevation sites along the west side of the range (Westerling et al. 2011; Geos Institute 2013).

More information on downscaled projected climate changes for the Sierra Nevada region is available in a separate report entitled *Future Climate, Wildfire, Hydrology, and Vegetation Projections for the Sierra Nevada, California: A climate change synthesis in support of the Vulnerability Assessment/Adaptation Strategy process* (Geos Institute 2013). Additional material on climate trends for the system may be found through the TACCIMO website (http://www.sgcp.ncsu.edu:8090/). Downscaled climate projections available through the Data Basin website (http://databasin.org/galleries/602b58f9bbd44dffb487a04a1c5c0f52).

Sensitivity to non-climate stressors

Blue oaks are also sensitive to a number of non-climate stressors that may interact with climate stressors to increase species vulnerability, including invasive species, grazing, habitat conversion, and disease. Exotic annual grasses compete more effectively with oak seedlings for water than native perennials (Gordon et al. 1989), and have been shown to significantly reduce oak seedling emergence, growth and survival, (Gordon et. al 1989, Danielsen 1990, and Gordon and Rice 1993 cited in Tyler et al. 2006). The impacts of invasive grasses may exacerbate the effects of climate-driven reductions in soil moisture, further reducing blue oak recruitment.

Livestock and wildlife grazing also impact blue oak sensitivity by increasing mortality and reducing seedling recruitment. For example, while still on the tree, acorns are susceptible to mortality due to insects (predominantly weevils and moth larvae), birds (including jays, magpies, and acorn woodpeckers), and mammals (including mice, squirrels, deer, pigs, and cattle) (Griffin 1980b, Koenig et al. 2002 cited in Tyler et al. 2006). Grazing has also been implicated in recruitment failure, although studies have yielded conflicting results (Tyler et al. 2006). Some studies identify predation of blue oak acorns, seedlings, and saplings by rodents and deer as a major source of mortality (Borchert et al. 1989, Callaway 1992, and Swiecki et al. 1997b cited in Tyler et al. 2006; Adams and McDougald 1995), while Hall et al. (1992) suggest that grazing intensity plays a smaller role in seedling survival than seasonality of grazing. Spring and summer grazing of seedlings by livestock and wildlife alike is associated with significantly lower survivorship than areas in which seedlings were exposed only to winter grazing (Hall et al. 1992). Losses to predation may be magnified by climate-driven future reductions in recruitment, due to decreased soil moisture.

Blue oak occurs predominantly on private lands in California where habitat conversion to agriculture and residential development reduce blue oak extent and abundance (Bolsinger 1988; Pavlik et al. 1991). Reduction in suitable habitat may exacerbate future climate-driven reductions in population and distribution.

The introduced pathogen *Phytophthora ramorum* affects oaks in coastal and montane forests of California (Rizzo et al. 2002). Moisture is essential for survival and sporulation of *P. ramorum*, and the duration, frequency, and timing of rain events during winter and spring play a key role in inoculum production, and heavy late-spring rain associated with El Niño events (e.g., 1998) may have played a role in the current distribution of *P. ramorum* in California (Meentemeyer et al. 2004). Increases in winter rain may produce optimal conditions for the pathogen in some areas, and modeling projects future oak infection risk to be moderate and high in scattered areas of the Sierra Nevada foothills in Butte and Yuba counties (Meentemeyer et al. 2004).

Adaptive Capacity

The capacity of blue oak to adapt to changes in climate will likely be facilitated by its wide distribution and extensive dispersal capacity. The blue oak woodland type, ranging from open savannas to dense woodlands, ranks first in terms of total land area among California oaks (Davies et al. 1998 cited in Tyler et al. 2006), and the large population in the Sierra Nevada is well connected across a broad elevational and latitudinal range. The adaptive capacity of blue oaks is also facilitated by their tolerance of a wide range of environmental conditions and ability to modify physiology in response to unfavorable environmental conditions (e.g., drought). For instance, during dry years, blue oaks will lose leaves early to reduce water loss (McCreary 1990).

However, the adaptive capacity of blue oaks may be constrained by limited natural regeneration, which has been noted in portions of its range (Bartolome et al. 1987; Bolsinger 1988; Tyler et al. 2006). Blue oak seedlings and saplings are present but relatively rare in many stands, and absent from others, with some stands showing no evidence of tree recruitment within the past 50 years. However, low mortality rates of adults, estimated between 2 to 4% per decade (Swiecki et al. 1993), may be sufficient to allow replacement even at low sapling survival rates.

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P.O. Box 11195
Bainbridge Island, WA 98110

EcoAdapt.org
+1 (206) 201 3834