Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Riparian Vegetation/Natural Riverbank

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

Vulnerability Component	**Score**
Sensitivity	High
Exposure	High
Adaptive Capacity	Moderate
Vulnerability	**High**

Overall vulnerability of the riparian vegetation habitat was scored as moderate-high. The score is the result of high sensitivity, high future exposure, and moderate adaptive capacity scores.

Key climate factors for riparian vegetation include altered streamflow, timing of snowmelt/runoff, storms, and drought. Changes in streamflow volume and timing, as well as changes in the frequency and timing of floods, affect vegetation composition and structure, potentially reducing habitat quality for riparian wildlife. Earlier timing of snowmelt and runoff contributes to lower late spring and summer flows, while increased drought frequency and severity exacerbates water stress for riparian species.

Key disturbance mechanisms for riparian vegetation include wildfire, flooding, and grazing; all of these can impact this habitat directly by removing riparian vegetation and indirectly by altering stream hydrology.

Key non-climate factors include dams, levees, and water diversions, groundwater overdraft, and agricultural and rangeland practices, all of which further fragment and destroy habitat, alter stream hydrology, and lower the water table, ultimately impacting vegetation composition and structure.

The distribution of riparian vegetation is shrinking in many areas because of development and/or changes in land use; agricultural and rangeland practices and dams, levees, and water diversions can act as significant barriers to dispersal as well. Riparian habitats are naturally heterogeneous, with diverse species composition and habitat structure, and efforts to conserve riparian habitat for wildlife in areas of development pressure are growing.

Management potential for amphibians was scored as moderate-high. Incentive programs may provide funding and/or technical assistance to help private landowners modify land-use practices and restore native vegetation. Large restoration projects, such as the Yolo Bypass, illustrate how breaching levees and restoring riparian vegetation benefit many ecosystem functions and provide non-structural flood control for urban or agricultural areas.

Climate Change Vulnerability Assessment: Riparian Vegetation/Natural Riverbank

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Introduction

Description of Priority Natural Resource

Riparian vegetation/natural riverbank refers to the vegetation that grows along the shores of freshwater rivers and lakes as well as the meander-belt processes that shape the habitat. As a river meanders, the bank on one side erodes while sediments accumulate on the opposite side, destroying old habitat and creating new substrate to be colonized, creating a constant succession of vegetation types adapted to this dynamic process. A shrub zone dominated by species of willow (*Salix* spp.) and mulefat (*Baccharis pilularis*), is the earliest successional stage, colonizing exposed sand or gravel bars. If the stands are protected from flooding for 15 to 20 years, a willow woodland eventually emerges. Still higher and further back in the floodplain, a riparian forest develops, dominated by cottonwoods in association with oak, white alder, willows, California bay-laurel, sycamore, and walnut, and white alder, depending on location. Mature riparian forests are complex in architecture and provide important ecosystem services including wildlife habitat and refugia, bank stabilization, and flood attenuation.

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".

As part of the Central Valley Landscape Conservation Project, workshop participants identified riparian vegetation as a Priority Natural Resource for the Central Valley Landscape Conservation Project in a process that involved two steps: 1) gathering information about the habitat's 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 riparian vegetation as a Priority Natural Resource included the following: the habitat has high management importance, and it is important for connectivity and fish and bird habitat. Please see Appendix A: "Priority Natural Resource Selection Methodology" for more information.

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	High	High
Extreme events: drought	Moderate-high	High
Extreme events: storms	High	-
Increased flooding	-	High
Increased wildfire	-	Moderate-high
Soil moisture	Moderate	-
Timing of snowmelt/runoff	High	High
Overall Scores	**High**	**High**

Potential refugia: *Refugia are limited because there is not much riparian habitat. However, groundwater-dependent ecosystems may be less sensitive to warming temperatures and increased evapotranspiration than areas that are snow- or rainwater-dependent (Vose et al. 2016).*

Streamflow

Sensitivity: *High (high confidence)*
Future exposure: *High (high confidence)*

Climate-driven changes in streamflow may reduce the abundance of native early-successional tree species and increase drought-tolerant, late-successional herbaceous and woody species, including invasive/non-native species (Perry et al. 2012). Altered streamflow may also shift the distribution of riparian vegetation, as decreased streamflow could negatively affect sediment movement and seed dispersal (Poff et al. 1997; Graf 2006), while increased streamflow could lead to increased flooding, erosion, and vegetation removal (Perry et al. 2012). These changes are likely to result in lower diversity and abundance in the riparian vegetative community, and could have cascading impacts to the adjacent terrestrial ecosystem (Nakano et al. 1999).

Timing of snowmelt & runoff

Sensitivity: *High (high confidence)*

Future exposure: *High (high confidence)*

Hydrological models project larger and more frequent winter floods as rain-on-snow events and winter snowmelt become more common in the headwaters (Hamlet & Lettenmaier 2007). Total annual water year runoff has increased for the Sacramento River basins and decreased for the San Joaquin River basins, but both areas experienced decreases in spring runoff (April-July), which declined by 9% for the Sacramento River basins and declined by 7% for the San Joaquin River basins; these trends may continue through 2050 (Hunsaker et al. 2014).

Warmer temperatures have already resulted in reduced snowpack, greater proportions of rainfall compared to snowfall, increased rain-on-snow events, and earlier snowmelt in many areas of the western U.S., with the biggest changes observed in rivers with low-elevation headwaters (Regonda et al. 2005; McCabe & Clark 2005); this trend is also evident at higher elevations (Clow 2009). Reduced snowpack may also decrease flow volumes at the start of the recession (Yarnell et al. 2010). Earlier spring snowmelt in snowmelt-dominated rivers would likely lead to late-season drying and increased water stress for vegetation (Perry et al. 2012). Earlier peak flows would also reduce recruitment success for riparian species that rely on flooding for seed dispersal and germination, such as cottonwoods and willows (Rood et al. 2005; Stella et al. 2006).

Storms

Sensitivity: *High (high confidence)*

More intense summer monsoon rainstorms and more frequent winter frontal rainstorms in the monsoon region would likely increase flooding in monsoon-dominated rivers (Vivoni et al. 2009). Changes in the timing or severity of storms could have complex, species- and community-specific impacts on riparian plant growth, survival, recruitment, population dynamics, geographic distributions, and community composition and structure (Perry et al. 2012).

Drought

Sensitivity: *Moderate-high (high confidence)*

Future exposure: *High (high confidence)*

Over the coming century, the frequency and severity of drought is expected to increase due to climate change (Hayhoe et al. 2004; Cook et al. 2015; Diffenbaugh et al. 2015; Williams et al. 2015), as warming temperatures exacerbate dry conditions in years with low precipitation, causing more severe droughts than have previously been observed (Cook et al. 2015; Diffenbaugh et al. 2015). Regardless of changes in precipitation, warmer temperatures are expected to increase evapotranspiration and cause drier conditions (Cook et al. 2015). Recent studies have found that anthropogenic warming has substantially increased the overall likelihood of extreme California droughts, including decadal and multi-decadal events (Cook et al. 2015; Diffenbaugh et al. 2015; Williams et al. 2015).

Drought has significant effects on riparian vegetation both directly and indirectly by impacting riparian structure and composition. Low soil moisture can lead to water stress, earlier spring phenology, decreased photosynthesis and growth, and even mortality (Perry et al. 2012). Riparian forests may be more vulnerable to widespread tree mortality from "hotter droughts" (Allen et al. 2015), and drought may also exacerbate the impacts of other stressors (e.g., insects, pathogens, wildfire) and drive an increase in large-scale disturbance events (Millar & Stephenson 2015). Cumulative water deficit may be the most important variable predicting shrub distribution in arid regions (Dilts et al. 2015).

Individual species have different capacities to avoid or tolerate drought by controlling their leaf area, osmotic potential, leaf conductance, and the maintenance of turgor (Nilsen et al. 1984). Plants that are able to access groundwater, such as those with more developed root systems, may avoid the effects of drought in some areas (Ehleringer & Dawson 1992).

Soil moisture

Workshop participants did not further discuss this climate factor beyond assigning a sensitivity and/or exposure score.

Sensitivity: *Moderate (high confidence)*

Climatic changes that may benefit the habitat:

- More storms are associated flooding may increase the resilience of riparian habitat and provides increase the habitat area, enhancing habitat availability for fish

Temperature is projected to increase by roughly 5-6°F during the 21st century (Bureau of Reclamation 2015). Although precipitation models for California are highly uncertain, some projections suggest that annual precipitation in the Sacramento and San Joaquin River Basins will remain quite variable over the next century, increasing slightly by 0.6% in the Sacramento River Basin and decreasing by 4.2-5.3% in the San Joaquin River Basin by 2050 (Bureau of Reclamation 2015).

Substantial drying during the hot summer months this time will affect hydrologic regimes, which impact riparian vegetation composition, structure, extent, and functioning (Poff & Zimmerman 2010). In general, a decline in minimum flows and increased intermittency is likely to lead to increased dominance of exotic species such as *Tamarix* spp., replacing native cottonwood (*Populus* spp.) and willow (*Salix* spp.; Stromberg et al. 2010). Modeling studies indicate that some arid areas in the Southwest could experience a reduction of almost a third of their current riparian area by the end of the century due to drying (Serrat-Capdevila et al. 2007).

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.

Overall impact of non-climate factors: High (high confidence).

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

Human activities have constricted and altered the composition and functioning of many of these riparian vegetation systems. Introduced species have replaced native riparian species, especially in disturbed areas (Stromberg et al. 2010).

Dams, levees, & water diversions

> ***Sensitivity:*** *High (high confidence)*
> ***Current exposure:*** *High (high confidence)*
> ***Pattern of exposure:*** *Consistent across the landscape.*

Dams, levees, and water diversions and their associated flow regulation have reduced flood magnitude and frequency, altered flood timing, and impeded sediment movement and seed dispersal (Poff et al. 1997; Graf 2006), which impact vegetation composition and structure (Stromberg et al. 2007). More intermittent flows can reduce herbaceous species diversity and cover along stream channels (Stromberg et al. 2007), and a shift from wetland pioneer trees (e.g., cottonwood, willow) to more drought-tolerant shrub species including *Tamarix* spp. (invasive) and *Bebbia* spp. (Kerns et al. 2009).

Groundwater overdraft

> ***Sensitivity:*** *High (high confidence)*
> ***Current exposure:*** *Moderate-high (high confidence)*
> ***Pattern of exposure:*** *Consistent across the landscape.*

In arid and semiarid regions, groundwater is an important source of water for plant, wildlife, and human communities. Groundwater-dependent riparian systems are sensitive to changes in depth of the water table caused by extraction of water for human use, which can impact plant physiology, structure, and community dynamics (Naumburg et al. 2005). However, responses to drops in the water table are species-specific, and are heavily influenced by factors such as drought and flooding tolerances and rooting depth (Naumburg et al. 2005). Large-scale groundwater extraction may cause adverse environmental impacts on riparian and stream systems because of the close linkages between groundwater and biogeochemical cycles and ecological processes (Loáiciga 2002, 2003). Excessive groundwater overdraft can result in decreased river runoff or spring flow, and land subsidence (Zektser et al. 2004).

Agricultural & rangeland practices

Sensitivity: *Moderate-high (moderate confidence)*
Current exposure: *High (high confidence)*
Pattern of exposure: *Consistent across the landscape.*

The Central Valley is dominated by agricultural development, with 56% of the valley classified as irrigated or non-irrigated farmland (Newbold 2002). Agricultural development in this region has been possible due to a massive water distribution system that transfers water from the north to arid central and southern parts of the state (Duffy & Kahara 2011). Water management practices intended to maintain reservoir storage and deliver water to municipal, agricultural, and industrial users frequently reduce flow variability, often by decreasing and magnitude and/or frequency of high flows (Perry et al. 2012). Earlier and larger irrigation water withdrawals could also substantially reduce late-spring and summer flows (Eheart & Tornil 1999), potentially compounding projected reductions in streamflow and further increasing plant and animal water stress (Perry et al. 2012).

Urban/suburban development

Sensitivity: *Moderate (high confidence)*
Current exposure: *High (high confidence)*
Pattern of exposure: *Localized around current development.*

Flood control and water storage and diversion projects have promoted urban and agricultural development within the Central Valley, leading to substantial vegetation change, stream channelization, increased grazing, and nutrient pollution (Patten 1998; Brinson & Malvárez 2002).

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 (high confidence)*

Flooding

Future exposure: *High (high confidence)*

The frequency and magnitude of winter floods are projected to increase across much of the western United States (Leung et al. 2004; Kim 2005; Dettinger 2011).

The composition of riparian vegetation is largely determined by flooding, both natural and as the result of dam operations (Junk et al. 1989; Ohmart 1996). Major floods can result in stream bank scouring and the removal of riparian vegetation, which resets succession and allows early seral species (including invasive species) to pioneer the recently disturbed sites (Stromberg et al. 1993). However, floods benefit riparian vegetation by creating openings in typically dense riparian assemblages, transporting seeds and vegetative propagules, saturating floodplains to encourage seedling growth, and depositing nutrient-rich sediments that promote germination and recruitment, particularly of cottonwood (Stromberg et al. 1993). More frequent large floods may negatively impact beaver (*Castor canadensis*) and other semi-aquatic mammals, which can heavily influence the structure of riparian vegetation (Perry et al. 2012). Finally, more frequent and larger floods could increase groundwater recharge in semiarid and arid areas, where most recharge occurs through dry streambeds after heavy rainfalls and floods (Karl et al. 2009).

Wildfire

Future exposure: *Moderate-high (high confidence)*

Because moisture is readily available, riparian vegetation is generally very productive and often have high stem densities, biomass, and potential fuel loads (Van de Water & North 2011). Because of this, riparian habitats are susceptible to severe wildfire (Olson & Agee 2005), although fire regimes are dependent on geomorphology, hydrology, vegetation, and microclimate; fire regimes often differ from those in the surrounding upland areas (Dwire & Kauffman 2003). Extreme weather conditions, such as hot, dry wind storms can contribute to particularly severe fires in riparian areas, which alter vegetation structure and composition (Van de Water & North 2011). More frequent fires can facilitate the transition of woody vegetation to grasses, further increasing flammability and the likelihood for more fires (Dwire & Kauffman 2003). The loss of woody riparian vegetation to fire also reduces shading over streams, contributing to increase water temperatures (Beakes et al. 2014).

Grazing

Warming temperatures and less soil moisture is likely to reduce grazing forage and available water for livestock grazing, and could exert additional pressures on riparian areas (Vose et al. 2016).

Many riparian areas are heavily grazed, which can impact riparian ecosystems both directly and indirectly (Ohmart 1996). Grazing can also affect the ecology of riparian ecosystems by reducing plant cover and forage availability, reducing root growth, shortening the season of forage production, and exposing the soil to erosion (Vallentine 1989). Additional negative effects include excessive consumption and trampling of native-plant seedlings, soil compaction, destabilization of channel banks, increased stream sediment concentrations, and displacement of wildlife (Lusby et al. 1971; Kauffman & Krueger 1984; Ohmart 1996; Scott et al. 2003). Overgrazing has also been partly implicated in the decline of quaking aspen in some regions (Bartos & Campbell 1998). The combination of a number of exceptionally dry years and intensive grazing pressure can alter vegetation composition and structure, which may also increase the susceptibility to fire (Vose et al. 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, Integrity, & Continuity	Low-moderate
Landscape Permeability	Low
Resistance & Recovery	Low-moderate
Habitat Diversity	Moderate-high
Other Adaptive Capacity Factors	Moderate
Overall Score	**Moderate**

Extent, integrity, and continuity

Overall degree of habitat extent, integrity, and continuity: *Moderate (high confidence)*
Geographic extent of habitat: *Transcontinental (high confidence)*
Structural and functional integrity of habitat: *Fairly degraded (high confidence)*
Continuity of habitat: *Isolated and/or quite fragmented (high confidence)*

The extent of riparian vegetation with the Central Valley has declined by approximately 89% since the mid-1800s; of the remaining area, about half has been disturbed or degraded (Katibah 1984). The distribution of riparian vegetation is also shrinking because of land-use practices and development (Chornesky et al. 2015). In most cases, riparian areas are more fragmented than the stream channel itself[1].

Although there are significant barriers to riparian habitats, they function as ecological corridors for a wide array of plants and animals, connecting headwaters to lower elevation wetlands in some areas (Perry et al. 2012). Because riparian habitats occur along elevational gradients and connect terrestrial and aquatic habitats, they may provide climate refugia and facilitate range shifts under changing climate conditions (Seavy et al. 2009)

Landscape permeability

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

Levees are a key landscape barrier for riparian habitats, although the impact is strongly dependent on levee location[1].

Resistance and recovery

Overall ability to resist and recover from stresses: *Low-moderate (high confidence)*
Resistance to stresses/maladaptive human responses: *Low-moderate (high confidence)*
Ability to recover from stresses/maladaptive human response impacts: *Low-moderate (high confidence)*

Riparian areas are generally wetter than surrounding areas and can provide a buffer against extreme temperatures (Bakker & Slack 1985; Meave & Kellman 1994). For example, riparian vegetation can maintain cooler water temperatures by shading water from sunlight (Sridhar et al. 2004) and provide pockets of cool water (Chu et al. 2008).

The rate of change is an important factor in plant survival within riparian habitats (Scott et al. 1999; Shafroth et al. 2000). For example, slow and steady groundwater overdraft may allow the roots of some tree species, such as cottonwood, to elongate enough to keep pace with the drop in the water table, allowing the tree to survive (Scott et al. 1999). However, although established plants may be able to survive rapid drawdown of water for short periods of time, cottonwood sapling mortality may be as high as 100% (Shafroth et al. 2000).

Habitat diversity

Overall habitat diversity: *Moderate-high (high confidence)*
Physical and topographical diversity of the habitat: *Moderate (high confidence)*
Diversity of component species within the habitat: *High (high confidence)*
Diversity of functional groups within the habitat: *Moderate-high (moderate confidence)*

Component species or functional groups particularly sensitive to climate change:
- Altered competitive interactions with invasive species

Keystone or foundational species within the habitat:

- Cottonwood
- Valley oak (*Quercus lobata*)
- Gooding's black willow (*Salix gooddingii*)
- Sycamore (*Platanus* spp.)

Riparian habitats are generally diverse in species composition and habitat structure, and these factors help make these systems more resilient to the effects of climate change (Perry et al. 2012). However, the presence and abundance of invasive species, such as *Tamarix* spp., can drastically alter species composition and structure and lower system resilience (Stromberg et al. 2007).

Management potential

Workshop participants scored the resource's management potential.

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

Value to people

Value of habitat to people: *Moderate-high (high confidence)*
Description of value: *Aesthetics, birding.*

Support for conservation

Degree of societal support for managing and conserving habitat: *Moderate-high (high confidence)*

Degree to which agriculture and/or rangelands can benefit/support/increase the resilience of this habitat: *Moderate-high (low confidence)*
Description of support: *More fencing and/or limits on agriculture and rangeland practices would support the habitat.*

Degree to which extreme events (e.g., flooding, drought) influence societal support for taking action: *Moderate-high (moderate confidence)*
Description of events: *When land is flooded, people want to take action; however, this can be positive or negative.*

Likelihood of converting land to habitat

Likelihood of (or support for) converting retired agriculture land to habitat: *Moderate (moderate confidence)*
Description of likelihood: *There is support for agricultural land to be converted to floodplain.*

Likelihood of managing or alleviating climate change impacts on habitat: *Moderate (moderate confidence)*
Description of likelihood: *Can use setback levees, use easements, and/or adjust water operations.*

Proactive actions that are aimed at increasing the resilience and resistance of riparian vegetation to the impacts of climate change may include increasing the scale of protected area networks and connected private lands (Heller & Zavaleta 2009), securing water rights for environmental flows (Palmer et al. 2008), implementing water conservation measures or cropping pattern adjustments (Lellouch et al. 2007; Purkey et al. 2008), and restoring riparian vegetation to increase habitat connectivity, promote linkages between aquatic and terrestrial ecosystems, expand thermal refugia for wildlife, and protect genetic diversity (Heller & Zavaleta 2009; Seavy et al. 2009). Restoration activities could also include restoring riparian vegetation to shade streams and provide bird habitat, invasive species removal, and rare species protection (Palmer et al. 2008, 2009). Breaching levees in order to reconnect river channels with their floodplains can greatly benefit ecosystem function and provide non-structural flood control for urban or agricultural areas (Poff 2002; Golet et al. 2006). The engineered floodplains of the Yolo Bypass on the Sacramento River are a good example of the effectiveness of this strategy (Sommer et al. 2001).

Incentive programs for funding, technical assistance, and infrastructure can help private landowners to modify land-use practices and restore native vegetation for conservation (Norton 2000; Langpap 2006). Public outreach may promote setting houses back from the rivers and limiting development within the floodplains[1].

The implications of adaptation actions could be linked with models of future climate scenarios, land cover, water demand and water management (e.g., (Brekke et al. 2004; Vicuna et al. 2007; Harrison et al. 2008; Purkey et al. 2008; Rajagopalan et al. 2009) and biological response models (Harrison et al. 2008) to identify the most feasible strategies and to help guide decision making. Integrating regional water resource management plans across ownerships and interests may help improve restoration outcomes, and there are potential sources of funding, such as money from the state bond initiatives (i.e., California Department of Water Resources; Chornesky et al. 2015).

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[1] Expert opinion, Central Valley Landscape Conservation Project Vulnerability Assessment