Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Wetland Obligate Plants

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

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

Overall vulnerability of wetland obligate plants was scored as moderate-high. The score is the result of moderate-high sensitivity, high future exposure, and moderate adaptive capacity scores.

Key climate factors for wetland obligate plants include the timing and amount of precipitation, soil moisture, drought, and air and water temperature. These drivers influence plant diversity and composition, as well as recruitment, growth, and survival.

Key non-climate factors for wetland obligate plants include agricultural and rangeland practices, dams, levees, and water diversions, urban/suburban development, nutrient loading, groundwater overdraft, land use change, pollution and poisons, and hunting. These non-climate pressures will likely interact with climate pressures and disturbances and potentially result in habitat loss, degradation, or changes in management practices that alter habitat quality for wetland obligate plants.

Key disturbance regimes for wetland obligate plants include flooding, wildfire, wind, and grazing. Changes in flooding magnitude and duration can substantially impact water availability for wetland plants. Wildfire has variable impacts, stimulating sprouting and seeding for some species, but potentially increasing erosion and reducing shade. Moderate grazing can stimulate diversity, while wind events can enhance erosion and affect vegetation survival. Wetland obligate plants exhibit a moderate degree of specialization; they utilize a variety of wetland habitats, and often rely on other wetland-affiliated species (e.g., specialized pollinators).

Wetland obligate plant populations in the Central Valley are relatively healthy and stable and exhibit moderate connectivity, despite historic wetland loss in the region. Urban development, land use conversion, and agricultural and rangeland practices can disrupt habitat continuity and create dispersal barriers for wetland obligate plants by affecting the movement patterns of key seed dispersers (e.g., waterbirds). Wetland obligate plants exhibit moderate-high diversity, driven largely by the diversity of wetland types, hydroperiods, and management regimes within the study region. Although wetland plants are generally intolerant to changes in hydrology and soil moisture, their resistance to these pressures is enhanced via active management; most of the wetlands in the Central Valley are heavily managed in order to maintain waterfowl hunting opportunities and/or in response to incentive programs for conservation benefits.

Management potential for wetland obligate plants was scored as moderate-high and will likely stem from wetland protection and restoration efforts via incentive programs, and renewed interest in managing wetlands to maintain ecosystem services under a changing climate.

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Introduction

Description of Priority Natural Resource

Wetland obligate plants are diverse, ranging from annuals to perennials and from generalists to extreme specialists[1]. Within a given wetland, plant species composition and diversity is dependent on how much water is available, how long during the year that water persists, and whether or not the wetland is managed for hunting, as well as wetland size, water source, and geomorphology (Ortega 2009; Casazza et al. 2012; Thorne et al. 2016).

Wetland obligate plant species include cattails (*Typha* spp.), tule (*Schoenoplectus acutus*), and bulrushes (*Schoenoplectus* spp.), and sedges (*Carex* spp.), as well as the cultivated plants swamp Timothy (*Heleochloa schenoides*) and smartweed (*Polyganum* spp.; Ortega 2009).

As part of the Central Valley Landscape Conservation Project, workshop participants identified wetland obligate plants 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 group'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 the wetland obligate plants as a Priority Natural Resource included the following: the species group has high management importance, and the species group's conservation needs are not entirely represented within a single priority habitat. 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
Air temperature	Moderate-high	High
Extreme events: drought	High	High
Extreme events: more heat waves	-	High
Increased flooding	-	Moderate-high
Precipitation (amount)	High	High
Precipitation (timing)	High	-
Soil moisture	High	-
Water temperature	Moderate-high	Moderate-high
Overall Scores	**High**	**High**

Climate change is likely to alter habitat availability for wetland obligate plants. Statewide, one percent or less of the current area of freshwater marsh will remain suitable by the end of the century, and the small areas of marsh that are still suitable will likely occur as vegetation refugia (Thorne et al. 2016). Within the Central Valley, areas that remain suitable and/or may become suitable for marsh habitat are located primarily on the eastern side of the valley, except for a small area that could potentially become suitable located on the far northwestern edge (Thorne et al. 2016).

Drought

> ***Sensitivity:*** *High (high confidence)*
> ***Future exposure:*** *High (high confidence)*
> ***Potential refugia:*** *Groundwater supported wetlands or highly managed refuges that stabilize the system.*

Compared to the preceding century (1896-1994), drought years in California have occurred twice as often in the last 20 years (1995-2014; Diffenbaugh et al. 2015). Additionally, the recent drought (2012-2014) has been the most severe drought on record in the Central Valley (Williams et al. 2015), with record accumulated moisture deficits driven by high temperatures and reduced, but not unprecedented, precipitation (Griffin & Anchukaitis 2014; Williams et al. 2015). Additionally, the frequency and severity of drought is expected to increase due to climate change over the next century (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).

Some wetland plants are adapted to seasonal drying (Zedler 2003), but substantial drying during the summer months will likely alter wetland hydrologic regimes and shift wetland vegetation composition, structure, extent, and function (Poff & Zimmerman 2010). Reduced wetland hydroperiods are likely to alter plant community diversity and habitat suitability, particularly for species with longer aquatic life stages (Marty 2005). Similarly, prolonged drought periods may negatively affect permanent wetlands and wetland obligate plants (e.g., see Holden et al. 2012; Abatzoglou & Kolden 2013). For example, excessive drying or drought could shift some permanent wetlands to seasonal wetlands, thereby impacting plant composition and diversity. Additionally, drought conditions could facilitate the spread of exotic species, such as tamarisk (*Tamarix* spp.) or other non-native species that are more drought-tolerant (Stromberg et al. 2010). However, some wetland obligate plants may be able to survive extreme dry conditions by surviving as a seed (Baskin & Baskin 1998).

Drought sensitivity may vary between annual and perennial plant species. Annuals may be more vulnerable due to time scale of drought, as annual plants currently benefit from irrigation in seasonal wetlands during the spring and summer. During an extended drought, water for irrigation is increasingly scarce (difficult to compete with other users), and thus annual plants may not produce seeds needed to re-propagate. This will likely be a bigger issue in the San Joaquin Valley compared to Sacramento Valley, and less of an issue in the Delta[1].

Precipitation (amount)

Sensitivity: *High (high confidence)*

Future exposure: *High (high confidence)*

Precipitation (timing)

Sensitivity: *High (high confidence)*

Overall, there is a slight decreasing trend in precipitation for central and southern California but with increased variability in precipitation (Hunsaker et al. 2014). Although water from snowmelt and rainfall can buffer water shortages during the winter and spring, the southern portion of the Central Valley is overall more sensitive to precipitation and water availability changes due to its drier climate (Kahara et al. 2012).

In general, shifting rainfall patterns may affect the future persistence of plant species that have adapted to historical rainfall patterns (CA Natural Resources Agency 2010), including wetland obligate plants. Changes in the timing and amount of precipitation will affect regional hydrology and the persistence and functioning of wetlands, as well as their component species, such as wetland obligate plants (Meyers et al. 2010; Null et al. 2013). By affecting wetland hydroperiods, precipitation changes may alter wetland plant composition and diversity, which is dependent on wetland size, shape, water source, geomorphology, and management. For example, when water depth is more than one meter, most vegetation is either anchored or floating hydrophytes, such as water lilies, duckweed, or pondweed (Thorne et al. 2016). Sensitivity to precipitation shifts will likely vary by species, since some species are able to tolerate high variability in growing season onset and duration timing (Zedler 2003). Wetland plants in the Sacramento Valley where water resources are not as scarce may be less sensitive to precipitation shifts because the effects of drying may be reduced or delayed (Medellín-Azuara et al. 2007; Reiter et al. 2015).

Soil moisture

> ***Sensitivity:*** *High (high confidence)*

Between 1951-1980, climatic water deficit increased by 2 mm in the Central Valley, compared to an average of 17 mm statewide (Thorne et al. 2015). Thorne et al. (2015) project that climatic water deficit is expected to increase by 131 mm in the Central Valley (compared to 140 mm statewide) by 2070-2099 under a drier scenario and 44 mm (compared to 61 mm statewide) under a wetter scenario.

Soil moisture is a dominant factor that regulates the distribution, productivity, and survival of wetland obligate plants (Running et al. 2004). A lack of soil moisture can lead to water stress, earlier spring phenology, decreased photosynthesis and growth, and even mortality (Perry et al. 2012). Individual wetland plant species have different capacities to avoid or tolerate soil moisture reductions by controlling leaf area, osmotic potential, leaf conductance, and the maintenance of turgor (Nilsen et al. 1984). Wetland plants with more developed root systems and that are able to access groundwater may be less sensitive to changes in soil moisture (Ehleringer & Dawson 1992). There can also be a gradient of plant sensitivities to soil moisture within some wetlands from deep to shallow areas (Bauder 2005).

Air temperature

> ***Sensitivity:*** *Moderate-high (high confidence)*
> ***Future exposure:*** *High (high confidence)*
> ***Potential refugia:*** *Near Delta, cold air drainage areas near foothills, vernal pools in Sacramento Valley.*

If soil moisture is adequate, warming air temperatures could increase photosynthesis and growth rates for many wetland obligate plants (Perry et al. 2012). Alternatively, warming temperatures, particularly higher maximum temperatures, could lead to heat stress and reduced wetland plant growth (Perry et al. 2012). Temperatures above 45°C (113°F) damage or kill leaf tissue of most plant species, and temperatures between 25-45°C (77-113°F) can reduce germination, growth, flowering, fruit ripening, and seed set (Wahid et al. 2007). Additionally, some plants may experience phenologic mismatches if temperatures warm (Perry et al. 2012).

Water temperature

> ***Sensitivity:*** *Moderate-high (moderate confidence)*
> ***Future exposure:*** *Moderate-high (high confidence)*
> ***Potential refugia:*** *The Delta and Sacramento Valley as the San Joaquin Valley warms.*

Warming water temperatures may prolong anoxic conditions, which can develop whenever water tables are high; anoxic periods strongly affect wetland plant community composition (Castelli et al. 2000). Additionally, high water temperatures may increase plant growth rates but negatively affect germination[1]. Water temperature tolerances for most wetland obligate plants are unclear[1].

Heat waves

> ***Future exposure:*** *High (high confidence)*
> ***Potential refugia:*** *Groundwater supported wetlands or highly managed refuges that stabilize the system.*

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	Moderate-high
Dams, levees, & water diversions	High	High
Groundwater overdraft	Moderate-high	Moderate-high
Land use change	Moderate-high	Moderate
Nutrient loading	High	High
Other factors	Moderate-high	Moderate-high
Pollution & poisons	Moderate-high	Moderate-high
Urban/suburban development	High	Moderate
Overall Scores	**High**	**Moderate-high**

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 for agriculture and other human uses can change streamflow dynamics, including high- and low-flows, affecting wetland plant species composition and structure (Stromberg et al. 2007). Future changes in water management to maintain reservoir storage and deliver water to municipal, agricultural, and industrial users are likely to reduce flow variability, particularly by decreasing flood magnitude and/or frequency (Perry et al. 2012); a reduction in flooding will have major effects on wetland geomorphology and ecology, and subsequently, on wetland obligate plants. For example, as streamflows become more intermittent, the diversity and cover of herbaceous wetland obligate plants may decline (Stromberg et al. 2010). Perennial wetland plant species can be significantly impacted as more water is diverted and groundwater tables decline, driving shifts in floodplain species composition from wetland pioneer trees (*Populus* spp., *Salix* spp.) to more drought-tolerant shrub species, including *Tamarix* spp. (non-native) and *Bebbia* spp. (Kerns et al. 2009).

Nutrient loading

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

Excess nutrients, such as nitrogen and phosphorus, can increase algal production, decrease dissolved oxygen, and alter the species composition of wetland communities (Carpenter et al. 1998; Klose et al. 2012). Additionally, excessive nutrient loading can lead to increased invasive species abundance in some areas (Gerhardt & Collinge 2003). Although natural levels of some of these nutrients are relatively high in some areas, additional concentrations can be delivered to wetlands via runoff from agricultural and urban activities (Carpenter et al. 1998). Agriculture is the primary source of nutrient loading in the Central Valley, but urban runoff from wastewater treatment plants, industrial sites, and fertilizer applications can also contribute significant additions (Carpenter et al. 2007; Klose et al. 2012).

Agricultural & rangeland practices

Sensitivity: *High (high confidence)*
Current exposure: *Moderate-high (high confidence)*
Pattern of exposure: *Consistent across the landscape, but particularly in the Tulare Basin.*

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). In fact, nearly 93% of all water used in the region is for agricultural production. Earlier and larger irrigation water withdrawals could substantially reduce late spring and summer flows (Eheart & Tornil 1999), thereby compounding projected reductions in available water and further increasing plant stress (Perry et al. 2012). Wetland plants can be obliterated by incompatible agricultural and rangeland practices[1].

Urban/suburban development

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

> ***Sensitivity:*** *High (high confidence)*
> ***Current exposure:*** *Moderate (high confidence)*
> ***Pattern of exposure:*** *Localized around existing cities.*

Groundwater overdraft

> ***Sensitivity:*** *Moderate-high (high confidence)*
> ***Current exposure:*** *Moderate-high (high confidence)*
> ***Pattern of exposure:*** *Consistent across the landscape, but worse in the south half of the Central Valley. Exposure depends on water table depth.*

Groundwater is an important source of water for plants and humans, especially in arid and semiarid regions, and a change in groundwater depth due to over-drafting may affect vegetation physiology, structure, and community dynamics (Naumburg et al. 2005). Generally, decreasing water tables as result of overdraft increases plant water stress and reduces or eliminates live biomass (Zektser et al. 2004). However, responses are species-specific and depend on plant drought and flood tolerances and rooting depth. Large-scale groundwater extraction may cause adverse environmental impacts on riparian, stream, and wetland systems because of the close linkages between groundwater and biogeochemical cycles and ecological processes (Loáiciga 2002, 2003).

Hunting

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

The majority of wetland habitat in the Central Valley is managed for hunting (Gilmer et al. 1982), and funds for wetland protection and restoration are largely provided by the sale of Federal Migratory Bird Hunting and Conservation Stamps ("duck stamps"; Gilmer et al. 1982). Subsequently, many hunters support policies and management practices that benefit waterfowl and management of their wetland habitat (North American Waterfowl Management Plan 2012), indirectly benefitting wetland obligate plants. Species composition within wetlands managed for hunting tend to include plants that are valued as a food source for waterfowl (Casazza et al. 2012) and many wetlands are managed for seed production of swamp Timothy (*Heleochloa schenoides*) and smartweed (*Polyganum* spp.; Ortega 2009). Other management activities that maintain wetlands for waterfowl and affect wetland obligate plants include flood regime management, burning, and disking (Kahara et al. 2012). In some cases, wetlands have been converted when hunting value declines (Gilmer et al. 1982), and without hunting, wetland vegetation will likely change[1].

Pollutions & poisons

> ***Sensitivity:*** *Moderate-high (moderate confidence)*
> ***Current exposure:*** *Moderate-high (high confidence)*

Pattern of exposure: *Consistent across the landscape, but depends on pollutant.*

Roadway contaminants, mosquito-control pesticides, and agricultural pesticide and herbicide use may negatively impact wetland water and soil quality (U.S. Fish and Wildlife Service 2005). Pollutions and poisons can have direct impacts on wetland obligate plants, but can also indirectly affect this species group by altering wetland management, which ultimately impacts plants. For example, the direct impact of mercury on plants is less than potential changes in wetland management in response to mercury issues, such as a requirement to curtail mercury methylation[1]. Mercury forms in anoxic sediment, especially surface sediment in wetland environments (Windham-Myers et al. 2014). Wetlands actively managed for agriculture, such as rice, tend to have substantially higher concentrations of mercury – up to 95-fold higher than non-agricultural permanently-flooded and seasonally-flooded wetlands (Windham-Myers et al. 2014).

Land use change

Sensitivity: *Moderate-high (high confidence)*
Current exposure: *Moderate (high confidence)*
Pattern of exposure: *Localized around existing cities.*

Because wetlands are generally found on flat, fertile substrates, such as floodplain and valley floors, they were prime locations for historical conversion (Frayer et al. 1989). Since 1849, there has been a 90% reduction in wetland acreage across California (CA Natural Resources Agency 2010), and more than 95% of wetlands have been lost through conversion to urban development or agriculture in the Central Valley (Gilmer et al. 1982). Exacerbating this loss is population growth and continued water demand for agriculture and development (Duffy & Kahara 2011). Contemporary land conversions of greatest concern are wetland conversion to agricultural uses and vineyards[1].

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

Sensitivity: *Moderate-high (no confidence assessed)*
Future exposure: *Moderate-high (high confidence)*

Wetland obligate plants are adapted to the historical wetland flooding patterns in the Central Valley, with flooding occurring typically during winter months. However, because flooding mechanisms (snowmelt versus rain) differ between basins, there are large differences in the timing that wetlands receive their water (Duffy & Kahara 2011). Increased flood events as a result of climate change could convert vernal pools to emergent vegetation (Euliss et al. 2004), but could also act as a positive event for other habitats with wetland obligate plants[1]. If flood events are intense but short-lived, the total time flooded over the year could be lower, potentially reducing habitat suitability for wetland obligate plants[1].

Additionally, many of the river systems that feed Central Valley wetlands are now highly managed by dams, levees, and bypasses, which control flow variability and essentially eliminate natural flood regimes; most wetlands now rely on managed water supplies for seasonal flooding (CA Natural Resources Agency 2010). Changes in the frequency and magnitude of floods as a result of human management will affect wetland obligate plant species composition and structure (Stromberg et al. 2007; see non-climate factors section below). Water captured by dams and delivered by canal or through stream channels is in high demand as it provides water for a variety of uses. Demand for this water increases every year, as does the cost, and many wetland managers now rely on irrigation drain water, wastewater discharges, low priority water contracts, non-binding agreements with water districts, and groundwater pumping (CA Natural Resources Agency 2010). Increasing water demand will likely compound climate-induced changes in hydrology is future water demand (Medellín-Azuara et al. 2007), placing additional stress on water supplies (Kahara et al. 2012).

Wildfire

Sensitivity: *Moderate (no confidence assessed)*

Compared to surrounding terrestrial areas, wetlands tend to have relatively high levels of biomass and fuel loads (Van de Water & North 2011), which makes them susceptible to high-severity fires (Olson & Agee 2005). As temperatures warm, wetland areas may become increasing susceptible to wildfire. Fires that occur during extreme weather conditions (e.g., hot, dry wind storms) can be particularly severe (Van de Water & North 2011). More frequent and severe fires may increase sediment runoff and reduce shading from nearby woody vegetation, increasing wetland water temperatures (Dwire & Kauffman 2003; Miller et al. 2003; Pettit & Naiman 2007; Barnett et al. 2008). Additionally, wildfires that burn cattails (*Typha* spp.) or tule (*Schoenoplectus acutus*) can significantly increase soil compaction[1].

However, many species of wetland grasses are adapted to fire, which can stimulate sprouting and seeding; these include cordgrasses (*Spartina* spp.), bulrushes (*Schoenoplectus* spp.), and cattails, although some sedges (*Carex* spp.) do not re-sprout readily (Sugihara 2006; Thorne et al. 2016). In seasonal wetlands, wildfire is usually applied by managers via prescribed burning to reset succession and increase species richness and vegetative cover (Sugihara 2006).

Wind

Sensitivity: *Low-moderate (no confidence assessed)*

Wind events are naturally variable and therefore long-term historical records are sparse in wetlands. Additionally, future projections of extreme weather events are difficult to model (Toreti et al. 2013). Nevertheless, wind disturbances are geomorphologically and ecologically important for wetland obligate plants because they can affect a large area (Yih et al. 1991) and effects on vegetation and soils may be permanent on an ecological time scale (Wanless et al. 1994). For instance, high magnitude wind disturbances can affect wetland soil (sediment, deposition, and erosion), root growth, and vegetation survival, especially along coastal areas (Cahoon 2006). Wind can also decrease vernal pool hydroperiods, but helps with soil turnover in larger water bodies[1].

Grazing

Drought may reduce grazing forage and available water for livestock in terrestrial areas and could thereby exert additional grazing pressure on wetland areas (Vose et al. 2016). The combination of a number of exceptionally dry years and intensive grazing pressure can substantially alter wetland vegetation composition and structure, which then can increase susceptibility to fire. In some systems, these changes could shift the habitat composition to early seral vegetation, thereby losing some of the wetland shading effects from mature trees (Vallentine 1989).

Although intensive grazing can be detrimental for some wetland plants and their habitats, moderate grazing has the potential to be beneficial. Moderate cattle grazing is currently used in Central Valley wetlands to increase species richness and vegetative cover (Sugihara 2006); however, sheep grazing is not beneficial for wetland obligate plants[1].

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**: Moderate (high confidence)*
> ***Dependency on one or more sensitive habitat types:** High (high confidence)*
>> ***Description of habitat:** Vernal pools, seasonal wetlands, permanent wetlands, channel connected wetlands, groundwater/spring/seep supplied wetlands.*
>
> ***Dependency on specific prey or forage species:** Low (high confidence)*
> ***Dependency on other critical factors that influence sensitivity:** Moderate (high confidence)*
>> ***Description of other dependencies:** Vernal pool pollinators, seed dispersers (shrews, salt marsh harvest mouse, waterbirds).*

Wetland obligate plants are highly dependent on wetland habitats as well as other wetland species. For instance, some of the relatively large-flowered annuals in vernal pools depend on a number of specialized insects pollinators (Thorp & Leong 1998). Some of these annuals plants also provide an important food resource for many birds (Silveira 2000).

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	Low-moderate
Intraspecific Species Group Diversity	Moderate-high
Resistance & Recovery	Low-moderate
Other Adaptive Capacity Factors	Moderate
Overall Score	**Moderate**

Extent, status, and dispersal ability

Overall degree extent, integrity, connectivity, and dispersal ability: *Moderate (high confidence)*
Geographic extent: *Occurs across the study region (high confidence)*
Health and functional integrity: *Moderately healthy (moderate confidence)*
Population connectivity (north-south): *Patchy with connectivity between patches (high confidence)*
Dispersal ability: *Moderate-high (high confidence)*

Central Valley wetlands covered an area of four million acres in the mid-1800s, but habitat extent has declined significantly since, as much of this area was lost by the mid-1980s due to filling, agricultural production, and land use conversion. Currently, 179,232 acres of seasonal wetlands and 26,322 acres of permanent and semi-permanent wetlands exist in the region (Central Valley Joint Venture 2006). There is significant year-to-year variation in the area and connectivity of flooded habitat (Reiter et al. 2015), and factors such as drought can drastically reduce the area of flooded habitat within a single season (Elphick 2004). However, flooded croplands may provide many of the same ecosystem functions as wetlands and increase wetland habitat continuity (Elphick 2000). The distribution of wetland obligate plants is localized, and southern wetland obligate plant groups are more degraded than northern groups. Many species are endemic, while many others are transboundary[1]. Wetland obligate plant dispersal occurs via wind or animal transport (Elphick 2004).

Landscape permeability

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

Land use conversion and agricultural/rangeland practices can create dispersal barriers for wetland obligate plants, although the degree of impact depends on how much these factors increase habitat fragmentation and create isolated wetlands. For example, shifts in agricultural crops due to climate change (e.g., rice to other crops) could negatively affect some native plant dispersers, such as waterbird species (Elphick 2004), undermining seed and rhizome dispersal. Reduced dispersal opportunities could be further compounded with drying of some seasonal wetlands due to climate change, which creates a more fragmented landscape (Bakker et al. 1996). Grazing can also influence wetland plant dispersal; overgrazing can lower water tables, increasing fragmentation, and mistimed grazing can cause cattle to eat plants before they go to seed. However, vernal pool grazing may facilitate seed dispersal via cattle, although some species are more dependent on waterbirds than cattle for dispersal[1].

Urban development and increased drought are expected to place greater demands on California's electricity supply, which will indirectly affect the water supply for irrigation and wetlands (OEHHA 2013). Dam, water diversions, and levees have a localized impact on dispersal[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: *Moderate (moderate confidence)*

Although wetland obligate plants are generally intolerant to changes in hydrology and soil moisture, most of the wetlands in the Central Valley are heavily managed and many are valued as waterfowl habitat for hunting (North American Waterfowl Management Plan 2012). Therefore, resistance to climate-driven pressures is tied to hunter support as well as incentive programs, both of which fund habitat management and offset water costs (Duffy & Kahara 2011). For example, incentive programs for funding, technical assistance, and infrastructure can help private landowners modify land use practices and restore native wetland vegetation for conservation (Norton 2000; Langpap 2006). Examples of these habitat programs include the Natural Resources Conservation Service's (NRCS) Wetlands Reserve Program and U.S. Fish and Wildlife Service's (USFWS) Partners for Fish and Wildlife Program, which restore, enhance, and protect wetland habitat through voluntary easement agreements, as well as the California Department of Fish and Wildlife's (CDFW) California Waterfowl Habitat Program and its Landowner Incentive Program, which provide financial and technical support for wetland habitat management (DiGaudio et al. 2015).

Species group diversity

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

Wetland obligate plants are highly diverse. Life history strategies include both annuals and perennials, and genetic diversity varies depending on the species. Habitat specificity amongst component plants varies, ranging from generalists (e.g., tule) to highly specialized species (e.g., vernal pool endemics). Although not all plants exhibit behavioral plasticity, some plants can elect to spread by seed or rhizome, or reproduce sexually or asexually. Phenotypic plasticity is similarly variable between species, with some species able to go dormant during the winter, while other species (e.g., vernal pool species) exhibit more limited flexibility. Overall, phenotypic plasticity is limited by water residence time/hydroperiod[1].

Wetland plant diversity is driven by water availability, timing, and depth, and human management practices (Ortega 2009; Casazza et al. 2012; Thorne et al. 2016). Topographic wetland variation and other physical attributes can also create a more heterogeneous habitat, which can support a high degree of plant biodiversity (Kahara et al. 2012).

Other Factors

Overall degree to which other factors affect habitat adaptive capacity: *Moderate (high confidence)*

Population growth
Infrastructure, labor, and funding for adding water to wetlands
Endangered Species Act
Diversion curtailments/instream flow requirements

Population growth

The adaptive capacity of wetland obligate plants is dependent on flow conditions, which are affected by the region's growing population. For instance, the Lower San Joaquin River can experience very low flow conditions, offering little to no flows to dilute watershed drainage in critically dry years. In response, the Central Valley Regional Water Quality Control Board has adopted a requirement for discharges from irrigated lands (Ortega 2009). During these situations, wetland managers are asked to modify their normal water management by draining wetlands to match their discharge and meet load allocations (Ortega 2009); however, it is not entirely clear how these changes may impact different wetland plant species. Instream flow requirements designed to enhance fish habitat are likely to further reduce water availability for wetland species, especially during drought periods (Tanaka et al. 2006; Howitt et al. 2013; Reiter et al. 2015).

Population growth is projected to increase by 19-30% by 2025 in California (Public Policy Institute of California 2006). A larger population will increase the demand for agricultural production, water resources, and land for development. These factors, combined with climate change, will likely impact wetland plant species through loss of habitat and reduced water availability (Gilmer et al. 1982; Ackerman et al. 2006; Medellín-Azuara et al. 2007).

Infrastructure, labor, and funding for adding water to wetlands

It is legally permitted to add water to wetlands, but infrastructure, labor, and funding are lacking; it will likely be difficult to secure water[1].

Management potential

Workshop participants scored the resource's management potential.

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

Value to people

Value to people: *Moderate (high confidence)*
Description of value: *Indirect value through valuing wetlands for water quality, hunting, and other valued species habitat.*

Support for conservation

Degree of societal support for management and conservation: *High (high confidence)*
Description of support: *Same degree of support as permanent wetlands (legislative, regulatory, and hunting support). These plants and hydric soils are indicators of wetland habitat. There are many policies that ensure no net loss of wetlands, and that support preservation or restoration of wetland area. There are many economic ties to wetland presence.*

Degree to which agriculture and/or rangelands can benefit/support/increase resilience: *Moderate-high (high confidence)*
Description of support: *Grazing can benefit vernal pools. Agriculture and rangelands between wetlands gives buffer between wetlands and urban areas, reducing fragmentation. Some marginal agriculture lands will be converted to wetlands. Agricultural lands are restorable; urban land really is not. Vernal pools can't be restored from agricultural land due to deep ripping.*

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

Description of events: *Flooding from major natural disasters (e.g., Hurricane Katrina) increases support for wetlands as buffers. Drought decreases support because of competition for water; people are forced to prioritize for health and public safety.*

Likelihood of converting land to support species group

Likelihood of (or support for) converting retired agriculture land to maintain or enhance species group: *Moderate-high (high confidence)*
Description of likelihood: *Some marginal agricultural lands will be converted to wetlands. The Wetland Reserve Program retires marginal land to create wetlands. Likelihood is low-moderate for vernal pools; they are less likely or impossible to convert from land that was deep-ripped.*

Likelihood of managing or alleviating climate change impacts:

Managed wetlands: *Moderate-high (high confidence)*
Vernal pools: *Low-moderate (high confidence)*
Description of likelihood: *The timing and availability of water allocations or precipitation will be important. It is harder to manage vernal pool hydrology; in managed wetlands, there is a higher chance of alleviating impacts because of higher manipulative ability with water. There may also be opportunity to mitigate temperature increases by timing water release into the system.*

Management objectives and techniques have evolved in the Central Valley over the last few decades, and there are now a number of incentive programs to support wetland restoration and enhancement (Ackerman et al. 2006; Central Valley Joint Venture 2006; North American Waterfowl Management Plan 2012). For instance, many agricultural lands in the Central Valley are enrolled in the USDA's Environmental Quality Incentives Program and receive technical assistance through the Conservation Technical Assistance Program (Duffy & Kahara 2011). Similarly, the Wetlands Reserve Program (WRP) was created by the NRCS as part of the 1990 Farm Bill and is designed to compensate landowners for converting flood-prone farmland to wetlands (Kahara et al. 2012). Since it began, this program has resulted in the restoration of about 29,000 hectares of wetlands in the Central Valley. Actively managed WRP wetlands support special status species than sites under low or intermediate management (Kahara et al. 2012; DiGaudio et al. 2015).

Although many wetlands in the Central Valley have been converted or degraded, managed and unmanaged wetlands provide a number of important ecosystem services, such as groundwater recharge, flood storage, water quality abatement, and biodiversity support (Duffy & Kahara 2011). There is also a growing desire to restore Central Valley wetlands in light of climate change (Seavy et al. 2009). Specific management activities may be focused on retaining water and actively managing vegetation by planting, burning, mowing, or disking, which has the potential to attract waterbirds for hunting (Kahara et al. 2012).

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