Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Permanent Wetlands

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

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

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

Key climate factors considered for permanent wetland habitats include snowpack and precipitation amount. Changes in these climatic factors have significant effects on wetland hydrology, primarily by affecting water availability.

Key disturbance regimes for permanent wetland habitats include flooding, wind, and wildfire. Natural scouring from flooding and high peak flows can benefit permanent wetlands by resetting succession and allowing early successional plants to establish; however, changes to the magnitude and duration of flooding events can prevent this important process. Wind has a minor impact on permanent wetlands, although major windstorms can affect wetland soil, root growth, and vegetation survival over the long term. Wildfire has been suppressed in the Central Valley and now is usually applied by managers via prescribed burning to reset succession.

Key non-climate factors for permanent wetland habitats include land use change, invasive and problematic species, nutrient loading, pollution and poisons, and waterfowl hunting. These non-climate factors will likely interact with climate factors and disturbances and potentially result in habitat loss, degradation, or changes in management practices that alter habitat quality.

Land use change and agricultural/rangeland practices represent barriers for wetland species movement and lead to hydrological changes, which can negatively impact wetland biota. Permanent wetland habitats exhibit moderate diversity, but most have limited physical and topographical diversity. There is a growing desire to restore Central Valley wetlands in light of climate change.

Management potential for Permanent Wetlands was scored as moderate. Permanent wetlands have a significant capacity to adapt to climate change because they are highly managed, used for agricultural production, and their water levels can be controlled to achieve particular management goals. Specific management activities may include retaining water, especially during winter migrations, and actively managing vegetation by planting, burning, mowing, or disking, which also has the potential to attract waterbirds for hunting. However, population growth, Endangered Species Act listings, and instream flow requirements may affect the wetland management capacity.

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Introduction

Description of Priority Natural Resource

Permanent wetlands have standing surface water year-round, and include both managed and unmanaged wetlands. They are too wet for most terrestrial vegetation and tend to undergo wet and dry cycles due to fluctuating water levels (CA Natural Resources Agency 2010). Presently, more than 90% of wetlands in the Central Valley are managed, two-thirds of which are in private ownership (Central Valley Joint Venture 2006). Currently, there are 26,322 acres of permanent and semi-permanent wetlands in the Central Valley, but wetlands remain in only a fraction of their former landscape extent.

As part of the Central Valley Landscape Conservation Project, workshop participants identified the permanent wetland habitat 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 the permanent wetland habitat as a Priority Natural Resource included the following: the habitat has high management importance, and because the habitat provides important ecosystem services such as critical habitat for many species, flood protection, and water quality abatement (Duffy & Kahara 2011). 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 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
Extreme events: drought	Moderate	Moderate
Precipitation (amount)	Moderate-high	-
Snowpack amount	High	High
Timing of snowmelt/runoff	-	Moderate-high
Overall Scores	**Moderate-high**	**Moderate-high**

> ***Potential refugia:*** *Sacramento Valley will be most likely to retain permanent wetlands, as will the reservoirs/farm ponds in the Coast Range and Sierra foothills. San Francisco Bay and coastal marshes (Suisun Marsh) will also have water and new tidal wetlands may be created in the delta and baylands and will serve as refugia for lost freshwater permanent wetlands. However, benefits of these new habitats vary by species group and season (breeding vs. wintering), and they are unlikely to help the giant garter snake (Thamnophis gigas).*

Snowpack amount

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

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).

Wetlands exhibit sensitivity to changes in snowpack at higher elevations, as a decline in snowpack can lead to decreased late spring and summer flows (Perry et al. 2012) and less available water during the dry summer months (Yarnell et al. 2010). Snowpack from mountainous areas surrounding the Central Valley plays a large part in water storage and supply, which includes irrigation for permanent wetlands (Knowles & Cayan 2002; Scanlon et al.

2012). Earlier snowmelt and spring peak flows may result in in lower diversity and abundance in the riparian vegetative community, and could have cascading impacts to the adjacent terrestrial ecosystem (Nakano et al. 1999). Changes in snowpack and snowmelt timing that lead to altered hydrologic regimes such as lower minimum flows and increased intermittency 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).

Precipitation (amount)

Sensitivity: *Moderate-high (high confidence)*

Models indicate a wide range of potential future changes in precipitation for California and the Central Valley. The direction of change is uncertain, with some models projecting more overall average rainfall and others projecting less rainfall, however, by the mid and late century, most models project drier conditions than the historical annual average (Cayan 2012).

In addition to potential changes in average rainfall, models project changes in precipitation patterns, such as increased variability (Hunsaker et al. 2014) and an increase in frequency of intense storms and shifts in seasonality (Dettinger 2011).

Changes in the frequency, abundance, and nature of precipitation events affects regional hydrology and the persistence and functioning of wetlands (Meyers et al. 2010; Null et al. 2013). For example, decreased total precipitation and increased variability in precipitation can affect water availability and the ability to manage wetlands (especially restored wetlands) in the Central Valley (Kahara et al. 2012). Precipitation changes can also influence a wetland's hydroperiod (i.e., the timing and duration of flooding), which can subsequently affect wetland functions and services (CA Natural Resources Agency 2010). For example, freshwater marshes in the Sacramento Basin were historically fed by winter precipitation and resulting floods, while marshes in the San Joaquin Basin were fed by snowmelt runoff, resulting in distinct differences in flood timing (Duffy & Kahara 2011).

The southern portion of the Central Valley is more sensitive to precipitation and water availability changes due to its drier climate, although water from snowmelt and rainfall can help buffer water shortages during the winter and spring (Kahara et al. 2012). Prolonged warming temperatures and a longer dry season could shift some permanent wetlands to seasonal wetlands, allowing more xeric plants to encroach some wetlands thus changing their composition (Bartolome et al. 2014). Substantial water shortages could also result in earlier drawdown and/or reduced irrigation, which could have similar impacts (Eheart & Tornil 1999). Drier conditions can also decrease the availability of food for some wetland species, such as waterbirds and shorebirds (Naylor 2002; Moss et al. 2009).

Drought

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

Longer or more severe droughts are likely to impact water availability and thus habitat extent, although the effects may be reduced or delayed in the Sacramento Valley where water resources are not as scarce (Medellín-Azuara et al. 2007; Reiter et al. 2015). Substantial drying during the summer months affects hydrologic regimes, with impacts to wetland vegetation composition, structure, extent, and functioning (Poff & Zimmerman 2010). During drought years, soil moisture must be recharged before runoff occurs[1].

Managed wetlands are less sensitive to drought than to other factors because stored water may help compensate for decreased water availability[1]. Reductions in permanent wetland acreage due to water availability are well documented (e.g., Reiter et al. 2015), and drought will undoubtedly affect the distribution and presence of wetlands in the future (Thorne et al. 2016).

Timing of snowmelt & runoff

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

In the Sacramento and San Joaquin basins, April-July runoff volume has decreased over the last 100 years by 23% and 19% respectively, reflecting earlier timing of peak flows (Anderson et al. 2008).

An earlier and potentially shorter spring recession due to less snowpack can limit the extent of suitable habitat and recruitment success for some plant species, as adequate flow conditions occur less often during the timing of seed dispersal (Rood et al. 2005; Stella et al. 2006).

Climatic changes that may benefit the habitat:

- Any of the above factors could benefit permanent wetlands if they shift in the right direction (e.g. increase in precipitation and snowpack, decrease in drought)

Total annual water year runoff has been increasing for the Sacramento River basins and decreasing for the San Joaquin River basins, trends that are projected to continue at least through 2050 (Hunsaker 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. Overall impact of non-climate factors: Low-moderate (high confidence).

Non-Climate Factor	Sensitivity	Current Exposure
Groundwater overdraft	Low-moderate	Low-moderate
Invasive & other problematic species	Moderate-high	Moderate-high
Land use change	Moderate-high	Moderate-high
Nutrient loading	Moderate-high	Moderate-high
Other factors	Moderate	Moderate-high
Pollution & poisons	Low-moderate	Moderate-high
Overall Scores	**Moderate**	**Moderate-high**

Land use change

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

Wetlands are particularly sensitive to changes in land use. Because wetlands are generally found on flat, fertile substrates, such as floodplain and valley floors, they were prime locations for historical wetland conversion (Frayer et al. 1989). More than 95% of wetlands have been lost through conversion to urban development or agriculture in the Central Valley (Gilmer et al. 1982). Population growth and the continued water demand for agriculture and development exacerbate these losses (Duffy & Kahara 2011), and future water demand is expected to increase with expanding urban populations (Medellín-Azuara et al. 2007), placing additional stress on existing water supplies (Kahara et al. 2012).

Currently, more than 90% of wetlands in the Central Valley are managed and two-thirds of those are in private ownership (Central Valley Joint Venture 2006). Managed wetlands are substantially impacted by upstream impoundments, diversions, and added surface water, which affect wetland hydroperiod (CA Natural Resources Agency 2010). Levees, riverbank revetments, spring boxes, dams, and other manmade structures can also affect wetlands (CA Natural Resources Agency 2010). Although some wetlands still flood naturally, most now rely on managed water supplies for seasonal flooding. These water sources, typically captured in dams and delivered by canal or through stream channels, are in high demand as they provide water for everything from agriculture and urban use to management of wetlands and instream flows for fish (CA Natural Resources Agency 2010). 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).

Invasive & other problematic species

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

Permanent wetlands are sensitive to invasive species that compete with or prey upon native species, ultimately displacing them and altering wetland function and services. Examples of invasive wetland species include bullfrogs (*Lithobates catesbeianus*), the Louisiana red crayfish (*Procambarus clarkia*), Brazilian milfoil (*Myriophyllum aquaticum*), invasive cordgrass (*Spartina alterniflora*), and bluegill (*Lepomis macrochirus*) (CA Natural Resources Agency 2010). Large floods can also result in long-term vegetation compositional shifts by removing much of the existing vegetation and allowing early seral or invasive species to pioneer the recently disturbed sites (Lambert et al. 2010). Some wetlands are sensitive to tamarisk (*Tamarix* spp.), which can spread and dominate areas in a relatively short amount of time (Reynolds & Cooper 2010).

Nutrient loading

Sensitivity: *Moderate-high (high confidence)*
Current exposure: *Moderate-high (high confidence)*
Pattern of exposure: *Localized to areas where wetlands are part of an agricultural landscape. For example, azola water fern invasions have been a problem due to nutrient loading in various locations across the region.*

Wetlands naturally have a lot of nutrients, which is beneficial, and wetlands also have the ability to accommodate incoming nutrients from runoff (CA Natural Resources Agency 2010). 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). 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 for 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. 1998; Klose et al. 2012). Excessive nutrient loading can also lead to increased invasive species abundance in some areas (Gerhardt & Collinge 2003).

Hunting

Sensitivity: *Moderate (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 the 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 their wetland habitat (North American Waterfowl Management Plan 2012). In some cases, wetlands have been converted when hunting value declines (Gilmer et al. 1982). Across the United States, the number of waterfowl hunters has declined since the 1970s, despite more liberal hunting policies and rebounding waterfowl populations (North American Waterfowl Management Plan 2012).

Pollution & poisons

> ***Sensitivity:*** *Low-moderate (low confidence)*
> ***Current exposure:*** *Moderate-high (high confidence)*
> ***Pattern of exposure:*** *Widespread, valley-wide, variety of different pollutants. In general, contaminants are a bigger issue in the Delta and north of the Delta. Mercury is more of a problem in the Delta and Sacramento Valley from gold mining. In the San Joaquin Valley, heavy metals and salts are coming in from pumped groundwater.*

Important pollutions and poisons for permanent wetland habitats include mercury and other heavy metals, salts, and agricultural runoff (Domagalski et al. 2000). Pesticide and herbicide use on adjacent farmland may negatively impact wetland water and soil quality with potential impacts on humans (U.S. Fish and Wildlife Service 2005). Roadway contaminants and mosquito-control pesticides can also impact wetlands and have negative effects on invertebrates and other organisms (U.S. Fish and Wildlife Service 2005).

One of the most concerning toxic metals is mercury, which forms in anoxic sediment, especially surface sediment in wetland environments (Windham-Myers et al. 2014); the effects of mercury toxicity on wildlife can include physical, neurological, developmental, reproductive, and behavioral problems (Wolfe et al. 1998; Scheuhammer & Sandheinrich 2007). 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). The unique characteristics of agricultural wetlands — slow-moving shallow water, manipulated flooding and drying, abundant labile plant matter, and management for wildlife — also increase mercury exposure to local biota, as well as facilitating export to downstream habitats during uncontrolled winter-flow events (Windham-Myers et al. 2014). Mercury is going to be regulated as a pollutant and wetlands will be seen as a source of mercury going into the Delta, which poses a threat to wetlands because the focus will likely change from managing for wildlife to managing for mercury[1].

Groundwater overdraft

> ***Sensitivity:*** *Low-moderate (low confidence)*
> ***Current exposure:*** *Low-moderate (high confidence)*
> ***Pattern of exposure:*** *Localized; groundwater overdraft levels are highest in the San Joaquin Valley, and next highest in the Sacramento Valley; they are lowest in the California Delta/Suisan Marsh.*

Groundwater overdraft may strongly affect permanent wetlands in the San Joaquin Valley, but is likely to have little or no effect on permanent wetlands in the Sacramento Valley (Vulnerability Assessment Workshop, pers. comm., 2015).

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)*

The identified disturbance regimes (i.e., flooding, wind, wildfire) are highly managed, limiting the sensitivity of permanent wetlands[1]. Grazing acts as a disturbance regime in some foothill wetlands found in the foothills, typically impacting stock ponds, but doesn't usually affect the valley floor[1].

Flooding

Hydrological models predict larger and more frequent winter floods as rain-on-snow events and winter snowmelt become more common in headwaters (Hamlet & Lettenmaier 2007). Higher peak flows are likely to increase spring flooding (Jackson et al. 2011). Natural scouring from flooding and high peak flows can benefit permanent wetlands by resetting succession and allowing early successional plants to establish; however, changes to the magnitude and duration of flooding events are important factors in this process[1]. Although natural scouring from high water flows used to have an important effect on wetlands, tractor disking as a habitat management technique has eliminated the need for scour[1]. This practice resets succession, allowing early successional plants to succeed[1].

Wetlands in the Central Valley were historically fed by flooding during the winter, although flood mechanisms and timing differed by basin (Duffy & Kahara 2011). For instance, in the Sacramento Basin, wetlands were fed by flooding during winter precipitation, while in the San Joaquin Basin they were fed by flooding during snowmelt runoff (Duffy & Kahara 2011). Higher spring peak flows require larger releases of stored water from reservoirs in order to meet flood control requirements (Kiparsky & Gleick 2003; Anderson et al. 2008), which results in a net loss of spring runoff that is normally stored and decreases wetland water availability for the summer growing season and post-harvest flooding practices (Anderson et al. 2008).

Dams, levees, and bypasses control flow variability and essentially eliminate natural flood regimes (Central Valley Joint Venture 2006). Most wetlands now rely on managed water supplies for seasonal flooding (CA Natural Resources Agency 2010). Changes in water management to maintain reservoir storage and deliver water to municipal, agricultural, and industrial users can reduce flood magnitude and/or frequency, which could impact natural or unmanaged wetlands (Perry et al. 2012).

Wildfire

Wildfire has been suppressed in the Central Valley and now is usually applied by managers via prescribed burning to reset succession in thick climax wetlands[1].

Permanent wetlands can be very productive and tend to accumulate high levels of biomass and fuel loads (Van de Water & North 2011), which make them susceptible to high-severity fires (Olson & Agee 2005). Although fire regimes differ among wetland types due to differences in geomorphology, hydrology, vegetation, and microclimate (Dwire & Kauffman 2003), warmer temperatures may increase the susceptibility of some wetlands to drought and potentially more frequent fire (Bixby et al. 2015).

Changes in precipitation and soil moisture are also likely to affect wetland fire risk as some areas become drier and more susceptible to fire. However, seasonal wetland areas may be at a higher risk of drying and potentially burning compared to permanent areas.

Wind

Wind has a relatively minor negative impact on permanent wetlands[1], although major windstorms can affect wetland soil, root growth, and vegetation survival over the long term (Wanless et al. 1994; Cahoon 2006).

Permanent wetlands are somewhat sensitive to extreme weather events, such as windstorms. These extreme weather events are naturally variable and therefore long-term historical records are sparse in riparian areas. Furthermore, future projections of extreme weather events are difficult to model (Toreti et al. 2013). Nevertheless, wind disturbances are geomorphologically and ecologically important because they can affect large areas (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 (Cahoon 2006).

Adaptive Capacity

Workshop participants scored the resource's Adaptive Capacity and the overall score used to calculate climate change vulnerability.

Adaptive Capacity Component	Score
Extent, Integrity, & Continuity	Low-moderate
Landscape Permeability	Low-moderate
Resistance & Recovery	Moderate
Habitat Diversity	Moderate
Other Adaptive Capacity Factors	Low-moderate
Overall Score	**Low-moderate**

Extent, integrity, and continuity

Overall degree of habitat extent, integrity, and continuity: *Low-moderate (high confidence)*
Geographic extent of habitat: *Occurs across study region (high confidence)*
Structural and functional integrity of habitat: *Altered but not degraded (high confidence)*
Continuity of habitat: *Isolated and/or quite fragmented (high confidence)*

Historically, Central Valley wetlands covered an area of four million acres (in the 1850s), but much of this was lost by the mid-1980s when only 544,600 acres remained (Frayer et al. 1989). The Tulare Basin once contained the largest block of wetland habitat in the state, providing an area of over 500,000 acres (Central Valley Joint Venture 2006). However, due to agricultural production, freshwater wetland area has increased by about 30% from the mid-1980s (Frayer et al. 1989) to today. Currently, there are 26,322 acres of permanent and semi-permanent wetlands in the Central Valley; more than 90% of wetlands in the Central Valley are managed, two-thirds of which are in private ownership (Central Valley Joint Venture 2006). There are less permanent wetlands relative to seasonal wetlands in the San Joaquin Valley; only 5% of the historical extent of permanent wetlands remains (Gilmer et al. 1982).

Landscape permeability

Overall landscape permeability: *Low-moderate (high confidence)*
Impact of various factors on landscape permeability:
- ***Land use change:*** *Moderate-high (high confidence)*
- ***Agricultural & rangeland practices:*** *Moderate-high (high confidence)*

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 to develop. These factors, combined with climate change, pose a major threat to wetlands. Warming temperatures, particularly during the summer, are expected to decrease the production of some agricultural products and put greater demands on California's electricity supply, which will indirectly affect the supply of water for wetland irrigation (OEHHA 2013).

Land use change can act as a landscape barrier. For example, if rice crops change to another crop, it would further reduce the connectivity between permanent wetlands. In particulr, shifts from rice to other crops could have negative impacts on some species of waterbirds (Elphick 2004). In fact, the presence of flooded fields can enhance the landscape connectivity and permeability for some wetland species (Frayer et al. 1989; Elphick 2000), and the associated canals may also provide wildlife corridors used by species such as the giant garter snake, which moves between wetlands, canals, and flooded cropland within their large home ranges (Huber et al. 2010; Wylie et al. 2010).

Resistance and recovery

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

Similar to seasonal wetlands, permanent wetlands in the Central Valley are highly managed habitats and many are used primarily for agricultural production. Although agriculture in the Central Valley has been identified as being highly vulnerable, there is significant capacity to adapt (Jackson et al. 2011). For example, 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). 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 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 habitat management (DiGaudio et al. 2015). Most permanent wetlands are under some kind of easement, refuge, or other protection (Central Valley Joint Venture 2006).

Habitat diversity

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

Component species or functional groups particularly sensitive to climate change:

- Fish
- Reptiles
- Tricolored blackbird (*Agelaius tricolor*)

Keystone or foundational species within the habitat:

- Tule species

Although most wetlands have limited physical and topographical diversity, many are highly managed and water levels can be controlled to achieve particular management goals. For instance, actively managed wetlands have the potential to support more waterfowl than sites under low or intermediate management (Kahara et al. 2012). Hydrology is the most important determinant of wetland ecosystem function, creating more variable habitat that can support high levels of biodiversity and influencing the presence and abundance of wildlife (Kahara et al. 2012). Nevertheless, habitat availability is likely to be a significant limiting factor for waterfowl (Central Valley Joint Venture 2006), and has been associated with health, body condition, daily flight distances, and shifts in density and regional distribution in waterbirds (Fleskes et al. 2005; Ackerman et al. 2006; Hénaux et al. 2012).

Other Factors

Overall degree to which other factors affect habitat adaptive capacity: *Low-moderate (low confidence)*

Population growth
Safe Harbor Agreements
Diversion curtailments/instream flow requirements

Population growth

It is likely that climate factors will interact with increased demand from expanding urban populations, impacting wetland habitats indirectly through reduced water availability (Gilmer et al. 1982; Ackerman et al. 2006; Medellín-Azuara et al. 2007). 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 to develop. These factors, combined with climate change, will likely impact wetland habitats through loss of habitat and reduced water availability (Gilmer et al. 1982; Ackerman et al. 2006; Medellín-Azuara et al. 2007).

Safe Harbor Agreements

The presence of special status species on privately-owned lands can discourage conservation efforts due to the additional requirements that must be met to prevent “take” of a species protected by the Endangered Species Act (DiGaudio et al. 2015). Safe harbor agreements can promote restoration projects by allowing the incidental take of endangered species in exchange for habitat improvements that will benefit that species (Seavy et al. 2009; DiGaudio et al. 2015).

Diversion curtailments/instream flow requirements

The Lower San Joaquin River can experience very low flow conditions, offering little to no flows 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 permanent wetlands.

In addition, instream flow requirements designed to enhance fish habitat are likely to further reduce water availability, especially during drought periods (Tanaka et al. 2006; Howitt et al. 2013; Reiter et al. 2015).

Management potential

Workshop participants scored the resource's Management Potential.

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

Overall management potential: *Moderate (high confidence)*

Value to people

Value of habitat to people: *Moderate (high confidence)*
Description of value: *There is a no net loss policy for wetlands; overall, the benefits of wetlands are well-recognized although people tend to support wetland conservation when they do not have another use for the land. Permanent wetlands are valued less than flooded cropland and seasonal wetlands.*

Support for conservation

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

Description of support: *Permanent wetlands have legislative, regulatory, and hunting support. This habitat does not have as much public support as seasonal wetlands or agriculture because it requires water year-round, which society sometimes wants for other uses.*

Degree to which agriculture and/or rangelands can benefit/support/increase the resilience of this habitat: *High (high confidence)*
Description of support: *Rice helps make permanent wetlands more resilient because it adds additional habitat area. Groundwater pumping for rice and other agricultural crops provides a source of water (although this cannot go on forever). Groundwater depletion can negatively impact permanent wetlands, but it is not currently widespread. Most wetlands are fed by surface water instead of groundwater, and are on top of clay hardpan.*

Degree to which extreme events (e.g., flooding, drought) influence societal support for taking action:
Frequent flooding: *Moderate-high (moderate confidence)*
Drought: *Low-moderate (high confidence)*
Description of events: *Frequent flooding may increase awareness of the importance of wetland ecosystem services (e.g., flood protection), while drought reduces support because water is needed for other uses.*

Likelihood of converting land to habitat

Likelihood of (or support for) converting retired agriculture land to habitat: *Low-moderate (moderate confidence)*
Description of likelihood: *There are several programs (such as the federal farm bill) that provide incentives, but these programs could use more funding and currently do not compete well with other motivations for land use. There are few incentives to retire farmland, except when there is not enough water; only marginal farmland has been restored to habitat via these incentive programs. Commodity prices are at high levels right now, making restoration difficult and in some cases causing conversion of habitat to farmland.*

Likelihood of managing or alleviating climate change impacts on habitat: *Low-moderate (moderate confidence)*
Description of likelihood: *Society would have to prioritize wetland management over other uses of water. However, the possibility of being able to manage/alleviate the impacts of climate change are good because wetlands are highly managed. If society has the water and the will, wetlands can be buffered against the impacts of climate change.*

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 around conservation easements that compensate landowners for converting flood-prone farmland to wetland (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, with actively managed WRP wetlands supporting more waterfowl and 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). For instance, flooded rice fields can provide important wetland ecosystem services (Elphick & Oring 2003) and influence the distribution of waterfowl (Fleskes et al. 2005). Potential management activities include focusing 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). In order to buffer against a late season shortage in stored water, operational changes can be put into place over the course of the year[1]. Maintaining a mosaic of cover and more open habitat is important for the giant garter snake (*Thamnophis gigas*) and nesting habitat (Halstead et al. 2010).

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