Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Seasonal Wetlands

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

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

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

Key climate factors for seasonal wetland habitats include precipitation amount and timing, snowpack amount, and timing of snowmelt/runoff. These factors impact wetland hydrology, primarily by affecting water availability.

Flooding, grazing, and wildfire are the most important disturbance regimes for seasonal wetland habitats; however, disturbances rarely occur naturally, and land managers must mimic natural disturbance regimes to reset succession.

Key non-climate factors include hunting, land use change, invasive and problematic species, and nutrient loading. These non-climate factors will likely interact with climate factors and disturbances resulting in habitat loss and/or changes in management practices that alter habitat quality.

The extent of seasonal wetlands in the Central Valley has decreased by over 95% since the mid-1850s, and less than 200,000 acres of seasonal wetlands remain; however, flooded croplands provide many of the same benefits, increasing habitat continuity. Land use change and agricultural/rangeland practices act as landscape barriers, fragmenting habitat and decreasing landscape permeability. Habitat diversity is high, and varied physical and structural factors (e.g., topography, water depth, vegetation) support extremely high levels of avian species diversity, with over 200 documented species utilizing this habitat. Because seasonal wetlands depend on irrigation for flooding and soil moisture, economic costs of water provisioning may decrease the resistance of seasonal wetlands to changing climate conditions.

Management potential for rice croplands was scored as moderate and is largely focused on preserving habitat value for waterbirds and shorebirds, supported by several conservation-focused policies and incentive programs (e.g., the Wetlands Reserve Program).

Table of Contents

Introduction

Description of Priority Natural Resource

Seasonal wetlands are wetlands that are inundated part of the year; the overwhelming majority of seasonal wetlands are managed by flooding, disking, and burning. Typical hydrological cycles include fall flooding and drawdown in the spring followed by irrigation to maintain soil moisture (Ortega 2009; Duffy & Kahara 2011). In the Central Valley, over half of the seasonal wetlands are located in the San Joaquin and Suisun basins (Central Valley Joint Venture 2006). Seasonal wetlands are dominated by herbaceous vegetation, including sedges (*Carex* spp.), rushes (*Eleocharis* spp. and *Scirpus* spp.), bulrushes (*Schoenoplectus* spp.), cattails (*Typha* spp.), and other emergent hydrophytic species. Species composition is determined partially by water depth (Sugihara 2006; Thorne et al. 2016), and many wetlands are managed for seed production of swamp Timothy (*Heleochloa schenoides*) and smartweed (*Polyganum* spp.; Ortega 2009).

As part of the Central Valley Landscape Conservation Project, workshop participants identified the [PNR] 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 seasonal wetlands habitat as a Priority Natural Resource included the following: the habitat has high management importance, and the habitat provides critical ecosystem functions and services including food production and breeding and wintering habitat for migratory birds, groundwater recharge, and flood attenuation. 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
Extreme events: drought	Moderate	Moderate
Other factors	High	Low-moderate
Precipitation (amount)	High	-
Precipitation (timing)	High	-
Snowpack amount	High	High
Timing of snowmelt/runoff	High	Moderate-high
Overall Scores	**High**	**Moderate-high**

> ***Potential refugia:*** *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 north-western edge (Thorne et al. 2016).*

Statewide, 1% 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).

Future water demand is expected to increase as climate changes interact with expanding urban populations (Medellín-Azuara et al. 2007), and increased demand is likely to place additional stress on water supplies for seasonal wetland irrigation (Kahara et al. 2012). Annual streamflow is expected to decline throughout the Central Valley, heavily impacting water supplies (Medellín-Azuara et al. 2007; Ficklin et al. 2013). Statewide water scarcity (e.g., the current gap between water needs and water delivery) is projected to increase from 2% to 20% by the year 2050, even taking adaptive factors into account (Medellín-Azuara et al. 2007).

Snowpack amount

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

Potential refugia: *Sacramento Valley (water is more secure); seasonal wetlands may be lost in the San Joaquin Valley.*

Reduced snowpack, which is tied to increased air temperatures and shifts in snow-to-rain ratios, could contribute to summer water shortages, altered streamflow patterns, and changes in natural flooding regimes (Miller et al. 2001; Knowles & Cayan 2002; Kiparsky & Gleick 2003; Vicuna et al. 2007). Snowpack from mountainous areas surrounding the Central Valley plays a large part in water storage and supply, releasing meltwater gradually to recharge aquifers and flow downstream into the Valley (Knowles & Cayan 2002; Scanlon et al. 2012; California Rice Commission 2013). This water is typically of high quality (e.g., low salinity, dissolved minerals, and nutrients) and is one of the primary sources of water for wetland irrigation throughout the Central Valley (Domagalski et al. 2000; Scanlon et al. 2012).

Timing of snowmelt & runoff

Sensitivity: *High (high confidence)*
Future exposure: *Moderate-high (high confidence)*
Potential refugia: *Sacramento Valley (water is more secure); seasonal wetlands may be lost in the San Joaquin Valley.*

Warmer temperatures are leading to earlier spring snowmelt and peak flows (Hayhoe et al. 2004; Stewart et al. 2005; Thorne et al. 2015), changing the timing and amount of water available in regions that receive much of their water from snowmelt (Moser et al. 2009; Yarnell et al. 2010; Thorne et al. 2015). 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).

Earlier snowmelt accelerates the release of water from snowpack, leading to earlier and higher peak flows, followed by reduced summer flows and longer periods of summer drought (Yarnell et al. 2010). The timing of runoff is especially important for seed germination and production in seasonal wetlands, and seed production is highest when spring drawdown occurs very slowly through evaporation (Naylor 2002).

Higher peak flows are likely to increase spring flooding (Jackson et al. 2011), which requires larger releases of stored water from reservoirs in order to meet flood control requirements (Kiparsky & Gleick 2003; Anderson et al. 2008). This results in a net loss of spring runoff that is normally stored, and decreases water availability for the summer growing season and post-harvest flooding practices (Anderson et al. 2008).

Precipitation (amount)

Sensitivity: *High (high confidence)*

The Central Valley receives little precipitation, over 90% of which occurs between November and May (Duffy & Kahara 2011), and the majority of the water supply comes from snowpack in the mountains (Knowles & Cayan 2002; Scanlon et al. 2012).

Precipitation (timing)

Sensitivity: *High (high confidence)*

Managed wetlands require summer irrigation and fall flooding, with the bulk of irrigation occurring during the driest part of the year (e.g., Aug-Nov; Central Valley Joint Venture 2006).

Increased drought

Sensitivity: *Moderate (high confidence)*
Future exposure: *Moderate (moderate confidence)*
Potential refugia: *Sacramento Valley (water is more secure); seasonal wetlands may be lost in the San Joaquin Valley.*

Longer or more severe droughts are likely to impact water availability and wetland extent, although 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).

During drought years, open water habitat in the Central Valley (which includes wetlands, flooded croplands, rivers, and lakes/ponds) is drastically reduced, with the greatest impacts occurring during the dry season and in the Tulare and San Joaquin basins (Reiter et al. 2015). Drier conditions reduce food availability for waterbirds and shorebirds that depend on wetland habitat (Naylor 2002; Moss et al. 2009), and McLandress et al. (1996) also found that young mallards are less likely to breed in dry years.

Seasonal wetlands are potentially less sensitive to drought than other habitats because there are ways to compensate for temperature increases and decreased water availability if stored water is available[1].

During drought years, soil moisture must be recharged before runoff occurs[1].

Sea level rise

Future exposure: *Low-moderate (confidence not assessed)*
Potential refugia: *The Delta could lose its seasonal wetlands to sea level rise; the Sacramento Valley and San Joaquin Valley will not be affected by this factor.*

Sea level rise may impact cranes[1].

Climatic changes that may benefit the habitat:

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

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
Groundwater overdraft	Low-moderate	Moderate
Invasive & other problematic species	Moderate-high	Moderate-high
Land use change	Moderate-high	Moderate-high
Nutrient loading	Moderate-high	Moderate
Other factors	High	Moderate-high
Pollution & poisons	Moderate	Low-moderate
Overall Scores	**Moderate-high**	**Moderate**

Hunting

Sensitivity: *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 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). Hunters also support policies and management practices that benefit waterfowl, and indirectly, seasonal wetland habitat (North American Waterfowl Management Plan 2012). In some cases, wetlands are converted when hunting value declines, and, similarly, many wetlands are drained after the close of hunting season, reducing available habitat for wintering waterbirds and shorebirds (Gilmer et al. 1982). Across the US, 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). Changing demographics of hunters could impact the sustainability of seasonal wetlands in the Central Valley1, because two-thirds of this habitat is privately owned/managed (Central Valley Joint Venture 2006).

Hunting is the primary cause of mortality in northern pintails (*Anas acuta*) and mallards (*A. platyrhynchos*), two of the most common wintering waterbirds in the Central Valley. However, high hunting mortality is balanced by very low natural mortality, and bag limits are based on waterfowl populations to prevent overharvesting (Fleskes et al. 2007). Hunting can impact avian behavior as well, including daily movement patterns and habitat selection in northern pintails, decreasing abundance (Casazza et al. 2012). Maintaining daytime refugia in sanctuaries and managing habitats to minimize natural mortality would increase waterfowl abundance and, indirectly, hunting opportunities (Fleskes et al. 2007; Casazza et al. 2012).

Invasive & other problematic species

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

Similar to vernal pools, seasonal wetlands are relatively harsh environments because they undergo alternating periods of flooding and drying, and many common invasive species are unable to tolerate either long periods of inundation or drought (Zedler 2003; Bartolome et al. 2014). Warmer temperatures may increase evapotranspiration and speed drying, allowing more xeric plants to invade seasonally-flooded wetlands (Bartolome et al. 2014). It is likely that water shortages resulting in earlier drawdown and/or reduced irrigation would have similar impacts.

Land use change

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

The vast majority of Central Valley wetlands (>95%) have already been lost through conversion to urban development or agriculture (Gilmer et al. 1982). The conversion of wetlands to rice fields, rather than to agriculture of less waterfowl value, likely reduced the negative impacts of wetland loss, especially in the northern Central Valley where rice production is very high (Gilmer et al. 1982; Elphick 2000; Fleskes et al. 2005). Around 179,000 acres of seasonal wetlands remain, and all are heavily managed (Central Valley Joint Venture 2006). Unprotected wetlands are vulnerable to future land use conversion, and many privately-owned wetlands, which comprise two-thirds of all seasonal wetlands in the Central Valley, remain unprotected (Central Valley Joint Venture 2006).

Nutrient loading

Sensitivity: *Moderate-high (high confidence)*
Current exposure: *Moderate (high confidence)*
Pattern of exposure: *Consistent across the landscape; wetland complexes are typically interwoven with agriculture, and often share the same recycled water. Regional variation would likely depend on the source of water for a particular wetland.*

Excess nutrients, including nitrogen (N) and phosphorus (P), reach seasonal wetlands through runoff from both agricultural and urban activities, as well as through atmospheric deposition (Carpenter et al. 1998; Duffy & Kahara 2011). While agriculture is the primary source for nutrient loading in the Central Valley, wastewater treatment plants, industrial sites, and fertilizer can contribute nutrients to urban runoff (Carpenter et al. 2007; Klose et al. 2012). Because nutrients (especially N) are limiting factors for many plant species, increased nutrient availability can increase production of algae, decrease dissolved oxygen, and alter the species composition of plant, invertebrate, and aquatic vertebrate communities (Carpenter et al. 1998; Klose et al. 2012).

Pollution & poisons

Sensitivity: *Moderate (moderate confidence)*
Current exposure: *Low-moderate (moderate confidence)*
Pattern of exposure: *Localized; it depends on the pollutant. Mercury is an issue in the Delta and Sacramento Valley, but salts are an issue in the San Joaquin Valley.*

Groundwater overdraft

Sensitivity: *Low-moderate (low confidence)*
Current exposure: *Moderate (high confidence)*
Pattern of exposure: *Localized; groundwater overdraft levels are highest in the southern San Joaquin Valley, and next highest in the Sacramento Valley. They are lowest in the California Delta/Suisan Marsh. In some places, wetlands are completely dependent on groundwater, including Kern and Pixley National Wildlife Refuges.*

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 (high confidence)*

Climax wetlands have thick vegetation; managers go in with fire and then disking to reset succession1. Early successional plants that emerge after disturbance provide much more food than late successional species such as cattail (*Typha* spp.) and tule (*Scirpus* spp.)[1]. However, it is important not to eliminate all areas with cover. 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).

Flooding

Historically, Central Valley seasonal wetlands were flooded by winter precipitation and spring overbank flooding from rivers, with wetlands in the Sacramento Valley receiving more precipitation and the San Joaquin Valley flooding from snowmelt runoff (Duffy & Kahara 2011; Kahara et al. 2012). Floods and associated scouring were an important disturbance in this habitat, but dams, levees, and bypasses now control flow variability and have eliminated natural flood regimes (Central Valley Joint Venture 2006). Seasonal wetlands offer floodwater storage, which may buffer nearby communities from large, unpredictable floods during extreme precipitation events and/or higher peak flows during spring runoff (Kiparsky & Gleick 2003; Duffy & Kahara 2011).

Grazing

Current exposure: *Low (confidence not assessed)*

Moderate grazing is currently used in Central Valley marshes to increase species richness and vegetative cover (Sugihara 2006). Grazing can impact vegetation height, residual dry matter, and the amount of marsh cover; however, impacts vary depending on the timing and intensity of grazing (Carroll et al. 2007; Richmond et al. 2012). For instance, in areas that are grazed in the summer and fall (July-October), vegetation height does not differ by the beginning of the March nesting season for birds, and by the end of nesting season vegetation is higher in grazed fields, which may offer additional protection for hatch year birds (Carroll et al. 2007). Grazing may negatively impact water quality (Craun et al. 2005), and localized grazing impacts may be higher in areas where cattle congregate for drinking and cooler temperatures (Richmond et al. 2012).

Wildfire

Seasonal wetland management typically includes prescribed fire, which may be used to increase species richness and vegetative cover (Sugihara 2006). Many species of marsh grasses are adapted to fire, which can stimulate sprouting and seeding; these include cordgrasses (*Spartina* spp.), bulrushes, and cattails, although some sedges do not re-sprout readily (Sugihara 2006; Thorne et al. 2016). Biomass production within freshwater marshes is high, creating ample fuel for high-intensity fires (Sugihara 2006). Historically, seasonal wetlands may have impacted upland fire regimes by providing additional fuel and/or limiting spread when water was present (Sugihara 2006).

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	Moderate-high
Landscape Permeability	Low-moderate
Resistance & Recovery	Moderate
Habitat Diversity	Moderate
Other Adaptive Capacity Factors	Low-moderate
Overall Score	**Moderate**

Extent, integrity, and continuity

Overall degree of habitat extent, integrity, and continuity: *Moderate-high (high confidence)*
Geographic extent of habitat: *Occurs across study region (high confidence)*

Structural and functional integrity of habitat: *Minor/moderate alterations (high confidence)*
Continuity of habitat: *Isolated and/or quite fragmented (high confidence)*

In the 1850s, Central Valley wetlands covered an area of 4 million hectares, but these habitats were lost by the mid-1980s when only 544.6 thousand 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). Currently, there are 179,232 acres of seasonal wetlands in the Central Valley, with over half of that area located in the San Joaquin (61,000 acres) and Suisun (32,000 acres) basins (Central Valley Joint Venture 2006). There is significant year-to-year variation in the area of flooded habitat (Reiter et al. 2015), and factors such as drought can drastically reduce the area of flfooded habitat within a single season (Elphick 2004). Flooded croplands can provide many of the same ecosystem functions as seasonal wetlands, increasing habitat continuity for species dependent on this habitat type (Elphick 2000).

Landscape permeability

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

Land use conversion to urban or agricultural use is a continual threat to seasonal wetlands (Duffy & Kahara 2011). Two-thirds of the remaining area of seasonal wetlands is privately owned (Central Valley Joint Venture 2006), and these areas may be more vulnerable during periods of drought when the cost of water is very high (Medellín-Azuara et al. 2007; Reiter et al. 2015). Infrastructure related to urban and agricultural development can fragment habitat (Gilmer et al. 1982; Huber et al. 2010). However, the existence of flooded cropland enhances landscape permeability for wetland species (Frayer et al. 1989; Elphick 2000), and associated canals may also provide wildlife corridors used by species such as the giant garter snake, which move between wetlands, canals, and flooded cropland within their large home ranges (Huber et al. 2010; Wylie et al. 2010). However, changes in agricultural practices (e.g., decreased post-harvest flooding) can occur when water costs are high, rapidly reducing the area of flooded habitat (Reiter et al. 2015).

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)*

Seasonal wetlands are highly managed habitats, and are primarily valued as waterfowl habitat for the purposes of hunting (North American Waterfowl Management Plan 2012). Resistance to climate-related stresses is largely related to the economic support coming from hunters, as well as incentive programs, both of which fund habitat management and water costs (Duffy & Kahara 2011). Reduced water availability, especially over longer time periods, is likely to result in reduced habitat extent due to the potentially prohibitive cost of water (Elphick 2004; Medellín-Azuara et al. 2007; Reiter et al. 2015), especially in the Tulare and San Joaquin basins where a large proportion of seasonal wetlands occur (Central Valley Joint Venture 2006). Incentive programs and conservation-focused policies may increase the resistance of seasonal wetlands to the impacts of climate change by encouraging restoration and management practices that support wildlife (Duffy & Kahara 2011; Kahara et al. 2012; DiGaudio et al. 2015).

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 (high confidence)*
Diversity of functional groups within the habitat: *High (high confidence)*

Component species or functional groups particularly sensitive to climate change:

- Tricolored blackbird (*Agelaius tricolor*)
- Salt marsh harvest mouse (*Reithrodontomys raviventris*) in Suisun

Vegetation in seasonal wetlands is comprised primarily of tall emergent hydrophytes, including sedges, rushes, bulrushes, and cattails, with species distribution partially dependent on water depth (Sugihara 2006; Thorne et al. 2016). Species composition within sanctuaries can differ from that in wetlands managed for hunting, with the latter including more plants valued as a food source for waterfowl (Casazza et al. 2012); swamp Timothy and smartweed are among the species commonly managed for seed production (Ortega 2009). Variations in topography and other physical attributes create a more heterogenous habitat with the ability to support very high biodiversity, including up to 200 species of birds from many different avian guilds (e.g., dabbling ducks, large waders, aerial predators, aerial insectivores, marsh birds, upland birds, etc.; Kahara et al. 2012). Overall, Central Valley flooded habitats provide stopover and wintering habitat for birds traveling the Pacific Flyway, including 10-12 million waterfowl each year (Gilmer et al. 1982; Elphick 2000). 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
Endangered Species Act
Diversion curtailments/instream flow requirements

Population growth

Human populations are expected to expand to over 50 million people by 2050 compared to a current population of 35 million, and may reach 90 million by the end of the century (Landis & Reilly 2003). Continued urban/suburban development requires additional infrastructure and resources, which can contribute to habitat loss and fragmentation (Gilmer et al. 1982; Huber et al. 2010), increased pollution and invasive species (U.S. Fish and Wildlife Service 2015), and increased wildlife mortality (Fleskes et al. 2007; U.S. Fish and Wildlife Service 2015), among other impacts. 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).

Endangered Species Act

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

In-stream flow requirements designed to enhance fish habitat are likely to further reduce water availability for wetlands, 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-high
Societal support	Moderate
Agriculture & rangeland practices	High
Extreme events	Moderate
Converting retired land	Low-moderate
Managing climate change impacts	Moderate
Overall Score	**Moderate**

Value to people

Value of habitat to people: *Moderate-high (high confidence)*

Description of value: *People are more excited about supporting wetlands than flooded agriculture. The benefits of wetlands are well recognized, and there are policies in place requiring no net loss of wetlands. People support wetlands when they don't have another use for the land.*

Support for conservation

Degree of societal support for managing and conserving habitat: *Moderate (moderate confidence)*
Description of support: *Regulatory, legislative. Continued commitment and investment of hunters is necessary to preserve and manage the habitat, but the costs of managing a duck club are considerable, especially in the southern San Joaquin Valley (Tulare Basin/Kern area) where water is expensive and sometimes unavailable. The costs of managing a duck club include water provisioning, mosquito abatement, infrastructure (water control structures, levees), and vegetation management (burning, disking). Hunter recruitment and retention are also needed, as licenses and duck stamps fund the majority of wetland protection/restoration in the Central Valley, and the number of hunters has declined and hunter demographics are changing.*

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 seasonal wetlands more resilient because it increases the extent of flooded habitat, and groundwater pumping for rice and other crops provides a source of water (although this can't go on forever). Groundwater depletion can negatively impact wetlands, although it is not yet widespread. Most wetlands are fed by surface water, not groundwater, and are located on top of clay hardpan.*

Degree to which extreme events (e.g., flooding, drought) influence societal support for taking action: *Moderate (high confidence)*
Flooding: *Moderate-high (moderate confidence)*
Drought: *Low-moderate (high confidence)*
Description of likelihood: *Frequent flooding may increase awareness of the importance of wetland ecosystem services (flood protection). 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: *Only marginal farmland has been restored to wetland habitat via Farm Bill incentive programs. Commodity prices are high right now, and it is hard to compete with that; in fact, conversion of habitat to farmland is occurring in some areas.*

Likelihood of managing or alleviating climate change impacts on habitat: *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 the system is highly managed. Land managers may be able to buffer wetlands from climate change impacts if water is available, as well as policies that support wetland irrigation.*

The creation of the North American Waterfowl Management Plan in 1986 and the Central Valley Joint Venture in 1988 has contributed to changes in policies and management practices and has helped create incentive programs to support wetland restoration and enhancement (Ackerman et al. 2006; Central Valley Joint Venture 2006; North American Waterfowl Management Plan 2012). Wetlands restored through these efforts have been successful at providing habitat for diverse bird species, including many special status species (DiGaudio et al. 2015). Management of seasonal wetlands in the Central Valley typically involves activities designed to bring in and retain water, vegetation management (e.g., planting, burning, mowing, disking), and attracting waterbirds for hunters (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]. Because wetlands are actively managed, timing of water level drawdown in spring, irrigations, and fall flood-up can be manipulated to compensate for certain climate change impacts (Ortega 2009; Duffy & Kahara 2011).

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