Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Flooded Croplands

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 flooded cropland 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 flooded croplands include reduced snowpack amount and changes in precipitation that limit water availability, including stored water for irrigation. Flooding, disease, and wind are the most important disturbances, and extreme conditions can harm crops and/or the birds and animals that utilize this habitat type.

Key non-climate factors include land use change and commodity prices, which may respond to or interact with climate factors and disturbances resulting in economic losses and changes in crop selection and management practices.

Management potential for flooded croplands was scored as moderate. Conservation-focused policy and incentive programs have helped increase habitat availability and quality, but farmers are likely to face increased economic pressure under future climate conditions and flooded fields may be converted to non-flooded crops, fallowed, or developed.

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Introduction

Description of Priority Natural Resource

Flooded croplands are a habitat type that remains in active agricultural use, typically producing rice, corn, wheat, and alfalfa within the Central Valley. Rice fields comprise the largest percentage of flooded cropland, and are primarily grown within the Sacramento Valley (see Rice Croplands summary). Corn, wheat, and other field crops are less likely to be flooded, and most non-rice flooded cropland is located in the Sacramento-San Joaquin River Delta and the Sutter Basin within the Sacramento Valley, and in small areas within the southern regions including the San Joaquin Valley and the Tulare Basin (Reiter et al. 2015). Flooded cropland is inundated continuously or periodically with <1 cm to 25 cm of water for 5-10 months of the year (California Rice Commission 2013; Sesser et al. 2016). Finely-textured soils with poor drainage are most suitable for flooded croplands, and the depth and duration is carefully controlled (Fleskes et al. 2005; California Rice Commission 2013).

The area of flooded cropland in the Central Valley has increased since the mid-1980s, especially in the Sacramento Valley. Flooded cropland habitat provides many of the ecosystem services historically offered by 4 million acres of wetlands, of which over 90% have been lost. Flooded croplands are vital for migrating and wintering birds, with up to 60% of waterfowl within the Pacific Flyway passing through the Central Valley each year. Although the structure of flooded croplands is relatively homogeneous, differences in crop choices, management practices, and timing and depth of flooding provides conditions suited for ducks, geese, wading birds, and shorebirds, as well as numerous other wildlife species.

As part of the Central Valley Landscape Conservation Project, workshop participants identified the flooded croplands 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 flooded croplands habitat as a Priority Natural Resource included the following: the habitat has high management importance, and because flooded cropland provides a high proportion of habitat for wintering waterfowl and shorebirds, especially in the Delta and Sacramento Valley regions. 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
Precipitation (amount)	Moderate-high	-
Snowpack amount	High	High
Timing of snowmelt/runoff	-	Moderate-high
Overall Scores	**Moderate-high**	**Moderate-high**

> ***Potential refugia:*** *Northern regions are at lower risk of losing flooded cropland, while the San Joaquin Valley (especially around the Tulare Basin) will have less water for flooding crops and are likely to lose this habitat type.*

Changes in climate are expected to cause crop yields to decline in California, although CO_2 fertilization may reduce the impact. However, modeled crop yields vary based on the factors taken into account (namely, future management practices and water availability for agriculture). A modeling study projecting crop yields for Yolo County under two climate scenarios (assuming current management practices) predicted crop yield decreases of -2.4% for wheat by 2050, and yield increases of +1.7% and +3.5% for rice and alfalfa, respectively (Jackson et al. 2009). They found that early heat waves had a negative impact on rice growth, with May-July heat waves reducing growth by -6.1% (the greatest monthly impact was for May), and the incorporation of drought as a factor further reduced rice growth by -6.9%. However, heat waves and drought did not greatly impact the growth of alfalfa or wheat (Jackson et al. 2009). Across the Central Valley, Lee et al. (2011) found that, under a high-emissions climate scenario, rice yields could decline by -10% and wheat yields could decline by up to -14% by the year 2094, while alfalfa is expected to experience only minimal declines of -2% (Lee et al. 2011). Yields primarily responded to temperature increases and greater variation in precipitation (Lee et al. 2011), with a likely outcome of reduced acreage in wheat and more in alfalfa (Lee & Sumner 2015).

Snowpack amount

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

Potential refugia: *Flooded cropland is more likely to remain in the Sacramento Valley where water is more secure.*

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 rice cropland irrigation throughout the Central Valley (Domagalski et al. 2000; Scanlon et al. 2012). 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).

Precipitation (amount)

Sensitivity: *Moderate-high (high confidence)*

Precipitation in the Central Valley is on a north-south gradient, with more rain falling in the northern regions; annual amounts range widely from 165-611 mm per (Scanlon et al. 2012). The majority of the annual amount of precipitation is received during winter storms that fall outside of the growing season (79-85% between Nov and Mar), and the excess surface water after storms is used to flood post-harvest croplands (Scanlon et al. 2012). Precipitation also affects water availability during the growing season, as well as stored water available for irrigation (Kiparsky & Gleick 2003). Warming temperatures are likely to increase evapotranspiration and competition for water resources, and the amount of water available for cropland flooding is likely to decline under warmer, drier conditions (Kiparsky & Gleick 2003).

Drought

Sensitivity: *Moderate (high confidence)*
Future exposure: *Moderate-high (high confidence)*
Potential refugia: *Flooded cropland is more likely to remain in the Sacramento Valley where water is more secure.*

More frequent, longer, or more severe droughts are expected to significantly reduce water in this region (Medellín-Azuara et al. 2007; Reiter et al. 2015). Decreased water availability will likely increase agricultural costs (Medellín-Azuara et al. 2007), and may have the greatest impacts on rice and other crops with high water demands, potentially causing changes in flooding practices, shifts in crop selection, or land use change (Jackson et al. 2011).

Warmer temperatures typically increase evapotranspiration, exacerbating the impacts of dry conditions and contributing to more frequent, longer, and more severe periods of drought (Cook et al. 2015; Diffenbaugh et al. 2015; Williams et al. 2015). Reiter et al. (2015) found that periods of drought was directly related to a decline in open water habitat in the Central Valley (which includes rice and other flooded croplands, as well as wetlands, rivers, and lakes). Impacts were greatest during the dry season (July-October), although the effects of drought varied across the region (Reiter et al. 2015). Declines in open water habitat were delayed by a year in northern regions (e.g., the Sacramento Valley) because stored water reserves and water management practices slow the impact of drought on habitat, but the San Joaquin and Tulare basins responded immediately because of their dependency on water transfers from the Sacramento Valley (Reiter et al. 2015). Meeting in-stream flow requirements during drought periods causes additional stress on water availability (Tanaka et al. 2006; Reiter et al. 2015).

Timing of snowmelt & runoff

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

Warmer temperatures are already 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 the snowpack, leading to earlier and higher peak flows, followed by reduced summer flows and longer periods of summer drought (Yarnell et al. 2010). 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).

Climatic changes that may benefit the habitat:

- Any of the above factors could benefit flooded croplands if they shift in the right direction

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	Moderate	Low-moderate
Land use change	Moderate-high	Moderate-high
Other factors	Moderate-high	High
Overall Scores	**Moderate-high**	**Moderate-high**

Land use change

> ***Sensitivity:*** *Moderate-high (high confidence)*
> ***Current exposure:*** *Moderate-high (high confidence)*
> ***Pattern of exposure:*** *Conversion from agricultural to urban development is occurring everywhere, but the rate of conversion is highest around urban areas. There is more flooded cropland in the Sacramento and Delta regions, however, so impacts to birds and giant garter snakes are greatest in the north where there is the most urban expansion.*

The majority of Central Valley agriculture is vulnerable to changes in land use, especially urban development around the Sacramento-San Joaquin Delta and in the area between Sacramento and Fresno (Jackson et al. 2012). Land use changes in the Delta are driven primarily by urban development and flood risk, while changes in the Sacramento-Fresno corridor are driven by urbanization and soil salinity (Jackson et al. 2012). Overall, the area of flooded cropland increased between 1988 and 2000, with the majority of the change coming from increases in flooded rice fields (Fleskes et al. 2005). Since 2000, there has been relatively little change in the area of flooded croplands (Reiter & Liu 2011).

Groundwater overdraft

> ***Sensitivity:*** *Moderate (low confidence)*
> ***Current exposure:*** *Low-moderate (high confidence)*
> ***Pattern of exposure:*** *Groundwater overdraft levels are highest in the San Joaquin Valley, next highest in the Sacramento Valley, and lowest in the California Delta/Suisan Marsh. There is not a lot of flooded cropland in the San Joaquin Valley where they are using more groundwater, and not much fall-winter flooding going on south of Stockton.*

Groundwater is used for flooding crops if there is not adequate rainfall, and accounts for 60% of the water used for agriculture irrigation (Scanlon et al. 2012). However, groundwater extraction is largely driven by cost and availability because it is unregulated[1]. Groundwater overdraft creates issues with water quality (salinity), as well as with quantity/allocation[1].

Other Factors: Water transfers

> ***Overall sensitivity to other factors:***
> > ***Water transfers:*** *Moderate-high (high confidence)*

Water transfers provide a way to redistribute water allocations, and their use may increase under future climate conditions (Kiparsky & Gleick 2003; Elias et al. 2015). Agriculture accounts for the largest amount of water use in the Central Valley, but urban development and increasing human populations is expected to increase demand (Elias et al. 2015). Water transfers generate revenue for farmers, especially during periods of drought, but may result in reduced acreage of flooded cropland where some fields must be idled due to lack of water supply (Medellín-Azuara et al. 2007; California Rice Commission 2013; Elias et al. 2015) and corresponding shifts in density and abundance of wildlife dependent on this habitat (Ackerman et al. 2006; Halstead et al. 2010).

Commodity prices

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

Higher-revenue crops are grown on more productive soil, and changes in market prices, urbanization, and weather can cause economic losses (Jackson et al. 2012). Low commodity prices over a period of time may cause changes in the area of flooded cropland, with farmers shifting towards crops that are more economically viable (California Rice Commission 2013); similarly, high prices can increase the area of flooded cropland (Fleskes et al. 2005; Howitt et al. 2013). For example, high commodity prices in 2008 and 2009 caused spikes in the acreage devoted to corn, wheat, and rice (Howitt et al. 2013). Diversified farms and agricultural economies are more likely to endure fluctuations in market prices (Jackson et al. 2012).

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 (confidence not assessed)*

The identified disturbance regimes (i.e., flooding, wind, wildfire) are highly managed, limiting the sensitivity of flooded croplands[1]. The impacts of grazing can affect wetlands in the foothills (i.e., stock ponds), but less so on the valley floor[1]. Maintaining a mosaic of cover and open habitat is important for many wildlife species, including birds and the giant garter snake (*Thamnophis gigas;* Halstead et al. 2015)

Flooding

Flooded cropland is often found in low-lying floodplains, and annual flooding regimes are carefully managed (Howitt et al. 2013). In the event of large storms, flooded croplands offer flood storage, reducing impacts farther inland (Duffy & Kahara 2011). However, the timing and severity of natural flooding can impact crops. Late spring flooding may delay tilling and planting, and can destroy young plants too late in the season for farmers to replant (Jackson et al. 2011). Large floods can also damage or destroy agricultural and/or water delivery infrastructure (Jackson et al. 2011). Changes in the timing of snowmelt and runoff could increase the likelihood of spring flood events, requiring the release of more water from reservoirs to minimize large floods (Kiparsky & Gleick 2003). Most existing flood control infrastructure in the Central Valley is not equipped to handle large, unpredictable floods, and increasingly extreme precipitation events would likely overwhelm existing facilities (Kiparsky & Gleick 2003). The Yolo Bypass does provide flood control for the Sacramento Valley, and croplands within the bypass area are at greater risk of flooding; future changes in water releases to manage fish habitat may have large impacts on agriculture (Howitt et al. 2013).

Disease

Warmer temperatures may alter the types of diseases that affect both wildlife and crops (e.g., rice), as diseases that are currently limited by cold temperatures expand into new areas and/or disease organisms and vectors become more likely to overwinter (Jackson et al. 2009; Hénaux et al. 2012; Brown et al. 2013; Elias et al. 2015). The high concentration of migrating birds passing through the Central Valley can increase the transmission of diseases such as avian influenza, avian cholera, and botulism, which are spread more readily in low-quality crowded habitat (Gilmer et al. 1982; Hénaux et al. 2012).

Wind

Wind can disturb young plants, as well as lodge crops, making them difficult to harvest and potentially decreasing yield and altering decisions about crop planting and management[1]. Wind can also affect the migration of birds dependent on flooded croplands (Beason 1978; Bruderer & Liechti 1995), providing tailwinds that lower energy expenditure during flight; however, severe weather (which is more likely during the spring migration) may prevent movement in birds on the ground and/or blow migrating birds off course.

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	Low-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: *Transcontinental (high confidence)*
Structural and functional integrity of habitat: *Altered but not degraded (high confidence)*
Continuity of habitat: *Fairly continuous with some breaks (high confidence)*

Historically, Central Valley wetlands covered an area of 4 million hectares (in the 1850s), but were lost by the mid-1980s when only 544.6 thousand acres remained (Frayer et al. 1989). The area of flooded cropland increased in the late 1980s and 1990s, however, with winter-flooded rice in the northern Central Valley increasing by 46% between 1989 and 2000 (Fleskes et al. 2005). This change was due to both an increase in the area of rice and in the proportion of rice that was flooded. Between 2000-2010, the total area of Central Valley flooded habitat (includes croplands and managed wetlands) was estimated to be 100,000-200,000 hectares (ha), depending on the season (Reiter & Liu 2011). This area declined over the 2000-2010 study period at a rate of 1-3% per year (total loss was 11-31%); habitat loss was greatest in the Sacramento Valley where the extent of flooded habitat was greatest, but the Suisun, Delta, and San Joaquin basins also saw declines (Reiter & Liu 2011; Reiter et al. 2015).

South of the Sacramento Valley, flooded croplands are less extensive and acreage varies more year-to-year, with the greatest fluctuations in the Tulare and Delta Basins (Reiter & Liu 2011). Flooded cropland acreage is at its lowest in the late summer, at which point it is concentrated in the Delta and in the San Joaquin and Tulare basins. By December, over 200,000 ha of open water is present, with the majority of that area occurring as flooded cropland (Fleskes et al. 2005; Reiter et al. 2015). Factors such as flooding, drought, and commodity prices can drastically reduce the area of flooded habitat within a single season, increasing the vulnerability of flooded cropland habitat to outside factors (Elphick 2004).

Landscape permeability

Overall landscape permeability: *Moderate-high (high confidence)*
Impact of various factors on landscape permeability:
Urban/suburban development: *Moderate-high (high confidence)*
Land use change: *Moderate (high confidence)*

As human populations increase in the Central Valley, so does the infrastructure required to support urban centers, including reservoirs, water delivery systems, and roads/highways (Gilmer et al. 1982). These can create significant barriers to movement for wildlife dependent on flooded cropland habitat (Huber et al. 2010), including stopover and wintering habitat for waterfowl (Gilmer et al. 1982; Fleskes et al. 2005). The existence of flooded cropland habitat enhances landscape permeability for wetland species, as the vast majority of natural wetlands have been lost (Frayer et al. 1989; Elphick 2000). Canals associated with flooded croplands 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).

Resistance and recovery

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

Water supply/crop idling: *Moderate-high (moderate confidence)*
Urban development: *Moderate (moderate confidence)*

Ability to recover from stresses/maladaptive human response impacts: *Moderate (moderate confidence)*

Water supply/crop idling: *High (moderate confidence)*
Urban development: *Low (moderate confidence)*

Flooded croplands are highly managed habitats, and are valued in large part for their agricultural products; given the economic emphasis on this habitat type, resistance and recovery are primarily dependent on human decision-making processes based on commodity prices, crop health and yield, and farming/management practices (Stralberg et al. 2010; Jackson et al. 2011, 2012). Changes in economics or policy that impact farmers can rapidly reduce the area of flooded cropland within the Central Valley (Elphick 2004). Incentive programs and conservation-focused policies may increase resistance of flooded croplands by helping farmers to continue or expand crop planting and flooding practices that support wildlife (Duffy & Kahara 2011; Kahara et al. 2012). Over the short-term, the habitat is highly resilient to low water supplies and crop idling practices[1].

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: *Moderate-high (high confidence)*

Component species or functional groups particularly sensitive to climate change:

- Herps (e.g., amphibians and reptiles)
- Tricolored blackbird (*Agelaius tricolor*)

Keystone or foundational species within the habitat:

- Rice

Other critical factors that may affect habitat diversity:

- Soil type diversity

Flooded croplands in the Central Valley provide habitat for 10-12 million waterfowl annually, which includes up to 60% of waterfowl traveling the Pacific Flyway and 20% of the population on the continent (Gilmer et al. 1982; Elphick 2000). Despite the highly managed nature of this habitat, flooded croplands are able to fulfill many of the ecosystem functions of seasonal wetlands, slightly reducing the negative impact of historical habitat loss (Gilmer et al. 1982; Elphick 2000, 2004; Fleskes et al. 2005). Within agricultural areas, flooded fields have twice as much species richness for waterbirds than non-flooded fields (Sesser et al. 2016), and most numerous species include mallards, American coot (*Fulica americana*), northern pintail (*Anas acuta*), white-faced ibis (*Plegadis chihi*), western sandpiper (*Calidris mauri*), dunlin (*Calidris alpina*), and mixed geese flocks (*Chen* spp. and *Anser* spp.). Species of conservation concern that commonly utilize flooded cropland habitat includes tule greater white-fronted geese (*Anser albifrons elgasi*), long-billed curlew (*Numenius americanus*), Swainson's hawk (*Buteo swainsoni*), and giant gartersnake (Halstead et al. 2010; U.S. Fish and Wildlife Service 2015; Sesser et al. 2016). Mammals commonly associated with flooded croplands include mink, otter, raccoon, and coyote (Elphick 2000; Jackson et al. 2011; Sesser et al. 2016).

Within flooded cropland habitats, heterogeneity is low, although some variation is present between fields of differing crop types, farming practices (e.g., amount of stubble and grain left post-harvest, burning, and disking), and water depths (Elphick 2000; Fleskes et al. 2003, 2013; Strum et al. 2013; Sesser et al. 2016). Waterbirds and shorebirds are quite sensitive to water depth, with dabbling ducks found in deeper water, while wading birds and shorebirds are typically found in fields with shallow flooding (Elphick 2000; Strum et al. 2013; Sesser et al. 2016). Post-harvest treatment (e.g., baling, stubble incorporation) and the availability of flooded habitat during critical times such as the fall migration period impact the carrying capacity of flooded cropland (Fleskes et al. 2005, 2013; Sesser et al. 2016). Habitat availability is likely a limiting factor for waterbird populations, especially during the dry months that coincide with fall migration (Central Valley Joint Venture 2006). Habitat availability 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

Population growth, which is expected to continue over the coming century, places increasing demands on land use and natural resources within the Central Valley. 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).

Future water demand is expected to increase along with the human population. Statewide, water scarcity is expected to increase from 2% (current scarcity) to 20% by the year 2050, even taking adaptive factors into account (Medellín-Azuara et al. 2007). The added costs of water scarcity and operational costs would be an additional $400m; agriculture would feel the largest impacts, both directly because of water availability, and through economic losses (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, especially during drought years (Tanaka et al. 2006; Howitt et al. 2013; Matchett et al. 2015).

Management potential

Workshop participants scored the resource's management potential.

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

Value to people

Value of habitat to people: *High (high confidence)*
Description of value: *This habitat is valued for habitat and recreation.*

Support for conservation

Degree of societal support for managing and conserving habitat: *High (moderate confidence)*
Description of support: *This habitat is supported by the value of agricultural products and hunting.*

Degree to which agriculture and/or rangelands can benefit/support/increase the resilience of this habitat: *High (high confidence)*

Description of support: *Flooded cropland is defined by agriculture, so if agricultural policies provide incentives for flooding certain crops then there is a benefit for this habitat. There have programs in the Farm Bill to encourage adoption of these practices. The Nature Conservancy also has a Bird Returns incentive program to encourage flooding and other beneficial practices, such as not disking. As water grows increasingly scarce there will need to be these additional motivations.*

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

Drought: *Moderate-high influence, moderate confidence*

Flooding: *Low-moderate influence, high confidence*

Description of events: *Flooding rice in the fall and winter for habitat may lose public support in drought years; irrigating in the summer and spring will have better support. Because rice is a crop with lower value, it could have a hard time competing with perennial crops. Flooding due to climate change may improve society support because the Sutter and Yolo bypasses will be more likely to be maintained as flooded cropland instead of converting to orchards or houses.*

Likelihood of converting land to habitat

Likelihood of (or support for) converting retired agriculture land to habitat: *Low (low confidence)*

Description of likelihood: *Conversion of retired agricultural land to flooded cropland is unlikely, and this factor is not expected to contribute to the habitat adaptive capacity.*

Likelihood of managing or alleviating climate change impacts on habitat: *Low (moderate confidence)*

Description of likelihood: *Incentive programs would be necessary in order to allow the purchase of water for maintaining flooded cropland, even with increases in drought or changes in rainfall patterns.*

The creation of the North American Waterfowl Management Plan in 1986 and the Central Valley Joint Venture in 1988 has contributed to changes in management practices, shifting policies and incentive programs toward wetland restoration, habitat improvement, and enhanced value of agricultural lands (Ackerman et al. 2006; Central Valley Joint Venture 2006; North American Waterfowl Management Plan 2012). Initiatives such as The Nature Conservancy's BirdReturns program (The Nature Conservancy 2014) are helping to create pop-up wetlands during critical periods for migrating and wintering birds, increasing habitat availability and quality. However, water resources limited by climate conditions and increased demand are likely to increase economic pressure on farmers, making it more difficult to maintain flooded cropland (Ackerman et al. 2006; Medellín-Azuara et al. 2007).

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