Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Rice Croplands

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

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

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

Key climate factors for rice cropland habitats include drought, snowpack amount, timing of snowmelt/runoff, and water temperature, which primarily impact water availability (e.g., stored water for irrigation) and water quality (e.g., water temperature for crop growth). Flooding, insects, disease, and wind are the most important disturbances for rice cropland habitats, and have the potential to harm crops and/or the birds and animals that utilize this habitat type.

Key non-climate factors include dams, levees, and water diversions and urban/suburban development. Both of these are related to expanding human populations, which will increase demand for water and other resources, and 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 rice cropland in the Central Valley has increased over the last several decades, especially in the Sacramento Valley. Although habitat diversity is very low, both in terms of structure and plant species diversity, rice croplands are vital habitat for migrating and wintering birds, with up to 60% of waterfowl within the Pacific Flyway passing through the Central Valley each year.

Management potential for rice croplands was scored as moderate. Management practices, such as the timing and depth of flooding, allow rice croplands to resist small changes in climate conditions; however, ongoing water shortages make it difficult for farmers to maintain rice cropland habitat. Management potential for rice croplands is largely focused on preserving habitat value for waterbirds and shorebirds.

Conservation-focused policies and incentive programs have helped increase habitat availability and quality, but farmers are likely to face increased economic pressure under future climate conditions and currently flooded fields may be converted to non-flooded crops, fallowed, or developed.

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Introduction

Description of Priority Natural Resource

Rice croplands are a habitat type in active agricultural use, and rice fields comprise the largest percentage of flooded cropland. Rice (*Oryza sativa*) is primarily grown within the Sacramento Valley, although some rice is grown in the Sacramento-San Joaquin River Delta as well (Ackerman et al. 2006; California Rice Commission 2013). Rice fields are flooded to a depth of 8-15 cm for 5-10 months of the year in order to reduce weed pressure, flush out accumulated salts, increase soil moisture, aid in the decomposition of rice straw residue, and provide habitat for wintering waterbirds and shorebirds (Fleskes et al. 2005; California Rice Commission 2013). Finely-textured soils with poor drainage are most suitable for flooded croplands, and the depth and duration of flooding in rice croplands is carefully controlled (Fleskes et al. 2005; California Rice Commission 2013).

As part of the Central Valley Landscape Conservation Project, workshop participants identified the rice 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 rice croplands habitat as a Priority Natural Resource included the following: the habitat has high management importance, and its conservation requirements are not met entirely by the flooded croplands habitat type. Please see Appendix A: "Priority Natural Resource Selection Methodology" for more information.

Vulnerability Assessment Methodology

During a two-day workshop in October of 2015, 30 experts representing 16 Central Valley resource management organizations assessed the vulnerability of priority natural resources to changes in climate and non-climate factors, and identified the likely resulting pressures, stresses, and benefits (see Appendix B: "Glossary" for terms used in this report). The expert opinions provided by these participants are referenced throughout this document with an endnote indicating its source[1]. To the extent possible, scientific literature was sought out to support expert opinion garnered at the workshop. Literature searches were conducted for factors and resulting pressures that were rated as high or moderate-high, and all pressures, stresses, and benefits identified in the workshop are included in this report. For more information about the vulnerability assessment methodology, please see Appendix C: "Vulnerability Assessment Methods and Application." Projections of climate and non-climate change for the region were researched and are summarized in Appendix D: "Overview of Projected Future Changes in the California Central Valley".

Vulnerability Assessment Details

Climate Factors

Workshop participants scored the resource's sensitivity to climate factors and this score was used to calculate overall sensitivity. Future exposure to climate factors was scored and the overall exposure score used to calculate climate change vulnerability.

Climate Factor	Sensitivity	Future Exposure
Air temperature	Low-moderate	High
Altered stream flow	-	High
Extreme events: drought	High	High
Extreme events: more heat waves	-	High
Increased flooding	-	Low-moderate
Precipitation (amount)	Moderate	Moderate-high
Precipitation (timing)	Moderate	Moderate
Snowpack amount	High	High
Soil moisture	Moderate	-
Timing of snowmelt/runoff	Moderate-high	Moderate
Water temperature	Moderate-high	High
Overall Scores	**Moderate-high**	**Moderate-high**

> ***Potential refugia:*** *Refugia will occur wherever there is a secure source of water, which often depends on water rights and water district boundaries. Duck clubs and wildlife refuges near cropland have an "integrated constituency of interest" that would ensure water during the winter. Areas with groundwater availability and pumping infrastructure could also act as refugia; however, there is not a lot of infrastructure for pumping groundwater in the Sacramento Valley because there hasn't been the need. There are also restrictions on water transfers away from giant garter snake* (*Thamnophis gigas*) *mitigation lands.*

Changes in climate are expected to cause crop yields to decline in California, although CO_2 fertilization may reduce the impact (Lee et al. 2011). However, modeled crop yields vary widely depending on the factors taken into account (e.g., CO_2 fertilization, changes in water availability, and management practices). For instance, Lee et al. (2011) found that, under a high-emissions climate scenario, rice yields are expected to stay relatively steady until 2050, and then decline steadily with a projected decrease of 4% by 2075 and 10% by 2094. Jackson et al. (2009) predicted an overall increase of 1.7% for rice yields, though they found that early heat waves had a negative impact on rice growth, with May-July heat waves reducing growth by 6.1% (May heat waves had the greatest impact). Incorporating drought reduced rice growth to 6.9% (Jackson et al. 2009). Lee et al. (2011) found that rice yields responded primarily to increases in temperature and greater variation in precipitation (Lee et al. 2011).

Future water demand is expected to increase as climate changes interact with expanding urban populations. Statewide, water scarcity is expected to increase from 2% (current gap between water needs and water delivery) 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).

Drought

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

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

Warmer temperatures 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 had a significant effect on the area of 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 are usually delayed because stored water reserves and water management practices slow the impact of drought on habitat (Reiter et al. 2015). The San Joaquin and Tulare basins respond immediately because of their dependency on water transfers from the Sacramento Valley, and more frequent, longer, or more severe droughts would be likely to significantly reduce water in this region (Medellín-Azuara et al. 2007; Reiter et al. 2015). Meeting in-stream flow requirements during drought periods is likely to cause additional stress on water availability (Tanaka et al. 2006; Reiter et al. 2015). Decreased water availability will also 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).

Snowpack amount

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

Snowmelt from mountainous areas surrounding the Central Valley plays a large part in water storage and supply for flooding rice croplands, 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).

Water temperature

Sensitivity: *Moderate-high (moderate confidence)*
Future exposure: *High (high confidence)*
Potential refugia: *Currently the west side of the valley is the most impacted, so the east side of the valley is a potential refuge. In the future, impacts will be valley-wide and magnified during drought years, with no refugia remaining.*

In the United States, increases in water temperature over the last century are correlated with rising air temperatures and earlier snowmelt (Webb & Nobilis 2007; Yarnell et al. 2010; Hill et al. 2014), with the greatest rates of increase occurring in or near urban areas (Kaushal et al. 2010). Reduced river discharge, such as occurs during periods of very low flow or drought, can increase water temperatures dramatically; for instance, a 40% decrease in river discharge may drive an additional 3.8°C increase in water temperature (van Vliet et al. 2011). Water temperature in the highly developed Central Valley is also dependent on reservoir depth, channel flow, and upstream management (OEHHA 2013). Water temperatures at a monitoring station in the southern Delta show annual and decadal variation that corresponds to natural patterns of variation in air temperature and precipitation, but no clear upward trends over the last 20 years (OEHHA 2013). However, rising air temperatures and lower flows are likely to cause water temperatures to rise in the future (OEHHA 2013).

Because shallow water warms quickly, maintaining deeper water depths in flooded fields may reduce temperature fluctuations and increase production of emergent insects by increasing invertebrate survival and biomass (Moss et al. 2009). However, deeper water may not be feasible under warmer and/or drier conditions due to limited water supply and higher costs (Moss et al. 2009).

Cold water temperature stunts rice production, and could also affect decomposition rates in flooded fields[1].

Timing of snowmelt & runoff

Sensitivity: *Moderate-high (high confidence)*
Future exposure: *Moderate (low confidence)*
Potential refugia: *None.*

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).

Precipitation (amount)

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

Large rainfall events have an immediate positive effect on the habitat; however, too much rain falling on rice fields can make water depth a problem for foraging shorebirds, although water depths are unlikely to reach the preferred depth for dabbling ducks based only on precipitation (Strum et al. 2013).

Precipitation (timing)

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

Heavy rain in the late spring and early summer may delay tilling and planting (Jackson et al. 2011); likewise, early fall rain can interfere with the timing of harvest[1]. The ability to flood fields post-harvest is dependent on precipitation timing, especially winter rainfall (Scanlon et al. 2012).

Soil moisture

Sensitivity: *Moderate (moderate confidence)*

Low soil moisture causes water to seep into the ground quickly, requiring increased water use to keep up [1].

Air temperature

Sensitivity: *Moderate (low confidence)*

Future exposure: *High (high confidence)*
Potential refugia: *Rice could be moved towards the delta to track increasing temperatures. Currently, the delta is mostly too cold for rice.*

Heat waves

Future exposure: *High (high confidence)*
Potential refugia: *None.*

Jackson et al. (2009) found that early heat waves had a negative impact on rice growth, especially from May to July (May heat waves had the greatest impact).

Streamflow

Future exposure: *High (low confidence)*
Potential refugia: *Areas with off-stream water storage could act as refugia during both high and low flows.*

Medellín-Azuara et al. (2007) projected a 22-41% decrease in annual streamflow in the Central Valley.

Lower stream flows causes additional stress on water availability because water must be allocated to meet in-stream flow requirements for fish (Tanaka et al. 2006; Reiter et al. 2015). Fields where the farmer uses riparian water for irrigation are more vulnerable to impacts from low stream flows[1].

Climatic changes that may benefit the habitat:

- Air temperature: Warmer temperatures could benefit growth, although there are trade-offs because evapotranspiration increases as well
- Precipitation timing and increased storms: Heavy winter rainfall aids flooding in rice croplands, and storm events can help create pop-up wetlands in rice fields
- Water temperature: Increased water temperature would be beneficial if water diversions were allowed

Non-Climate Factors

Workshop participants scored the resource's sensitivity and current exposure to non-climate factors, and these scores were then used to assess their impact on climate change sensitivity.

Non-Climate Factor	Sensitivity	Current Exposure
Agriculture & rangeland practices	Low-moderate	Low-moderate
Dams, levees, & water diversions	High	High
Groundwater overdraft	Low	Low
Invasive & other problematic species	Moderate	Low
Land use change	Low	Low-moderate
Other factors	Moderate	-
Urban/suburban development	Moderate-high	Moderate
Overall Scores	**Moderate**	**Low-moderate**

Dams, levees, & water diversions

Sensitivity: *High (high confidence)*
Current exposure: *High (high confidence)*
Pattern of exposure: *Dependent on water infrastructure in all areas.*

Rice cropland is dependent on surface water provided by the vast system of dams, levees, and water diversions that provide water storage, water delivery, and flood control within the Central Valley (Frayer et al. 1989). The canals surrounding rice cropland can offer reliable aquatic habitat and movement corridors for giant garter snakes, which utilize canals, cropland, and seasonal marshes throughout their large home ranges (Huber et al. 2010; Wylie et al. 2010).

Climate change is likely to have heavy impacts on water infrastructure in the Central Valley, and climate factors will interact with increased demand from expanding urban populations (Medellín-Azuara et al. 2007). Reduced water availability will result in higher operational costs and possible crop idling or conversion, especially for agricultural sectors such as rice that use large amounts of water and depend almost entirely on irrigation for their water supply (Medellín-Azuara et al. 2007). Changes in the timing of snowmelt and increased proportions of annual precipitation occurring as rain may place additional strains on flood control infrastructure, which is not well equipped to deal with large, unpredictable floods (Kiparsky & Gleick 2003).

Urban/suburban development

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

> ***Pattern of exposure:*** *Most urban growth is projected to occur south of where the majority of rice is grown. However, location of the urban land use change is irrelevant because what matters is the impact of development on water demand and cost. During drought periods, Sacramento valley rice received water but the San Joaquin Valley did not because they had no water rights.*

Development has accelerated in the Central Valley over the last century, causing habitat loss across the region. In 1939, urban development covered 151.2 thousand acres, but this increased to 1.1 million acres in the mid-1980s (Frayer et al. 1989) and has continued to expand rapidly since then, especially around the Sacramento-San Joaquin Delta and in the area between Sacramento and Fresno (Jackson et al. 2012). Despite an overall increase in the area of rice cropland during that period, 22.6 thousand acres of land were converted from rice cropland to urban development between 1939 and the mid-1980s (Frayer et al. 1989). 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). Urban/suburban development requires additional resources, and increasing demand and changing climate conditions will likely reduce water availability and place additional economic pressure on farmers, making it more difficult to maintain flooded cropland (Gilmer et al. 1982; Ackerman et al. 2006; Medellín-Azuara et al. 2007).

Agricultural & rangeland practices

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

Changes in agricultural practices on rice fields (e.g., not flooding in winter) may decrease habitat value to wildlife, although, changes in agricultural practices related to other crops do not impact rice[1].

Invasive and other problematic species

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

A new invasive weed (*Ludwigia decurrens*) has become an issue in the Central Valley, but has not yet had an economic impact yet[1]. Rice blast (a fungal disease) could also be a potential problem[1].

Commodity prices

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

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 could 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).

Land use change (crops)

Sensitivity: *Low (moderate confidence)*
Current exposure: *Low-moderate (high confidence)*
Pattern of exposure: *Localized in areas where other crops can be grown.*

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).

The planting of more water intensive crops (especially perennial crops) could create additional competition with rice for water[1]. However, 70% of rice cropland in California won't support other crops because of the soil type, so this is not a great risk[1].

Groundwater overdraft

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

Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment

Rice Croplands

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

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:** Low-moderate (moderate confidence)*

Flooding

***Future exposure:** Low-moderate (low confidence)*
***Potential refugia:** Areas not in the bypasses will be less likely to flood.*

Large areas of rice cropland are found in the low-lying floodplains along the Yolo Bypass, where they offer flood storage and protection for inland areas (Duffy & Kahara 2011; Howitt et al. 2013). Flooding practices in rice fields are highly managed, but the timing and severity of natural flooding can negatively impact crops (Jackson et al. 2011; Howitt et al. 2013). 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). Flooding may also limit foraging access for shorebirds, as most species are unable to use fields where the water depth is over ~15 cm (Taft et al. 2002; Strum et al. 2013).

Insects

Climate change is likely to affect the range, distribution, and population dynamics of insects. Warmer temperatures may increase winter survival, extend the length of the growing season, shorten generation lengths, and alter phenotypic traits including size, density, and life history strategies (Bale et al. 2002). The rice water weevil (*Lissorhoptrus oryzophilus*) is one of the most important insect pests affecting rice croplands in the Central Valley and worldwide, and can reduce crop yields by 10-25% (Aghaee & Godfrey 2014). Pesticides are still one of the primary defenses against rice weevils, and management strategies such as post-harvest flooding, draining fields several days after seeding, and straw manipulation treatments can be used to minimize weevil outbreaks (Aghaee & Godfrey 2014). It is likely that climate changes will limit some insect species while allowing others to move into the area, changing the composition of insect pests (Karuppaiah & Sujayanad 2012).

Mosquitos could increase with warmer air and water temperatures, and this can be associated with increased pesticide use; farmers are under pressure not to provide mosquito habitat at any time[1].

Disease

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). Diseases associated with fungus, in particular, could worsen with increased temperature and decrease rice production[1]. Warmer temperatures may alter the types of diseases that affect both wildlife and crops if diseases that are currently limited by cold temperatures expand into new areas and/or if 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).

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 bird migration, providing tailwinds that lower energy expenditure during flight (Bruderer & Liechti 1995; Newton 2010); 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 (Beason 1978; Newton 2010).

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
Resistance & Recovery	High
Habitat Diversity	Low
Other Adaptive Capacity Factors	Low-moderate
Overall Score	**Low-moderate**

Extent, integrity, and continuity

Overall degree of habitat extent, integrity, and continuity: *Workshop participants indicated that this section was not applicable for rice cropland habitats.*

Winter-flooded rice in the northern Central Valley increased by 47% (25,000 ha) between 1988 and 2000, due to both an increase in the percentage of rice fields that were flooded, as well as an increase in rice acreage (Fleskes et al. 2005). Rice acreage as a whole had already increased five-fold between 1930 and 1980, with a peak of ~580,000 ha acres of rice located primarily in the Sacramento Valley (California Rice Commission 2013).

Landscape permeability

Overall landscape permeability: *No landscape barriers were identified by workshop participants, and landscape permeability was not assessed.*

Resistance and recovery

Overall ability to resist and recover from stresses: *High (confidence not assessed)*
Resistance to stresses/maladaptive human responses: *High (confidence not assessed)*
Ability to recover from stresses/maladaptive human response impacts: *High (confidence not assessed)*

Rice 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). Climate factors such as drought and/or changes in economics or policy that impact farmers can rapidly reduce the area of rice cropland within the Central Valley (Elphick 2004; Reiter et al. 2015). 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).

Rice fields will be most productive and most resistant to climate impacts where there are senior water rights[1]. Stored water is a buffer against lack of water rights[1].

Habitat diversity

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

Rice cropland provides critical 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, rice croplands are able to fulfill many of the ecosystem functions of seasonal wetlands, slightly reducing the negative impact of historical wetland habitat loss (Gilmer et al. 1982; Elphick 2000, 2004; Fleskes et al. 2005). Within agricultural areas, waterbird species richness in flooded fields is double that in non-flooded fields (Sesser et al. 2016); the most numerous species include mallard (*Anas platyrhynchos*), 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 use flooded cropland habitat include 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).

Although the vegetation within rice cropland habitat is homogenous, there is some variation in habitat structure due to farming practices (e.g., amount of spilled grain, timing and depth of flooding, and straw management; Elphick 2000; Fleskes et al. 2003, 2013; Strum et al. 2013; Sesser et al. 2016). This allows differential use by many species of waterbirds and shorebirds that are sensitive to water depth; for example, dabbling ducks are 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). Harvest and post-harvest treatment (e.g., baling, stubble incorporation), as well the timing of habitat availability impacts the carrying capacity of flooded cropland (Fleskes et al. 2005, 2013; Petrie et al. 2014; 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:

Trade issues: *Low-moderate (moderate confidence)*

Strong international markets have contributed to the increase in rice cropland, with high prices encouraging farmers to maintain or expand production (Gilmer et al. 1982; California Rice Commission 2013). It is difficult to predict the impact of climate change on global trade for rice and other agricultural commodities; however, it is likely that factors such as drought and shifting distributions of insect pests will contribute to changes in demand (Bale et al. 2002; Karuppaiah & Sujayanad 2012; Elias et al. 2015).

Forty percent of California rice is sold under GAT agreements; this could change, and would impact rice cropland extent (Vulnerability Assessment Workshop, pers. comm., 2015).

Management potential

Workshop participants scored the resource's management potential.

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

Value to people

Value of habitat to people: *Moderate (high confidence)*
Description of value: *Hunters and birders value this habitat for recreation opportunities, while conservation practitioners value rice for habitat. The community values local food production, and this habitat is also valued as open space and for groundwater recharge. The habitat may not be valued in situations where people believe rice croplands use too much water or encourage mosquitos, or when people are not aware that rice is being produced.*

Support for conservation

Degree of societal support for managing and conserving habitat: *Low-moderate (moderate confidence)*
Description of support: *Hunting creates financial revenue. Legislative support includes the burning act, which supports flooding. Otherwise, legislative support is low because most legislatures do not have agriculture in their districts.*

Degree to which agriculture and/or rangelands can benefit/support/increase the resilience of this habitat: *High (high confidence)*
Description of support: *This habitat is highly dependent on the timing of water application.*

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

Description of events: *Drought has a negative effect on societal support because of rice water use. During flooding, rice croplands offer flood relief and safety.*

Likelihood of converting land to habitat

Likelihood of (or support for) converting retired agriculture land to habitat: *Moderate (high confidence)*
Description of likelihood: *There is moderate-high support for keeping water on the land pre-harvest, which would minimize impacts to rice croplands. There is more support for flooding because society values growing crops over conservation. There is low-moderate support for post-harvest flooding, because no crops are being grown. There is more support for winter flooding because it supports migratory birds.*

Likelihood of managing or alleviating climate change impacts on habitat: *Low-moderate (high confidence)*
Description of likelihood: *Depends on water availability. Without dam construction, there will be more extreme competition for water and higher evapotranspiration, but this is unlikely. Rice as a plant is resilient, but we need to build the infrastructure for water storage to be successful.*

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). It is important to consider the amount of habitat that will be necessary to support waterfowl in the future; this can include calculations related to bird density, distribution, and food availability (Central Valley Joint Venture 2006; Petrie et al. 2014).

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