Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Amphibians

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

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

Overall vulnerability of the amphibian species group was scored as moderate with high confidence. The score is the result of moderate sensitivity, moderate-high future exposure, and moderate adaptive capacity scores.

Key climate factors for amphibians include drought, precipitation amount, and water temperature. Drought and precipitation influence aquatic habitat availability, which can affect recruitment, while water temperature influences breeding timing, development rates, and fitness.

Key non-climate factors for amphibians include agriculture and rangeland practices, urban/suburban development, land use change, impervious surfaces, roads, highways, and trails, and pollutions and poisons. These factors contribute to direct mortality (e.g., road kill, pesticide exposure) and destroy, fragment, and degrade habitat, affecting amphibian recruitment, distribution, and dispersal opportunities.

Key disturbance mechanisms for amphibians include disease, flooding, and grazing. Amphibians are vulnerable to a variety of diseases, which can increase mortality or reduce fitness. Flooding can introduce and/or remove predatory non-native species, and grazing has variable impacts (e.g., can help control plants and maintain water availability in vernal pools, but may increase sedimentation). Amphibians exhibit a moderate-high degree of specialization due to high dependence on aquatic habitat for reproduction.

Amphibian populations in the Central Valley and surrounding foothills are declining; populations are patchily distributed and dispersal distances are relatively low. Urban/suburban development, agricultural practices, and roads/highways act as landscape barriers, preventing movement and/or increasing mortality during dispersal. This species group exhibits moderate-high diversity, with most species exhibiting phenotypic plasticity during larval development, and some species exhibiting behavioral plasticity in habitat use. Aestivation, burrowing, and other life history strategies may increase the resilience of this species group in the face of climate change.

Management potential for amphibians was scored as moderate. Management options include managing artificial ponds to provide breeding habitat and increasing native habitat restoration efforts (e.g., through the Wetlands Reserve Program).

Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment: Amphibians

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Introduction

Description of Priority Natural Resource

Amphibians in the Central Valley depend on aquatic habitat for breeding and larval rearing, while adults utilize a variety of aquatic and terrestrial habitats (Zeiner et al. 1990).

Species considered as part of this vulnerability assessment of amphibians are western spadefoot toad, western toad, and California newt, as well as red-legged frogs, yellow-legged frogs, and California tiger salamanders, although less information was incorporated for these latter species since they have individual assessments.

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

Precipitation (amount)

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

There has been a slight trend towards decreased and more variable precipitation in central and southern California over the last 100 years (Hunsaker et al. 2014). Although precipitation models for California are highly uncertain, some projections suggest that annual precipitation will remain quite variable over the next century, and may increase slightly in the Sacramento River Basin and decrease slightly in the San Joaquin River Basin by 2050 (Bureau of Reclamation 2015), and precipitation extremes may increase (Toreti et al. 2013).

Reduced precipitation volume may negatively affect amphibian reproduction and fitness by reducing aquatic habitat availability, which amphibians rely on for breeding and larval portions of their life cycle (Corn 2005; Walls et al. 2013). For example, spring rainfall fills vernal pool habitat, and rainfall volume, pool structure, and water depth determine pool inundation length (Morey 1996). In general, ponding duration must exceed the development time for amphibian species in order to allow successful recruitment; the western spadefoot toad (*Scaphiopus hammondii*) requires standing water for at least 5 weeks after breeding (Morey 1996), and the California tiger salamander (*Ambystoma californiense*) requires several weeks longer for successful metamorphosis (Jennings & Hayes 1994). Ponding duration also influences fitness (Morey 1996; Denver et al. 1998). Moyle (1996) found that ponding duration was positively correlated with western spadefoot toad size and fat stores at metamorphosis, which are linked with long-term fitness in many amphibian populations. Finally, reduced precipitation volume may limit adult activity; precipitation amount is positively correlated with above-ground activity of adult western spadefoot toads (Jennings & Hayes 1994) and migration activity of the California newt (*Taricha torosa*) (Zeiner et al. 1990).

Drought

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

Compared to the preceding century (1896-1994), drought years in California have occurred twice as often in the last 20 years (1995-2014; Diffenbaugh et al. 2015). Additionally, the recent drought (2012-2014) has been the most severe drought on record in the Central Valley (Williams et al. 2015), with record accumulated moisture deficits driven by high temperatures and reduced, but not unprecedented, precipitation (Griffin & Anchukaitis 2014; Williams et al. 2015). Comparatively, the frequency and severity of drought is expected to increase due to climate change over the next century (Hayhoe et al. 2004; Cook et al. 2015; Diffenbaugh et al. 2015; Williams et al. 2015), as warming temperatures exacerbate dry conditions in years with low precipitation, causing more severe droughts than have previously been observed (Cook et al. 2015; Diffenbaugh et al. 2015). 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).

Reduced water availability due to drought is likely to have negative impacts on amphibian reproductive success (Corn 2005; Walls et al. 2013). For example, drought may reduce breeding site availability (Corn 2005; Walls et al. 2013) or reduce adult survival. Additionally, premature drying of ephemeral pools can lead to complete or partial larval mortality (Morey 1996). However, some species (e.g., western spadefoot toad) can accelerate larval development in response to habitat desiccation, although there are likely tradeoffs between rapid development and fitness (Denver et al. 1998). The impacts of drought on amphibian reproductive success and long-term population stability are likely influenced by drought duration (Jones 2016), and prolonged droughts may alter amphibian distribution and metapopulation dynamics (Walls et al. 2013). However, drought could help control invasive bullfrog populations, which require permanent aquatic habitat (Cook & Jennings 2007).

Water temperature

Sensitivity: *Moderate-high (high confidence)*
Future exposure: *Moderate-high (high confidence)*
Potential refugia: *High elevation sites.*

As ectotherms, amphibian breeding timing, development rates, growth rates, body size, and metabolism are influenced by water temperature (Jennings & Hayes 1994; Ultsch et al. 1999). Warmer water temperature is likely to interact with hydroperiod to affect amphibian recruitment and fitness (O'Regan et al. 2014). For example, warming temperatures may accelerate larval development but simultaneously stimulate higher algal abundance, reducing resource competition that usually occurs in drying pools (O'Regan et al. 2014). As a result, O'Regan et al. (2014) found that cumulative impacts of warming/drying trials on three amphibian species were less than individual impacts of warming and/or drying.

Precipitation (timing)

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

Winter precipitation is likely to be a key driver of slightly shorter or substantially longer vernal pool inundation periods (Pyke 2004), affecting amphibian habitat. Vernal pools in the central part of the study region are likely to show the largest response to climate variability because they currently exhibit highly variable hydrology from year to year (Pyke 2005). Comparatively, vernal pools in the southern (severely water-limited) and northern (water-rich) end of the study region may show less response to climate change due to their more predictable hydroperiod (Pyke 2005). In general, precipitation shifts are likely to interact with land use practices and habitat loss to cause variable impacts on pool hydrology, and thus on amphibian populations at the site and landscape level (Pyke 2004; Pyke & Marty 2005).

Storms

Sensitivity: *Low-moderate (high confidence)*

Water reductions and reduced storm frequency (both within and between breeding seasons) could reduce breeding site availability and make hydroperiods too short for larval development (Walls et al. 2013).

Workshop participants did not further discuss the following factors beyond assigning scores.

Soil moisture

Sensitivity: *Moderate (high confidence)*

Air temperature

Future exposure: *Low-moderate (high confidence)*

Heat waves

Future exposure: *Low-moderate (high confidence)*

Climatic changes that may benefit the species group

- Increases in precipitation, soil moisture, storms, and water temperature (to a point) could:
    - Provide breeding habitat for amphibians
    - Increase the rate of larval development
    - Increase survival of adults
    - Provide disease resistance to *Batrachochytrium dendrobatidis*

Shifts in air temperature and precipitation will likely interact with one another to alter regional wetland hydroperiods, affecting habitat availability and quality for some amphibians (Pyke 2004; Pyke & Marty 2005; Pyke 2005; Lawler et al. 2010).

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	Moderate-high	High
Impervious surfaces	Moderate-high	Moderate
Invasive & other problematic species	Low-moderate	Low-moderate
Land use change	Moderate-high	Moderate-high
Nutrient loading	Low-moderate	Moderate
Pollution & poisons	Moderate-high	High
Roads, highways, & trails	Moderate-high	Moderate-high
Urban/suburban development	Moderate-high	Low-moderate
Overall Scores	**Moderate-high**	**Moderate-high**

Agricultural & rangeland practices

Sensitivity: *Moderate-high (high confidence)*
Current exposure: *High (high confidence)*
Pattern of exposure: *Widespread, though rangeland has less effect than agriculture.*

Agricultural conversion has contributed to wetland habitat loss, fragmentation, and degradation; and thus, has likely contributed to the decline of amphibian populations in the Central Valley (Holland 1998; Davidson et al. 2002; Holland 2009; Witham et al. 2014). Additionally, agricultural practices increase amphibian exposure to pesticides and herbicides (Davidson et al. 2002), potentially increasing mortality (Davidson et al. 2002; Relyea 2009) or reducing fitness (Sparling et al. 2001; Sparling & Fellers 2007). Agricultural ground-disturbance activities (e.g., plowing, trenching, grading, deep ripping) can also increase siltation, suffocate larvae (U.S. Fish and Wildlife Service 2005), and kill aestivating adults[1].

Pollution & poisons

Sensitivity: *Moderate-high (high confidence)*
Current exposure: *High (high confidence)*
Pattern of exposure: *Widespread.*

Aside from habitat destruction, pesticides may be the largest contributor to amphibian population declines in the Central Valley and surrounding foothills (Davidson et al. 2002). For example, windborne pesticide exposure has been linked with population declines of ranid amphibian species at multiple elevations in the Sierra Nevada foothills and mountains, with relative declines mirroring relative increases in pesticide levels (Davidson et al. 2002). Several common pesticides used in Central Valley agricultural areas can depress tadpole cholinesterase activity, which can negatively affect growth, function, and survival (Sparling et al. 2001; Sparling & Fellers 2007). Species with longer tadpole residency and species that are more closely affiliated with aquatic areas as adults are likely most vulnerable to water-borne contaminants (Sparling et al. 2001). Pesticide exposure is highest in areas east of the Central Valley and downwind of agricultural areas in the San Joaquin Valley. Exposure is lower and amphibian populations are more stable in coastal foothills and in the northern Sierra Nevada foothills downwind of the less agriculturally-intensive Sacramento Valley (Sparling et al. 2001).

Land use change

Sensitivity: *Moderate-high (high confidence)*
Current exposure: *Moderate-high (high confidence)*
Pattern of exposure: *Widespread.*

Land use conversion is the leading cause of vernal pool habitat loss in the Central Valley (Holland 2005), and the vast majority of Central Valley wetlands (>95%) have already been lost through conversion to urban development or agriculture (Gilmer et al. 1982). Land use change contributes to amphibian habitat destruction and fragmentation (including upland sites and aquatic breeding areas; U.S. Fish and Wildlife Service 2005), ultimately affecting amphibian gene flow, dispersal, and persistence (Davidson et al. 2002).

Roads, highways, & trails

Sensitivity: *Moderate-high (high confidence)*
Current exposure: *Moderate-high (high confidence)*
Pattern of exposure: *Widespread, but acts at small, localized scales.*

Amphibians are vulnerable to road-kill, particularly as they migrate between upland and aquatic breeding habitats (Trombulak & Frissell 2000). Vulnerability likely depends on species; nocturnal species may be less vulnerable due to reduced traffic at night, and more mobile species (e.g., frogs) may be less vulnerable because they require less time to cross roads (Gibbs & Shriver 2005). Roads, highways, and associated ditches may also completely prevent dispersal, depending on their design (Gibbs & Shriver 2005).

Impervious surfaces

Sensitivity: *Moderate-high (high confidence)*
Current exposure: *Moderate (high confidence)*
Pattern of exposure: *Highly localized; associated with roads, parking lots, etc.*

Impervious surfaces change stream and wetland hydroperiods, which can affect amphibian breeding and recruitment and alter amphibian assemblages (Hamer & McDonnell 2008). Runoff from impervious surfaces is also typically high in pollutants and contaminants that are harmful to amphibians (Hamer & McDonnell 2008). Additionally, impervious surfaces prevent burrowing[1].

Urban/suburban development

Sensitivity: *Moderate-high (high confidence)*
Current exposure: *Low-moderate (high confidence)*
Pattern of exposure: *Localized; developed/developing areas.*

Urban/suburban development has contributed to the decline of amphibians in the Central Valley (Davidson et al. 2002) by fragmenting or eliminating upland habitat and aquatic breeding habitat, including vernal pools (Morey 1996; Bartolome et al. 2014) and other wetland areas (Gilmer et al. 1982). Urban/suburban development can also affect amphibian populations by altering habitat quality (Hamer & McDonnell 2008). For example, urbanized areas often alter hydroperiods of nearby wetlands and streams by increasing runoff and/or diverting water for human use, which can drive shifts in amphibian population numbers and community assemblages (Davidson et al. 2002; Hamer & McDonnell 2008).

Nutrient loading

Sensitivity: *Low-moderate (high confidence)*
Current exposure: *Moderate (high confidence)*
Pattern of exposure: *Localized.*

Nutrient loading can increase parasitism and deformity (e.g., see Johnson & Chase 2004).

Invasive & other problematic species

Sensitivity: *Low-moderate (high confidence)*
Current exposure: *Low-moderate (high confidence)*
Pattern of exposure: *Localized to fish introductions via flooding.*

Invasive fish can prey on amphibian larvae if flooding brings them into contact (U.S. Fish and Wildlife Service 1996; Paoletti et al. 2011).

Disturbance Regimes

Workshop participants scored the resource's sensitivity to disturbance regimes, and these scores were used to calculate climate change sensitivity.

Overall sensitivity to disturbance regimes: *Moderate (high confidence)*

Disease

Amphibians are vulnerable to a variety of diseases, including fungal infections, iridoviruses, and bacterial infections. For example, chytrid fungus (*Batrachochytrium dendrobatidis*) is known to infect several amphibians with already declining populations in California, including the California red-legged frog (*Rana draytonii*), the California tiger salamander (Padgett-Flohr 2008), and the foothill yellow-legged frog (*Rana boylii*) (Davidson et al. 2007). Impacts and susceptibility vary by species (Carey et al. 1999; Padgett-Flohr 2008), but disease can lead to mortality (Carey et al. 1999) or indirectly impact fitness by affecting growth (Davidson et al. 2007), energy expenditure (Padgett-Flohr 2008), or other behavioral parameters. Kiesecker et al. (2001) posit that climate change may increase amphibian disease risk by reducing water availability at oviposition sites, increasing larval exposure to ultraviolet-B radiation and subsequently causing higher infection rates.

Amphibians do exhibit some resistance to disease; for example, antimicrobial peptides in the skin and digestive tract help control disease-carrying microorganisms (Carey et al. 1999). However, recent research on foothill yellow-legged frogs indicates that pesticide exposure may decrease peptide levels and frog disease resistance (Davidson et al. 2007).

Flooding

Future exposure: *Moderate (high confidence)*
Potential refugia: *Ephemeral wetlands isolated from flood events.*

Many amphibian species breed in seasonal or ephemeral wetlands because aquatic predators are not able to persist in these areas (Zedler 2003). Seasonal flooding facilitates fish movement between different water bodies (Baber et al. 2002), potentially introducing larval predators into pond breeding areas (Baker et al. 2011). Alternatively, floods may increase habitat suitability for stream-dwelling amphibians by scouring and remove invasive predators (e.g., crayfish, bullfrogs; Gamradt & Kats 1996; Doubledee et al. 2003).

Grazing

Grazing may have variable impacts on amphibian populations. For example, grazing may help maintain water in vernal pool systems by reducing plant cover and evaporative demand, increasing habitat suitability for amphibians even with climate change-related declines in water availability (Marty 2005; Pyke & Marty 2005). Comparatively, grazing may have negative impacts on amphibian breeding sites by increasing erosion, sedimentation (U.S. Fish and Wildlife Service 1996), and soil compaction [1]. For example, sedimentation can decrease western toad larval growth and survival by smothering important food resources (Wood & Richardson 2009).

Dependency on habitat and/or other species

Workshop participants scored the resource's dependency on habitat and/or other species, and these scores were used calculate climate change sensitivity.

Overall degree of specialization*: Moderate-high (high confidence)*
Dependency on one or more sensitive habitat types: *High (high confidence)*
Description of habitat: *Ephemeral wetlands (breeding habitat).*
Dependency on specific prey or forage species: *Low-moderate (high confidence)*

Amphibians require aquatic habitat for breeding (Zeiner et al. 1990; Jennings & Hayes 1994). Several species obligatorily reproduce in vernal pools, such as the western spadefoot toad (Morey 1996), while other species, such as the western toad (*Anaxyrus boreas*), can reproduce in various aquatic environments, including natural and artificial ponds and pools (e.g., stock ponds, irrigation canals; Zeiner et al. 1990). Similarly, adult amphibian dependence on aquatic habitat varies amongst species, with some exhibiting largely terrestrial occupancy (e.g., western toad; Zeiner et al. 1990) and others exhibiting close ties with aquatic environments (e.g., foothill yellow-legged frog; Kupferberg et al. 2008). Adult amphibians tend to be prey generalists, consuming a variety of arthropods, while larvae tend to have more specialized diets of algae and aquatic invertebrates (Zeiner et al. 1990).

Adaptive Capacity

Workshop participants scored the resource's adaptive capacity and the overall score was used to calculate climate change vulnerability.

Adaptive Capacity Component	Score
Extent, Status, and Dispersal Ability	Moderate
Landscape Permeability	Low-moderate
Intraspecific Species Group Diversity	Moderate-high
Resistance & Recovery	Moderate-high
Overall Score	**Moderate**

Extent, status, and dispersal ability

Overall degree extent, integrity, connectivity, and dispersal ability: *Moderate (high confidence)*
Geographic extent: *Transboundary (high confidence)*
Health and functional integrity: *Fairly degraded (high confidence)*
Population connectivity: *Patchy, with some connectivity (high confidence)*
Dispersal ability: *Low-moderate (high confidence)*

Relative to historic distributions, pond-dwelling amphibian populations have declined and shifted to higher elevations in the Central Valley, with the greatest losses occurring in the Sacramento and San Joaquin Valleys, and smaller declines occurring in the Coast Range foothills (Fisher & Shaffer 1996; Davidson et al. 2002). Many remnant amphibian populations in the Central Valley are fragmented (Fisher & Shaffer 1996). Dispersal is local, and most amphibians do not disperse significant distances (Zeiner et al. 1990).

Landscape permeability

Overall landscape permeability: *Low-moderate (high confidence)*
Impact of various factors on landscape permeability:
- ***Urban/suburban development:*** *High (high confidence)*
- ***Roads, highways, & trails:*** *Moderate-high (high confidence)*
- ***Agricultural & rangeland practices:*** *Moderate-high (high confidence)*
- ***Land use change:*** *Moderate (high confidence)*

Amphibians typically cannot disperse through urban/suburban areas (Hamer & McDonnell 2008). Roads and highways limit amphibian dispersal by increasing mortality via road kill and/or blocking movement (Trombulak & Frissell 2000; Gibbs & Shriver 2005), with larger roads having greater impacts[1]. Rangelands have less of an impact than agriculture (see Agricultural & rangeland practices section above).

Resistance and recovery

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

Several amphibians utilize aestivation or burrowing to avoid environmental stress (Jennings & Hayes 1994; Jones & Stokes 2004), including changes in precipitation (amount and timing), drought, increased water and air temperatures, and heat waves. Amphibians have evolved life history strategies that confer some resistance to environmental variability (Walls et al. 2013), which can allow rapid recovery under improved conditions, provided adults are available to breed[1]. However, climate change paired with other non-climate factors may test the limit of these adaptations (Walls et al. 2013).

Species group diversity

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

Amphibians require aquatic habitat for breeding, although there is some variability in the hydroperiod required for development (Zeiner et al. 1990; Jennings & Hayes 1994). Some species display flexibility in aquatic habitat selection, using natural or artificial pool areas (Zeiner et al. 1990). Amphibian species do show some plasticity in age and size at metamorphosis (Morey 1996; Morey & Reznick 2004), and larval development responds to environmental variables including temperature, food supply and quality (Arendt 2006), drying, and predators[1]. Additionally, amphibians exhibit some behavioral plasticity in breeding timing[1].Genetic diversity is probably reduced by habitat loss and fragmentation, and is lower for toads than treefrogs[1].

Management Potential

Workshop participants scored the resource's management potential.

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

Value to people

Value to people: *Moderate (moderate confidence)*
Description of value: *People generally like frogs (maybe less for toads), but often they are ignored rather than highly valued.*

Support for conservation

Degree of societal support for management and conservation: *Low-moderate (high confidence)*
Description of support: *Currently, there is little regulatory support for wetlands with short hydroperiods and the adjacent uplands on which these species depend. No specific regulation (e.g., ESA, etc.) for these species.*

Degree to which agriculture and/or rangelands can benefit/support/increase resilience: *Moderate-high (moderate confidence)*
Description of support: *Rangelands can be managed to better support these species. Intensive agriculture probably can't do much to improve conditions.*

Degree to which extreme events (e.g., flooding, drought) influence societal support for taking action: *Low-moderate (moderate confidence)*
Description of events: *Not sure how society would connect extreme events to these species without a lot of education.*

Likelihood of converting land to support species group

Likelihood of (or support for) converting retired agriculture land to maintain or enhance species group: *Moderate-high (moderate confidence)*
Description of likelihood: *Including ephemeral wetlands in a mosaic of uplands would be a relatively simple way to benefit these species in retired agricultural lands, and this practice would likely be palatable to most people.*

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

Description of likelihood: *Most focus will be on other species or habitats.*

Agricultural ponds may be utilized for sustaining amphibian populations (Knutson et al. 2004), and urban/suburban ponds may also promote landscape connectivity and facilitate persistence of amphibian populations in the Central Valley (De La Torre 2013). Amphibians may benefit from restoration or management activities developed for other habitats and species; for example, wetland restoration on agricultural lands through programs like the Wetland Reserve Program will likely benefit amphibian populations (Rewa 2005).

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[1] Expert opinion, Central Valley Landscape Conservation Project Vulnerability Assessment Workshop, Oct. 8-9, 2015.