Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Yellow-legged Frog

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

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

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

Key climate factors for foothill yellow-legged frogs include altered flow regimes, water temperature, precipitation timing, and storms. Precipitation timing, storms, and altered stream flows (including high and low flows) influence egg and tadpole survival by exposing larval stages to scouring, desiccation, stranding, or displacement; water temperature influences breeding timing, larval development, size, and survival.

Key non-climate factors for foothill yellow-legged frogs include dams, levees, and water diversions, invasive and problematic species, and pollution and poisons. Dams fragment and destroy habitat, and can significantly alter downstream thermal, hydrologic, and sediment regimes, affecting overall frog survival and recruitment. Invasive bullfrogs compete with frog larvae for available algal resources and invasive smallmouth bass prey directly on frog larvae; both of these species thrive in altered watercourses. Agricultural pesticides are linked with declining frog populations, and can increase disease or predation susceptibility.

Key disturbance regimes for the foothill yellow-legged frog include disease, flooding, and wildfire. Disease can undermine growth, flooding can scour or strand and desiccate eggs and larvae, wildfire can increase sedimentation, and both wildfire and flooding can also reduce riparian vegetation and increase habitat with suitable water temperatures.

Foothill yellow-legged frogs display a mostly R-selected reproductive strategy; they take around 2 years to reach reproductive maturity, and egg clutches usually consist of 300-1200 eggs. Foothill yellow-legged frogs are stream channel habitat specialists, and in their larval stage they are prey specialists, foraging on algae.

Foothill yellow-legged frog populations are reduced relative to historical numbers and exhibit patchy distribution, which increases vulnerability to extirpation as a result of human activity or extreme events. This species disperses along stream corridors, and habitat connectivity and genetic exchange are limited by dams, levees, and water diversions and by urban/suburban development.

This species exhibits low intraspecific species diversity, although genetic diversity does exist between populations in different river basins. This species has low resistance to climate changes and human activities, likely as a partial result of high dependence on stream habitats and low behavioral diversity.

Management potential for foothill yellow-legged frogs was scored as low-moderate. management options may include regulatory support, since this species is listed as a California Species of Special Concern, and managing reservoir releases to mitigate negative impacts on downstream frog populations.

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Introduction

Description of Priority Natural Resource

There are three species of yellow-legged frog: the foothill (*Rana boylii*), Sierra Nevada (*Rana sierrae*), and Sierra Madre (*Rana muscosa*) yellow-legged frog (Zeiner et al. 1990). This assessment only considers foothill yellow-legged frogs because the distributions of Sierra Nevada and Sierra Madre yellow-legged frogs do not clearly align with the Central Valley study area boundaries (California Department of Fish and Wildlife 2016). Additional information on the vulnerability of Sierra Nevada and Sierra Madre yellow-legged frog species can be found in Kershner (2014) and Hauptfeld & Kershner (2014). The foothill yellow-legged frog is a stream-dwelling frog, and within the study area, can be found in the foothills of the Sierra Nevada and Coast Range (Jennings & Hayes 1994; Kupferberg 1996; Kupferberg et al. 2008).

As part of the Central Valley Landscape Conservation Project, workshop participants identified the yellow-legged frog as a Priority Natural Resource for the Central Valley Landscape Conservation Project in a process that involved two steps: 1) gathering information about the species' 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 yellow-legged frog as a Priority Natural Resource included the following: the species has high management importance, and the species' conservation needs are not entirely represented within a single priority habitat or species group. 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
Altered stream flow	High	High
Extreme events: drought	Moderate	High
Extreme events: storms	Moderate-high	-
Increased flooding	-	Moderate
Increased wildfire	-	Moderate-high
Precipitation (amount)	Moderate	High
Precipitation (timing)	Moderate-high	High
Snowpack amount	Moderate	Moderate
Timing of snowmelt/runoff	Moderate	Moderate
Water temperature	High	Moderate-high
Overall Scores	**Moderate-high**	**Moderate-high**

Stream flow

> ***Sensitivity:*** *High (high confidence)*
> ***Future exposure:*** *High (high confidence)*
> ***Potential refugia:*** *Spring-fed systems.*

Shifts in the magnitude, timing, and duration of peak flows, subsequent flow pulses, and low flows may affect foothill yellow-legged frog recruitment by reducing egg and tadpole survival and fitness (Kupferberg et al. 2008). Foothill yellow-legged frogs have evolved synchronized breeding and oviposition to occur after peak spring snowmelt flows, which helps to avoid high flow scouring while capitalizing on peak water availability (Kupferberg 1996; Kupferberg et al. 2008). Shifts in the timing or magnitude of peak flows, including pulses following spring peak flows, may increase egg mass scouring, sweep away tadpoles, and/or force tadpoles to find refuge, which limits foraging opportunities and ultimately negatively affects growth, development, and future recruitment (Kupferberg et al. 2008). Shifts in flow regimes, whether due to climate change or dam operations, may also affect available algal forage, influencing tadpole development rates, size, and fitness (Kupferberg et al. 2011a; Furey et al. 2014). Rapid stream flow declines also threaten this species, as eggs are vulnerable to desiccation and tadpoles can be stranded if stream flows decline too quickly (Kupferberg et al. 2008).

Water temperature

Sensitivity: *High (high confidence)*
Future exposure: *Moderate-high (moderate confidence)*
Potential refugia: *Upstream areas/higher elevations.*

Seasonal water warming cues yellow-legged frog breeding (Kupferberg 1996), and water temperature influences development rates and body size (Kupferberg 1996; Kupferberg et al. 2011b). Warmer water temperatures result in faster development (Kupferberg 1996; Kupferberg et al. 2011b), while cold water temperatures (e.g., from dam releases) can inhibit growth and development (Ashton et al. 1998; Wheeler et al. 2015) and/or affect algal quantity and quality available for tadpole forage (Kupferberg et al. 2011a; Furey et al. 2014). For example, cold water releases on the regulated Trinity River caused delayed oviposition and metamorphosis and resulted in smaller metamorphs, potentially due to restricted tadpole foraging activity or reduced stream productivity (Wheeler et al. 2015). Critical larval thermal maximums are thought to be around 26°C (79°F), and oviposition has been observed at temperatures from 8-20°C (46-68°F; Zweifel 1955), although recent evidence indicates that temperatures must be at least 10°C (50°F) for oviposition to begin (Hayes et al. *in press* cited in Wheeler et al. 2015). Additionally, warmer water temperatures may increase disease risk (Kupferberg et al. 2009).

Precipitation (timing)

Sensitivity: *Moderate-high (high confidence)*
Future exposure: *High (low confidence)*
Potential refugia: *Diversity of stream sizes, redundancy in the landscape, different sources of water.*

Spring precipitation that occurs after peak flows can inhibit recruitment by contributing to temporary high flows and scour (Kupferberg 1997b). Winter precipitation may help control invasive bullfrogs by scouring overwintering bullfrog larvae (Kupferberg 1997b).

Storms

Sensitivity: *Moderate-high (high confidence)*

Strong, late storms can temporarily increase stream flow, potentially causing egg scour, larval displacement, or enhanced larval energetic costs (Jennings & Hayes 1994; Kupferberg et al. 2008).

Precipitation (amount)

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

Potential refugia: *Diversity of stream sizes, redundancy in the landscape.*

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). Increased precipitation variability and percent of dry years may restrict yellow-legged frog distribution (Lind 2005). Drier conditions may cause some streams to transition from perennial to intermittent or even to ephemeral channels, which could drastically impact the suitability for stream flow-dependent species (Myrick & Cech 2004), such as yellow-legged frogs.

Drought

Sensitivity: *Moderate (moderate confidence)*
Future exposure: *High (high confidence)*
Potential refugia: *Spring-fed systems.*

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). Regardless of changes in precipitation, warmer temperatures are expected to increase evapotranspiration and cause drier conditions (Cook 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 and drier conditions may contribute to a contraction of foothill yellow-legged frog distribution away from southerly and lower elevations; some of these patterns are already evident (Davidson et al. 2002).

Timing of snowmelt & runoff

Sensitivity: *Moderate (high confidence)*
Future exposure: *Moderate (moderate confidence)*
Potential refugia: *Coast Range habitat areas.*

Yellow-legged frog breeding is strongly tied to major runoff pulses in winter and spring (Kupferberg 1996; Kupferberg et al. 2008; see stream flow section above). Eggs are laid after high flows, but if there is another large water pulse, eggs can be washed away and the year's reproductive class is lost (Kupferberg et al. 2008).

Snowpack amount

Workshop participants did not further discuss factor beyond assigning scores.

Sensitivity: *Moderate (moderate confidence)*
Future exposure: *Moderate (moderate confidence)*
Potential refugia: *Coast Range habitat areas.*

Climatic changes that may benefit the species

- Snowmelt & runoff timing and precipitation timing: if snowmelt, runoff, and precipitation occur later, it keeps water in the system longer.
- Increased water temperature: can benefit frog reproduction in shaded systems.
- Drought: can help suppress bullfrogs in invaded systems by affecting bullfrog tadpoles.

Due to the high dependency of yellow-legged frogs on stream habitat (Kupferberg 1996; Kupferberg et al. 2008), this species is likely to be affected by climate-driven changes in habitat condition. For example, overall water availability may decline both as a result of climate change (Knowles & Cayan 2002; Miller et al. 2003; Vicuna & Dracup 2007; Vicuna et al. 2007) and increased human demand (Medellín-Azuara et al. 2007), particularly as it is projected that there will be more "critically dry" water years in the future within the study region (Null et al. 2013).

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
Dams, levees, & water diversions	High	High
Invasive & other problematic species	Moderate-high	Moderate-high
Nutrient loading	Low-moderate	Moderate
Pollution & poisons	High	High
Urban/suburban development	Moderate	Low-moderate
Overall Scores	**Moderate-high**	**Moderate-high**

Dams, levees, & water diversions

Sensitivity: *High (high confidence)*
Current exposure: *High (high confidence)*
Pattern of exposure: *Consistent across the landscape (dams are widespread).*

Dams, levees, and water diversions have contributed to yellow-legged frog habitat loss and fragmentation (Kupferberg et al. 2008). Dams can also elevate frog mortality and degrade remaining habitat quality and suitability by inundating upstream areas and altering downstream flow regimes, pulse timing, temperature regimes, and sediment budgets (Kupferberg et al. 2008; Olson & Davis 2009). Negative impacts may be particularly acute during low precipitation periods (Lind 2005) or when stream flow pulses are decoupled with other environmental variables related to breeding and recruitment (e.g., water temperature, algal growth;

Kupferberg et al. 2008). For example, reservoir releases for flood control, power production, and recreation demands are typically much larger and more frequent than spring floods in natural systems, typically leading to more significant impacts on yellow-legged frogs (e.g., higher clutch mortality; Kupferberg et al. 2008). As a result, yellow-legged frog populations in managed watercourses are typically much smaller than populations in natural water courses (Kupferberg et al. 2008). Cold-water dam releases can also impair frog development (Ashton et al. 1998; Wheeler et al. 2015) and alter algal forage availability and quality (Kupferberg et al. 2011a; Furey et al. 2014). Additionally, altered hydroperiods favor several invasive predators (Moyle & Light 1996; Marchetti et al. 2004).

Water diversions for agricultural flood irrigation can compound declines in water availability (Olson & Davis 2009), and gold-mining and other disturbances to the riverbed are problematic for this species[1].

Pollutions & poisons

Sensitivity: *High (high confidence)*
Current exposure: *High (high confidence)*
Pattern of exposure: *Consistent across the landscape with variability in sources and magnitude between the Coast Range and Sierra Nevada. Magnitude of exposure in the Sierra Nevada foothills is greater than in the eastern foothills of the Coast Range.*

Yellow-legged frogs are very sensitive to contaminants, possibly more so than other California frogs[1]. Wind-borne pollutants from agricultural areas in the Central Valley are linked to population declines of foothill yellow-legged frogs in the Sierra Nevada foothills, with populations declining proportionally with increases in agrochemical exposure (Davidson et al. 2002). Pesticides can suppress amphibian immune systems, increasing their vulnerability to disease (Taylor et al. 1999). For example, carbaryl decreases yellow-frog peptide levels, potentially undermining their ability to suppress chytrid fungus infection and growth (Davidson et al. 2007). Carabyl exposure has also been linked to increased foothill yellow-legged frog mortality in the presence of the invasive predatory signal crayfish (*Pacifastacus leniusculus*) (Kerby & Sih 2014). Contaminants can also be present in runoff, and current environmental levels of several toxins are believed to be harmful to this species (Sparling & Fellers 2007).

Invasive & other problematic species

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

Foothill yellow-legged frogs are vulnerable to several invasive species, including bullfrogs (*Rana catesbeiana*; Kupferberg 1997b) and smallmouth bass (*Micropterus dolomieu*; Paoletti et al. 2011). Foothill yellow-legged frog abundance typically declines in areas with bullfrogs, likely due to competition between bullfrog and frog tadpoles for algal resources (Kupferberg 1997b). Bullfrog tadpoles outcompete frog tadpoles for high quality algal forage, leading to reduced survivorship and growth in frog larvae (Kupferberg 1997a, 1997b). Smallmouth bass prey on frog larvae (Paoletti et al. 2011). Many of these non-native predators thrive in watercourses that are managed or are subject to flow diversion (i.e., have altered flow regimes; Moyle & Light 1996; Marchetti et al. 2004). Yellow-legged frogs are also sensitive to non-native algae (Kupferberg et al. 2011a) and plants[1].

Urban/suburban development

> ***Sensitivity:*** *Moderate (high confidence)*
> ***Current exposure:*** *Low-moderate (high confidence)*
> ***Pattern of exposure:*** *Localized, with more development around larger cities along foothills (e.g., Marysville and Yuba City), populations along the Feather River.*

Foothill yellow-legged frog populations along the American River are further upstream than Sacramento's urban areas, so they may be less exposed to urban/suburban development[1].

Nutrient loading

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

Areas harboring yellow-legged frogs experience nutrient loading through application of upstream fertilizers and manure from grazing. Nutrient loading affects algal growth[1]; depending on the type of algae present, it could hurt or help yellow-legged frog, since some algae serves as a nutritious food source, while other algae is not nutritious enough to support metamorphose (Kupferberg et al. 2011a).

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 (moderate confidence)*

Climate change is expected to increase the incidence of severe wildfire, high-intensity storms, and rain-on-snow events (Cannon & DeGraff 2009), all of which could affect disturbance frequency and exposure in yellow-legged frog habitat.

Wildfire

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

Direct impacts of wildfire on this species are unknown (Olson & Davis 2009). However, landslides and sedimentation events following wildfires may alter or degrade available stream breeding habitats, contribute to extirpation of isolated frog populations (Hossack & Pilliod 2011), and/or fragment populations (Olson & Davis 2009). The threat of post-wildfire debris flows is expected to increase and become more widespread under climate change (Cannon & DeGraff 2009). Wildfires may also alter riparian vegetation structure and composition, affecting stream and terrestrial shading (Olson & Davis 2009).

Flooding

> ***Future exposure:*** *Moderate (moderate confidence)*
> ***Potential refugia:*** *Tributary streams, diversity of stream sizes, redundancy in the landscape.*

Foothill yellow-legged frogs have evolved to accommodate winter and spring peak flows characteristic of California's Mediterranean climate. For example, eggs are typically laid in late spring after peak flows, are selectively laid in areas with slow water velocity, and feature adhesion properties to reduce their chance of being swept away (Kupferberg et al. 2008). Other characteristics that allow yellow-legged frogs to survive flooding/peak flows include strong swimming ability, utilization of slow-velocity refugia, anchoring to substrate (tadpoles), and temporary uphill migration (adults) (Zeiner et al. 1990; Kupferberg et al. 2008). However, even with these adaptations, this species is still vulnerable to flooding, which can scour egg clutches, kill or strand tadpoles, and/or inhibit tadpole growth and foraging by forcing them to take shelter (Kupferberg et al. 2008). In general, older life stages are more resilient to flooding than egg and larval stages (Kupferberg et al. 2008). Vulnerability to shifting flood regimes is also influenced by stream channel geomorphology and channel shape, which influence water velocity and refugia microsites (Kupferberg et al. 2008). Flooding may also reduce riparian vegetation, potentially increasing habitat suitability in shaded stream reaches by elevating water temperature (Kupferberg et al. 2008).

Disease

Yellow-legged frogs are only moderately sensitive to disease[1]. Chytrid fungus (*Batrachochytrium dendrobatidis*) has been found to reduce juvenile yellow-legged frog growth, which may impact future recruitment (Davidson et al. 2007). Foothill yellow-legged frogs are also sensitive to parasitic copepod (*Lernaea cyprinacea*) outbreaks, which can cause morphological deformities and reduce body size, potentially affecting future fitness and recruitment (Kupferberg et al. 2009). Copepod outbreaks may be exacerbated by climate changes such as warmer water temperatures and reduced flows (Kupferberg et al. 2009). Yellow-legged frogs are likely also sensitive to egg mass fungal infections and parasites (Ashton et al. 1998), and may be vulnerable to *Saprolegnia* fungal infection and diseases known to affect related species, including the bacterial disease "red leg" (*Aeromonas hydrophila*) and ridoviruses (*Ranavirus* spp.) (Olson & Davis 2009).

Life history and reproductive strategy

Workshop participants scored the resource's life history and reproductive strategy, and these scores were used calculate climate change sensitivity.

> ***Species reproductive strategy, representing generation length and number of offspring****: Displays mainly R-selected characteristics (high confidence)*
> ***Average length of time to reproductive maturity:*** *1-3 years*

Foothill yellow-legged frogs lay eggs in late spring or early summer (March-June; Kupferberg et al. 2008; Lind et al. 2011), with each egg clutch typically containing 300-1200 eggs (Zweifel

1955). Larvae metamorphose in late summer or early fall before winter floods (Jennings & Hayes 1994; Kupferberg et al. 2008). Length of time to reproductive maturity is variable between years, depending on temperature; more research is needed[1]. Males can breed as early as 1 year old, while females typically breed starting at 2 years or older (Zweifel 1955). The lifespan of this frog is not well known, but similar species live between 10-12 years (Olson & Davis 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****: High (high confidence)*
> ***Dependency on one or more sensitive habitat types:*** *High (high confidence)*
> > ***Description of habitat:*** *Rocky streams.*
>
> ***Dependency on specific prey or forage species:*** *Moderate-high (high confidence)*

All life stages of the foothill yellow-legged frog are tied with stream environments. Adults are typically found close to water, and utilize streams for cover, refugia, and over-wintering (Kupferberg et al. 2008). Adults typically select breeding sites in wide, shallow river areas, which may be less vulnerable to rapid shifts in river velocity (Kupferberg 1996). Breeding sites typically feature rocky substrate, which may provide refugia from increased current during peak flow periods (Jennings & Hayes 1994). Egg masses are lain on channel substrates, and larvae exist in the stream channel through early fall (Kupferberg et al. 2008). While sub-adults and adults are prey generalists, tadpoles are dependent on algae, including epiphytic diatoms (Zeiner et al. 1990; Jennings & Hayes 1994); algal assemblages determine tadpole survival, growth rates, size, and time to metamorphosis (Kupferberg 1997a, 1997b; Kupferberg et al. 2011a; Furey et al. 2014).

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	Low-moderate
Landscape Permeability	Low
Intraspecific Species Diversity	Low
Resistance	Low
Overall Score	**Low**

Extent, status, and dispersal ability

Overall degree of extent, integrity, connectivity, and dispersal ability: *Low-moderate (moderate confidence)*
Geographic extent: *Occurs across the state (moderate confidence)*
Health and functional integrity: *Declining (high confidence)*
Population connectivity: *Patchy with some connectivity (moderate confidence)*
Dispersal ability: *Low-moderate (low confidence)*
Maximum annual dispersal distance of species: *1-5 km (low confidence)*

The foothill yellow-legged frog is a California Species of Special Concern (Jennings & Hayes 1994). Current populations can be found in Oregon, the Sierra Nevada foothills, interior foothills of the Coast Range, and along the coast (Jennings & Hayes 1994). Populations seem to be doing best in the Coast Range foothills, and this may be due to less pesticide use and fewer dams in the Coast Range[1]. However, relative to historical records, the number of yellow-legged frog populations across the species range has been significantly reduced and populations are widely scattered (Jennings & Hayes 1994; Lind 2005), increasing their vulnerability to extirpation from extreme events or human activities (Olson & Davis 2009). Foothill yellow-legged frogs utilize stream courses for dispersal (Zeiner et al. 1990; Lind 2005), although dispersal distances are likely small (400-800 m; Olson & Davis 2009).

Landscape permeability

Overall landscape permeability: *Low (high confidence)*
Impact of various factors on landscape permeability:
- ***Dams, levees, & water diversions:*** *High (high confidence)*
- ***Urban/suburban development:*** *Moderate-high (moderate confidence)*

Dams fragment frog habitat, prevent dispersal (Kupferberg et al. 2008; Olson & Davis 2009), and limit genetic exchange (Lind et al. 2011), since stream networks and hydrologic basins act as key dispersal corridors (Lind 2005). Urban/suburban areas and affiliated infrastructure (e.g., roads) prevent dispersal and are associated with lower numbers of yellow-legged frogs (Lind 2005; Olson & Davis 2009).

Resistance

Resistance to stresses/maladaptive human responses: *Low (high confidence)*

Foothill yellow-legged frogs do not exhibit high resistance to climate impacts (e.g., shifts in flood magnitude) or human land uses (e.g. dams, agricultural and urban development; reviewed in Olson & Davis 2009).

Species diversity

Overall species diversity: *Low (low confidence)*
Diversity of life history strategies: *Low-moderate (moderate confidence)*
Genetic diversity: *Low-moderate (low confidence)*
Behavioral plasticity: *Low (moderate confidence)*
Phenotypic plasticity: *Low-moderate (low confidence)*

Breeding timing adaptations related to shifts in water availability have not been documented in this species (Kupferberg et al. 2008). Similarly, it does not appear to have evolved to recognize and avoid non-native predators such as the smallmouth bass (Paoletti et al. 2011). The foothill yellow-legged frog shows high fidelity for breeding sites, using the same locations year after year, which may be indicative of low behavioral plasticity or dispersal (Zweifel 1955). This species does exhibit some genetic diversity, particularly between river basins and along a latitudinal gradient (Lind 2005; Lind et al. 2011). For example, northern (i.e., Oregon) and southern (i.e., from the Sierra Nevada foothills in Kern County) populations are genetically different from populations in the core of this species' range (i.e., foothills around the Central Valley; Lind et al. 2011). Historic connectivity within the Sacramento-San Joaquin River Basin likely contributed to genetic exchange, but current genetic diversity within the largest clade – which contains many populations from the Central Valley – is currently low (Lind 2005; Lind et al. 2011).

Management potential

Workshop participants scored the resource's management potential.

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

Value to people

Value to people: *Low-moderate (moderate confidence)*
Description of value: *They have no economic value and they are not readily visible, but they are considered charismatic.*

Support for conservation

Degree of societal support for management and conservation: *Moderate (moderate confidence)*
Description of support: *Yellow-legged frogs are a California Species of Special Concern, and the IUCN lists them as "near-threatened", but they are not listed under the Endangered Species Act or California Endangered Species Act.*

Degree to which agriculture and/or rangelands can benefit/support/increase resilience: *Low (high confidence)*
Description of support: *This species does not really occur in agricultural landscapes; they do occur in some rangelands areas. Not clear how these could be managed for frogs except to limit grazing near streams.*

Degree to which extreme events (e.g., flooding, drought) influence societal support for taking action: *Low (moderate confidence)*
Description of events: *It is unclear how much these events change how people think about frogs. It is possible that drought could increase support up to a certain level, until there are restrictions on human water use – then support might decline.*

Likelihood of converting land to support species

Likelihood of (or support for) converting retired agriculture land to maintain or enhance species: *Low (high confidence)*
Description of events: *Yellow-legged frog habitat does not overlap with agricultural lands.*

Likelihood of managing or alleviating climate change impacts: *Moderate (moderate confidence)*
Description of likelihood: *There is potential for the frogs to move upstream, so the potential for managing or alleviating climate change impacts depends on the availability of upstream habitat.*

This species has some regulatory protection as a California Species of Special Concern (Jennings & Hayes 1994). River management on dammed reaches will likely be important for maintaining this species into the future (Kupferberg et al. 2008; Olson & Davis 2009; Wheeler et al. 2015). For example, peak flow and subsequent pulse timing and magnitude should be managed to avoid negative impacts on yellow-legged frog breeding and recruitment (Kupferberg et al. 2008; Olson & Davis 2009). Similarly, minimum stream flows should be maintained to sustain habitat, avoid desiccation, and maintain population connectivity within streams and between river and tributary habitat (Kupferberg et al. 2008; Olson & Davis 2009). However, there may be management conflicts between amphibians, salmonids (which require cold-water releases), and human water needs (Wheeler et al. 2015).

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