California Red-Legged Frog (*Rana draytonii*) and San Francisco Garter Snake (*Thamnophis sirtalis tetrataenia*)

Climate Change Vulnerability Assessment for the Santa Cruz Mountains Climate Adaptation Project

This document represents an initial evaluation of mid-century climate change vulnerability for the California red-legged frog and San Francisco garter snake in the Santa Cruz Mountains region based on expert input during an October 2019 vulnerability assessment workshop as well as information in the scientific literature.

Species Group Description

The California red-legged frog (*Rana draytonii*) is endemic to California and Baja California, and is the largest native frog in western North America[1]. It is a highly aquatic species, but adult frogs also utilize terrestrial habitats for estivation during the dry season as well as for movement between aquatic areas[1,2]. California red-legged frogs are typically found in and around ponds, perennial creeks/streams, wetlands, swales, cattle ponds, retention basins, and drainage ditches[1,3].

San Francisco garter snakes (*Thamnophis sirtalis tetrataenia*) are found within a very small coastal range in San Mateo and northern Santa Cruz counties[4]. They forage in freshwater marshes and other aquatic habitats (e.g., ponds, reservoirs, drainage ditches) and use upland habitats for overwintering, reproduction, and movement between aquatic areas[5].

Vulnerability Ranking

High Vulnerability

Low → High

Mod Confidence

Both California red-legged frogs and San Francisco garter snakes are sensitive to climate stressors and disturbances such as warmer water temperatures, increased disease, more frequent/severe flooding, and altered wildfire regimes, as well as those that impact water availability (e.g., precipitation changes, increased drought, altered stream flows). These changes impact red-legged frogs and garter snakes by increasing physiological stress and mortality rates, reducing reproductive success, and altering habitat availability and quality. Non-climate stressors (e.g., land-use conversion to development and agriculture, invasive species, exposure to pesticides, roads/highways/trails, dams/water diversions, illegal collection) further exacerbate species sensitivity to climate-driven changes by causing direct mortality, reducing food resource availability, and/or impacting habitat availability, quality, and connectivity.

Both species considered within this group have experienced significant population declines, which in the Santa Cruz Mountains region are largely a result of habitat loss as well as the presence of invasive species. Remaining habitats are increasingly fragmented, and isolation of remnant populations reduces genetic diversity and enhances the risk of local extirpation due to stochastic events (e.g., severe drought, wildfire). These two species receive regulatory support in the form of federal and state protection, and public support for management is relatively high. Management strategies designed to reduce the vulnerability of California red-legged frogs and San Francisco garter snakes to climate change may include protection of remnant natural habitat and important movement corridors, creation of artifical habitat (e.g., stock ponds managed to provide suitable conditions), and management of invasive species.

Sensitivity and Exposure

High Impact — Low → High — Mod Confidence

Sensitivity is a measure of whether and how a species is likely to be affected by a given change in climate and climate-driven factors, changes in disturbance regimes, and non-climate stressors. **Exposure** is a measure of how much change in these factors a species is likely to experience.

Sensitivity and future exposure to climate and climate-driven factors

California red-legged frogs and San Francisco garter snakes are sensitive to changes in climate factors that reduce the extent and quality of aquatic habitats, which impact reproduction (for California red-legged frogs) and prey availability (for San Francisco garter snakes).

Climate Stressor	Trend Direction	Projected Future Changes
Precipitation	▲ ▼	• Shorter winters and longer, drier summers likely, with higher interannual variability[6,7]
Drought	▲	• Increased frequency of drought years, including periods of prolonged and/or severe drought[6,8]
Streamflow	▲ ▼	• Generally, wet season flows are projected to increase and dry season flows are projected to decrease[9]
Water temperature	▲	• 1.1–2.0°C (2.0–3.6°F) increase in mean summer stream temperature by the 2090s[10]

- **Changes in patterns of precipitation (e.g., amount and timing), increased drought,** and **associated changes in streamflow** alter pond and wetland hydroperiods and can result in drying that reduces available breeding habitat for California red-legged frogs[5,11]. Lower pond water levels and shorter hydroperiods may increase predation of frogs[12], though these conditions can also limit the presence of invasive aquatic species that negatively affect them[1]. Severe and/or prolonged periods of drought are likely to decrease frog recruitment and dispersal, and can lead to increased mortality and population declines[5,11,12]. By contrast, increases in precipitation may expand habitat availability, allowing increased opportunities for reproduction and dispersal[5,11].

  Habitat drying is also likely to impact the San Francisco garter snake[3], which forages for amphibians in aquatic environments[4]. Some researchers have observed decreased survival of juveniles during years when frog reproduction declined due to drought[13], suggesting that climate-driven changes in frog populations could play a role in San Francisco garter snake population dynamics as well.

- **Warmer water temperatures** may accelerate frog larval development rates[5,14], potentially benefitting California red-legged frogs. However, effects on tadpole development are unknown[3].Water temperature also influences pathogen potential and the growth of vegetation that impacts habitat quality for both species (e.g., locations for egg deposition, cover from predators, anoxic conditions)[3].

Sensitivity and future exposure to climate-driven changes in disturbance regimes

California red-legged frogs and San Francisco garter snakes are sensitive to changes in disturbance regimes that directly impact survival as well as those that alter habitat quality and availability.

Disturbance Regimes	Trend Direction	Projected Future Changes
Disease	▲	• Expansion of the projected future climate niche for *Bd* in northern temperate ecosystems[15]
Storms & flooding	▲	• Increased storm intensity and duration, resulting in more frequent extreme precipitation events and flooding[6,16,17]
Wildfire	▲	• Slight to moderate increase in wildfire risk, particularly in areas of higher rainfall[18,19]

- The **introduced chytrid fungus** *Batrachochytrium dendrobatidis* (*Bd*) originated in Asia and has spread globally[20]. Although it has not been well-studied in California red-legged frogs, *Bd* has been implicated in population declines for many other amphibian species[20,21]. A recent study of 4 ranid frog species in the western U.S found that *Bd* reduced frog survival by 6–15%, with lower survival rates occurring within California red-legged frogs compared to the other 3 species[22]. Studies of other frog species suggest that *Bd* may increase mortality to a greater degree in populations that are already experiencing stress due to factors such as unusually warm temperatures, altered hydrology, and the presence of American bullfrogs (*Rana catesbeiana*)[21,23]. Because they are disease-tolerant, American bullfrogs can also play a role in spreading the chytrid fungi[24].
- **Increased storms and associated flooding** could impact California red-legged frog recruitment, as seasonal flooding is known to wash away or strand and desiccate eggs and tadpoles in affected stream reaches[1]. However, winter flooding has greater negative impacts on bullfrog populations than it does on California red-legged frogs[25], suggesting that climate-driven increases in flooding may benefit red-legged frogs by reducing the presence of invasive bullfrogs. Flooding could also benefit both California red-legged frogs and San Francisco garter snakes by increasing overall wetland habitat[3].
- **Altered wildfire regimes** may increase California red-legged frog mortality when they occur during migration or estivation in upland habitats[1]. However, frogs may survive wildfire by taking cover in wetlands[3]. Indirectly, California red-legged frogs may be impacted by changes in water quality due to increased sedimentation from runoff[3].

Dependency on habitat and/or other species

Both California red-legged frogs and San Francisco garter snakes depend on aquatic (e.g., ponds, wetlands, perennial streams) and upland habitats[2,4]. California red-legged frogs breed in aquatic habitats, and adult frogs also require access to cool, moist microsites in riparian and upland habitat for aestivation during dry periods[1,2]. San Francisco garter snakes utilize grassy upland areas for both breeding and overwintering[4,13], but forage on the edges of ponds and shallow marshes where habitat conditions are suitable for frogs that make up their primary food source[5].

California red-legged frogs are prey generalists, consuming a wide variety of aquatic macroinvertebrates[5]. San Francisco garter snakes are more specialized and prey almost exclusively on co-occurring amphibians such as Pacific tree frogs (*Pseudacris regilla*) and California red-legged frogs[3,4,13,26].

Sensitivity and current exposure to non-climate stressors

Non-climate stressors can exacerbate California red-legged frog and San Francisco garter snake sensitivity to changes in climate factors and disturbance regimes by directly increasing mortality and/or indirectly by impacting habitat availability and connectivity.

- **Land-use conversion for residential/commercial development** and **agriculture** in the Santa Cruz Mountains region has resulted in significant modification and loss of freshwater aquatic habitats over the past century, severely impacting California red-legged frog and San Francisco garter snake populations[1,4,5]. However, artificial ponds in agricultural areas can provide habitat for these species[4,11], and may become increasingly important under warmer, drier future conditions.
- **Invasive American bullfrogs** compete for shared resources and prey upon larval and juvenile California red-legged frogs[5,27], reducing frog recruitment and causing extirpation of the species from heavily-impacted areas[1,5]. Bullfrogs are typically associated with larger, deeper ponds that hold water year-round[28], and their expansion has been implicated in the decline of California red-legged frogs[5].
- Anecdotal evidence suggests that **invasive water fern** may reduce habitat quality for California red-legged frogs by creating anoxic conditions[29]. This may become more of a concern in the future as climate change tends to favor the growth of invasive vegetation[30].
- **Roads, highways, and recreational trails** are associated with increased risk of direct mortality (e.g., vehicle strikes) and habitat fragmentation for California red-legged frogs and San Francisco garter snakes[1,30]. Within the Santa Cruz Mountains region, high road densities are associated with significantly increased risk of extirpation for San Francisco garter snakes[30], and proximity to roads and trails reduces the likelihood of California red-legged frog presence in ponds[28].
- **Agricultural pesticides** are known to increase frog larval mortality in aquatic communities, even at very low concentrations[31]. Studies also suggest that wind-borne transport of chemicals from surrounding agricultural areas may be associated with declines in several amphibian species[32], including California red-legged frog populations in other portions of their range[32,33].
- **Dams and water diversions** alter stream hydrology, impacting habitat availability and quality for California red-legged frogs[5]. For example, water diversions used to irrigate spring and summer crops can expose and desiccate frog egg masses and/or increase predation risk[1]. Dams can also aid the spread of invasive species into downstream reaches where formerly intermittent streams shift towards regulated perennial flows[1].
- **Illegal collection** of San Francisco garter snakes represents an ongoing threat to the species, and it thought to have contributed to their decline at some sites[4].

Adaptive Capacity

Low Adaptive Capacity

Low → High

High Confidence

Adaptive capacity is the ability of a species to accommodate or cope with climate change impacts with minimal disruption.

Species extent, integrity, connectivity, and dispersal ability

California red-legged frogs have been reduced to 30% of their historical range in California, largely due to habitat loss, degradation, and fragmentation[5]. Although this species is more abundant in the Santa Cruz Mountains region compared to some other portions of its range[1], continued land-use conversion threatens remaining habitat areas and isolates remnant populations where human infrastructure limits movement across the landscape[3]. Although they usually migrate short distances between breeding and upland non-breeding sites, California red-legged frogs do have the potential to move relatively long distances (as much as 2.8 km [1.7 mi])[1,2], increasing the ability of this species to colonize newly suitable habitat and/or respond to environmental stressors.

San Francisco garter snakes have been extirpated from many locations where they were historically found, although the overall size of their range has changed little[4]. Although little data exists about population trends in this species, remnant populations are likely declining or are at risk of decline[4]. San Francisco garter snake populations are also increasingly isolated due to habitat loss and fragmentation as well as natural barriers that restrict movement and gene flow[4,34]. Additionally, this species disperses very short distances, usually staying within 100-200 m (330–660 ft) of pond foraging habitat and winter upland habitat[4]. Low dispersal distances and increasing isolation of remaining populations enhance the risk of local extirpation due to stochastic events such as severe drought or wildfire[34].

Intraspecific/life history diversity

San Francisco garter snakes have low genetic diversity, and studies suggest the species is at risk of inbreeding depression, particularly in the northern portion of their range[34]. Diversity within life history strategies is relatively unknown for this species, but they do display some flexibility in habitat use[4].

Genetic diversity for California red-legged frogs is currently unknown, though it is thought to be high[3]. The species does possess a variety of behavioral adaptations (e.g., reduced swimming activity in early stages of development) in response to the presence of invasive bullfrogs, likely as a result of predation and competitive pressure[27].

Resistance and recovery

Both California red-legged frogs and San Francisco garter snakes have low resistance to environmental stressors and disturbances, and recovery from impacts is slow due to the isolation of remnant populations[3].

Management potential

Public support for management of these species is relatively strong, and is aided by organizations such as the Midpeninsula Regional Open Space District that provide constituency support for their management and conservation[3]. California red-legged frogs receive regulatory support from their listing as a threatened species under the U.S. Endangered Species Act[5] and as a Species of Special Concern in California[35], while the San Francisco garter snake is federally- and state-listed as an endangered species .

The impacts of climate change may be managed for these species to some degree, though it is unlikely that they can be completely alleviated[3]. Management options focused on reducing climate change vulnerability may include engaging private landowners to provide artificial habitat on agricultural land (e.g., stock ponds), which could then be managed to maintain suitable conditions (e.g., hydroperiod, vegetation structure/type)[1]. One study also found that restored habitat for San Francisco garter snakes within urbanized areas can support healthy populations, suggesting that these areas can be used to supplement larger tracts of natural habitat[38]. Overall, protection of small ponds and wetlands from development and increased human activity (e.g., roads and hiking trails)[28] and preventing the spread of invasive bullfrogs[25,27] are likely to be critical. Upland habitat and migration corridors are also important to consider in protection efforts[2], as both species utilize a variety of habitat types for breeding, foraging, and estivation[2,4].

Recommended Citation

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Further information on the Santa Cruz Mountains Climate Adaptation Project is available on the project page (http://ecoadapt.org/programs/awareness-to-action/santa-cruz-mountains).

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